MEMORANDUM
RM-6180-NLM
APRIL 1970

APPLICATIONS OF ADVANCED TECHNOLOGY TO UNDERGRADUATE MEDICAL EDUCATION

J. A. Farquhar, R. Bretz, A. S. Ginsberg,
T. L. Lincoln, R. J. Mellone and G. F. Mills

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The RAND Corporation
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PREFACE

This Memorandum, which concerns undergraduate medical education, describes alternative ways in which technology might increase both the quality and quantity of such education, and details a comprehensive plan for further study of this problem.

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Rudolph Bretz is a Consultant to the RAND Corporation.

SUMMARY

This Memorandum concerns undergraduate medical education, and the ways in which advanced technology might bring about substantial changes in both the quantity and quality of graduates. Five such applications are described:

1) Computer-assisted instruction;
2) Computer-assisted self-evaluation;
3) An ultra-microfiche retrieval and display system;
4) Electronic Video Recording (EVR);
5) Two multimedia aids known as the "Clinical Encounter Simulator" and the "Patient Management Decision Aid."

The goals of applying technology to medical education are discussed, and questions are raised that must be answered prior to any attempt at widespread implementation of the systems described. The remainder of this Memorandum is concerned with sketching out possible directions for future research. Two examples of the form and possible results of such research are provided.

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I. INTRODUCTION

This Memorandum, concerning the application of advanced technology to medical education, focuses on undergraduate and graduate medical education. However, much of the ensuing discussion also is relevant to problems of continuing medical education.

Medical education is an attractive area for research because 1) it costs considerably more to educate a medical student for one year than a student in any other discipline, and 2) the knowledge necessary for a medical student is not only in the *cognitive* domain (the case with most disciplines), but also concerns the *psychomotor* and to some extent the *affective* domains. Thus a technological "aid" successful in medical education is likely to be applicable to other disciplines.

Such devices, described in the following sections, are practicable using existing technology, although some non-existent or prototype systems are used in the full description. The initial description is a "scenario," which gives an immediate subjective appreciation of the nature, benefits, and capabilities of the devices described. The scenario is helpful as a means of translating rather dry conceptualization and design results into an interesting format that describes not only the relevance and preferred nature of the devices in question, but also the atmosphere attendant to a technologically-assisted educational environment.

The following scenario describes portions of the medical-education process. The descriptions provided are supplements to current medical education, not replacements for such necessities as patient contact or education in the basic sciences. Section III discusses goals of technology in education, and the relationship of these goals to the scenario.

Although serving a valuable purpose, the scenario has obvious and severe limitations. Useful for subjective description, the scenario often fails to detail the actual systems that might support the innovation described. Therefore, the scenario is intended to raise questions concerning effectiveness and methods of employment and deployment. Section IV delineates many of these questions, and describes research methods for effective use. Section V, a stylized treatment of two scenario items, illustrates the gross nature of results from analyses like those outlined in Sec. IV.

II. A SCENARIO

Roger is 31 years of age, married, and the father of two children. He has a Ph.D. in organic chemistry from Midwestern University, and is now Assistant Professor of Chemistry at Downtown College.

Because his father was a veterinarian, Roger briefly considered going into medicine. Ultimately, he settled on chemistry. After completing his Masters in chemistry at Midwestern University, he worked a year for the Delaware Corporation, a large industrial chemical firm. Roger found the industrial environment oppressive and anonymous, and switched to industrial research at the Haven Corporation. Dissatisfied again, he returned to Midwestern to complete his Ph.D.

At Midwestern, Roger began to synthesize a Rauwolfia derivative, active against hypertension. His thesis work was financed by an NIH grant. But with his work only half completed, he was "scooped" by a Hungarian worker who published the synthesis. Thereafter, Roger experimented with related products and, with the collaboration of a pharmacologist, he tested these products for antihypertensive activity.

Together they became interested in identifying the active antihypertensive configuration in this class of molecules, and published a paper on their results. They also were intrigued with the biological site of action and did a number of thought-provoking experiments. In this way, Roger was introduced to the complexities of biological systems. Much had changed from the time when he had worked as a technician in his father's practice.

