Photos by Michael Macor / The Chronicle

Thomas Low, associate director of robotics at SRI International, and robotics software engineer Boone Adkins work with a Taurus robot designed and created at the Menlo Park headquarters.

Pioneer computer research lab celebrates a milestone

By Benny Evangelista

Seven decades of research at SRI International in Menlo Park have spawned hundreds of technologies that people take for granted, from computer mice and smog-control measures to the Siri voice-controlled assistant and the Internet itself.

Now, as the research and development center celebrates its 70th birthday this month, it is working on innovations for future generations, such as wearable technology that helps disabled people walk or artificial intelligence that takes care of banking transactions with simple voice commands.

"So are those things possible?" said SRI President Stephen Ciesinski. "People come to us because they want us to create the impossible for them. So we view those as opportunities and challenges that our folks just love to work on."

Stanford University trustees created the independent research center on Nov. 6, 1946, using a former U.S. Army hospital in Menlo Park. Originally named the Stanford Research Institute, the nonprofit center now has about 2,100 employees worldwide, including scientists, engineers and policy researchers, who are celebrating the milestone all month.

Kerri Carder-McCoy carries balloons through the offices where festivities to celebrate SRI's 70th anniversary will continue all month.

"People come to us because they want us to create the impossible for them."

Stephen Ciesinski, president, SRI International

The center's charter is to work with government agencies and private businesses, which sponsor research to develop technology spanning a wide swath of fields, including computing, biosciences, education, robotics and engineering.

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The center's goal is to help its project sponsors develop innovations. But it largely remains in the background "because frankly, our partners don't want us to talk so much about SRI," Ciesinski said. "That's one of the reasons we're not as well-known, because they want to get all the attention, and sort of rightfully so, so we're in the back room in many cases."

Although SRI hasn't had a "single super-dramatic" invention, it has played a major role in Silicon Valley history, said Marc Weber, curatorial director for the Computer History Museum's Internet history program.

Some of its best known innovations include the computer mouse, developed as a wooden-clad prototype in the early 1960s by SRI's Douglas Engelbart, whose work helped build online systems, word processing and an early version of hyperlinks.

"From a computer history point of view, (the mouse) was a standout," Weber said.

The institute has had a hand in about 60 spin-offs, including public firms like Sunnyvale's Intuitive Surgical, which makes a robotic system that doctors can use to perform certain surgeries. Last year, SRI teamed with Google's life sciences division and Johnson & Johnson to create Mountain View's Verb Surgical, another robotic surgery startup.

It might be best known for Siri, the voice-activated personal assistant that is now owned by Apple. (The name Siri doesn't stem from SRI, but from the Norwegian name of its co-creator's daughter.)

And in 1976, SRI connected two distinct networks — its wireless packet radio network and the Defense Department's ARPANET — to create what is considered the first Internet connection.

"It's hard to overestimate the importance of SRI for networking," Weber said. "It's arguably the one birthplace for the Internet."

And Shakey, a mobile robot introduced by SRI's artificial intelligence center in the 1960s, was "the ancestor" of today's self-driving cars, Weber said. One of SRI's current projects is a motorcycle-driving robot being developed for Yamaha Motor.

The company has also had a hand in developing laser eye surgery, the magnetic ink account numbers printed on all checks, and the federal Head Start education program. Its technology has also led to color television, HDTV and Blu-ray Discs.

Also, in 1947, researchers began studying the effects of the smog that enveloped the Los Angeles Basin, which led to federal action on air pollution.

"With our innovations, there's a lot more than meets the eye," Ciesinksi said.

SRI researchers also keep finding ways to find other applications for technology developed by the center. Siri software, for example, originally stemmed from a five-year, $150 million military contract involving Stanford and Carnegie Mellon universities to develop more ways that troops in the field could interact with computers, Ciesinski said.

SRI has recently formed a Center for Aging to use technology like artificial intelligence, robotics and voice recognition to help with the challenges of people who are living longer, he said.

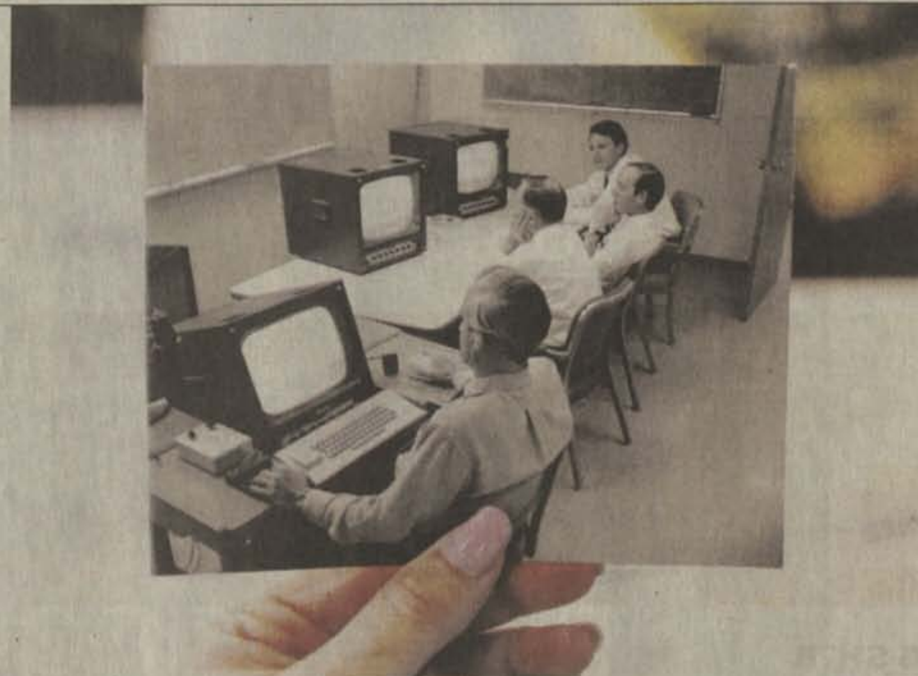
For example, SRI is working on wearable technology that can assist elderly or disabled people lift their hands or pick up something. Or help them "do a simple thing like sitting down or walking" without wearing a bulky "Iron Man outfit," Ciesinski said.

And researchers are developing wearables that can warm a specific part of the body that might be affected by poor circulation.

"So you could develop in your clothing extremely local heating and cooling that wouldn't take up as much energy as filling up a room twice or three times the size," he said.

The breadth of the center's work can be astonishing. Inside a robotics lab one day last week, Thomas Low, associate director of robotics, was running tests on controlling a bomb-diffusion robot's arms with an Oculus Rift, one of the commercially available virtual reality headsets that went on sale this year. Low has worked for SRI for 32 years.

"When you talk to somebody who's been saved by robotic surgery or any of the things that we have done, it makes you feel like you've actually not wasted your life," he said.



Michael Macor / The Chronicle

A 1968 photograph of the first demonstration of a computer mouse by Doug Engelbart at the SRI Augmentation Research Center is shown at SRI.

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Two Early Interactive Computer Network Experiments

David Hemmendinger
Union College

Two early networking experiments joined a time-sharing computer at the System Development Corporation with systems at the Stanford Research Institute briefly in 1963 and at the MIT Lincoln Laboratory in 1966–1967. Both were influenced by J.C.R. Licklider's interest in resource sharing and included experiments with the interactive use of remote programs.

The second half of the 1960s saw considerable research in computer networking in the United States and England. The best-known network is the Arpanet, which began operating in 1969, while in England, Donald Davies planned a national network, the first small version of which was roughly contemporaneous with the initial Arpanet tests.[1] Both of these networks used packet switching, proposed by Davies and by Paul Baran of the Rand Corporation, that became the norm for long-distance computer networks. There were earlier network experiments, however, most of which have received little documentation. This article describes two of them, both using a time-sharing computer at the System Development Corporation (SDC) in Santa Monica, California. The first was a short-lived connection in 1963 between SDC and the Stanford Research Institute (SRI), while the second was a better-known experiment that connected SDC with the TX-2 computer at MIT Lincoln Laboratory in Cambridge, Massachusetts, in 1966–1967. The latter is often cited as the first long-distance network connection, and an online book called it "the seminal experiment," although it misdated it as 1965.[2] One reason it is better-known may be that it was conducted by Larry Roberts, who later became the head of the Arpanet project. It is interesting, however, that in each case the results of the experiment were never published except in internal technical reports and memoranda.

Resource Sharing

In the late 1950s, several researchers proposed versions of time-sharing to allow multiple teletype or other terminal connections to a computer to be active concurrently.[3,4] This would allow several users to test and debug programs online and, more generally, allow interactive sessions while still using computer time efficiently. Time-sharing systems appeared in the early 1960s, including one at SDC on its AN/FSQ-32 (Q-32) system.[5] J.C.R. Licklider, director of the ARPA Information Processing Technology Office (IPTO) from 1962–1964, was a major proponent of time-sharing and used his position to fund time-sharing projects. His interest in it was part of a larger interest in exploring human-computer interaction, and it came to include an interest in networking computers together for the sake of resource sharing and collaborative work.

Computers were networked to exchange information as early as the late 1950s, when the SAGE (Semi-Automatic Ground Environment) system used computer communication to coordinate radar information.[6] These networked computers did not give operators the ability to invoke user-level programs remotely. Rather, they transmitted digital information by telephone and radio, using a fixed set of programs. The network experiments that this article describes, by contrast, allowed a system user to invoke any suitable program on the remote computer.

In an April 1963 memo to members of the "Intergalactic Computer Network," Licklider imagined working at one computer site and

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bringing in programs from other computers. Although his notion of importing binary programs from remote computers was problematic, because they would be architecture-specific, he also wrote

> When the computer operated the programs for me, I suppose that the activity took place in the computer at SDC, which is where we have been assuming I was. However, I would just as soon leave that on the level of inference. With a sophisticated network-control system, I would not decide whether to send the data and have them worked on by programs somewhere else, or bring in programs and have them work on my data. I have no great objection to making that decision, for a while at any rate, but, in principle, it seems better for the computer, or the network, somehow, to do that.[7]

Histories of the ARPA IPTO office such as *Transforming Computer Technology* by Arthur Norberg and Judy O'Neill[8] describe its work as being guided by Licklider's vision of resource sharing and collaborative work, a vision that his successors, Ivan Sutherland and then Robert Taylor shared.

Time-sharing, one part of the realization of that vision, had its origins in the interests of academic computer centers in promoting effective computer use in the write-test-debug cycle of program development. Initially, according to Norberg and O'Neill,[9] a computer network was a time-shared computer with remote terminals, such as the SDC Q-32 and the MIT Compatible Time-Sharing System. Unlike the development of time-sharing, computer networking as communication among multiple computers appears to have been initiated largely through IPTO funding and encouragement to connect computers together.

It is perhaps not surprising that networking was promoted in a top-down fashion. While one institution could become more efficient by time-sharing its computer, networking computers at several institutions might be seen as providing others with access to a scarce resource. In fact, reports on the early reception of the idea of an Arpanet indicate just that. Robert Taylor reported about a 1967 ARPA network meeting saying, "Most of the people I talked to were not initially enamored with the idea. I think some of the people saw it initially as an opportunity for someone else to come in and use their cycles."[10] Later, as we know, people became enthusiastic about the opportunity for collaborative work, confirming Licklider's expectations.

Other histories of the development of the Arpanet and the Internet, including those by Janet Abbate[11] and Katie Hafner and Matthew Lyon,[12] support the notion that computer networking was spurred by the ready availability of IPTO funding. The remainder of this study will look at how that worked in two instances and will look briefly at some other possible early network projects for which evidence is less clear.

Sources

Several articles on the SDC Q-32 time-sharing system mention that it had a network connection, but there are only a few published mentions of its use, none of which are detailed. These include a book and a lecture by Charles Bourne, along with an SRI technical report. The 1966 SDC-LL connection is described in an article by Thomas Marill and Larry Roberts. Both experiments are also mentioned in *A History of Personal Workstations*[13] and in a University of California, Los Angeles PhD dissertation.[14]

Unfortunately, there is no comprehensive archive of SDC technical documents. The Charles Babbage Institute Burroughs archives include some SDC documents, but none describe network experiments, although they are mentioned in an annual research report for 1966. More is available from Lincoln Laboratory, both in online quarterly research reports at the Defense Technical Information Center, which are quite sketchy, and in some documents in the LL archives. I have also consulted several oral histories by Robert Taylor and Larry Roberts, and I have benefited from emailed correspondence with people who worked on the two projects.

The SRI-SDC Experiment

The SDC Q-32 ran an early time-sharing system (TSS) that went into operation in mid-1963. The 1964 paper that presented the TSS[15] briefly mentions a network connection with a Control Data CDC 160A at SRI, more than 300 miles away. The actual connection was between the 160A and a PDP-1 that was the communications front end for the Q-32. The network was used by an SRI program to do full-text searches of a bibliographic database stored on the Q-32. Its designer, Charles Bourne, worked on information retrieval with Douglas Engelbart and was later director of the University of California Institute of Library Research. He described the project in an SRI technical report,[16] the 1999 Conrad

Figure 1. Control Data CDC-160A workstation at SRI. For this interactive workstation, operators used Engelbart's five-key "chordal" keyset (not shown) that allowed one hand to type while the other used a light pen. (Courtesy of SRI International)

Memorial Lecture,[17] and a 2003 book.[18] It was a proof-of-concept system intended to demonstrate the feasibility of both full-text search for strings of words and bibliographic terms, and it was part of Engelbart's Augmenting Human Intellect project that was supported in part by IPTO. According to a later account by Engelbart,[19] they had proposed using an interactive workstation connected to a local computer, but Licklider asked them instead to put the database on the SDC Q-32 system and build a networked connection to it. (IPTO had also funded the Q-32 time-sharing system.) This interactive computer-computer network ran the search software on the remote Q-32, with the SRI CDC machine providing the user interface. The search program with its remote connection was demonstrated successfully on a small set of documents in late 1963, although some of its planned capabilities, such as Boolean operators in search strings, were not implemented. Its demonstration was supposed to have used 50 records at SDC, but defects in many of them meant that only seven records were actually used.

Work on the system was apparently abandoned shortly after the demonstration because the project lost funding. In his lecture, Bourne said that SRI projects "went where the money was" and that they didn't find funding agencies for the bibliographic project after SRI funds went to projects related to the Cold War. According to his book that, although he was the project manager, he had forgotten about the never-named project until he was conducting research for the book more than three decades later.

