Development of the IBM 1500 Computer-Assisted Instructional System

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The IBM 1500 Instructional System was the only commercial system produced by a single manufacturer that had an integrated student terminal configuration providing a keyboard and light pen response mode, CRT-based graphics, audio, and static film projection. Experimental instructional systems had been developed by IBM prior to a prototype version of the 1500 Instructional System, which was tested at Stanford University. A production version of the 1500 System with changes in the CPU and the audio system and having the capability to run a maximum of 32 student stations was installed in over 30 sites beginning in the late 1960s. IBM’s commitment to the development of this system was extensive but short-lived, as most sites were unable to maintain funding support for the system. In retrospect, the IBM 1500 System had capabilities yet to be supported on the microcomputer systems of the 1990s.

The increasing availability of microcomputers and their apparent multipurpose utility has prompted some educators to suggest that they are likely to be the ideal instructional device, replacing such long-lived materials as books. While it might appear that computers are a recent import to the field of education, concerted efforts to adapt them for instructional purposes can be traced to the 1950s. Although mechanical teaching machines gained short-lived popularity in North America, in some parts of Western Europe, and even in the former Soviet Union in the latter half of the 1950s and early 1960s, their instructional capabilities were limited primarily because of constraints imposed by their mechanical operation. Noting these limitations and applying some of the psychological principles used in teaching machines, engineers made several attempts to create computer-based instructional systems. Most of these initial devices, such as the different versions of the Solartron Adaptive Keyboard Instructor (SAKI) designed by Gordon Pask and his associates beginning in 1953, were intended only for one particular instructional task. Such dedicated machines were not suitable for general applications in education, since they could not be adapted easily to different instructional processes. To reach the large education market with its wide diversity of instructional requirements, the greatest chance for success lay in the development of a computer-based system that could accommodate many different instructional requirements.

Several attempts were made during the mid to late 1950s by commercial firms, some in collaboration with researchers at universities, to design multipurpose computer-based instructional systems. Most of these endeavors either were discontinued as unfeasible or their development and deployment proceeded slowly. For example, Thompson, Ramo, Wooldridge Inc. (known as TRW since 1965) designed a computer-controlled instructional device known as the Mentor. Though designed for instructional purposes, Mentor was derived from an existing data processing computer system. While the Mentor was capable of presenting instruction in a variety of subjects, its cost was too high for most schools and other educational institutions. Rath reports that TRW did not sustain its interest in developing computer-based instructional devices. Although the Plato computer-assisted instruction system developed in 1960 did enter the commercial market eventually in a modified form, its initial use was limited to the University of Illinois and immediate environs. One firm that did pursue the development of an integrated multimedia computer-based instructional system was IBM.

IBM’s initial experiments

Although one version of a teaching machine devised by Harvard psychologist B.F. Skinner was developed to the prototype stage in the late 1950s by the Electric Typewriter Division of IBM, another division of the company was experimenting at the same time with adapting computers to function as instructional devices. While Skinner was not involved directly with the development of a computer-controlled device, his theory of operant learning, also known as Skinnerian behaviorism, was embodied in the IBM device. According to Rath, Anderson, and Brainerd, the idea of using a computer as a teaching machine arose from a perceived need of “studying those psychological variables which are important in the design of teaching machines. Thus, we became interested in the general characteristics of teaching machines...
as opposed to the development of a particular machine" (p. 117). Rath\(^7\) notes that although this was the initial intent of the investigation team, the psychology department of IBM was of the impression that since the executive office was already interested in teaching machines, it might be prudent for other research to be carried out along these lines. "This led to the choosing of a teaching machine simulation instead of the human prediction of Markov chains or the analysis of complex motor responses, both of which had also been under consideration" (p. 60). Instead of theoretical and pedagogical factors, it was the perceived direction of corporate policy that motivated the psychology staff at IBM to research the use of computers for instruction.

An IBM Model 650 computer was used. Because a card reader and punch device is generally inappropriate for instructional purposes, an electric typewriter was modified and connected to the processor. Rath, Anderson, and Brainerd\(^8\) note that although the modified typewriter functioned satisfactorily, an input-output device designed specifically for on-line instruction was considered to be more desirable.

The computer was programmed to provide instruction in the subject of binary arithmetic only because of its importance to the understanding of internal computer operations and programming, and because binary arithmetic possesses fewer new concepts to learn than some other areas of mathematics. It appears that binary arithmetic was also selected because of technical limitations of the Model 650 computer,\(^6\) e.g., a main memory of approximately 4 Kbytes and no capability to drive a visual display.

The instructional format of this experimental system was similar to some mechanical teaching machines of the time. The computer first typed a set of instructions, definitions, and examples, followed by a question to be answered using the keyboard. Evaluation of the response began as soon as the first key was pressed, even though the response might require more than one character. If the character entered was correct, no action was taken by the computer and the user continued to enter any additional characters. If the entire answer was entered correctly, the computer proceeded immediately to the next question, disregarding any additional attempts made by the user. This procedure prevented the user from entering additional characters that might be incorrect.

If the user entered an incorrect character before the entire response was completed, the computer interrupted further input and typed the word "WRONG" followed by remedial information. The nature of the remedial information depended upon the number of errors previously made, i.e., the greater the number of errors, the more extensive the remedial information. After this remediation, the user was required to answer another question at the same level of difficulty as the initial question, or one that was simpler. The computer made this choice on the basis of the number of errors made in that portion of the program.\(^4\) Rath\(^7\) notes that entry of responses could be confusing to the user in two ways. First, the computer did not permit backspacing, so mistakes could not be corrected. Second, the computer moved the position of the print head one space to the right after each entry. This attribute can create a confusing record of the interaction. In an addition problem requiring the creation of a column of numbers, for example, the carriage return must be pressed after each number is typed. This causes the column to appear along an oblique path.\(^3\)

Although Rath, Anderson, and Brainerd\(^8\) tested their system with several students, they collected no experimental data. These authors also note that the computing capabilities of the Model 650 were not being used efficiently, since only one student could use the system at any one time even though the computer could operate several terminals through multiplexing.