After his thesis was accepted, Roger thought he would like to teach. He taught a year at a local high school, but he quickly decided that teaching at that level was not *a career for him. He therefore accepted a position at Downtown College.*

The students were bright and Roger enjoyed teaching. He particularly enjoyed counseling students. For fun, he audited several courses on biology, embryology, and comparative anatomy. Because of the direction his research was taking, he took a series of courses in general physiology, and thought more about going to medical school. First he asked his faculty friends and then he sought professional advice about how this might be done. Roger also wrote the deans of admissions of several medical schools.

The results were disappointing. Despite his obvious qualifications, many schools would not consider his application seriously. Those who invited him for an interview were skeptical about the long path ahead.

Most schools wanted applicants just out of college or just back from military service. The four-year curriculum was designed to be taken in cohort fashion. Provision for advanced standing gave more time for electives, but did not shorten the four-year course. Advanced standing generally depended upon completion of defined course work. Most schools pointed out that Roger, 31 years old, would complete school at age 35 and could expect to complete his residency by age 39 or 40; he would receive his board certification in internal medicine at about 42.

One exception was Zenith University, known for its innovative approach. At Zenith, the Dean of Admissions showed a real interest in Roger. Roger demonstrated many positive attributes--he had done interesting academic work, and he was interested in people. His career showed great resourcefulness. In various informal ways, he had learned much of the scientific material fundamental to medicine. However, his course credits hardly sufficed for pre-med. By the book, he would have to take courses for credit in undergraduate biology. He needed some nonscience courses, *perhaps English or history, to have the necessary liberal arts distribution. After taking these courses, Roger would be able to enter medical school in one year.*

But Zenith was prepared for Roger's situation. The Dean told Roger that it would be possible for Zenith to consider him for immediate admission, and to credit him with the education that he had acquired.

COMPUTER-AIDED SELF-EVALUATION

Roger first needed to assess his knowledge in order to have a rough idea of how much time he would need to spend in school, and how much more he needed to know to fulfill Zenith's preclinical-studies requirements.

Toward this end, Roger was ushered into a room containing a console station resembling a typewriter. The Dean of Admissions explained that Roger would be allowed to determine his own level of competence, and the portion of the medical curriculum he could validate. The Dean explained that this system could not make any final decisions, or provide information to the school for making a final decision. The system was merely to give Roger an idea of how much he already knew in order to determine how much time he needed to spend in medical school; one of Roger's main considerations in deciding to attend.

The Dean then dialed a number: (800) 317-8400. The console typewriter printed out:

> WELCOME TO THE SELF-ASSESSMENT PROGRAM. I WILL ATTEMPT TO ASSIST YOU IN DETERMINING YOUR PROBABLE LEVEL OF KNOWLEDGE TOWARD PURSUING A MEDICAL CAREER. ANSWER ALL THE QUESTIONS I ASK, AND I WILL PROVIDE YOU WITH A LIST OF YOUR KNOWLEDGE DEFICIENCIES. IN ADDITION, I WILL TELL YOU WHAT RESOURCES YOU MIGHT USE IN YOUR CURRICULUM, AND HOW LONG IT MIGHT TAKE YOU TO FINISH SCHOOL. NO

ONE WILL HAVE ACCESS TO THIS INFORMATION EXCEPT YOURSELF. TO BEGIN, A FEW FACTS:

Have you a BACHELORS DEGREE? (Y or N)

The system continued to elicit facts about Roger's educational background, followed by multiple-choice questions on his cognitive knowledge. In some cases, he was asked for specific facts; in others, he was provided with a "problem" statement and was asked about methods of inquiry and solution. At the close of the lengthy session, he was given a detailed scoring of his examination. Through an inferential scheme, Roger also was informed of how his knowledge matched the particular curriculum of Zenith.

Roger discovered that his knowledge of biochemistry and physiology exceeded the level generally expected of a medical student. His understanding of pharmacology, although spotty, exceeded Zenith's requirements in some areas. He knew a fair amount of gross anatomy, but lacked much of the human anatomy vocabulary.