Engelbart's reference to Bourne's short-lived project is the only other published mention of it that I have found. He added to his account: "For various reasons, not uncommon in pioneering ventures, that first year was unproductive relative to the purposes and plan of our project." Although Licklider was willing to continue support, Engelbart said that he couldn't offer enough funding. Figure 1 shows a photograph of that interactive workstation, from Bourne's report, which also mentions using a five-key "chordal" keyset to allow one hand to type while the other used a light pen.[20] It appears to be similar to what Engelbart used in his 1968 computer mouse demonstration.[21]

According to Bourne, the network ran at 2,000 bits per second (bps), using an AT&T 201A modem (on a 2-kHz line, according to Jules Schwartz).[22] If it used the then-new ASCII encoding, it would have run at about 200 characters/second. Although there are no further details of the network implementation in published accounts, interviews with programmers at both SDC and SRI provide further information.

Clark Weissman, one of the Q-32 system programmers, said that the network between SDC and SRI used two full-duplex telephone lines—one for commands to the Q-32 (for example `login`, `load`, and go) and the other for data to the program that the commands started.[23] (He noted that this arrangement was similar to CPU design, which separates data and control.) Both lines were connected to the PDP-1 that handled all terminal I/O to the system. As he remarked, the flaw of this design was that it required two lines, but the virtue of the design was it also requiring minimal modification of the operating system. Because the command and data streams were separate, the operating system executive (command interpreter) could operate without change, except that it would have to be able to treat the two phone lines in effect as separate terminals. It would first accept input from the command line, and when commands started running a program on the Q-32, that program would be assigned the data-line "terminal" for its input and output. Because the PDP-1 managed the terminals, any changes would have been made to its operating system rather than to the Q-32 system.

Len Chaitin, the SRI programmer who worked with Bourne to implement the full-text search program, also recalled the two-line design.[24] Both Weissman and he said that the network connection worked well; Chaitin said that a small amount of bit-checking was done in hardware. According to Chaitin, the network design was intended to be as simple as possible so that it might be used by others later, although that didn't happen. It is striking, however, in view of the difficulties that others found in using transcontinental telephone lines, that this simple arrangement was effective over a distance of several hundred miles.

I have found no SDC documents that describe either the SRI-SDC experiment or any further uses of the 2,000 bps link. It is still listed in the 1965 SDC annual research report,[25] which also cites a final report on its design,[26] but that document is not in the Babbage Institute SDC collection nor have I found it elsewhere.

Statements of "first" need to be made carefully, and they are generally not the most important characteristic of the object under consideration. Nonetheless, the 1963 SDC-SRI network appears to be the first that was designed and employed for interactive use, albeit briefly. There were earlier computer-computer networks—for example, in the SAGE system—that were used for data transfer, and it is possible that people found clever ways to use them interactively, but they were not designed for that purpose. More importantly, the SRI-SDC network was an early instance of a network set up to demonstrate the possibility of harnessing dissimilar computers in a single project that might take advantage of the strengths of each—data storage on the Q-32 and interactive terminal use on the CDC system. It is also an early example of how Licklider's interest in networking directly led to an experiment.

The LL-SDC Experiment

A 1967 review of the TSS performance calls the SDC-SRI network obsolete and refers to a connection between the Q-32 and the TX-2 at Lincoln Laboratory.[27] This is the one described by Thomas Marill and Larry Roberts,[28] often called the first interactive computer network connection. It is thus surprising that although their paper gives details of a planned network experiment, its results weren't published. There have been just a few mentions of them, such as by Roberts in a retrospective on the Arpanet[29] which said that communication was possible, but that the telephone lines were too slow and unreliable. That remark is unlike what participants recalled about the SDC-SRI link, which was that it was slow but reasonably reliable. Perhaps it reflects higher expectations of networked computing three years later.

The origin of the Marill-Roberts network experiment is unclear. According to Norberg and O'Neill's study of US military support for information processing,[30] Marill, who had just started the Computer Corporation of America (CCA), was looking for a contract in 1965 and gave IPTO a proposal for a network study, which IPTO set up as a subcontract under its Lincoln Lab contract.[31] Other accounts, such as the DARPA history of the Arpanet,[32] just refer to the project as being a subcontract of the ARPA contract with Lincoln Lab.

Marill's role in computer networking appears limited to this one experiment. He was a psychologist who had worked with Licklider for his MIT PhD. He subsequently joined Licklider at Bolt Beranek and Newman (BBN), where he worked on the psychology of perception, information retrieval, time-sharing, and artificial intelligence.[33] At CCA, Marill later worked on a variety of projects, including databases, information retrieval, and image recognition. In the late 1980s and 1990s, he was a researcher at the MIT Artificial Intelligence Laboratory, working on robotics and perception.

Roberts is well-known as the head of the Arpanet project, which he took over at the end of 1966, at the request of Robert Taylor, the third IPTO director.[34] He had attended a conference on the future of computing in Hot Springs, Virginia, in late 1964 at which conversations with Licklider persuaded him of the importance of computer networking.[35] He remarked about that meeting in an interview: "I was interested in communications, but I didn't have any strong direction at that point, or before that point."[36] At Lincoln Lab, he continued to work on computer graphics. He knew Marill and, in 1965–1966, was contract manager for Marill's project.

The Arpanet Collection[37] of the online Internet Archive[38] has material collected by Katie Hafner for her Internet book. It includes a set of letters that Marill gave her about his contract with Lincoln Lab.[39] His May 1965 proposal to Lincoln Lab for a networking project elicits a noncommittal response. That lead him to write to Roberts in more detail in June about his reasons for wanting to do the study in which he proposes to connect three computers. That is followed by a Lincoln Lab request in July that he submit a formal proposal. It is unclear from the letters who initiated the May proposal. It is unlikely that Marill would have proposed using the SDC Q-32 without having been given a reason to think that it would be available, either as a response to a proposal that he gave the IPTO or in a request that it had initiated. In the last letter in the collection (November 1965), Marill asks Roberts for a six-month contract extension, referring to a discussion that they had had a week earlier.

Marill's June 1966 report[31] was written during that six-month period; a third draft is dated 28 February[40] and is nearly identical to the final version. Its content reflects the early state of networking then. Like the plan for the later Arpanet, it presents resource sharing as a principal reason for having a network: to make specialized systems or programs accessible from any time-sharing system. It is presented largely as a feasibility study, and he devotes considerable space to a discussion of character coding and transmission and of available modems, with their costs. It explores telephone line options and recommends several, with the choice depending on usage. The one that the later Marill-Roberts paper proposed using, a 4-kHz Western Union voice-grade line with a 1,200 bps modem, was its recommendation for up to 50 hours/month of use.

The most interesting part of the report is its software section. Like the later Marill-Roberts paper, it outlined three strategies. Two required little change to the operating system. The first "quick-and-dirty" approach needed only to let a program communicate with two terminals, the user's and the remote computer. A user would start a program on the local system, and it would communicate with the remote computer first to log in and then to run a program on it, exchanging data with it as a user might do directly. As Marill remarked, the only other system change would be to provide a command to let the user program dial a telephone number.

The report added that without further change, such a connection would operate at teletype rates (11 characters/second). A higher-speed modem and line could increase the rate; Marill suggested that 100 characters/second would not strain the current hardware, although their processing time might degrade service on other lines. In fact, even steady transmission at that rate would have required no more than 1 to 2 percent of the SDC PDP-1 computational capacity to process the input, according to the interrupt-handling description in the PDP-1 manual.[41]

A second method would use separate lines for commands and data. With a single channel, the program or the operating system must parse all input to distinguish commands and data. With two channels, the system need not examine the data line at all because its content would go directly to a program. Although using two lines might seem costly, Marill suggested that it need not be because only one of them would need to be high speed, and the command connection would generally be made only briefly. We should recall that just such a two-line design was used for the SDC-SRI network. In his final section of recommendations, Marill mentioned the SDC-SRI network as a data-only link that was supplemented by a second line for commands, so he was evidently aware that the two-line design had been implemented.

The third method, mentioned as speculation, was to use a single high-speed line for both commands and data. It would need a protocol to distinguish commands from data, and Marill suggested only that possibly every *n*th bit or character might belong to a command stream so that the operating system would only need to count bits or characters to be able to recognize commands—a rather awkward design.

The three computers that Marill proposed using were the TX-2, the Q-32, and an IBM 7094 run by the MIT Project MAC for time-sharing research. He discusses the advantages of resource sharing between LL and Project MAC, but he doesn't say what led him to expect to use the 7094, and it never became part of his network experiment. According to Norberg and O'Neill, "the MAC people were not interested in participating";[42] another account says that IBM didn't want to get involved.[43] Marill's report says that the MAC 7094 had an IBM 7750 computer as a communications front end (like the PDP-1 at SDC), which had 1,200 bps lines, and his plan required no changes to MAC hardware or software. Once the experiment added a communication protocol, however, system software would need some change to be able to interpret it, and it is possible that that was a basis for nonparticipation, but no definite information is available. A 1967 memo by Marill simply stated, "for various reasons, this never came to pass."[44]

Lincoln Laboratory quarterly reports for 1966 and 1967 provide brief documentation of the rather slow progress in setting up the network during the year after the APEX operating system for the TX-2 was in use.

> The hardware, software, and operating requirements of a low-speed, multiplexed data-terminal sequence for TX-2 are being studied. Initial requirements are for a system which can communicate with other computers via "dialed-up" or leased phone lines at either teletype or 2000-bit/sec rates.[45] (Nov. 1965 to Jan. 1966)
>
> The logic design for the in-out unit required to interface telephone-line data terminals with TX-2 has been completed. ... Western Union Broadband Switching Service, a data set for 1200-bit-per-second asynchronous operation, and an automatic answering unit are being obtained for the data connection to System Development Corporation in Santa Monica, California.[46] (Feb. to April 1966)
>
> The [TX-2] computer now has a low-speed data channel which will be used for communication with remote consoles and with other computers. The first phase of the software required to use this hardware with the APEX time-sharing system is now being checked out. APEX has been changed to allow two new consoles, and the basic routines for sending and receiving streams of characters are ready. The first remote connection will be with the FSQ-32 computer at the System Development Corporation in Santa Monica, California.[47] (Aug. to Oct. 1966)
>
> The network link between the TX-2 and the AN/FSQ 32 at SDC has been exercised with mixed success. Significant demonstrations are planned for the next quarter.[48] (Nov. 1966 to Jan. 1967)
>
> The network link between the TX-2 and the AN/FSQ-32 at SDC has been used for several demonstrations. A distributed program which uses the Lincoln Reckoner at TX-2 and LISP at SDC has been created and run. Statements typed in at TX-2 are parsed at SDC and then given to the TX-2 Reckoner for calculation. Some statistics on network operation are being gathered.[49] (Feb. to April 1967)

The Marill-Roberts paper's principal addition to Marill's CCA technical report is the description of the communication protocol to be used. It broke messages into blocks of up to 119 characters, each with a start character denoting a message for the system or user, a stop character, and a checksum. There were also ACK and NACK characters for acknowledgments and resend-requests as well as several other control characters. Roberts later referred to these message blocks as packets, although of course there was no packet switching.[50] This protocol, with relatively small message blocks, would have permitted error recovery with the retransmission of one block or a few blocks, without the expense of having to retransmit an entire long message. This would have been at the cost of an addition of a small number of control characters, an overhead of a few percent at the most. In a 1988 interview, Roberts remarked that it was natural to think in such terms: "We were all thinking of blocks .... That's the way computers worked."[51]

A CCA memo in the Lincoln Lab archive proposed a more efficient protocol, which would let a second message block be transmitted without waiting for the previous one to be acknowledged, although the second block would not be terminated before that acknowledgment arrived. If the receiver reported an error in the first block, the second would be terminated immediately and the first resent.[52] This protocol would permit successive message blocks to be transmitted without delay as long as each ACK for a block was received while the next block was being sent. As the memo author, Bill Mann, now recalls,[53] the SDC people in charge of their end of the network preferred not to implement this more complex protocol. Instead, they used the simpler one that is in the Marill-Roberts paper and is also documented in a CCA memo.[54] Mann said that he objected to its inefficiency, and Roberts' reply was that the project was just a proof-of-concept test and that performance didn't matter, an interesting contrast to Roberts' later comments about the network's being too slow to be practical, although of course both responses are appropriate in their contexts.

A June 1966 memo to Roberts[55] outlined a proposed schedule for the experiment. In June and July, they would set up the TX-2 phone hardware, modify the APEX operating system to link to the Q-32, run a test program that has the modem at SDC echo characters back to the TX-2, and write a program to make a TX-2 terminal look like a Q-32 console. Then in August they would run a demonstration TX-2 program that used an SDC program "in a meaningful way." It mentioned further phases of the project and remarked that the timetable may need revision. There is no indication whether that was necessary.

Two progress reports describe further plans and what was realized. The first is about a January 1967 meeting in which Marill reported on network plans and lists 16 experiments.[56] Five were to be TX-2 programs that used the Q-32, four were Q-32 programs that would use the TX-2, and seven were to use a DEC 338 graphics terminal (a modified PDP-8) at Harvard to connect to one of the other two computers. The most ambitious ones were to use graphics displays, and the memo notes that these tests would require interim measures that violated networking principles by requiring changes in the remote programs and by not using a standard display language. Both the Q-32 and the TX-2 had graphics projects (including some by Roberts), making them candidates for remote experimentation.

The 1967 report commented that three TX-2 programs that used the Q-32 had been run, but flaws in the modems made them unreliable. Work on three counterpart programs on the Q-32 had started, but none of the remaining ones, including the graphics programs, had been started. A DEC 338 didn't became part of the network experiment, although one was set up later in Roberts' ARPA office.[57]

One of the three TX-2 programs that used the Q-32 was a console simulator that let users run remote programs. A second let a TX-2 user run TINT, an interactive Jovial language interpreter, as if it were local to the TX-2. The third, AT (Algebraic Translator), was the most interesting: it took mathematical expressions in standard infix form from the Lincoln-Writer, a special typing terminal, and sent them to a LISP program on the ~~TX-2~~ Q-32, which translated them into prefix notation and returned them to the TX-2 for evaluation by the Lincoln Reckoner program (called Basic Translator here), a calculator for scalar, vector, and matrix mathematics.[58] Marill credits Weissman with the idea for this program.[59] According to an April 1967 progress report,[60] these three programs ran reliably. Six of the remaining ones were canceled, another six were being reconsidered, and only a Q-32 console simulator for the TX-2 was still being planned, although deemphasized. There is no indication that any more programs were completed.