A second experimental project using a modified Model 650 computer as a teaching machine was launched by IBM in 1960.\(^3\) The modifications included the addition of multiplexing circuitry to handle 20 computer-controlled typewriters.\(^3\) Instructional materials were prepared for three subjects: stenotyping, statistics, and German reading. While the typewriters were satisfactory for instruction in statistics and German reading, a special keyboard was designed for stenotyping. Other devices designed for this system included a screen that could display alphabetic characters by means of nixie tubes, a random-access projector containing 1,000 slides, and cue lights corresponding to the keys of the keyboard.\(^3\)

**IBM 7010 System**

In 1961, IBM began another experimental project to facilitate the design of course materials to be delivered by computer and to assess the efficacy of such materials compared with traditional methods of instruction.\(^4\) Based at the IBM Research Center at Yorktown Heights, New York, the computer-controlled system consisted of a Model 7010 computer that could operate up to 40 Model 1050 teletype-like student terminals. The terminals could be located at remote sites and connected to the central processor through ordinary telephone lines. Many of the remote sites were at universities throughout the United States. Most of these institutions later acquired commercial versions of other IBM instructional systems.

An optional projection unit and an audio unit, controlled by computer, could also be connected to each terminal. The projection unit was a modified slide projector with a capacity of 80 images and a maximum seek time of less than 4 seconds. The audio unit was a modified tape recorder that, by means of a track encoded with digital information, could access specific messages at a speed 20 times that of normal playback. IBM subsequently marketed these random-access audio and visual units separately.

An authoring language called Coursewriter was developed by 1964 to facilitate the creation of course material by individuals unfamiliar with computer programming languages. The exact creation date of the Coursewriter language is obscure, however. Coursewriter uses a two-character mnemonic code and a set of parameters to signify instructional-like operations, as well as a macro facility to increase the efficiency of coding instructional sequences. Coursewriter I did not require extensive parameters for some commands because CRTs could not be used. In using the Coursewriter language, an author is required only to possess knowledge of the instructional-like operations of the computer, instead of having to know the grammar and syntax of a computer language unrelated to instruction. Although Coursewriter is related more to the process of instruction than are most programming languages, such authoring languages are considered to be low-level, since the author must first learn the significance of mnemonics representing commands to use the languages effectively, and use lengthy sequences of code to define an instructional strategy.

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Although Coursewriter I was used by several IBM instructional systems that were marketed, the 7010 group continued to develop and refine Coursewriter, so that a new version, Coursewriter II, was developed that could be used with CPUs less powerful than the 7010. Figure 1 depicts a small section of Coursewriter code.

While the 7010 System lasted until 1979, in many respects it represents the forerunner of later commercial instructional systems based on the Coursewriter language.

IBM 1400/1410/1440 Systems

In addition to IBM's research center experiments using Model 650 computers, another division of IBM, Field Services, developed a computer-based system for instructional purposes using the Coursewriter I language. This project involved the actual use of the system for instructing IBM customer engineers in the basic concepts of computation prior to taking a course covering the topic of the IBM 360 System. The first commercial CAI package using Coursewriter I was announced by IBM in October 1964. Given the experimental nature of the work using the Model 650, it seems reasonable that the announcement made in 1964 was the 1400/1440 System.

While intended primarily for instructional applications, the hardware for the system was designed for other purposes. Three versions appear to have been developed, the first using a Model 1401 CPU, the second using a Model 1410 CPU, and the third using a Model 1441 CPU. Model 1050 terminals were used, with some terminals also having audiovisual devices such as indexed slide projectors. Gordon describes the second version as comprising a Model 1410/1440 CPU with Model 1311 disk drives and Model 7330 magnetic tape.