In discussing these results with the admissions director, Roger discovered that with six to nine months of intensive self study, he could meet all preclinical science requirements. His greatest need would be in pathology, but with his background he could approach it in a novel way.

Thus reassured, Roger applied to Zenith Medical School and was accepted. His first weeks consisted of a flurry of orientation, book-buying, and reacquiring the study habits and concentration necessary for success in any graduate program. But the novel and exciting thing was acclimating himself to completely foreign pedagogical techniques.

In Roger's graduate study in chemistry, and in his own teaching experience, instruction had been conducted both through conventional lectures and labs geared to the pace of the group and the regular organization of course work.

At Zenith, lectures still existed, but they largely had become seminars that could be attended either directly or by television extensions. They also were available for television replay from a bank of control tapes. A large file of lectures by Nobel laureates had been collected and could be browsed at will.

In the past three years at Zenith, the number of admissions increased threefold, yet the faculty remained almost constant. A large portion of the teaching burden had been shifted to computers. Roger sat before a display screen, and used the device for the first time in "drill and practice" routines to acquire necessary vocabulary. Much of the tedium was relieved by turning this into games against the computer. "Anatomy Scrabble" was a favorite.

COMPUTER-ASSISTED INSTRUCTION (CAI)

The graphic capability offers more exciting and insightful instructional possibilities in biochemistry. The alternative pathways of intermediary metabolism are graphically displayed as are other biochemical processes involved, such as the transfer of free energy through ATP dephosphorylation. Roger can manipulate the graphic display to simulate experiments. In the simulation, it is possible to remove enzymes or block reactions so that intermediate products build up and are displayed. The same basic displays are used in biochemistry, pharmacology, internal medicine, and anesthesiology. The details are updated as new material is published and verified. Roger already recognizes that these displays will be a familiar and useful tool for continuing education.

A valuable use of the graphics system is in the teaching of anatomy. The student can display a sequential process of dissection in either the surgical or anatomical format, using a device such as a light pen to "cut through" tissue leading to underlying structures. In particular case dissections, unusual obstructions of blood vessels can be simulated to remind the student of anatomical variations. The effect of motion on contingent structures also can be followed in special displays.

Anatomy is linked directly to physiology and to the physiology of disease; the student can display a beating heart, and through manipulation observe various cross sections and cutaways. In addition, the support computer is capable of "simulating" various infarcts upon request, and Roger observes the physical manifestation of these and other abnormalities such as arrhythmia. Abstract network models of these arrhythmias are displayed and manipulated to show the conditional relationships involved and the effect of particular therapies. Roger can simulate arterial filbrillation in a "beating" network where the characteristics of muscles are represented as points with particular refractory times and transition characteristics. He also can simulate the effects of drugs; by changing parameters he can simulate the effect of guinidine. The display illustrates how, using the proper "dose," the rhythm of a damaged network can be returned to normal (by reducing the refractory time), and how an "overdose" can "short circuit" the entire system.

This full-color display capability and the use of the split screen are particularly valuable in pathology. For example, a stomach ulcer can be demonstrated by gastroscopy (using a fiber optics probe and a T.V. camera) and this result compared to the look of the stomach at operation, the surgical specimen, and the microscopic findings. The surgical anatomy of the stomach can be reviewed by animation.

Roger is able to spend as much or as little time as he wishes in teaching himself the preclinical sciences; however, since he is trying to finish as rapidly as possible, he spends a great deal of time studying. Many other students do the same: those with financial problems, those facing a long residency, and those who are highly motivated by the challenge offered through the self-pacing curriculum. Roger notes that many students are more relaxed about their studies, expecting to spend five or six years in medical school.

After four months of hard, independent study combined with lectures, Roger feels ready to enter the clinical studies. First, he is required to produce a paper on some aspect of the preclinical sciences. He decides to write a survey paper on the effect of catecholemines on intra-muscular electrical impulses.