There is less information about the SDC side of the network. The Charles Babbage Institute collection of Burroughs papers includes some technical memos from SDC, which Burroughs had acquired, but there does not appear to be anything among them about the network. The SDC 1966 annual research report[61] has a section by Weissman on programming systems, which mentions two network projects. One, for a network of SDS 940 computers at UC Berkeley, BBN, and SRI as well as at SDC was under design but apparently never implemented, while the other was the TX-2 connection. The report emphasized that it allowed a system to invoke programs on another, dissimilar one. It added that this method "could be the only way for the data processing community to truly share the programs and work of others." A section on time-sharing networks listed the Western Union 1,200 bps line that Marill described and referred to collaboration with CCA in modifying both the SDC PDP-1 and the TX-2 operating systems, which is consistent with the CCA documents. Its explanation of the lack of Q-32 programs using the TX-2 was that the resources of the APEX operating system on the latter were largely devoted to display programs and that protocols needed to be developed for such programs. The Q-32 was due to be replaced by an IBM 360 in 1967, and although the report suggested that the network project would be transferred to the new system, there is no indication that that happened.

Clark Weissman said that the network did use separate lines for commands and data—a slow one for the former and a fast one for the latter.[62] This would have been a natural thing for SDC to have done, having already used that simple design for its earlier network. There is no mention of a two-line network in extant SDC documents, however, and among the Lincoln Lab material, the only mention of what could be a two-line network is the reference to a low-speed channel for connections to other computers in the November 1966 LL progress report, which also refers to there being two new consoles on the TX-2. This is scant support, although if it means that the two consoles were for the low-speed and the 1,200 bps telephone lines, it would be consistent with what Weissman recalled.

Weissman also recalled that Roberts did not like the cost of two cross-country lines and didn't think that the two-line model was viable for networking. It is thus possible that a two-line network was initially tried, but it wasn't developed to the point of being documented in progress reports because it was due to be replaced by a single line with a protocol to separate commands and data.

It is unclear how long the LL-SDC network continued to be used. Roberts left for ARPA at the end of 1966, although in a paper presented at the first Symposium on Operating System Principles in Gatlinburg, Tennessee, in October 1967, he mentioned that the network "is now utilized by users to increase their capability."[63] There are no documents about the network in the Lincoln Laboratory archive for the rest of 1967. A February 1968 CCA memo again described the three programs that had been implemented and gave examples of the AT program that used the Q-32 Lisp, although by then the network was not in use because SDC had retired the Q-32.

Some of the earlier documents refer to plans to set up automatic telephone dialing from the TX-2. Marill's memo on the January meeting said that the dialer wasn't yet ready,[44] but a March 1967 CCA memo[64] reports that it had been done and that the TX-2 could dial out when a network call was made and also receive calls. Figure 2 is a block diagram of the TX-2 system,[65] although it doesn't indicate if it has automatic dialing capability.

Marill's last progress report has an example of a session with automatic dialing.[64] Figure 3 shows the AT program being run on the TX-2. The following is his explanation of it:

> Typing in "CCA" logs us in at 1320.13 Eastern time.
>
> Typing "AT" causes this program to start. It dials up SDC, logs in, loads LISP, transmits a LISP program for compilation by the LISP compiler, waits for the compilation to take place, and then waits for input from the Lincoln Writer.
>
> LISP was loaded on the Q-32 at 1021.9 (Pacific time), or 1.8 minutes after log in on the TX-2. This 1.8 minutes includes the time to select the desired program, "AT," and to type this selection in (I don't recall that any one was rushing at this point). By 1325.1 Eastern time, or 3.2 minutes later, the LISP program to be compiled had been transmitted, and the compilation had taken place.
>
> We now typed in a value for X, and a function to be evaluated. We do not have timing information here but estimate that the answer was typed out in less than one second. This includes the time to ship the algebraic string to the Q-32, have it compiled into Basic Translator [Reckoner] code, have the code shipped back, have the function evaluated, and the answer typed.

The CCA memos list network documentation and gathering statistics on its performance as tasks to be done, but there is no indication that they were carried out. The project did have two outcomes. It gave an example of a simple network connection and message protocol that could work, although its use didn't continue. Like the SRI-SDC

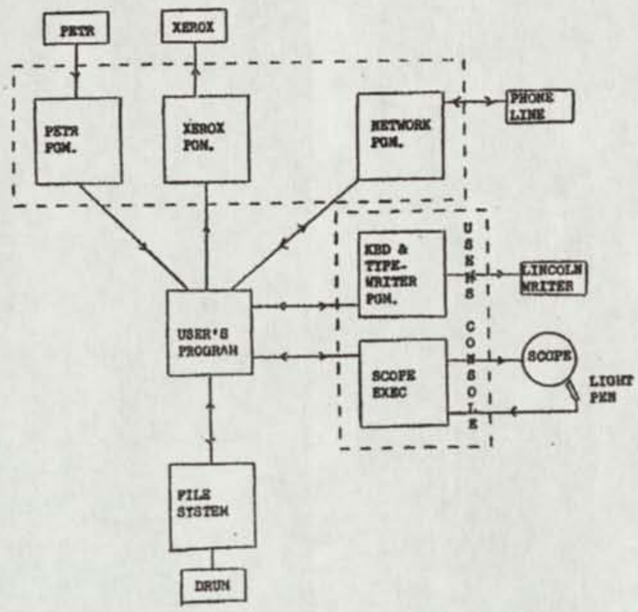

Figure 2. The network and TX-2 system. This block diagram does not indicate if it has automatic dialing capability. (Courtesy of the MIT Lincoln Laboratory archives.)

```
LOG IN CCA
    CCA IN 425 PGS , THU 16 FEB 67 1320.13
    BTR 2
AT
 DIALING SDC
 CONNECTED
 1967 FEB 16 1021.9 LISP 1.5 M2.6 7JA13 RL1447
   (EX CD)
   TLST
   BOPS
   UOPS
   (COMP EVBT TEST)
 X=7.012345
 (SIN X)*(SIN X) +(COS X)*(COS X)
   1.0000000
```

Figure 3. Example of a session with automatic dialing. The boldface text indicates user input, and the rest is output either from the APEX system (such as DIALING SDC) or from the Q-32 (such as the Lisp 1.5 line).

Once the program had been compiled, it gave results in a second or so—not a bad performance for transcontinental communication.

network, it also demonstrated the use of remote computational resources. In Marill's example, once the program had been compiled, it gave results in a second or so—not a bad performance for transcontinental communication. It would be interesting to know how often there were network errors, as it would be also for the earlier SRI-SDC connection, but I have not found any record of that information.

Both SDC and LL documents refer to using graphics displays. The participants did not develop the necessary protocols, which ideally would have required a device-independent format for messages, to be translated into device-specific code at each end. Although this ambitious goal was not reached, what was achieved is noteworthy as an early example of the resource sharing that the Arpanet was set up to do several years later.

Other Proposed Experiments

In their chapter on early IPTO networking contracts, Norberg and O'Neill mention several other proposed experiments, and I provide a little more information here. The first contract, in 1964, was with UCLA, and was to join its main computing center, one at the health sciences center, and its Western Data Processing Center, a local consortium. It was also to involve the SDC Q-32 system, but the three UCLA centers did not want to collaborate with one another,[67] and despite initial ARPA optimism, nothing ensued.

The 1966 proposal to connect SDS 940 computers at UC Berkeley, BBN, and SRI, mentioned earlier, was apparently intended to benefit from the convenience of networking one computer type. Although it did not involve an SDC system, a group met at SDC in June 1966 to produce a design document, edited by Wayne Lichtenberger.[68] I have not been able to find a copy of the document, and its editor does not recall it, although he said that its topic was consistent with what he was working on then.[69] There is no indication that this proposed project was implemented, and I have not found any mention of SDS participation.

IPTO also supported a project at Carnegie Mellon University (CMU) and Princeton University and IBM to network IBM 360/67s. A report on it[70] cites the Lichtenberger report as describing a similar project, presumably because both were intended to network a single computer model. The CMU project was implemented in 1968, at least as a prototype. It used point-to-point connections, unlike the Arpanet. The Network Working Group's Request for Comments (RFC 33) on the Arpanet host-to-host protocol mentioned it as not having influenced the Arpanet. It added:

> [E]arly time-sharing studies at the University of California at Berkeley, MIT, Lincoln Laboratory, and System Development Corporation (all ARPA sponsored) have had considerable influence on the design of the network. In some sense, the ARPA network of time-shared computers is a natural extension of earlier time-sharing concepts.[71]

Possible 1965 Experiment

Several online and published accounts, including the Computer History Museum's Internet timeline, give 1965 as the date of the SDC-LL experiment.[72] Although this is a mistake, there are also two oral-history interviews with Robert Taylor that mention a 1965 experiment. In a 2008 interview in the Computer History Museum's collection,[73] Taylor said that in 1965 he asked Larry Roberts to conduct a "bit reliability experiment" to help assess the feasibility of networking time-sharing systems and that Roberts subcontracted the work to Thomas Marill. The experiment was to use SDC and Lincoln Lab time-sharing systems because, Taylor said, he was funding both. A 1989 oral history interview with him at the Babbage Institute[10] has a similar account: in 1965 he had asked Roberts about some network reliability issues, and that Roberts had had the CCA "send some bits back and forth over some phone lines" between SDC and Lincoln Laboratory.

Taylor emphasized in a recent email[74] that this test was not to connect the Q-32 and the TX-2 for networking applications, but only to use the two systems "as senders and receivers of bits" briefly, just long enough to give an idea of the reliability of cross-country transmissions. Taylor's interviews don't give a more precise date for this work. As of late 1965, he believed that cross-country transmissions were feasible, he said in an email. He thought that this belief was based on what came from SDC and Lincoln Laboratory, a view that is consistent with his role in initiating the Arpanet project in February 1966.

Larry Roberts described this network test in email,[75] saying that in 1965 he had needed to determine the burst error rate on telephone lines to decide on an appropriate size for network message blocks. He said that he thought it most likely that he hadn't used a modem at all (the TX-2 didn't get one until mid-1966), but he instead used an analog-to-digital converter to connect a phone line to the TX-2, a technique he had previously used to help Amar Bose measure the frequency response of his living room in connection with loudspeaker design. He thought that he reported his results to Taylor.

None of the 1965 or 1966 Lincoln Laboratory reports mention this bit-transmission experiment. These recollections thus aren't enough to provide a definitive account of what may have been done in 1965. By both Taylor's and Roberts' accounts, the test would have been minor and brief, likely to have been too short-lived to have been documented. (Retrospectively, we are fortunate both that the outcome of any bit-shipping test suggested that a transcontinental connection was feasible and that its use led to a desire for something faster.)

Conclusion

I have described three network experiments that were motivated by the ARPA project of the first IPTO directors, J.C.R. Licklider, Ivan Sutherland, and Robert Taylor, to develop resource sharing and collaboration among computer centers. They were short-lived and lightly documented. The 1963 SDC-SRI link is interesting as a first experiment, but even more so as a "what might have been": a simple design that worked and that could have provided experience with linking dissimilar computers and using remote resources had it continued. It also gave SDC staff experience with networking, although there is little information about how that experience contributed to the later SDC-LL experiments.

These IPTO-funded experiments were largely the result of IPTO directors' promotion of computer networking.

Why is this experiment not better known, since it used one of the first time-sharing systems? One answer is that it ended after its initial demonstration. Another is, as Clark Weissman wrote in his email, that the SDC system was intended as support for the R&D done at sites like SRI and Lincoln Lab, although it also did research on information retrieval. According to Weissman, the Q-32 system was a national resource that was used by a number of university researchers, generally through remote dial-up connections. While SDC people did publish several papers on time-sharing issues such as scheduling, they did not publish much on details such as the two-phone-line network setup.

The other two experiments used the 1966–1967 SDC-Lincoln Lab link. One was the trial of the simple communication protocol with the transcontinental telephone line. It led Roberts to become dissatisfied with its speed, cost, and reliability and thus contributed to finding a better approach. The third experiment was the actual use of the Q-32 Lisp software by the Lincoln Reckoner, as a demonstration of the utility of such networking. Although nothing was published about this use of remote software, it is arguably the most important of the three because it is an example of automatically invoking software on a remote computer and using its results locally. As far as I am aware, there were no further demonstrations of such use until after the Arpanet was set up in 1969.

These IPTO-funded experiments were largely the result of IPTO directors' promotion of computer networking. Some participants, such as Roberts, became interested through contact with Licklider, while others were pursuing their own projects: Bourne's work on information retrieval and Marill's search for a contract. To a large degree, the initial motivation for conducting network experiments was top-down; several accounts say that researchers with large computers were not immediately eager to share them. Histories that trace computer networking to the visions of a few people are thus more appropriate here than in many areas. Contingency certainly played a role as well—for example, the confluence of events and needs that led Baran and Davies to develop packet switching, Wesley Clark's idea of the IMP (Interface Network Processor) to simplify the Arpanet implementation, and the influence of Davies' group on Roberts at the 1967 Gatlinburg meeting when he presented the idea of the Arpanet. Perhaps the most important reason that the Marill-Roberts paper on their planned experiment is frequently cited as an account of the first long-distance computer network is that Roberts headed the Arpanet project shortly after its publication. As with so many questions of what was the first *X*, the story is complicated. The early and briefly successful SDC-SRI network may have influenced a possible initial two-line design of the later network with Lincoln Laboratory, which could then have been used to investigate how to use a single telephone line with a communication protocol—an example of how a project that did not itself continue might have contributed to a subsequent one.

Finally, a report of the graphics section of Lincoln Laboratory, where Roberts worked, described the use of the SDC Lisp by the Lincoln Reckoner:

> The network contractor [CCA] has been asked to investigate the service facilities needed to make this link useful to general users. Until the problems of documentation, service facilities and instructional methods are solved, it is unlikely that a remote networked computer will be of much practical value to the general user.[76]

We have not yet completely solved the problems of documentation and instructional methods, but the operation of the Arpanet and the Internet that followed it have shown that their facilities have indeed been of considerable practical value to a great many users.

Acknowledgments

I thank Ed Coffman, Bill Mann, Larry Roberts, Robert Taylor, and Clark Weissman for discussions of networking, and Charles Bourne and Len Chaitin for information about the SRI project. The Charles Babbage Institute staff provided a copy of the 50-year old CCA technical report, and the MIT Lincoln Lab archivist, Nora Zaldivar, provided the CCA memos. Comments by anonymous reviewers helped to improve the article.

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copy to Susan P.