Figure 1. An example of Coursewriter II code.

```plaintext
Probl
de 0732
ld 07c5
dt 0,57f2,0740,07ftype the name of a gas which when burned
dt ,5777in a controlled manner produces water.
epi 7,12/2,7/10,12/probl-1
nx
br re
cal hydrogen/c1
dti 10,5/10,10/40,57Yes, hydrogen is correct
ad 17c5
cal h*dxg*n/c2
ad 17c5
dti 10,5/10,10/40,57hydrogen is what we want. Your

dt 12,5777spelling appears to be incorrect.
wa nitrogener/w1
dti 10,5/10,10/40,57No, nitrogen cannot combine with
dt 12,5777oxygen to form water.
wa n*tr*gn/w2
dti 10,5/10,10/40,57If you meant to type nitrogen, it
dt 12,5777cannot combine with oxygen to form water.
un
dti 10,5/10,10/40,57Hint: Think of the chemical formula
dt ,5777for water.
un
dti 10,5/10,10/40,57Hint: Burning requires oxygen, now
dt ,5777what gas combined with oxygen produces
dt ,5777water?
un
dti 10,5/10,10/40,57Well, the answer is hydrogen.
dt 12,5/3,12/77Water (H2O) is formed from oxygen and
dt 15,5777hydrogen as the equation suggests.
eu
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Institutions possessing IBM Model 1400/1410/1440 instructional systems

Although other educational institutions possessed Model 1401, Model 1410, and Model 1441 CPUs, only those institutions that used the Coursewriter I language are listed. A question mark (?) indicates that particular information was either not available or could not be confirmed.

1. University of Texas at Austin; 1965-1967; 1401 CPU with four Model 1050 terminals.
2. Providence College, Providence, R.I.; 1965 to ?; 1401 CPU with Model 1050 terminals and audiovisual devices.
3. University of Virginia, Charlottesville; 1965 to ?; 1401 CPU.
4. University of Oklahoma Medical Center, Oklahoma City; 1966 to 1968; 1401 CPU with four Model 1050 terminals (this configuration was created from a pre-existing data processing system).
5. ACCESS Computer Center, Des Moines, Ia.; ? to ?; 1401 CPU with Model 1050 terminals.
6. Anniston Public Schools, Anniston, Ala.; 1401 CPU with Model 1050 terminals.
7. Pennsylvania State University, University Park; 1965 to 1968; 1410 CPU with Model 1050 terminals.
8. The University of California at Irvine; 1965 to 1967; 1410/1440 CPU with 21 Model 1050 terminals.
9. IBM, Thomas J. Watson Research Center, Yorktown Heights, N.Y.; 1966 to ?; 1440 CPU coupled to a 7010 CPU experimentally. The system used Model 1050 terminals, some being remotely located and connected via telephone lines (State University of New York, Stony Brook; Institute for Learning and Instruction, New York, N.Y.; State University College, New Paltz, N.Y.).
10. Florida State University, Tallahassee; April 1966 to 1970; 1440 CPU with five typewriter terminals.
11. University of Texas at Austin; February 1967 to ?; 1440 CPU with 10 typewriter terminals, two Model 1050 terminals, and three audiovisual devices.
13. United States Army Academy of Health Science, Fort Sam Houston, Tex.; ? to 1975; 1440 CPU; claimed to be the last such system in use.

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6. Anniston Public Schools, Anniston, Ala.; 1401 CPU with Model 1050 terminals.
7. Pennsylvania State University, University Park; 1965 to 1968; 1410 CPU with Model 1050 terminals.
8. The University of California at Irvine; 1965 to 1967; 1410/1440 CPU with 21 Model 1050 terminals.
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10. Florida State University, Tallahassee; April 1966 to 1970; 1440 CPU with five typewriter terminals.
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The complete listing of Model 1400/1410/1440 systems is unavailable and has been difficult to compile because of a paucity of information, the sidebar at left lists those systems known to have existed, based on several research reports.

While the IBM projects established that a computer could function as a teaching machine, several limitations were revealed. First, it became apparent that computers designed primarily for business applications could not be modified easily for instructional purposes because of the need for specialized input and output devices. Second, large computers, although they could operate many terminals through multiplexing, were probably too expensive for most schools. Third, the lack of graphic images, such as provided by CRT terminals, was considered limiting by some educators. Fourth, while programs of instruction could be written for computers of that time, the individuals who performed the programming usually possessed specialized knowledge of computer languages and programming techniques, skills not usually possessed by educators. In spite of these limitations, IBM proceeded to develop an instructional system that addressed most of the limitations satisfactorily.

Prototyping the IBM 1500 Instructional System

Instructional systems such as Plato, which were designed either by university personnel or through collaborative ventures between companies and universities, likely encouraged IBM to develop a commercial version of their computer-controlled instructional system in conjunction with university personnel. IBM began collaborating with researchers at Stanford University beginning in 1964, probably because Stanford already possessed a functional experimental computer-controlled instructional system. Atkinson and Wilson report that this system was composed of components from a diversity of manufacturers, "Since there were no integrated computer-assisted instruction systems available at that time" (p. 5). While this statement is correct as far as commercially produced systems are concerned, it is important to note that a version of the Plato system produced by the University of Illinois was already functional.

The Stanford system was based initially on a Digital Equipment Corporation Model PDP-1 computer controlling up to six terminals. Disk drives connected to an IBM Model 7090 computer provided peripheral storage. Each terminal consisted of a Philco CRT display with a light pen, an IBM image projector that used 35-mm slides, and a Westinghouse random-access tape player. The system was tested using local elementary-school children being taught mathematics and language arts. The apparent success of this system resulted in the United States Office of Education awarding a large grant to Atkinson and Suppes in 1964 for the development of computer-based programs in reading and mathematics.
In conjunction with the awarding of the grant, IBM entered into an agreement with Atkinson and Suppes and with the Institute of Mathematical Studies in the Social Sciences at Stanford to develop a multimedia prototype computer-controlled instructional system later to be marketed commercially as the IBM 1500 System.6,11 Miller12 reports that the Instructional Systems Development Department (ISDD) of IBM was able to develop the system in 18 months, including the operating system, which took eight man-years of effort. The cost of developing the 1500 System was reported to be $30 million.13

The first prototype 1500 System used an IBM Model 1802 CPU with a 2-microsecond cycle speed and a 3-Kbyte memory. Connected to the CPU was a Model 1816 console, a Model 1501 station controller, two Model 1505 audio units, two Model 1518 typewriters, and 16 student stations.10,12 Storage consisted of a single Model 2402 tape unit and six Model 2310 disk drives. A Model 1443 line printer provided printed output of program code and student performance records. Program entry was accomplished through the keyboard or by a Model 1442 card reader/punch. The IBM Model 1800 series architecture was similar to the IBM Model 1130 used in the production versions of the 1500 System. The 1800 series, however, had additional features designed for process control applications.

The 1510 instructional display