THE PORTABLE LIBRARY

Roger's report is due the following Wednesday, but he has reached a dead end in researching his subject. Roger has been in a similar situation many times during his earlier graduate study. Then, he might have consulted *Chemical Abstracts* to see what had been written on the subject, or he might have reviewed the *Index Medicus*. Roger realizes that these searching techniques are doubtful at best, and is hesitant to invest valuable time in such an activity. Five years ago, Roger would have abandoned the effort and concluded the study short of his self-established goal.

But in this case, he has access to a portable Med-File. The Med-File is no larger or heavier than a small film projector. It uses circular magazines of microfiche, which are 12 in. in diameter and 3-1/2 in. high. Each magazine contains 300 ultra-microfiche, carrying 3600 images apiece, or a total of nearly 1-million page images. Each magazine is equivalent to 2000 books of 500 pages each; i.e., Roger, in checking out several magazines for the weekend, has taken home half of the library files.

Having this tremendous collection of journals, books, and other materials at his place of study is one thing, finding the information that he needs is another problem.

Here the Med-File proves most useful. Roger dials a telephone number, and places the telephone receiver in a cradle on the rear of the Med-File, connecting him to a central computer that carries indexing information for the magazines he has checked out.

The front of the Med-File has two screens and a keyboard. The screen displays information that the student uses in determining what items to retrieve. He may search through the indexing information at his own pace, displaying subject headings, subheadings, and actual references. Should he desire, he may construct Boolean relationships and ask for citations satisfying these criteria; e.g., all references dealing with both RADIOISOTOPES and GASTRIC ULCER.

When he discovers an appropriate reference, he may ask the Med-File to display the text of the article by mechanically accessing the pertinent microfiche and displaying it upon the other screen. The entire process is computer controlled; the student needs only to mount the necessary magazine on the Med-File.

ELECTRONIC VIDEO RECORDING

Not all of Roger's preclinical time is spent studying basic sciences. He also receives instruction that will prepare him for entry into clinical education. Again, much of this preparation takes place in a classroom. Particularly exciting to Roger is yet another electronic aid to his independent study. Available to the students are Electronic Video Recordings (EVR) of Clinicopathological Conferences. These "CPCs" are seminars in which several physicians discuss patients' case histories.

A richer set of visual information is available in the CPC than in the older lecture method. The visual findings of gastroscopy are part of the history, as are x-rays, in black and white and with pseudo-color enhancement to outline special regions. The decision sequence of the clinician interpreting the case is outlined by animation. Thus, Roger learns the difficult job of putting clinical information into an analytical format, reinforced by student CPCs that are designed for the student to work out for himself. Every month a new student CPC is set up so that the student may test his ability. Some of these are rather like CPCs in the *New England Journal of Medicine*, but others are on novel topics.

One CPC concerns an automobile accident case seen in a very busy emergency room. The history includes the tape from the television monitors in the emergency room (these are on much of the time, and the residents run play-backs of their work much as football players do). In this case, the patient dies of a bleeding intercostal artery. However, the only apparent symptom was two broken ribs. Much time had been spent, for example, at x-ray and doing lab work. The critical diagnosis was not made because of failures in communication and because the intern's attention had been diluted by irrelevant data. Roger becomes aware that physician judgment is important and difficult, and that there are serious failures. An important lesson is that some "pathology" does fail in the service system, often under conditions of overload.

The CPCs are used at Zenith in two ways: 1) in traditional classroom training, the instructor plays half of the EVR tape (over a specially equipped television set). Following this, he discusses with his class the history and possible diagnoses. Then the presentation diagnosis is shown, with interruptions for clarification and expansion; and 2) the student also uses the CPC recordings on his own. He inserts a tape cassette into a special set and sees and hears the case, interrupting at will to find reference materials (or his "Med-File") for clarification or further reading.

Roger finds the CPC tapes very helpful. He knows that he would only be "excess baggage" in a real clinical situation and would probably do more damage than good. The CPC cases and his increasing success in diagnosing them simultaneously increase his competence and his confidence. Roger also finds the CPCs useful as a reference device; he can stop the tape and study any single frame in detail. The machine's "fast-forward" and rewind features allow Roger to reference the tapes almost as rapidly as he would a textbook.