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OFFICE OF THE ASSISTANT LIBRARIAN
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August 18, 1986

Dear Roger:

As chairman of the Library of Congress Network Advisory Committee (NAC) and on behalf of the committee's members, I am pleased to welcome DIALOG Information Services, Inc. as a new NAC member and Charles Bourne as their representative. Please be advised that each NAC member organization should also appoint an alternate who will be able to attend NAC meeting when the delegate cannot attend.

Our forthcoming meeting on the topic of networking directions 1986-90, to be held on December 10-12, 1986 at the Georgetown Hotel in Washington DC, will continue discussions begun at the July 1986 meeting. Charles will receive the registration mailing, together with appropriate background information, at the proper time.

I am looking forward to the contribution of your organization as a new member of the Library of Congress Network Advisory Committee.

Sincerely,

Henriette

Henriette D. Avram
Assistant Librarian for
Processing Services

cc. Bourne

Mr. Roger K. Summit
DIALOG Information Services, Inc.
3460 Hillview Ave.
Palo Alto, CA 94304

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COMMISSION ON INTERNATIONAL RELATIONS

June 2, 1976

Mr. Charles P. Bourne, Director
Institute of Library Research
University of California
Berkeley, California 94720

Dear Mr. Bourne:

You have been invited to become a member of a larger survey group consisting of yourself and Ghanaian counterparts representing the CSIR in Accra, to survey the existing information infrastructure of Ghana and to recommend improvements in the areas to be described. The Group Leader will be a Ghanaian whose name will be provided to you shortly. We, in concert with IDRC, are suggesting that you act as Spokesman for the non-Ghanaian members of the group. You are expected to arrive in Accra on July 5, 1976 and it is anticipated that your task will be concluded by July 24, 1976. Mr. Joel J. Lloyd will send you further information concerning your visa, travel, etc.

The group will be expected to examine the existing information institutions and mechanisms, with particular attention to those serving health, agriculture, industry, and the sociotechnical requirements of Ghanaian users. You will be expected to identify the missing elements and requirements of a comprehensive information system that can be reasonably created and installed in Ghana and will meet the needs of the country. In carrying out this charge, you will have access to the reports and recommendations made by earlier survey groups and consultants. Upon completion of your field studies, and before leaving Ghana, you are to complete, in collaboration with your Ghanaian counterparts, a summary report of your findings and proposals.

In writing this report, it should be kept in mind that the project was conceived as a step-program in which the present assignment represents the first phase. You may wish to recommend, if you consider it desirable, a week-long Workshop of Ghanaian and foreign experts to be held late this year. The Workshop might be followed by longer term visits to Ghana by information specialists in each of the areas in which you have been asked to concentrate. It is not our intention, however, to pre-influence the recommendations of your report.

Sincerely,

Don Fink

D. Fink
Chairman
Committee on International Scientific
and Technical Information Programs

cc: S. Akhtar (IDRC), L. Burchinal, W. Copeland, P. Judge, J. Lloyd,
A. Neelameghan, E. Pronko, E. C. Rowan

SOURCE: CPB ~~25 MAY~~ 19 NOV 63

TITLE: Bibliography on User Requirements for Information

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Sample Report for File Input

ABSTRACT: A preliminary list of references to papers and reports that contain some information regarding the use of information, and users' requirements for information.

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TITLE: Bibliography on User Requirements for Information

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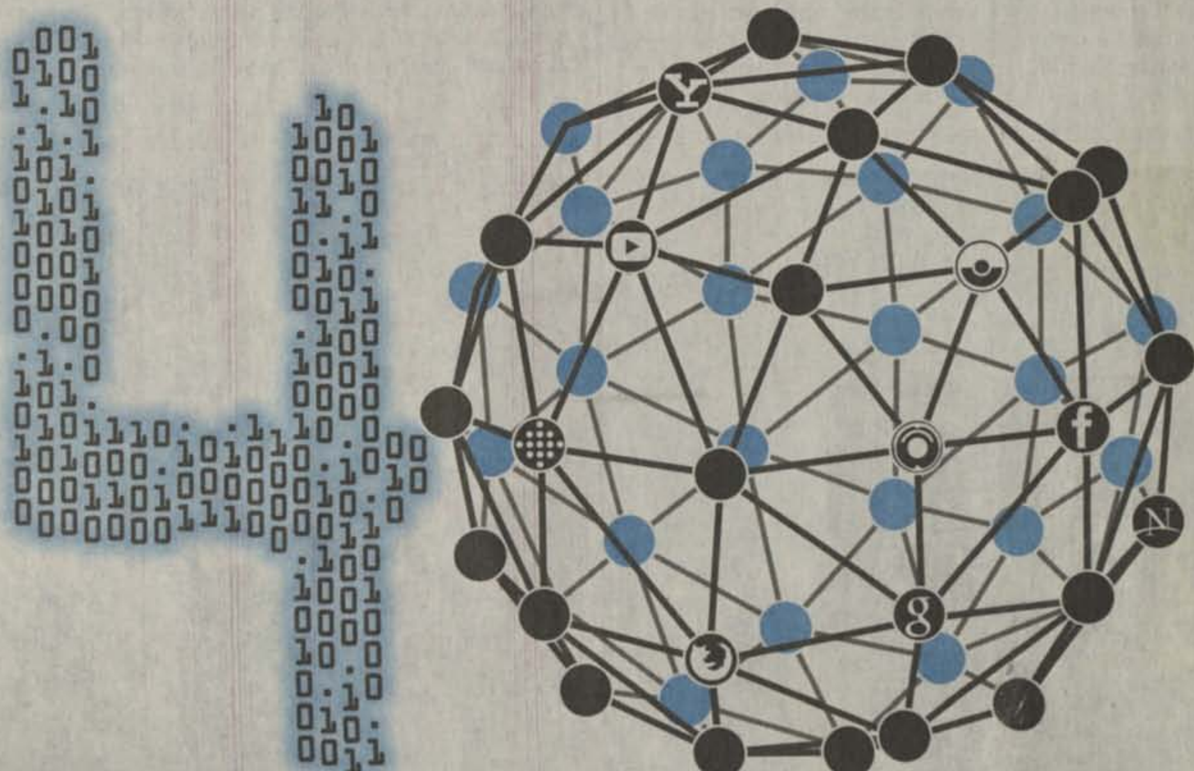
4 decades after a computer in the Bay Area connected to one in Boston, the effect of the Internet on our lives is hard to overstate



John Blanchard / The Chronicle

By Jessica Floum

It all started at the Alpine Inn Beer Garden, a biker bar in Portola Valley better known to regulars as Rossotti's, or just Zott's.

On Aug. 27, 1976, a team led by Don Nielson, then assistant director of telecommunications at Menlo Park engineering firm SRI International, drove a specially equipped van 6½ miles south and parked at Zott's. They ran a cable from the van's radio to a computer set up at a picnic table out back and used the radio to connect to another computer at the SRI office and on to Boston. The Internet was born.

Forty years later, people read the news on their phones, book beds in strangers' homes, stalk their friends on Facebook, post videos on YouTube, program their vacuuming robots and fitness-tracking watches, and chase invisible monsters through city streets. They also get hacked, spammed and harassed on a scale unimaginable at Zott's in the '70s, when the worst thing that might happen was getting cussed out for touching the wrong character's motorcycle.

> **The Internet "was the abolition of distance as a constraint on communication."**
>
> *Richard Bennett, 1970s software developer*

The digital future, with all its risks and opportunities, began to unfold that August day. But it was hard to imagine that at the time, even for Nielson.

"It is just too easy for people to think this was the beginning of the Internet," Nielson wrote in an email. "It is nice to see the event noted, but the capital-I Internet is so very much more."

Without the capital I, an internet is just a network of networks — more than one network connected together. That August day was actually among three contenders for the birth of the Internet — the network that, 40 years later, spans the globe and defines modern life.

In November 1977, Nielson's team did another test that showed even more promise. They successfully connected their packet radio in the van to computers in Los Angeles and London.

That, Nielson said, "illustrated with certainty that you could internetwork any place in the world. Distance was no longer an obstacle."

Internet continues on A9

FROM THE COVER

As Internet turns 40, a look at its earliest days

Photo courtesy Don Nielson

On Aug. 27, 1976, a team of researchers from SRI International sent what some believe is the first Internet transmission from the Alpine Inn Beer Garden in Portola Valley, popularly known as Rossotti's, or Zott's.

Internet from page A1

In the 1970s, Nielson's team used the still-experimental Transmission Control Protocol and Internet Protocol to run their tests of what would one day become the modern Internet. That network would get far bigger in 1983, when the Department of Defense switched its research network, Arpanet, to run completely on TCP/IP.

As the Internet was getting its footings in the '80s, Richard Bennett was developing networking software for Texas Instruments. The company had a corporate network connecting 70,000 employees and an internal electronic mail system.

Larry Downes was also experimenting with an external mail system at his job at Andersen Consulting, now known as Accenture. He thought the Internet was an "academic toy" that showed no commercial potential. It was clunky and difficult to use.

Downes, and many other doubters along the way, would soon be proved wrong.

In 1991, Sen. Al Gore of Tennessee sponsored a law that allowed for commercial use of the Internet. (In a 1999 interview with CNN, Gore described his role as taking "the initiative in creating the Internet," a statement that drew widespread ridicule.) UUNet, PSINet and Sprint emerged as some of the earliest Internet service providers.

The same law also helped fund the National Center for Supercomputing Applications, which opened a site at the University of Illinois at Urbana-Champaign. There, a graduate student named Marc Andreessen decided to build a browser for the World Wide Web, a system created by European researcher Tim Berners-Lee, which let people access words and images stored on any other Internet-connected machine.

Downes remembers seeing Andreessen demonstrate his Web browser, Mosaic, at an industry conference in the early '90s. His presentation "blew everyone's mind," Downes said.

"The audience went berserk," Downes said. "There was this moment where everyone realized everything we knew about computing was about to be undone, tossed and remade."

Andreessen's work on Mosaic led to Netscape, whose initial public offering in August 1995 kicked off the dot-com boom and put Web browsers on millions of computers. For many businesses and consumers, access to the Web was the main reason to get on the Internet in the first place. Yahoo, Excite, Infoseek and other Web portals followed. Google, started as a research project by Larry Page and Sergey Brin at Stanford in 1997, would eclipse them all.

Google, which allowed anyone to find almost any information stored on the Web, was an example of the Internet's purpose, said Bennett: "It was the abolition of distance as a constraint on communication."

In 1980, Paul Vixie dropped out of San Francisco's George Washington High School so he could program instead of going to class. Despite his lack of a diploma, he got a job at Digital Equipment Corp., where he worked on connecting DEC's network with the rest of the world.

James Tensuan / Special to The Chronicle

A plaque at the Alpine Inn notes the start of the Internet age in Portola Valley, where scientists sent a message to Boston from a computer behind the inn.

"Even though I was an employee at this company, I felt a greater affinity for the larger Internet community," Vixie said. "We had broadened our clan, and that was fun."

Vixie started getting emails from people in other countries as they, too, joined the Internet.

"This was also very exciting," Vixie said. "It became this global force without any government assistance. It was a whole bunch of people saying, 'Hey, let's talk to each other more.' "

Vixie loved that people could use the Internet to learn about people and cultures they didn't know.

"Humanity was trying to progenerate a collective digital nervous system and become a group mind," Vixie said.

But that nervous system would get infected. "Spam was waiting in the wings," Vixie said.

He entered a fraught battle with Sanford Wallace, the self-acclaimed "Spam King." After getting kicked off of every Internet service provider for sending spam, Wallace created a program in 1995 where he would give people free computers and an Internet connection so long as he could use their connection to send spam.

Frustrated, Vixie started the first antispam company, MAPS, the next year and shut down Wallace's operation, Cyber Promotions. He's spent the past 15 years at various companies trying to prevent unwanted communication — spam, hate speech, malware — for which he feels vaguely responsible.

"The Internet was never anybody's to control," Vixie said. "Nobody could have forced it to be one way or another. I would have paved a few roads differently if I knew how big it was going to get."

Spam has also spurred regrets for Nielson. The cost, he says, is incalculable.

"You can't put the genie back in the bottle very easily," said Nielson. "I can feel awkward and regretful about that."

Yet, he thinks the efficiency the Internet created has a "net positive effect."

"It's enormously powerful and pervasive and good," he said. "That doesn't mean it's perfect by any means."

"The main thing to appreciate is, the Internet is only 40 years old," Bennett said. "It's got a lot of life left in it. We've seen some pretty good hints of what it's capable of. We should prepare to be amazed."

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Charles P. Bourne

Mr. Bourne's current efforts are directed at using basic motion and time study principles for computer simulation and analysis of man-machine systems. He is also studying ways in which the equivalent of motion and time study techniques might be used to improve the efficiency of an individual's performance for mental tasks in the same way that it has helped with manual tasks.

In 1957 Mr. Bourne became a Research Engineer on the staff of the Institute. He has participated in a government project to investigate storage, retrieval, and reproduction techniques for a file of several million engineering drawings; engineering and operational evaluations of several new digital computer systems for various computer manufacturers; technical planning for digital computer installations; and a government project to design a comprehensive mechanized system for accumulating, reviewing, disseminating, storing, and retrieving abstracts of European technical literature. He also supervised the operation and programming effort for a large digital computer system currently used as part of a military reconnaissance system. He has provided product planning assistance for commercial information retrieval equipment, and has conducted system studies for the design of a very large associative memory for information retrieval problems. He has provided technical assistance in the design of the data processing and display portions of a world-wide bomb damage assessment center for the joint military services, and has also assisted in the evaluation of the data processing and display portions of a large air defense system. He has worked on pattern recognition and the processing of graphic information with digital computer techniques, as well as methods for automatically abbreviating and coding English text material. He has recently worked for the National Science Foundation on a study to determine requirements, criteria, and measures of performance of information storage and retrieval systems. He is currently working on cost analysis and simulation techniques for application to complex information systems. He is also studying the nature and extent of the practice of publication in microform. He is presently working on a task force of the National Academy of Sciences to study the overall information problems of people engaged in bio-medical research.

Mr. Bourne received a B.S. degree in Electrical Engineering from the University of California in 1957, specializing in digital computer design. In 1962, he received an M.S. degree in Industrial Engineering at Stanford University, specializing in data processing and motion and time studies.

Mr. Bourne has written several articles for technical journals, dealing with computers, information retrieval, and technical information problems. He is a member of the Institute of Radio Engineers, the American Documentation Institute, the National Microfilm Association, and the Association for Computing Machinery. He is currently a member of the Editorial Board and Executive Council of the American Documentation Institute, and co-editor of the journal, American Documentation.