In keeping with the design of the initial Stanford system, IBM produced a student terminal that contained a monochrome CRT display and a light pen. According to Atkinson,9 the light pen was included because “we have not as yet addressed ourselves to the problem of teaching first-grade children to handle a typewriter keyboard” (p. 227). The problem, of course, extends beyond simply handling a typewriter keyboard, since instructing first-grade children, who bring lit- tle understanding of the manner in which written language is used, presents additional pedagogical problems as well as human-computer interface problems.

Included with the CRT was a qwerty keyboard as an integral part of each student station. The combined CRT, light pen, and keyboard were designated as the 1510 instructional display (shown in Figure 2). The CRT was capable of displaying 16 lines of text, each containing a maximum of 40 characters displayed as white characters on a black background. The font matrix was 8 by 12 pixels; thus the CRT display surface provided a resolution of 192 pixels in vertical and 320 pixels in the horizontal axis. Each scan line of the CRT was interleaved from a “video disk” buffer located in a unit called a station controller and fed by coaxial cable to a specific terminal. As would be required for instructional purposes, true subscripts and superscripts were handled by positioning a character one half line lower or higher than the base line. Half-line addressing was accomplished by referencing the screen as containing 32 lines, and through the use of special key combinations including the index and reverse index keys when code was prepared on-line. A graphic unit consisting of a 16-by-36 dot matrix could also be defined. One hundred and ninety-two such graphic units could be stored and referenced for display. Larger graphics were created by positioning several units in appropriate proximity. The keyboard contained three shift lev-
comprising clear areas and one or more small black squares located in the area of the film used normally for the sound track. This digital code was projected simultaneously with its associated frame image onto a small panel holding 10 photocells located to the side of the ground-glass screen. The 10 photocells provided 210 unique addresses for the 1,024 frames. The shutter controlled whether an image would be displayed or not, but projection of the binary code was not controlled by this shutter. This arrangement allowed prepositioning the film to a specific frame in anticipation of its use without the student seeing all the images traversed in the search procedure. The search speed was 40 images per second; thus about 25 seconds would be the maximum access time in the worst case.

The 1501 station control

The prototype versions of the 1500 System, by means of a specially designed separate unit designated as the 1501 station control, could operate up to 16 student stations simultaneously (later augmented to 32 student stations). Atkinson states that the operational speed of the controller is sufficiently rapid “that from a student's viewpoint it appears that he is getting immediate attention from the computer whenever he inputs a response” (p. 227). This is an important feature in respect to the tenets of Skinnerian behaviorism.

The station control unit also contained a hard disk, referred to as the video buffer, with multiple read/write heads for refreshing the scan lines on each CRT, as well as circuitry for interpreting interrupt signals from the 1510 keyboards and light pens. The read/write heads for the video buffer were supplied in groups of eight to a maximum of four such groups. With this arrangement it was possible for a small system to possess only eight heads, with provision for expansion.

The 1505 audio adapter

In the prototype version of the 1500 System, aural information was provided by a large stand-alone unit referred to as the 1505 audio adapter. The audio adapter, intended to be located near the central processor, could be equipped with up to 10 separate tape drives, each designed to play tape cartridges containing 200 feet of 1/4-inch tape with a maximum capacity of two hours. Individual messages, however, were limited to a maximum of 5 minutes. Each tape was recorded with four tracks. Three tracks could be used for presenting up to 40 minutes of information, or for recording student responses and comments for later review by an instructor. One track was reserved for consecutive 14-bit binary addresses. The audiotape could be searched at a speed of 70 inches per second in a forward or backward direction to minimize access time.

Preparation of the audiotape was not a simple procedure, since it involved six steps beginning with narration of the original message, recorded on one track of a two-track tape played in one direction only. The second track contained a 400-Hz tone that was used to control other processes depending upon the length of a gap in the tone. Three gap lengths were used, two to control the processes required in recording the narration to the final cartridge and the third to provide the basis of synchronizing execution of the course with an audio message. Atkinson notes that with this arrangement it was possible to synchronize the movement of an object on the CRT with an audio message; for example, printed words on the screen could be pointed at by an object displayed on the screen and the corresponding words spoken, “much like the ‘bouncing ball’ in a singing cartoon” (p. 226). The use of such visual cues serves to capture and maintain the interest of the student and to facilitate the formation of associations between the sounds of the words and their written symbols. Producing the final audio cartridge also involved the substitution of message names used during the authoring process with the parameters of the message in terms of track, address, and message length. Aural information is usually delivered to the student through a headset equipped with an attached microphone.

Miller reports that the prototype version of the 1500 System was installed on July 10, 1966, at Brentwood School in a specially built laboratory. Atkinson reports, however, that the 1500 System did not become fully operational until late November 1966, “owing to systems and hardware difficulties” (p. 191). A reviewer of this article reports that the hardware difficulties were caused primarily by the 1505 audio adapter. The subcontractor for the design and production of the audio adapter was unable to meet IBM's specifications, and this resulted in a delay of one year.

The staff for the installation included a manager, two systems analysts, two systems programmers, an operator, and about 10 Coursewriter coders (primarily teachers), as well as four or five certified teachers trained in the use of the curriculum and system. The system was in operation 24 hours per day. This configuration of staff and operating schedule suggests that course material was being developed not much in advance of student use. Miller estimates that the cost of the project to Stanford was approximately one million dollars, half for curriculum development and half for equipment and building. The 1500 System at Brentwood School was operational for two years only. Following the cessation of federal funding for the project, the collaboration between IBM and the Stanford researchers ended, and the Stanford group continued to develop a different computer system for large-scale distribution of arithmetic drills to local and remote school sites. The latter development at Stanford eventually resulted in the for-
mation of the Computer Curriculum Corporation (CCC), which has pursued actively for a number of years the marketing of a drill-oriented instructional system.

Other prototypes of the IBM 1500 System