Roger realizes that it is a long step from the CPC tapes to the actual practice of medicine. In attempting to determine more about clinical medicine and how it might be taught, he has met and talked to Danny, a student midway through medical school. Danny describes to Roger the variety of aids that are used to "teach" medical practice and that serve to supplement the early and continuing live patient contact that all students must still experience. Danny then demonstrates one of the more impressive aids to Roger.

THE CLINICAL ENCOUNTER SIMULATOR

Danny has been studying the problem of pleural effusion and wishing that he might encounter a patient who exhibits this sign so that he might attempt to manage the case. Unfortunately, he sees no possibility of having access to such a patient. Rather than wait until his newly-acquired knowledge on the subject becomes stale, Danny decides to use the Clinical Encounter Simulator.

The simulator, in its simplest form, is a system of instructional media and devices in which the student plays a coordinating role. It is contained within a study carrel and is comprised of such familiar components as reference books, x-ray films, 2" x 2" slides, 8mm cartridge films, and audio recordings (Fig. 1). Direction of the student's

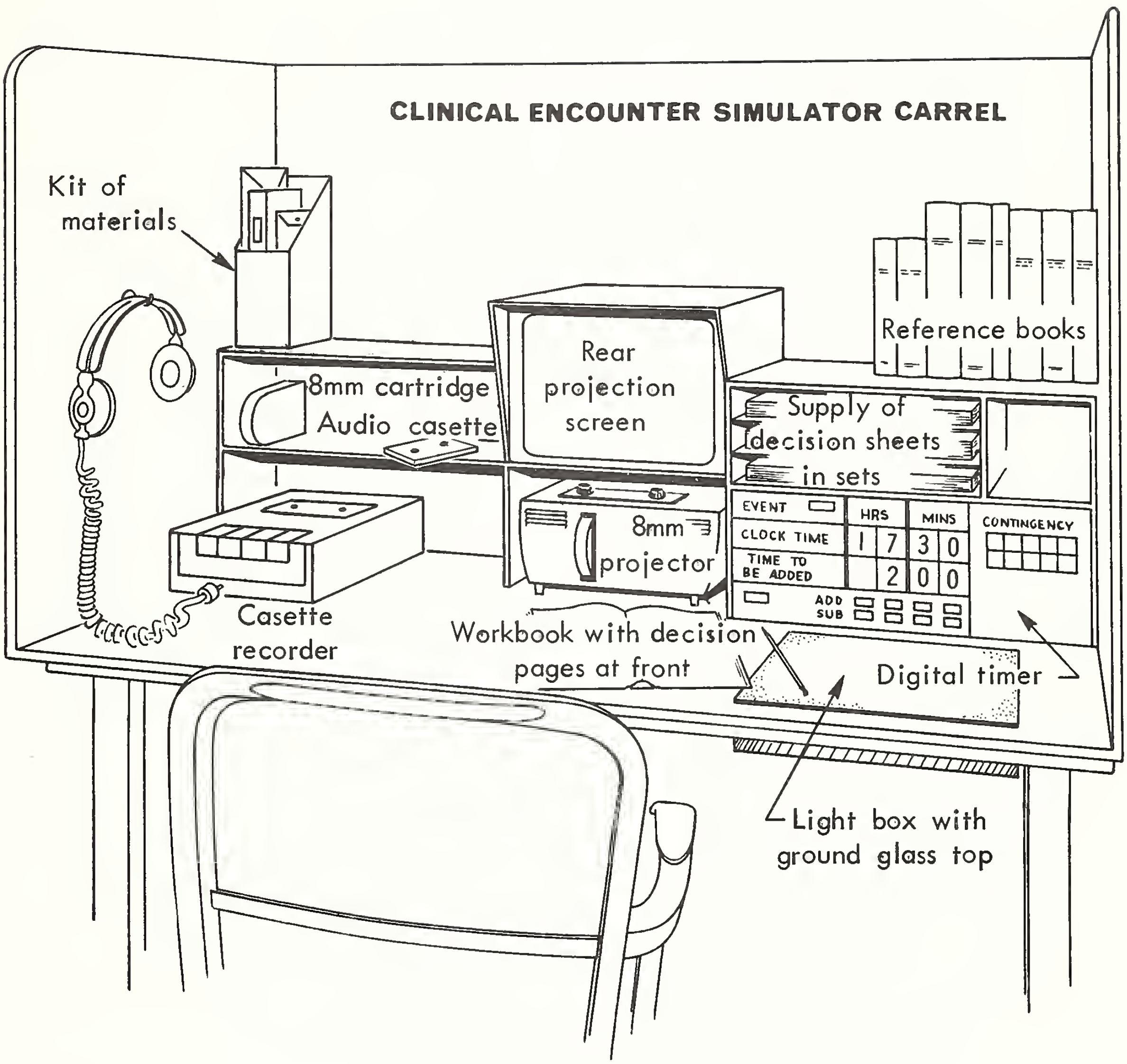

Fig. 1--Clinical Encounter Simulator Carrel

activities, and most of his information, is provided in a small workbook; many stored in the carrel, each specific to a given case. The student makes all decisions on special "decision sheets" for future record of the route followed in arriving at diagnosis and treatment. He erases black overprint, and reveals the workbook-page numbers where the results of tests or treatments are presented; the erasure remains as the permanent record. When done in successive columns, the order in which decisions were made also is evident. Two types of decision sheets are used: 1) test decision sheets, and 2) treatment decision sheets. A typical test decision sheet is shown in Fig. 2. Treatment decision sheets will look similar.[†]