Mr. Bourne also holds the post of Lecturer at the University of California School of Librarianship.

SURVEY OF THE UTILIZATION OF MECHANIZED IMAGE SYSTEMS

Charles P. Bourne*

ABSTRACT

The mechanized image storage and retrieval systems that have been developed to date are briefly reviewed and comments made on the number of instances and ways in which the equipment has actually been put into operation for a real application. The number of actual installations is found to be relatively small. Some suggestions are made to explain why these systems have not been more widely accepted.

INTRODUCTION

The technical and commercial community seems to be faced with an unusual and perhaps paradoxical situation. On one hand, we are faced with expanding paper work and problems of information management for business notes as well as published literature. We have many spokesmen proclaiming and describing the "information crisis" or "paper storm," and we see a flurry of activity by manufacturers and researchers to develop new equipment and techniques for application to these problems. On the other hand, we see a situation in which only a very small number of systems have actually been installed as operating systems. The explanation of this paradox seems to lie in the fact that most of the equipment, as presently designed, does not have the cost or performance factors that satisfy the present user needs. This point is discussed in more detail in the following sections, with particular attention to the mechanized image systems.

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*Stanford Research Institute, Menlo Park, California.

DESCRIPTION OF CURRENT MECHANIZED IMAGE SYSTEMS

A large number of mechanized image systems have been proposed. Only a fraction of these have been built and demonstrated, and an even smaller fraction has actually been delivered to a customer for actual use.* A good summary description of the characteristics of most of these systems in development or in use is given in a recent report by the National Bureau of Standards [1]. Consequently, there is no need to repeat that detailed information here. However, it is of interest to note some of the different systems that have been proposed:

System	Manufacturer or Developer
Automatic Image Retriever	Houston-Fearless Corporation
CRIS	Information Retrieval Corporation
Filesearch	FMA, Inc.
Filmorex	J. Samain
FLIP	Benson-Lehner Corporation
Lodestar with counting accessory	Recordak Corporation
Magnavue	Magnavox Corporation
Media	Magnavox Corporation
Metricard	Thompson Ramo-Wooldridge, Inc.
Minicard	Recordak Corporation
RADIR	Hallicrafters Company
Rapid Access Look-Up System	Ferranti-Packard
Rapid Access Look-Up System	National Bureau of Standards Engineering Research Associates Yale University
Reader-Finder	Massachusetts Institute of Technology
Verac 903	AVCO Corporation
Videofile	Ampex Corporation Radio Corporation of America
Walnut	IBM Corporation

*This paper has restricted its attention primarily to the larger mechanized image systems, and has not considered the simple motorized film viewers (e.g., Recordak Lodestar) to be in this category.

SALES AND ACCEPTANCE TO DATE

There have been at least ten manufacturers that have marketed arge mechanized image systems, some of them for over five years. Iowever, since 1957, the total number of these units sold in the Jnited States has been just a little more than the total number of competing manufacturers. Estimates of the unit and dollar sales volumes of several manufacturers are given in Figure 1, along with an indication of the date on which their equipment was first publicly described. This illustration lists only the models of equipment that were known to have been delivered to at least one customer, and are in present use. In that sense, it represents a list of the "successful" manufacturers. The data in Fig. 1 on prices, total sales volumes, and number of installations has been verified by some of the manufacturers. However, not all of the manufacturers would furnish this data, and estimates were used instead. Figure 1 shows an estimated total United States sales of approximately $6 million since 1957. This amounts to an equivalent annual sales volume of approximately $1 million per year, which is a small fraction of the estimated current microfilm equipment sales of $20 million per year.

Of all the systems described in Fig. 1, only the Magnavox Media and Ferranti-Packard Rapid Access Look-Up Systems have been installed in commercial organizations. All of the other systems have been installed in Federal government agencies. This means that to date, only $0.3 million worth of mechanized image systems have been sold and put into operation in private commercial organizations. Although there are a few additional systems on order, this is an extremely small number in relation to the amount of attention given the information problem and the efforts that have been expended by the manufacturers. Significantly, there have been no commercial installations in the 2,000 college and university libraries, the 1000 specialized technical information centers, or any other form of information center.

The equipment sold to commercial organizations has been used almost entirely for business record keeping and processing. Seven of the Ferranti-Packard units are used at Ellicott Drug Company in Buffalo, New York to call up RAMAC numbers assigned to a 25,000-item drug product inventory. One of the present media installations is at the International Association of Machinists in Washington, D.C., for membership dues records, correspondence files, and strike check records. The other media installation is at the Home Insurance Company in New York, for daily report records and other files within their home office.

System	1957	1958	1959	1960	1961	1962	1963	Est. No. of Units Installed & Operating	Approximate Unit Price	Total U.S. Sales (Est.)
Filmorex (1952)								15 (1 in U.S.)	$ 7,500	$ 10,000
FLIP (Benson-Lehner)		Δ						3	75,000	225,000
Minicard (Eastman-Kodak)		Δ						4	> 1,000,000	4,000,000
Rapid Access Look-Up System (Ferranti-Packard)				Δ				9	17,000	150,000
Walnut (IBM)					Δ			1	> 1,000,000	1,000,000
Media (Magnavox)					Δ			2	36,000	175,000
Filesearch (FMA, Inc.)					Δ			3	143-157,000	445,000
										$6,005,000

NOTE: These units represent the models of mechanized image systems that have been delivered to at least one customer, and are in present use.

Figure 1. Sales and Market Entry Date of Major Mechanized Image Systems.

There is very little information available primarily because of security restrictions, to describe how the equipment is being used in the government installations. The single U.S. Filmorex installation at the USAF Rome Air Development Center is being used in an experimental manner for searching document and report files. The FLIP equipment was used primarily to search files of recorded instrumentation data, rather than files of documents. Two File-search systems are installed in the Central Records Section of the USN Bureau of Ships to store and search a collection of Navy directives. One other Filesearch system is being used in a classified Air Force application. The location, cost, and application of the Minicard and Walnut systems have been designated as classified information.

As a side note, it might be mentioned that in contrast to the slow acceptance of the large systems, there has been a much more enthusiastic reception of the relatively small mechanized image systems, such as the Recordak Lodestar and Starlet readers. No exact figures have been released by the manufacturers, but it is estimated from other sources that there may be several thousand such units in operation today.

POSSIBLE REASONS FOR THE SLOW ACCEPTANCE

Many suggestions or comments can be made as to why this kind of equipment has not been more commercially successful. The suggestions in this paper are based primarily on personal observations and studies of present and proposed equipment of this type, as well as discussions with a number of representative users. They can only be considered as preliminary suggestions, or hypotheses, and not conclusions, since they are based on a somewhat limited amount of information. All of the following points of criticisms do not necessarily apply to all systems, although each system can generally be criticized on several points. In general, the problem or criticism seems to stem from three general areas:

(1) System economics;
(2) Performance characteristics; and
(3) Customer service.

System Economics—It seems that in most cases, the user has alternative approaches that are economically more attractive than the use of large mechanized image systems. In many cases, the user's most attractive alternative is to continue with his present method. This cost disadvantage is partly due to the relatively high cost of the equipment, but it is also due to the high conversion and operating costs of mechanized systems. For some of the large manual file systems currently in operation, for example, conversion costs would be on the order of a million dollars—mainly to develop the data base needed for the mechanized system. There do not appear to be many applications that can show a direct cost saving that would justify the change-over to a mechanized image system.

Performance Characteristics—With regard to desired performance characteristics, the system designer has been at a distinct disadvantage because of the fact that, for security and other reasons, there has been very little information available to describe how well the present systems are operating, what their shortcomings might be, and what improvements would be desirable. There is very little feedback from the present operating systems to guide the development and improvement of subsequent systems. Consequently, the equipment designers have not always developed equipment that adequately reflects the users' needs. In fact, many users could not use the presently available equipment—even if it were given to them free of charge. This is because the equipment, operating as a complete system, will not provide the necessary performance with regard to such quantitative characteristics as update cycle time, individual search response time, and daily volume of search requests. Many of the systems also fail to meet the desired performance requirements with regard to such subjective characteristics as ease and speed of error correction and file maintenance, ease and speed of access for single or multiple users for parallel searching or browsing, convenience to the users of the forms and media of the search products, capability to handle a variety of forms and types of input materials, and ease and speed of framing a search question for the system. In addition, the mechanized systems ordinarily perform only the central functions of storage and retrieval, whereas most applications require a variety of other functions (e.g., sorting, merging, listing). Several of the mechanized systems can conduct rather complex search questions with their built-in logical capability, but not all large image files need this capability. And those that could use this capability probably could still achieve it to an acceptable degree with an expansion of their present manual system.

One further shortcoming of most present mechanized systems is their limited capability to incorporate a variety of classification or indexing systems. This makes the equipment very inflexible for many users.

Customer Service—If the equipment is purchased as a means of solving a particular operational problem within an organization, then the prospective user expects to receive assistance in system design and conversion, personnel training, and possibly other assistance, such as service bureau facilities for file conversion. Manufacturers have not always offered or provided these services in the past, and have perhaps alienated some prospective customers as a result.

If the equipment is to be sold as part of an information system, then the user will look to the manufacturer with the hope that the information and the equipment can be obtained from the same source. This hope is being realized, indirectly, with several commercial catalog publishers, who are selling a package consisting of microform equipment as well as information in microform (e.g., military specifications or technical literature). However, few of the manufacturers have made arrangements to provide files of indexed microform of material of interest to many users, to accompany the equipment. It would seem to be extremely useful, for example, for an equipment purchaser to be able to obtain an indexed microform copy of such things as all the U.S. patents, or a copy of current ASTIA technical reports, that could be used on his equipment. This would be analogous to the present software situation in the data processing field, where a computer owner can obtain other people's programs from the manufacturer or a user group, and not have to develop the material himself. This can save the user a considerable amount of time and money. Part of the difficulty in developing microform software has been the copyright problem. However, there would still seem to be a large body of un-copyrighted material of interest to many users that could be provided with the image handling equipment. In any case, the equipment manufacturers have not made any significant steps to provide this type of microform software.

CONCLUSIONS

In spite of the great amount of publicity and activity devoted to the information problem and the use of mechanized information and image handling systems, there has been very limited user acceptance of this type of equipment, especially in non-government installations. One important difficulty seems to be the fact that the equipment generally cannot demonstrate a direct cost saving. One further difficulty seems to be the fact that the equipment designers have for the most part have either designated their systems to meet the requirements of a particular user's problem, or have not been completely aware and appreciative of the true operational needs of the potential users. Consequently, the equipment cannot meet the basic needs of large user groups.

REFERENCE

1. Bagg, T. C. and M. E. Stevens, "Information Selection Systems Retrieving Replica Copies: A State-of-the-Art Report" Tech. Note 157 of the National Bureau of Standards (December 31, 1961). 311 ref. (This report is available from the U.S. Government Printing Office for $1.25.)

Question and Answer Period:

N. Stahl - Emerson Consultants

Q. What was the name of the book that you referred to?
A. This is a report by Bagg and Stevens called "Information Selection Systems Retrieving Replica Copies, A State of the Art Report" Technical Note 157, National Bureau of Standards, available from the U. S. Printing Office for $1.25.

Heilprin - Council of Library Resources

Q. Assuming that you have analyzed that the reasons for a rather slow start, do you feel that there is a tendency among manufacturers, particularly of the bigger systems, to orient themselves to smaller systems? In other words, do you consider that this situation is likely to change?
A. In the exhibits of this convention I see evidence of continuing interest by manufacturers in developing mechanized image handling systems. However, the emphasis seems to have shifted to the development of more modest systems than have been proposed in the past. We see Recordak, for example now proposing a much more modest system than their earlier Minicard. It would be my guess that this is the route that people will take. I would guess that there will still be a few places where large mechanized image handling systems would be in order, but I think that most of the activity, as far as the market is concerned, would probably take place with the relatively small systems.

N. A. Vogel - Session Chairman

Any further questions? If not, I am going to take the liberty to make an observation, particularly in the light of the identity of the last questioner. Let's look back a little over a decade to another business, the computer business. It had a history

SURVEY OF THE UTILIZATION OF MECHANIZED IMAGE SYSTEMS

Charles P. Bourne

Stanford Research Institute
Menlo Park, California

ABSTRACT

The mechanized image storage and retrieval systems that have been developed to date are briefly reviewed and comments made on the number of instances and ways in which the equipment has actually been put into operation for a real application. The number of actual installations is found to be relatively small. Some suggestions are made to explain why these systems have not been more widely accepted.

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(Exclude simple motorized film viewers)

DESCRIPTION OF CURRENT MECHANIZED IMAGE SYSTEMS

A large number of mechanized image systems have been proposed. Only a fraction of these have been built and demonstrated, and ... even smaller fraction has actually been delivered to a customer for actual use.* A ... summary description of the characteristics of most of these systems in development or in use is given in a recent report by the National Bureau of Standards.[1]

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RADIR	Hallicrafters Company
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Rapid ~~Access Look-Up System~~ Selector	National Bureau of Standards Engineering Research Associates Yale University
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One further shortcoming of most present mechanized systems is their limited capability to incorporate a variety of classification or indexing systems. This makes the equipment very inflexible for many users.

Customer Service--If the equipment is purchased as a means of solving a particular operational problem within an organization, then the prospective user expects to receive assistance in system design and conversion, personnel training, and possibly other assistance such as service bureau facilities for file conversion. Manufacturers have not always offered or provided these services in the past, and have perhaps alienated some prospective customers as a result.

If the equipment is to be sold as part of an information system, then the user will look to the manufacturer with the hope that the information and the equipment can be obtained from the same source. This hope is being realized, indirectly, with several commercial catalog publishers, who are selling a package consisting of microform equipment as well as information in microform (e.g., military specifications or technical literature). However, few of the manufacturers have made arrangements to provide files of indexed microform of material of interest to many users, to accompany the equipment. It would seem to be extremely useful, for example, for an equipment purchaser to be able to obtain an indexed microform copy of such things as all the U.S. patents, indexes to Chem Abstract or a copy of current ASTIA technical reports, that could be used on his equipment. This would be analogous to the present software situation in the data processing field, where a computer owner can obtain other people's programs from the manufacturer or a user group, and not have to develop the material himself. This can save the user a considerable amount of time and money. Part of the difficulty in developing microform software has been the copyright problem. However, there would still seem to be a large body of un-copyrighted material of interest to many users that could be provided with the image handling equipment. In any case, the equipment manufacturers have not made any significant steps to provide this type of microform software.