In March 1966, before the initial prototype 1500 System was operational, IBM announced the system and endeavored to obtain agreements to sell or lease 1500 Systems to as many educational institutions as possible. In June 1966, for example, the University of Alberta entered into agreement with IBM for the rental of a 1500 System. The actual system hardware did not arrive on campus until 1968.

In expectation of the 1500 System's success in schools, industry, and the military, Miller11 reports that IBM's "response to this need has been impressive," and noted the purchase of Science Research Associates (SRA) of Chicago, an educational publishing house that had also marketed several teaching machines. Science Research Associates was reported to be developing courses in algebra, German, statistics, computer science, physics, chemistry, biology, and social science. Given the labor-intensive nature of preparing a course, these offerings represented an impressive commitment by IBM to support a system that had only been prototyped and tested for a short period of time with elementary-school children. IBM's anticipation of a large number of sales was likely encouraged by the fact that even with a CRT terminal, the 1500 System would be less expensive to acquire than the earlier 1400/1410/1440 Systems.

While the installation at the Brentwood School is referred to as being the prototype, evidence suggests that there were at least seven other preproduction prototypes completed and installed before delivery of production models began (see sidebar at right). It is likely that these prototypes were deployed to enable course materials to be produced before the release of the production models.

There were two major differences between the prototypes and the production models of the 1500 System. As far as can be established from existing evidence, production models of the 1500 System were supplied with a Model 1131 CPU, with the first installation being made at Pennsylvania State University. However, at least one IBM document indicates that the system could be ordered with a Model 1800 CPU.15 The precise reasons why Model 1131 CPUs were substituted for the Model 1800s in the production models are unclear. Probable reasons include the higher cost of the Model 1800 CPU, faster clock speed in the Model 1131, and difficulties connecting the maximum number of fully configured student stations to the Model 1800.

The production version of the IBM 1500 System

Initial brochures describing the 1500 System detailed the system as it was installed at Brentwood School, except that an IBM Model 1131 CPU was shown in place of the Model 1802 CPU. The system was advertised as being capable of accommodating up to 32 student stations. A diagrammatic representation of the system as initially advertised appears in Figure 4.

IBM promotional material14 for the 1500 System described it as consisting of an IBM Model 1131 CPU having 8,192 words of core storage with an additional 24,576 words in the CPU Model 1501 station controller, plus a 512,000-word disk, Model 2310 disks, the Model 1505 audio adapter unit, a Model 1442 card reader/punch, a Model 1132 printer, and the student configuration as having the 1510 display, the 1512 image projector, a light pen, and a 1518 typewriter. Three models of the 1131 CPU were available, each with different CPU cycle speeds and core-memory size. This configuration differed, however, from that installed at most sites, where one or more Model 2415 tape drives were included as well as a Model 1133 multiplexer.

1506 audio unit

Because the 1506 audio adapter unit could not be produced to specification, a different system was designed and manufactured. The replacement was a self-loading, reel-to-reel audio tape drive located at each student station and designated as the Model 1506 audio unit.

Each Model 1506 audio unit (see Figure 5) consisted of a housing containing the playback and recording mechanism, provision for the loading of tape reels, and jacks for the connection of combination headphones and microphone. Once the tape was loaded, an interlocking mechanism prevented further access to the tape by the student. The recording medium was 1/4-inch-wide magnetic tape connected to a special leader and trailer, and wound onto a 5-inch-diameter reel of a design unique to this machine. Each reel could hold up to 600 feet of

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**Known installations of preproduction prototype IBM 1500 Systems**

A question mark (?) indicates that particular information was either not available or could not be confirmed.

1. Science Research Associates (an IBM subsidiary), Chicago, Ill.; May 1967 to ?; used for the development of courseware and a specialized version of APL, referred to as MAT (Mathematics Algorithm Translator).
2. University of Texas at Austin; June 1967 to ?; 12 Model 1510 CRT terminals and three Model 1518 typewriter terminals.
3. Florida State University, Tallahassee; August 1967 to ?; 16 Model 1510 CRT terminals and 16 Model 1518 typewriter terminals with PDP-8 handling remote terminals.
4. Texas Christian University, Fort Worth; November 1967 to ?; eight Model 1510 CRT terminals and 10 Model 1518 typewriter terminals.
5. IBM Watson Research Center, Yorktown Heights, N.Y.; November 1967 to 1969; Model 1510 CRT terminals.
6. US Naval Academy, Annapolis, Md.; 1967 to 1973; Model 1510 CRT terminals.
tape. Each reel could contain a maximum of two hours and 40 minutes of information in message blocks lasting from a minimum of 0.5 second to a maximum of slightly less than 5 minutes. Some courses, such as the CARE course from Pennsylvania State University (a credit course for teachers about learning in handicapped children), required several reels to hold all the required information.

Preparation of instructional tapes for computer control could be undertaken from an instructional station, since each audio unit was connected through the multiplexer to the station control unit. Once a master tape was completed, additional copies could be prepared with special tape-duplicating equipment. While the original station control unit was designated Model 1501, a unit modified through the addition of circuitry and designated Model 1502 was required to accommodate the 1506 audio units. The 1506 audio unit could function in any one of three modes. In most instances the unit operated in terminal mode, where it was under the control of the CPU and the user was able to record information only when permitted by the course code. In sector address mode the unit may be used to record the address track by the computer, a process referred to as initializing. Sector addressing of the tape was accomplished using a flag bit followed by a 14-bit address, and terminated with the 14-bit address and a flag bit. Sector addresses were recorded every 250 milliseconds relative to the tape speed. The address could be interrogated by the CPU, thus providing a means by which correct positioning could be verified. The first eight sectors could also be used for tape identification, which could be interrogated by the CPU to determine whether the student had loaded the correct tape for the course being taken. The assembly mode involved the integration of the author’s narration tape with tape-addressing information to produce the master copy of a course-specific tape.

For a class requiring more than one reel of audiotape, special consideration had to be given to the problem of a student’s position in the course, because messages from the last tape as well as messages from the currently loaded tape might be required. This was not an unusual occurrence in lengthy courses, or in courses where the author allows the student to move back in the course for review. In these instances, additional tapes had to be prepared with special addressing formats that would maintain compatibility of sector addresses and the Coursewriter code.

Model 1133 multiplexer