CONCLUSIONS

In spite of the great amount of publicity and activity devoted to the information problem and the use of mechanized information and image handling systems, there has been very limited user acceptance of this type of equipment, especially in non-government installations. One important difficulty seems to be the fact that the equipment generally cannot demonstrate a direct cost saving. One further difficulty seems to be the fact that the equipment designers have for the most part have ~~either~~ designed their systems to meet the requirements of a ~~particular~~ single user's problem, or have not been completely aware and appreciative of the true operational needs of the potential users. Consequently, the equipment cannot meet the basic needs of more ~~large~~ general user groups.

— END —

REFERENCES

1. Bagg, T.C. and M.E. Stevens, "Information Selection Systems Retrieving Replica Copies: A State-of-the-Art Report" Tech. Note 157 of the National Bureau of Standards (December 31, 1961). 311 ref. (This report is available from the U.S. Government Printing Office for $1.25.)

System	1957	1958	1959	1960	1961	1962	1963	Est. No. of Units Installed & Operating	Approx. Unit Price	Total U.S. Sales (Est.)
Filmorex (1952)								15 (one in U.S.)	$7500	$ 10,000
FLIP (Benson-Lehner)		△						3	75,000	225,000
Minicard (Eastman-Kodak)		△						4	>1,000,000	4,000,000
Rapid Access Look-Up System (Ferranti-Packard)				△				9	17,000	150,000
Walnut (IBM)					△			1	>1,000,000	1,000,000
Media (Magnavox)					△			2	36,000	175,000
Filesearch (FMA, Inc.)					△			3	143-157,000	445,000
										$ 6,005,000

NOTE: These units represent the models of mechanized image systems that have been delivered to at least one customer, and are in present use.

Figure 1

Sales and Market Entry Date of Major Mechanized Image Systems

benson-lehner *corporation*

March 12, 1963

Mr. Charles P. Bourne, Research Engineer
Stanford Research Institute
Menlo Park, California

Dear Charlie:

Please forgive me for being so late in answering your letter concerning our modest experience in the information retrieval field.

With regard to the Filmorex, we have made no announcement of this equipment in America and at this time there are no plans for pursuing it since we have had problems in the operation of the machine. We have some product ides that I would like to discuss with you in the not too distant future, which could possibly take the place of Filmorex and many other machines being marketed.

I do not think our experience on the FLIP will be too helpful to you as there have been only three machine sold, and all to the military. We have none on order at this time nor do we expect to receive any orders for this equipment. As you know, this is a rather limited system and is extremely expensive. The units sold for approximately $75,000 each. As they were military in nature, I cannot tell you anything about the applications or the conversion costs.

In my opinion, Charlie, the reason that this kind of equipment has not been sold more extensively is due to its limitations and cost. It seems to me that the broad market of information retrieval, outside of the computer field, is yet to be filled. Our thinking is that an aperture card system with a relatively low cost retriever would be well accepted.

Sorry I couldn't be of more help to you.

Cordially,

BENSON-LEHNER CORPORATION

George

G. M. Ryan
President

GMR:adc

14761 Califa Street, Van Nuys, California
Telephone 781-7100 Cable Address: BENSON Los Angeles

Feb 18, 1963

Dear____________

For a special review paper for the National Microfilm Association's 12th Annual Convention in San Francisco next May, I am trying to review the progress (or lack of it) that has been made to date in the installation and use of mechanized image handling systems. Hopefully, the review will be able to summarize some factual data such as the number and type of installations made to date, as well as some of the cost data. In addition, some comments may be in order to suggest why there hasn't been more widespread acceptance and use of this type of equipment.

Since you are a knowledgeable representative of one of the major companies in this field, I thought that you might be able to provide me with some of this information. The information would be used in this review paper and published in the open literautre. I would be particularly interested in the answers to the following questions with regard to your________________ equipment.

1. Date of first public announcement:
2. Number of units installed:
3. Number of units on order:
4. Total dollar sales for units installed:
5. Location of the installations:
6. Types of files or applications that this equipment is being used for:
7. Conversion cost (per image or per page) to build up the machine file:
8. Types of software or services provided with the equipment:

If at all possible, I would like to have the information by March 1. To ensure accuracy and proper reporting I would prefer to have the information directly from the source, rather than assembling it in bits and pieces from previously published information and less reliable sources. That is precisely why I am writing to you.

I look forward to hearing from you.

Sincerely,

CPB

CABLE ADDRESS
KORECORDAK-NEW YORK

RECORDAK CORPORATION

TELEPHONE
SPRING 7-0110
AREA CODE 212

SUBSIDIARY OF EASTMAN KODAK COMPANY

EXECUTIVE OFFICES
770 BROADWAY · NEW YORK 3, N. Y.

March 4, 1963

Mr. C. P. Bourne
Research Engineer
Stanford Research Institute
Menlo Park, California

Dear Mr. Bourne:

Henry Jasper, Systems Representative of the Eastman Kodak Company, has referred to me your letter of February 15 with the request that I attempt to answer the questions you have listed. I am pleased to give you as much information as I can.

Relative to the date of the first public announcement of the Minicard System, I cannot be certain of this without some research through Eastman Kodak Company and in the interest of replying quickly, I did not pursue this. Perhaps you can discover information at the Stanford Research Institute which would help you, since Stanford Research Institute prepared "a preliminary study of the applicability of the Minicard System to Business Data Handling" in May of 1956 under S. R. I. Project No. I-1560. At least this is a tentative date when some sort of public announcement was made by reason of your study.

As to the Recordak Lodestar Reader the news release on it is dated March 1959 and on the Recordak Starlet Reader the news release is dated April 1961.

As to the number of units installed, the Minicard System is installed in the Federal Government in highly classified areas and we are not permitted to discuss where or how many units have been installed and the type of file or application for which this equipment is being used.

As to the Lodestar and Starlet Reader installations, these number in the thousands and it would be impractical to list the actual number or the location of such installations. The largest single users are Sears, Roebuck & Co. in their stores nationwide and the Social Security Administration in Washington, D. C. In addition extensive use is made by Information Handling Services in Denver, Colorado in a variety of programs dealing with vendors specifications. These installations, for Information Handling Services, involve not only the basic Lodestar Reader but also the Lodestar Reader-Printer.

As to the number of units on order we still have several contracts which require continuing installations and new applications are being developed which hold great promise for the future. Suffice it to say we are in a back order position.

We are not permitted to discuss the total dollar sales for units installed, I am sorry but this is company confidential information.

The types of files or applications where this equipment is being used, will of necessity have to be confined to the Lodestar or Starlet Reader applications. As mentioned above Minicard installations are considered highly confidential. The Lodestar and Starlet Readers are used in a variety of applications, but primarily the largest quantity are being used in the systems for disseminating information on parts lists, vendors specifications, correspondence files and a wide variety of similar types of installations.

To give you any estimate of the conversion cost per image or per page to build up a machine file is completely impractical. Too much depends on the nature of the file, the indexing required, the preparation of the media for microfilming, etc. I think it is appropriate to say that the system stands economic justification and perhaps this is the most important factor.

Recordak Corporation offers systems analysis, where required, and installation assistance on any of its microfilming systems.

Recordak Corporation will present a paper at the National Microfilm Association Annual Convention in San Francisco in May 1963, which carries the Recordak Lodestar Reader, and film in magazine concept, another step forward.

I hope the above information has been helpful and regret that, in the interest of getting this much to you quickly in view of your deadline of March 1, I am unable to amplify it to any greater extent. I only received your letter this morning and am in haste to get you this much.

With kindest regards.

Sincerely yours,

JP Eager

JPE:st

John P. Eager
Vice President

cc: Mr. H. E. Jasper, Eastman Kodak Company, Washington

Feb 18, 1963

Dear____________

For a special review paper for the National Microfilm Association's 12th Annual Convention in San Francisco next May, I am trying to review the progress (or lack of it) that has been made to date in the installation and use of mechanized image handling systems. Hopefully, the review will be able to summarize some factual data such as the number and type of installations made to date, as well as some of the cost data. In addition, some comments may be in order to suggest why there hasn't been more widespread acceptance and use of this type of equipment.

Since you are a knowledgeable representative of one of the major companies in this field, I thought that you might be able to provide me with some of this information. The information would be used in this review paper and published in the open literautre. I would be particularly interested in the answers to the following questions with regard to your________________ equipment.

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If at all possible, I would like to have the information by March 1. To ensure accuracy and proper reporting I would prefer to have the information directly from the source, rather than assembling it in bits and pieces from previously published information and less reliable sources. That is precisely why I am writing to you.

I look forward to hearing from you.

Sincerely,

CPB

EASTMAN KODAK COMPANY
APPARATUS AND OPTICAL DIVISION
400 PLYMOUTH AVE. N. ROCHESTER 4, NEW YORK

PLEASE ADDRESS REPLY TO:
WASHINGTON OFFICE
1015 WISCONSIN AVE.
WASHINGTON 7, D. C.

WASHINGTON
TELEPHONE:
FEderal 3-7900

March 1, 1963

Mr. Charles P. Bourne
Research Engineer
Stanford Research Institute
Menlo Park, California

Dear Charles:

Through an unfortunate delay in intra-company mail forwarding, your letter of February 15, 1963, addressed to me in Rochester, just arrived on my desk in Washington, D. C. this morning.

As a systems engineer type, I do not readily have available to me the comprehensive sales-type information you need on the number, location, dollar value, etc., of microfilm image retrieval systems installed or on order throughout the United States. Also, the kind of information which you are seeking as answers to the questions in your letter, properly should come from Recordak Corporation which is the marketing organization of Eastman Kodak Company for information retrieval systems and microfilm and photocopying equipment. Accordingly, I am forwarding your letter to Mr. John P. Eager, Vice President and Sales Manager, and also Director of Product Administration for the Recordak Corporation.

Although Mr. Eager will have the full story, I might mention that from all indications there is widespread acceptance of the magazine film concept in microfilm information retrieval systems in both Government and industry. There are Recordak automated information retrieval systems using magazine film with either visual code lines (Kodamatic indexing), image control, or binary code on microfilm which are in operation today for a wide range of applications. Some of the systems which come to mind are those in Sears, Roebuck Company stores (nationwide), in the Social Security Administration (Baltimore, Md.), in the Office of Naval Intelligence (Washington, D. C.), and the VSMF microfilm catalog file service (Information Handling Services, Inc., Denver, Col.).

It was nice hearing from you and I am sure that Mr. Eager will be able to comply with your request for factual information especially in view of your personal interest and research and writings on the state-of-the-art of mechanized information retrieval systems.

Sincerely yours,

Henry E. Jasper

Henry E. Jasper

cc: J. P. Eager

EASTMAN KODAK COMPANY
APPARATUS AND OPTICAL DIVISION
400 PLYMOUTH AVE. N. ROCHESTER 4 NEW YORK

PLEASE ADDRESS REPLY TO:
WASHINGTON OFFICE
1015 WISCONSIN AVE.
WASHINGTON 7, D. C.

March 1, 1963

Mr. John P. Eager
Vice President
Recordak Corporation
770 Broadway
New York 3, New York

Dear Mr. Eager:

Enclosed is a letter which I have just received from Mr. Charles P. Bourne, Stanford Research Institute, who is seeking factual information on the utilization of microfilm information retrieval systems. Also enclosed is a copy of my interim reply to Mr. Bourne wherein I have advised him that his request for information was being forwarded to you for answers to his questions.

By way of background information for you, Mr. Bourne is the author of a number of papers and study reports on the general subject of information storage and retrieval systems and is a bibliographer on the mechanization of information retrieval. Mr. Bourne is also a member of the Council of the American Documentation Institute. Among some of his published works are:

"The Historical Development and Present State-of-the-Art of Mechanized Information Retrieval Systems", American Documentation (April 1961).

"Requirements, Criteria, and Measures of Performance of Information Storage and Retrieval Systems", Final Report for NSF on SRI Project 3741, Stanford Research Institute (December 1961).

"A Review of the Methodology of Information System Design", Information Systems Workshop (Based on a conference sponsored by the ADI and UCLA under support of a grant from NSF and NASA, May 29-June 1, 1962).

I am sure that you will want to provide Mr. Bourne with substantial and factual information that there is an ever increasing acceptance and use of microfilm storage and retrieval systems to ensure accuracy and proper reporting in his special review paper for the NMA Annual Convention in San Francisco.

Very truly yours,

Henry E. Jasper

Henry E. Jasper
Research and Engineering

cc: Charles P. Bourne

15
Feb ~~18~~, 1963

Dear______________

For a special review paper for the National Microfilm Association's 12th Annual Convention in San Francisco next May, I am trying to review the progress (or lack of it) that has been made to date in the installation and use of mechanized image handling systems. Hopefully, the review will be able to summarize some factual data such as the number and type of installations made to date, as well as some of the cost data. In addition, some comments may be in order to suggest why there hasn't been more widespread acceptance and use of this type of equipment.

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I look forward to hearing from you.

Sincerely,

CPB

IBM

Advanced Systems Development Division
Monterey & Cottle Roads
San Jose 14, California

International Business Machines Corporation

~~XXXXXXXX~~
227-7100

February 25, 1963

Mr. C. P. Bourne
Research Engineer
Stanford Research Institute
Menlo Park, California

Subject: Information for your review paper per your request to Mr. N. Vogel of IBM.

Dear Mr. Bourne:

Your letter to Mr. Vogel has been referred to me, as Mr. Vogel is now the Manager of our East Coast Systems Laboratory and no longer connected with Project Walnut.

I will answer your questions in the order you have asked them. Each of these responses apply to Walnut.

1. The first public announcement was July 11, 1961.

2. One system was installed.

3. There are no units on order.

4. The total equipment cost is classified.

5. The location of the equipment is Washington, D. C.

6. The use of this equipment is classified.

7. Image conversion is the responsibility of the customer and I am unable to provide you with this amount.

8. Coupled with the Walnut equipment is a large computer index, strip viewers, and aperture card viewers. The output of Walnut is principally viewed.

Walnut was specifically designed as a "one-of-a-kind" system for a very special type job. Because of this design motivation, Walnut represents a "state of the art" system for the single application it was intended for but is not sufficiently flexible to attack economically the myriad of other problems the business world has to offer.

I am unable to help you regarding your questions on a Cypress machine.

If I can be of further assistance, please call me.

Very truly yours,

Jack
J. D. Kuehler

J. D. Kuehler
Manager
Project Walnut

JDK:bg

.. IBM Wilmot [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] .. [illegible] - [illegible]
[illegible] offered for [illegible] - [illegible] will be.
very expensive.