In addition to a major change in the manner in which audio was accommodated in the production version of the IBM 1500 System, multiplexing was allocated to a separate unit, rather than being handled through the station controller and any inherent architecture of the Model 1800 CPU. It is not clear why this was done; however, one reason might be that each of

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Figure 4. Schematic diagram of initial IBM 1500 configuration.

Figure 5. The Model 1506 audio unit.
the 32 stations could generate interrupts from a keyboard, a light pen, an audio unit, and the film projector, and that the CPU might be required to interrogate the status of the audio and film projector. Without an efficient multiplexer, delay in feedback to the student would likely become objectionable. Cost could also have been a factor.

Authoring languages

A new version of IBM's Coursewriter authoring language, referred to as Coursewriter II, was developed concurrently with the 1500 System. Coursewriter II, like the first version, was intended to facilitate programming by individuals without extensive background in, or knowledge of, computing. Because of the student terminal configuration, Coursewriter II contained additional complexity in that many more parameters were associated with most instructions. For example, as many as six parameters were necessary for the instruction to display text to the CRT screen. The use of audio and the film projector required additional codes to be developed. To some extent the problems associated with the increased complexity of the code were ameliorated by the use of on-line authoring, which allowed for checking the correctness of a statement's syntax on a line-by-line basis.

An interpreter for the programming language APL, identified as the Mathematical Algorithm Translator, or MAT, was made available for the system. With MAT, the 1500 System could also be used for complex calculations such as those for numerical and statistical analyses. Because of response-time delays, most installations that had MAT did not operate it simultaneously with the Coursewriter system unless the Model 2310 disk system was replaced with one of higher capacity and faster access time.

IBM 1500 installation sites

IBM anticipated leases and/or sales of the 1500 System to 40 educational institutions. As with many other instructional devices, actual interest in the 1500 System fell short of expectations. Although a listing of IBM 1500 System installations was not found in the literature, a list was compiled from various research reports (see sidebar on next page).

User enhancements and modifications

While some users of the 1500 System envisaged an integrated instructional system that could simply be plugged in and learning could then take place without any additional effort, most users realized that modifications and adjustments to the system were necessary to attain maximum efficiency. In some instances, innovative modifications and enhancements were made.

As can be seen from the sidebar, Pennsylvania State University was able to obtain additional 1500 Systems that were decommissioned at other institutions. Three additional systems were acquired beginning in 1970, with funding support from organizations outside the university, such as the United States Office of Education. Each of the three additional 1500 Systems was installed in a specially constructed trailer designed to permit the systems to be transported by truck to locations throughout the state (see Figure 6). The outside measurements of the trailers, or vans, as they were sometimes referred to, were 40 feet long; 12 feet, 6 inches high; 8 feet wide when closed; and 17 feet wide when parked with the sides expanded. Thus, the van itself could be used as a classroom as well as a transporter for the 1500 System. Each van was also equipped with a self-contained air conditioning unit required for climate control and cooling of the 1500 System. Vans remained at a location normally from six to eight weeks, usually next to a school where there was space and provision for the power connection.

Innovations at Pennsylvania State University were not limited to the development of mobile versions of the system. To accommodate the training of students in audiology, a simulation was developed using Coursewriter II and an interface to an external audiometer. The student could make adjustments to the audiometer as required in regular hearing assessment, and a drawing of a human figure on the CRT would respond by raising its hand indicating when the sound from the audiometer could be heard. Pennsylvania State, through the leadership of Harold Mitzel and Keith Hall, was instrumental in establishing an IBM 1500 Users Group. This group provided a valuable service in organizing and distributing software enhancements for the system, particularly algorithms (functions) for analyzing free-form responses. Eventually, this documentation exceeded the documentation of Coursewriter II itself, indicating the extent to which Coursewriter II had become inadequate for accommodating a wide range of instructional tasks. The IBM 1500 Users Group eventually became the basis of the Association for the Development of Computer-Based Instructional Systems (ADCIS), which continues to publish the Journal of Computer-Based Instruction.

Most 1500 System installations placed the student stations either contiguously with the CPU or in an adjacent room, primarily because of distance limits imposed by the use of coaxial cable. One notable exception was the system shared by three schools in Kensington, Maryland, under the aegis of the

Figure 6. Specially constructed trailers allowed the systems to be transported by truck.
Montgomery County Schools. The three schools, Albert Einstein High School, Newport Junior High School, and Pleasant View Elementary School, were located around a common playing field. The CPU, related equipment, and some terminals were located in the high school. Additional CRT and typewriter terminals were located in the other schools. Connecting these terminals required installing a cable in excess of the stated 2,000-foot limit. Although it is reported that the remote terminals functioned properly, it is also stated that only one remote site could be connected to the CPU at a time. Dunn and Wastler report that the cables were buried in some areas and carried overhead on poles in others. The overhead placement of the cable resulted in some unique and unforeseen problems involving induced voltage surges and lightning strikes.

Perhaps the longest-lived 1500 System installation (1968 to 1980) was at the University of Alberta, housed in the Division of Educational Research Services, Faculty of Education. A major factor contributing to the longevity of this installation was the wide range of full-length credit courses available, and supported by academic teaching staff from many different faculties. Courses developed locally as well as programs developed at other sites were made available. Courses developed locally include statistics; introduction to the Coursewriter II language and its use; introduction to APL and its use; fundamentals of data processing; introduction to reading and writing French; optics for first-year university physics students; precalculus mathematics; essentials of cardiology, which uses a specialized headphone set resembling a stethoscope; basics of immunization, including a simulation on the correct procedure for inserting hypodermic needles; simulated cases for the training of midwives; and introduction to machine tools.

Examples of courseware developed at other installations include introduction to electrical and electronic theory, from the US Army's installation at Fort Monmouth, New Jersey; and CARE I and CARE 4 programs, from Pennsylvania State University, to instruct teachers on the identification and accommodation of students with learning handicaps.

The University of Alberta's Faculty of Medicine played a major role in the development of courses and patient-management simulations for its own instructional program and for the Royal College of Physicians and Surgeons. In the latter part of 1970, using a mobile 1500 System rented from Pennsylvania State University, these medical courses and simulations were demonstrated at many medical schools in Canada and the United States. The course in cardiology was developed originally on the IBM 1500 System in the early 1970s. Following the closure of the 1500 System, the course migrated to Plato, and then to IBM PCs, where its use continues even now. It is unlikely that any other CAI course has such a lengthy history.

### Known installations of production IBM 1500 Systems

A question mark (?) indicates that particular information was either not available or could not be confirmed.

2. Science Research Associates (an IBM subsidiary), Chicago, Ill.; May 1967 to ?; 1800 CPU; used for the development of courseware and a specialized version of APL referred to as MAT (Mathematics Algorithm Translator).
3. University of Texas at Austin; June 1967 to ?; 1800 CPU with 12 Model 1510 CRTs and three Model 1518 typewriter terminals.
4. Florida State University, Tallahassee; August 1967 to ?; 1800 CPU with 16 Model 1510 CRT terminals and 16 Model 1518 typewriters with PDP-8 handling remote terminals. (This installation was likely the second deployment of the T.J. Watson prototype.)
5. Texas Christian University, Fort Worth; November 1967 to ?; 1800 CPU with eight Model 1510 CRTs and 10 Model 1518 typewriter terminals.
6. IBM, Thomas J. Watson Research Center, Yorktown Heights, N.Y.; November 1967 to 1969; Model 1800 CPU with Model 1510 CRT terminals.
7. US Naval Academy, Annapolis, Md.; 1967 to 1973; 1800 CPU with Model 1510 CRT terminals.
9. Pennsylvania State University, College Park; December 1967 to June 1977; 1131 CPU with eight Model 1510 CRT terminals, later expanded to 32 CRT terminals.
10. University of Alberta, Edmonton, Alta., Canada; March 1968 to March 1980; 1131 CPU with eight Model 1510 CRT terminals, later expanded to 20 CRTs and two Model 1518 typewriter terminals.
11. University of Illinois Medical Center, Chicago; March 1968 to ?; 1131 CPU with one Model 1510 CRT terminal and one Model CC-30 CRT terminal from Computer Communications Inc.
12. US Navy Naval Personnel and Training Research Laboratory, San Diego, Calif.; April 1968 to June 1972; 1131 CPU with eight Model 1510 CRT terminals, later upgraded to 16 CRT terminals.
13. Kansas City Public Schools, Kansas City, Mo.; July 1968 to 1971; 1131 CPU with eight Model 1510 CRT terminals, later upgraded to 17 CRT terminals and Model 1518 typewriter terminals.
14. Fairfield University, Fairfield, Conn.; August 1968 to 1978; 1131 CPU with Model 1510 CRT terminals.
15. North Carolina State University, Raleigh; October 1968 to November 1970; 1131 CPU with eight Model 1510 CRT terminals and eight Model 1518 typewriters.

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of continuous use. A videotape with examples of operational courseware was produced by the University of Alberta before its installation was closed.

One of the more tedious and error-prone procedures in preparing programs for the 1500 System was the entry of graphics using punch cards. To overcome this obstacle, the University of Alberta developed an interactive procedure for graphics construction that used the light pen. This was a major software advance, since it obviated the need to enter graphics in a form that required each pixel to be represented by a hole in a punch card. Creating such a representation was an error-prone, frustrating, and time-consuming process.

Another problem, but one that affected the user more than the course author or programmer, was the necessity of a user-controlled manual focusing mechanism for the 1512 image carrier. Although the projector mechanism as delivered was designed to hold the film flat, and thus in focus, heat from the projection lamp occasionally buckled the film enough to make the image appear slightly blurry. In critical instances, such as reproductions of X-ray images, any blurring would make it impossible to identify subtle changes in image density delimiting an organ or bone. A manual focusing mechanism consisting of a knob attached to a threaded rod connected in turn to the film carrier enabled individual adjustment of focus.

Some of the IBM 1500 System installations were considered either experimental, such as those at the University of Minnesota and Quebec City, or simply as adjuncts to more traditional methods of instruction. But the University of Alberta’s 1500 System was used as the primary source of instruction in most instances. Some of the courses, therefore, were extensive and required the student to spend considerable time to complete them. The cardiology course was estimated to require 30 hours, the electronics course required between 90 and 100 hours, and the statistics course required about 90 hours.20

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One of the more tedious and error-prone procedures in preparing programs for the 1500 System was the entry of graphics using punch cards.

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While the goal of many designers of instructional devices was to develop a device or system that could be the primary presenter of information, the attainment of this goal introduced

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17. University of Minnesota, Minneapolis; 1968 to 1970; 1131 CPU with six Model 1510 CRT terminals.
18. University of Oklahoma Medical Center, Oklahoma City; 1968 to 1969; 1131 CPU with Model 1510 CRT terminals.
19. IBM Systems Research Institute, New York, N.Y.; 1968 to 7; 1131 CPU with Model 1510 CRT terminals.
20. Brooklyn College of the City University of New York, N.Y.; 1969 to 7; 1131 CPU with Model 1510 CRT terminals.
21. IBM, San Jose Education Center, San Jose, Calif.; 1968 to 7; 1800 CPU with Model 1510 CRT terminals. (This installation was likely the second deployment of the Brentwood prototype.)
22. Rochester Institute of Technology, Rochester, N.Y. (National Technical Institute for the Deaf); 1969 to 1978; 1131 CPU with Model 1510 CRT and Model 1518 typewriter terminals.
23. State University of New York, Stony Brook; 1968 to 7; 1131 CPU.
25. Teachers College, Columbia University, New York, N.Y.; January 1969 to 7; 1131 CPU with five Model 1510 CRT terminals and one Model 1518 typewriter terminal.
27. Indiana State University, Terre Haute; 1969 to 7; 1131 CPU with TTY terminals.
28. Pittsburgh Public Schools, Pittsburgh, Pa.; 1969 to 7; 1131 CPU with Model 1510 CRT terminals.
29. Pennsylvania State University, College Park; 1970 to June 1977; first mobile installation with 1131 CPU and 16 Model 1510 CRT terminals.
30. Ministere de l’Education du Quebec, Quebec City, QC, Canada; 1970 to 1972; 1131 CPU with six Model 1510 CRT terminals. (Possibly the second installation of the system located previously at the University of Minnesota.)
31. Pennsylvania State University, College Park; 1973 to June 1977; second mobile installation; 1131 CPU with 16 Model 1510 CRT terminals. (This installation is likely the second deployment of the system installed in the Philadelphia School District.)
32. Pennsylvania State University, College Park; 1975 to June 1977; third mobile installation; 1131 CPU with 16 Model 1510 CRT terminals.
new pedagogical problems. The range of such problems facing a course author and instructor usually transcended those faced by most classroom teachers, contributing to the limited deployment and the demise of the 1500 System in general.