4 file units

→ [no. delivered in class.] —

→ doc. file - [illegible] 8½ × 14" [illegible] doc.

everything on-line Dec. 18
output [illegible] viewing rather than hard copy.

viewing
Choice, not IBM

— Viewer pos. — Reflection viewing by
Geicomb.

delivered 2 input converters ICON
file to op. and
viewer on file. - Q. C. on input to file.

two - MIPAC's

docs. - image files

[illegible] Kalin & Diazo (any gamma & any exposure
exposure latitude.
change
input resolution)

throughput now 1 25 [illegible] Diazo file [illegible].
principally Diazo in file room. - [illegible] positive output.

Feb 18, 1963

Dear ____________

For a special review paper for the National Microfilm Association's 12th Annual Convention in San Francisco next May, I am trying to review the progress (or lack of it) that has been made to date in the installation and use of mechanized image handling systems. Hopefully, the review will be able to summarize some factual data such as the number and type of installations made to date, as well as some of the cost data. In addition, some comments may be in order to suggest why there hasn't been more widespread acceptance and use of this type of equipment.

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I look forward to hearing from you.

Sincerely,

CPB

THE Magnavox COMPANY

Cable Address: Magnavox Telex 023-212 TWX 219 241-2995

BUETER ROAD, FORT WAYNE, INDIANA

February 25, 1963

Mr. Charles P. Bourne
Research Engineer
Stanford Research Institute
Menlo Park, California

Dear Mr. Bourne:

Thank you very much for your letter of February 15, requesting information regarding our MEDIA System.

In answer to your eight questions, may we offer the following information:

described at 9/61 ADI meeting in L.A.

1. MEDIA was first publicly announced in October, 1962.

2. We are in the process of making two installations at the present time.

3. As of this date, we do not have additional units on order but do expect to have within the next two months.

4. Our total sales dollars to date are $174,000.

5. One installation is being made at the International Association of Machinists in Washington, D. C. and a second installation is being made at the Home Insurance Company, New York City.

6. The Association of Machinists will be using the equipment for membership dues records, correspondence files, and strike check records. The Home Insurance Company will be using the equipment for daily report records and other files within their home office.

7. In general, it is difficult to cite a typical cost for conversion because of the variance in the various applications. It appears from our studies that most applications will involve approximately

FERRANTI PACKARD

FERRANTI-PACKARD ELECTRIC LIMITED

INDUSTRY STREET
TORONTO 15, ONTARIO
762-3661

February 27, 1963.

Mr. Charles P. Bourne
Research Engineer
Stanford Research Institute
Menlo Park
California, U.S.A.

Dear Mr. Bourne,

Thank you for your letter of February 18th, 1963, asking for specific information on our Rapid Access Look-Up System. Some literature is enclosed.

To answer your questions, the Rapid Access Look-Up System was first announced in June 1960, when we undertook to customebuild 7 units for Ellicott Drug Company, Buffalo, New York. A total of 9 units were built.

This equipment has been in use since the fall of 1960, and is used for calling up RAMAC numbers assigned to a 25,000 item drug product inventory.

As Ellicott Drug Company does preparation work for building up the file and filming of this, we do not have any cost figures.

No software was involved. We do however, maintain the equipment on a service contract with the Ellicott Drug Company.

To answer your question as to why more wide-spread acceptance and use of this type of equipment has not been obtained, I believe after an extensive market survey that it is not possible to build the type of equipment required to do a particular job at the price level the user wishes to pay. To this must be added the fact that no two companies seem interested in doing similar jobs with the same equipment.

The cost of extensive modifications required puts a unit of this type out of the ballpark when we consider the going prices of Microfilm equipment generally on the market, i.e. REKORDAK, etc.

I hope this information is of some use to you.

H. A. WATTIE
ADVERTISING, SALES PROMOTION
and PUBLIC RELATIONS
ELECTRONICS DIVISION

RAPID ACCESS LOOK-UP SYSTEM

for ELLICOTT WHOLESALE DRUG COMPANY

- 1 of 7 units supplied to Ellicott Wholesale Drug Company, Buffalo.
- Provides for look-up of item code numbers in order-entering.
- Total number of catalogue items - 25,000.
- Speed of average item look-up - $1\frac{1}{2}$ seconds.
- Employs 16 mm. film, utilizing digital frame codes for rapid selection.

FERRANTI PACKARD

RAPID ACCESS LOOK - UP SYSTEM

The Rapid Access Look-up System is designed for item look-up by proper page selection and projection on a screen.

The system employs a 16 mm. film loop driven at a speed of over forty inches per second. Each frame of the film includes a catalogue page and an alphabetic-binary code for page identification.

Selection of the proper page is made by keying the first three letters of the item required, on the control keyboard (which can be any standard electric model). When the third letter is keyed, the film drive operates. The film is driven and automatically stopped when the proper frame is reached, and the page containing the item required is projected on the screen.

The average selection time varies with the number of catalogue pages or film frames considered. As a typical example, one catalogue used in the Rapid Access System contains 25,000 items on 440 pages. The average page selection time is 1½ seconds. A reasonable extension to this example might be an average of three seconds to select one of 880 pages or an average of ¾ of a second to select one of 220 pages.

Special more elaborate systems are possible for the handling of extremely large catalogues having many thousands of pages. In these cases, individual economic considerations must be based on speed of look-up required and additional equipment costs.

FILMING

A typical filming table is shown in Fig. 2. This equipment is used to produce the film negative from which any number of positives for the look-up units can be inexpensively produced by any commercial microfilming organization.

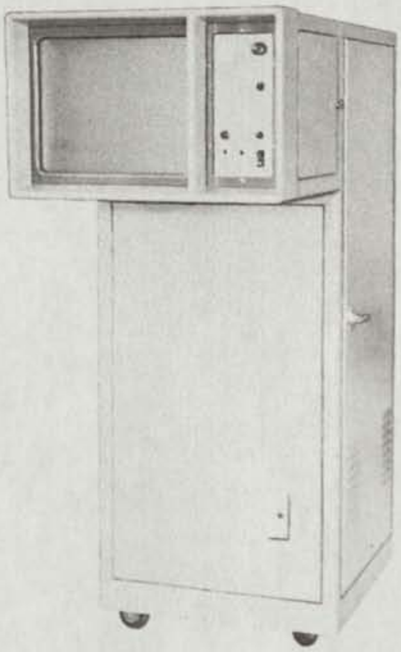

FIG.1 - LOOK-UP UNIT

The filming procedure is as follows:

1. Locate the first catalogue page manually in the frame.
2. Adjust the lamp intensity by the variac control until the photocell indicates the proper page illumination point marked on the light meter.
3. Read the last item on the catalogue page in the frame. Set one switch in each of the three banks of the Code Switch Matrix corresponding to the first three letters of the last item on the page; e.g. Kleenex. Set Switch K in the first row, Switch L in the second row and Switch E in the third row. This sets up a binary code corresponding to KLE in the Code Light Box.

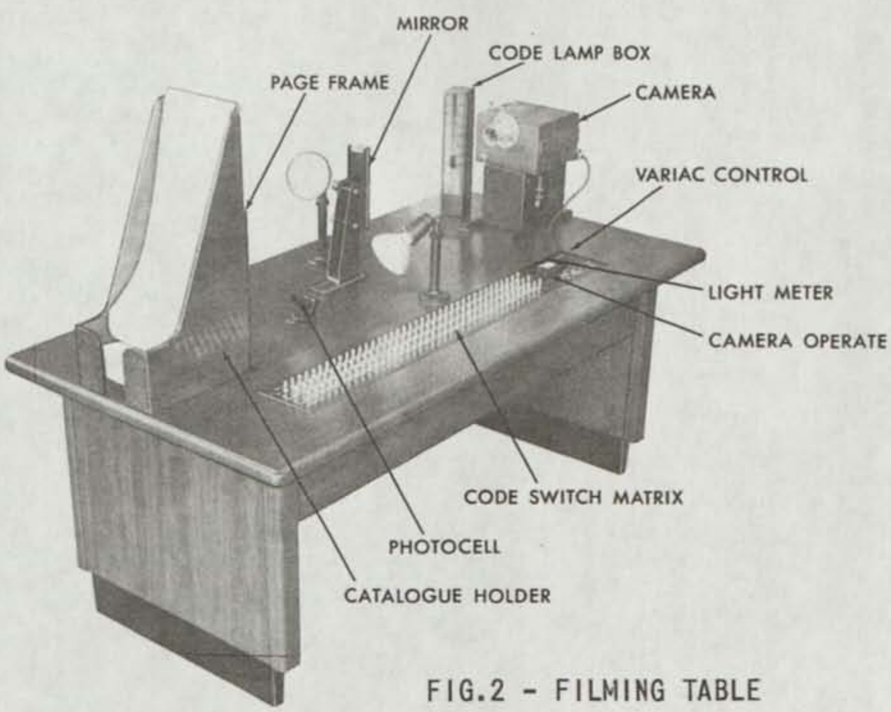

FIG.2 - FILMING TABLE

4. Depress the camera 'Operate' button. This operates the camera shutter for the required length of time for proper exposure and automatically advances the film to the next frame.
5. Reset the three switches in the Code Switch Matrix to their neutral positions.
6. Move the next catalogue page into the frame and repeat Steps 3, 4 and 5.

Using this equipment as outlined above, 440 pages can be filmed in less than sixty minutes. More elaborate filming equipment for automatic operation can be provided to effect a marked reduction in filming time.

The Code Light Box produces a reflection in the mirror so that each film frame includes the catalogue page and along the side, the particular code configuration corresponding to the first three letters of the last item of that particular page. See Fig. 3. It is this code that is being read as the film is driven at over 40" per second in the look-up unit. When the film code properly corresponds to the code generated by the look-up unit keyboard (i.e. the first three letters of the item required), the film is stopped 'on frame'.

LOOK-UP UNIT FILM DRIVE

In 1957 Ferranti-Packard developed a highly reliable differential-type drive mechanism for use in high speed punched paper tape readers. Since that time, such equipment has undergone many years of successful trouble-free operation in both military and commercial equipment. Aircraft, missile and submarine computer programming in the U.S. have all incorporated Ferranti-Packard high speed paper tape readers which were designed and manufactured in Canada. Typical punched paper tape starting and stopping times, using the differential drive, are 5/1000ths. of a second.

This standard proven drive-unit is the one chosen to drive the 16 mm. film in the Rapid Access Look-up System.

Fig. 4 shows the drive mechanism and the film loop. The drive is by a notched belt from a constantly operating motor. The differential film drive mechanism employs electro-magnetic braking for start-stop control.

A 5 mm. strip along the edge of the film is left blank in this application. It is in this area that the film rollers contact the film. This prevents scratching of the film by the drive interfering with the legibility of the projected page.

The film loop can be positioned in less than five minutes. Space and adjustments are provided to accommodate varying lengths of film loops. The projection system is a simplified unit with the minimum of adjustments. The projection lamp is a standard 100 watt unit and is easily replaced when necessary.

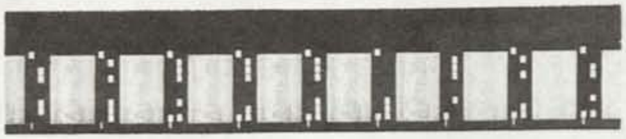

FIG.3 - SECTION OF FILM POSITIVE

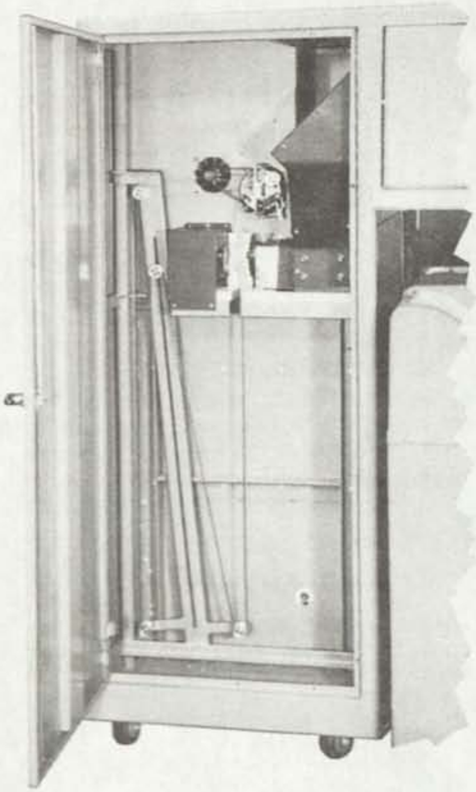

FIG.4 - DRIVE AND PROJECTION SYSTEM

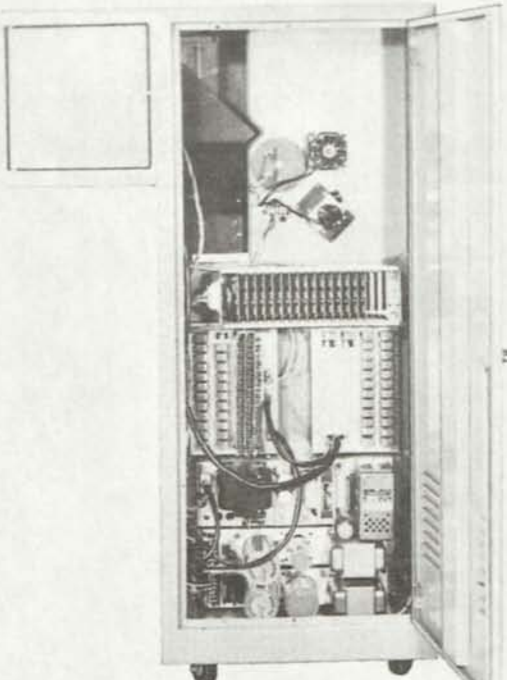

FIG.5 - ELECTRONIC CIRCUITRY AND POWER SUPPLIES

ELECTRONIC CIRCUITRY

The electronic circuitry of the system has been designed around solid-state transistors and diodes. Throughout, the design has been based on long-life, reliability and simplicity and ease of maintenance should this be required. All electronic components are of the highest quality, are standard items manufactured to North American specifications, and are readily available in Canada and the United States. Printed circuit cards are housed in a card file from which they can be quickly withdrawn and easily replaced. Miniature plug-in relays were chosen for reliability, compactness and economy. All circuit components are readily accessible as shown in Fig. 5.

APPLICATION

The Ferranti-Packard Rapid Access Look-up System can be economically employed wherever continuous or frequent catalogue or record look-up is required. Such fields might be: order-entering, telephone enquiry handling, for price confirmation in invoicing, in purchasing departments for vendor information, in insurance companies for policy records, in automotive organizations for spare parts records, etc.