Phasing out the IBM 1500 System

Finance was the most important factor that affected the initial rental or purchase of a 1500 System, the longevity of each installation, and IBM's commitment to development and support of the system. For example, the Ontario Institute for Studies in Education (OISE) in Toronto considered obtaining a 1500 System in 1967. Cost estimates were based on a configuration containing an 1311 CPU, one 1442 card reader/punch, one 1132 line printer, one 2310 disk drive, one 1501 station control unit, one 1505 audio adapter, 16 Model 1510 CRT terminals, four light pens, four Model 1512 image projectors, and one 1518 typewriter terminal. No mention is made, however, of an 1133 multiplexer — required apparatus if an 1131 CPU was to be used. On the basis of the estimated costs (approximately $640,000 for the installation and ancillary requirements), OISE decided against obtaining a 1500 System. The chairman of the then-extant Department of Information and Data Systems at OISE wrote, "the estimates of cost are sufficiently alarming. . . " (letter, L. McLean to S. Hunka, April 6, 1967). Even though some institutions were able to meet the financial challenge, several actions taken by IBM presaged the short life span of the 1500 System and the demise of individual installations.

In mid-1969, less than two years after the first delivery of a production version of the 1500 System, IBM announced that a new version of Coursewriter was available. Known as Coursewriter III, this version enabled programming and instruction to be carried out using several models of IBM's Model 360 computer, a machine that was already in common use among large educational institutions. Besides the new version of Coursewriter, a CRT terminal was also available for use with the Model 360 CPU. The terminal, referred to as the Model 2260 visual display, was similar in appearance to the 1510 CRT terminal used by the 1500 System. A major difference between the two displays was that the Model 2260 possessed an internal buffer to recycle the screen image, allowing it to be connected to the CPU without using coaxial cable. The Model 2260 terminal configuration lacked many of the features of the 1500 System, namely the light pen, audio unit, and image projector. The possibility of using Model 360 computers for instruction probably discouraged some institutions from investing in a 1500 System, since a Model 360 computer could be used for many other purposes but a 1500 System could not. It also appears that IBM wanted to sell its new products to industries rather than to educational institutions, possibly because the commercial market was viewed as being more stable and financially lucrative, since federal and local funds to universities were beginning to decline. By 1977, IBM had evolved a program product known as the Interactive Instructional System, based on Coursewriter III; it was intended to be run on existing IBM mainframes. One of the product's selling points was that it allowed the use of terminals for training as well as production tasks.

The next blow to the 1500 System came during 1970, when IBM announced that it was no longer pursuing development of the system. It seems likely that, given the development costs of the 1500 System, IBM did not recover its initial investment and foresaw little prospect of profit by continuing the development of a dedicated computer-based instructional system. The paucity of instructional programs for the 1500 System and the expense of developing them were also major factors contributing to the phasing-out.

The action taken by IBM to discontinue development of the 1500 System prompted some installations to search for other computer-based instructional systems and to phase out their 1500 Systems as soon as possible. Moreover, federal funding programs that enabled many institutions in the United States to obtain a 1500 System began to end in the early 1970s. While it may have been anticipated that institutional funding would replace federal funding, evidence shows that this occurred rarely, and then only for short periods. An example is the installation in the Montgomery County Schools, Maryland, for which federal funding ended June 30, 1971, after which the operating costs were underwritten by the school board, while the cost of leasing the 1500 System was absorbed by IBM. In spite of IBM's special support of the installation, a Plato IV computer-assisted instructional system was installed in 1973 as a replacement for the IBM 1500 System.

Other installations decommissioned their 1500 Systems as soon as special funding ended. For example, the 1500 System installed in the University of Oklahoma's Medical Center lasted only a short time because of such financial factors. While much instructional material had been created on the system in its first year of operation, and although the medical center hosted a conference on computer-based instruction during that time, lack of funding forced the installation to close. Pennsylvania State University, which had four 1500 Systems, one fixed and three mobile, is an example of a longer-lived system that suffered a similar fate.

While some principles of design in the 1500 System were ahead of their time, the advent of smaller computers with lower prices, larger memories, and faster CPUs meant that the 1500 System became uneconomical. Because the 1500 System could not accommodate more than 32 students at a time, while other computer-based systems such as Plato IV and TICCIT (Time-shared Interactive Computer-Controlled Information Television) could handle many more, the 1500 System was not as cost-effective as competing systems. While some installations addressed the problem of moving courses to a new system by reprogramming using a different authoring language, others discontinued much of their computer-based instructional work.

In April 1977, IBM announced that it would discontinue the rental and maintenance for the 1502 station control and all components of the student stations, effective April 1980. By the time of this announcement, however, most 1500 Systems had already been decommissioned. In 1978, only three 1500 Systems were operational: the University of Alberta, the Rochester Institute of Technology, and Fairfield University. By 1980, the last of these installations was decommissioned, bringing to a close IBM's involvement in dedicated computer-controlled instructional systems.

Many current courseware developers using such hardware as the Macintosh with the Authorware Professional authoring system or a PC using the Tencore authoring system...
find it difficult to believe that a system developed over 25 years ago provided many of the interactive instructional features available today. They also find it difficult to envisage that a CPU having only 64 Kbytes of memory, and hard disks rarely exceeding one-tenth the capacity available on a typical microcomputer, were capable of servicing 32 student stations. If instructional use of the microcomputer increases — and history would suggest that this is by no means a foregone conclusion, notwithstanding a repetition today of outlandish claims by a new group of experts — course authors will continue to encounter problems that had largely been accommodated very adequately by the 1500 System, e.g., student registration, routing, and performance recording and analysis systems.

It seems there are always some educators who claim that each new hardware and software development will revolutionize education. It is predicted that these new revolutionary developments will be characterized by the buzzwords “multimedia,” “networking,” and “virtual reality.” The words are different from those used 25 years ago, but the claims are likely to be as outlandish and just as in accurate.

References


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