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In the filming procedure, the original catalogue can be in any one of many forms. One convenient form, as shown in Fig. 2, employs a printed catalogue from a commercial tabulator or line printer on a fan-fold type stock. This arrangement can be simply handled and is chosen as being often readily available from existing equipment at a minimum of cost.

QUESTIONS AND ANSWERS

During recent demonstrations of the Rapid Access Look-up System, many questions were asked by prospective users. Some of the more pertinent questions and answers follow:

1. QUESTION: For this particular look-up unit; what is the maximum and minimum number of frames practical?

   ANSWER: The answer to this depends on the frequency the catalogue is normally used and the speed of access required. A 50-page catalogue might be practical if it had to be used continuously. Similarly a 5000-page catalogue could be accommodated if the increased access time to an average of about 18 seconds were practical.

2. QUESTION: How are catalogue changes handled?

   ANSWER: It is recommended that changes as they occur be handled manually until the number of such changes becomes impractical to handle manually, at which time a new film incorporating all such changes would be made - perhaps once per month. Individual frame or block changes are possible but require special consideration.

3. QUESTION: When an item is looked up, the page displayed is the first page on which items containing the first three letters are located. What do you do if items starting with the same three letters carry over to the next or succeeding pages?

   ANSWER: The look-up unit is equipped with a 'step-button'. By depressing this button, the film can be advanced one frame or one page at a time.

4. QUESTION: If a key punch is modified for application with the look-up unit, can the key punch still be used for conventional purposes?

   ANSWER: Yes, the modifications are very simple, requiring about an hour to complete. There are no intermediate black boxes' required, and the key punch can be used conventionally without regard for the look-up unit if this should be needed.

5. QUESTION: Are any special power requirements necessary?

   ANSWER: No. The units plug in to normal 115 volt, 60 cycle, single-phase outlets. The Look-Up Unit requires about 3 amperes and the Filming Unit about 6 amperes.

6. QUESTION: What amount of operator training is required?

   ANSWER: Very little. It has been found that a trained typist or key punch operator can compentently utilize this equipment with as little as a thirty-minute familiarization period.

The Look-Up Unit and the Filming Equipment are available either on a sale or lease basis. Depending on the rate of film changes, it may be more economical to have the filming done at a Ferranti-Packard filming centre than to have your own filming equipment. These will be located at various points as may be required.

Maintenance arrangements can be made on a contract or as-called-for basis or, alternatively Ferranti-Packard will train your own personnel to competently service the equipment.

FERRANTI-PACKARD ELECTRIC LIMITED
ELECTRONICS DIVISION, INDUSTRY STREET, TORONTO 15, ONT.

FERRANTI ELECTRIC INC.
30 ROCKEFELLER PLAZA, NEW YORK 20, N.Y., U.S.A.

Feb 18, 1963

Dear____________

For a special review paper for the National Microfilm Association's 12th Annual Convention in San Francisco next May, I am trying to review the progress (or lack of it) that has been made to date in the installation and use of mechanized image handling systems. Hopefully, the review will be able to summarize some factual data such as the number and type of installations made to date, as well as some of the cost data. In addition, some comments may be in order to suggest why there hasn't been more widespread acceptance and use of this type of equipment.

Since you are a knowledgeable representative of one of the major companies in this field, I thought that you might be able to provide me with some of this information. The information would be used in this review paper and published in the open literautre. I would be particularly interested in the answers to the following questions with regard to your______________ equipment.

1. Date of first public announcement:
2. Number of units installed:
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6. Types of files or applications that this equipment is being used for:
7. Conversion cost (per image or per page) to build up the machine file:
8. Types of software or services provided with the equipment:

If at all possible, I would like to have the information by March 1. To ensure accuracy and proper reporting I would prefer to have the information directly from the source, rather than assembling it in bits and pieces from previously published information and less reliable sources. That is precisely why I am writing to you.

I look forward to hearing from you.

Sincerely,

CPB

FERRANTI-PACKARD ELECTRIC LIMITED

INDUSTRY STREET
TORONTO 15, ONTARIO
762-3661

February 21, 1963.

Mr. Charles P. Bourne
Research Engineer
Stanford Research Institute
Menlo Park
California, U.S.A.

Dear Mr. Bourne,

Thank you for your letter of February 18th, 1963, asking for specific information on our Rapid Access Look-up System. Some literature is enclosed.

To answer your questions, the Rapid Access Look-up System was first announced in June 1960, when we undertook to custom build 7 units for Ellicott Drug Company, Buffalo, New York. A total of 9 units were built.

This equipment has been in use since the fall of 1960, and is used for calling up RAMAC numbers assigned to a 25,000 item drug product inventory.

As Ellicott Drug Company does preparation work for building up the file and filming of this, we do not have any cost figures.

No software was involved. We do however, maintain the equipment on a service contract with the Ellicott Drug Company.

To answer your question as to why more wide-spread acceptance and use of this type of equipment has not been obtained. I believe after an extensive market survey that it is not possible to build the type of equipment required to do a particular job at the price level the user wishes to pay. To this must be added the fact that no two companies seem interested in doing similar jobs with the same equipment.

Cont.

FERRANTI-PACKARD ELECTRIC LIMITED

The cost of extensive modifications required puts a unit of this type out of the ballpark when we consider the going prices of Microfilm equipment generally on the market, i.e. REKORDAK, etc.

I hope this information is of some use to you.

Yours very truly,

H.A. Wattie
Advertising, Sales Promotion
& Public Relations
Electronics Division

HAW/mt

c/c copy to

G.W.L. Davis

RAPID ACCESS LOOK-UP SYSTEM

for ELLICOTT WHOLESALE DRUG COMPANY

- 1 of 7 units supplied to Ellicott Wholesale Drug Company, Buffalo.
- Provides for look-up of item code numbers in order-entering.
- Total number of catalogue items - 25,000.
- Speed of average item look-up - $1\frac{1}{2}$ seconds.
- Employs 16 mm. film, utilizing digital frame codes for rapid selection.

RAPID ACCESS LOOK - UP SYSTEM

The Rapid Access Look-up System is designed for item look-up by proper page selection and projection on a screen.

The system employs a 16 mm. film loop driven at a speed of over forty inches per second. Each frame of the film includes a catalogue page and an alphabetic-binary code for page identification.

Selection of the proper page is made by keying the first three letters of the item required, on the control keyboard (which can be any standard electric model). When the third letter is keyed, the film drive operates. The film is driven and automatically stopped when the proper frame is reached, and the page containing the item required is projected on the screen.

The average selection time varies with the number of catalogue pages or film frames considered. As a typical example, one catalogue used in the Rapid Access System contains 25,000 items on 440 pages. The average page selection time is 1½ seconds. A reasonable extension to this example might be an average of three seconds to select one of 880 pages or an average of ¾ of a second to select one of 220 pages.

Special more elaborate systems are possible for the handling of extremely large catalogues having many thousands of pages. In these cases, individual economic considerations must be based on speed of look-up required and additional equipment costs.

FILMING

A typical filming table is shown in Fig. 2. This equipment is used to produce the film negative from which any number of positives for the look-up units can be inexpensively produced by any commercial microfilming organization.

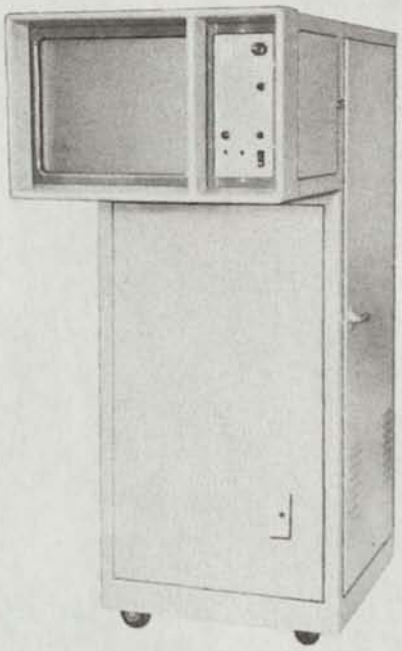


FIG. 1 - LOOK-UP UNIT

The filming procedure is as follows:

1. Locate the first catalogue page manually in the frame.
2. Adjust the lamp intensity by the variac control until the photocell indicates the proper page illumination point marked on the light meter.
3. Read the last item on the catalogue page in the frame. Set one switch in each of the three banks of the Code Switch Matrix corresponding to the first three letters of the last item on the page; e.g. Kleenex. Set Switch K in the first row, Switch L in the second row and Switch E in the third row. This sets up a binary code corresponding to KLE in the Code Light Box.

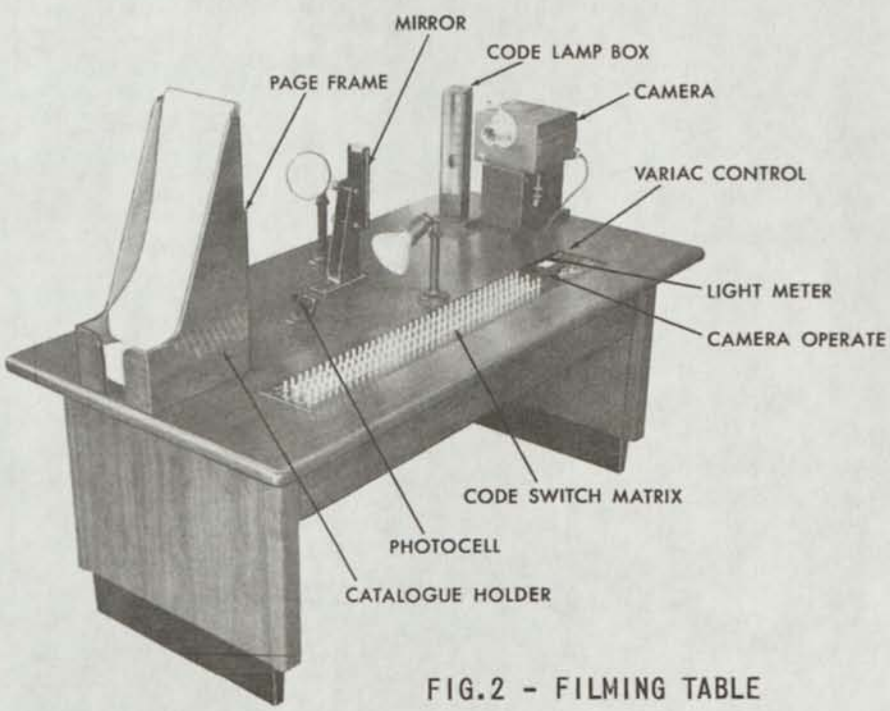


FIG. 2 - FILMING TABLE

4. Depress the camera 'Operate' button. This operates the camera shutter for the required length of time for proper exposure and automatically advances the film to the next frame.
5. Reset the three switches in the Code Switch Matrix to their neutral positions.
6. Move the next catalogue page into the frame and repeat Steps 3, 4 and 5.

Using this equipment as outlined above, 440 pages can be filmed in less than sixty minutes. More elaborate filming equipment for automatic operation can be provided to effect a marked reduction in filming time.

The Code Light Box produces a reflection in the mirror so that each film frame includes the catalogue page and along the side, the particular code configuration corresponding to the first three letters of the last item of that particular page. See Fig. 3. It is this code that is being read as the film is driven at over 40" per second in the look-up unit. When the film code properly corresponds to the code generated by the look-up unit keyboard (i.e. the first three letters of the item required), the film is stopped 'on frame'.

LOOK-UP UNIT FILM DRIVE

In 1957 Ferranti-Packard developed a highly reliable differential-type drive mechanism for use in high speed punched paper tape readers. Since that time, such equipment has undergone many years of successful trouble-free operation in both military and commercial equipment. Aircraft, missile and submarine computer programming in the U.S. have all incorporated Ferranti-Packard high speed paper tape readers which were designed and manufactured in Canada. Typical punched paper tape starting and stopping times, using the differential drive, are 5/1000ths. of a second.

This standard proven drive-unit is the one chosen to drive the 16 mm. film in the Rapid Access Look-up System.

Fig. 4 shows the drive mechanism and the film loop. The drive is by a notched belt from a constantly operating motor. The differential film drive mechanism employs electro-magnetic braking for start-stop control.

A 5 mm. strip along the edge of the film is left blank in this application. It is in this area that the film rollers contact the film. This prevents scratching of the film by the drive interfering with the legibility of the projected page.

The film loop can be positioned in less than five minutes. Space and adjustments are provided to accommodate varying lengths of film loops. The projection system is a simplified unit with the minimum of adjustments. The projection lamp is a standard 100 watt unit and is easily replaced when necessary.

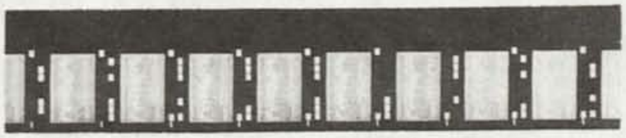
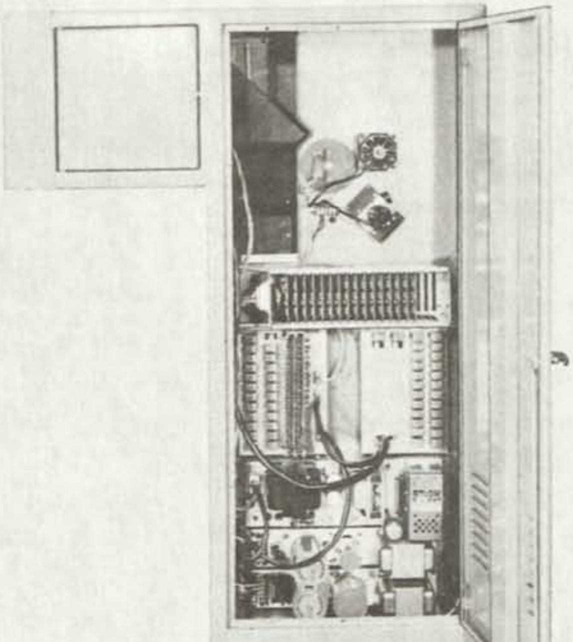


FIG.3 - SECTION OF FILM POSITIVE

FIG.4 - DRIVE AND PROJECTION SYSTEM



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Greg Walden [FMA] phone call 11 March 1963

3 Filesearch units have been installed

1 more to be installed in a European bank in May

Sales: System #1 115 + 24 + 4 = 143

2 115 + 24 + 4 = 143

3 129 + 24 + 4 = 157

$443