Many clinical cases can only be simulated well if a possibility exists for introducing unexpected events; e.g., emergencies with which the student must cope, or conditions that develop as a result of the passage of time. Therefore, passage of time is an important dimension of the simulation. Each action that the student takes involves, in real life, a certain time component that should be accumulated by the simulator so that events dependent on time will logically occur. In the more complex and expensive simulator, this function is handled by the computer. In this less expensive version, it is managed by a device called the "Digital Timer," also referred to as the "clock." Figure 3 illustrates this device. At each decision, the learner is directed to enter a certain amount of time into the clock by setting up the time to be added, using the add buttons at the bottom, and then adding this time to the displayed clock time by punching the

---

[†]One sheet provides room for approximately 30 tests; however, two or three sheets will probably be required to hold all the possible tests that might be relevant to a given set of case histories. A single sheet could fit a set of cases, and another sheet might be prepared for another set of cases that would contain some identical tests and some different ones.

DECISION SHEET: TESTS Case #______ Date __________

	DECISION POINT NO.	1	2	3	4	5	6	7	8	9	10	11	12	13
	DAY	M							Tu					
	CLOCK TIMES	1100	1115	1130	1230		1530	1545	1745					
	Events	■	■	■	■	62	■	■	■	62	■			
	History		■	■	■	■								
	Physical Examination	■		■	■	■								
3h	Blood tests	■	■	■	16	■								
3h	Urine tests	■	■	■	18	■								
1h	P.A. & lat. chest films		■	22	■	■								
2h	Protein test				■	■	■	12	■					
15m	Thoracentesis					■	8	■	■					
2h	Gram smears						■	10	■					
2h	Acid fast smears						■	11	■					
24	Cytologic examination						■	■	15	■				
24	Pleural needle biopsy						■	9	■					
2h	Glucose tests						■	7	■					
	etc.													

Assume all cells are black except those erased above

Fig. 2--Sample Decision Sheet

master add button at the lower left. The student starts each encounter by setting an arbitrary day and time on the clock face. Weekdays during daylight hours are the easiest times to work the case; night and weekend times present special challenges since hospitals and laboratories are short-staffed and it takes considerably longer to get the results of most tests. The clock automatically adjusts for these factors; when x amount of time is set on the "time to be added" counter, the clock checks the day and time and, if it is outside regular hours, adjusts accordingly.

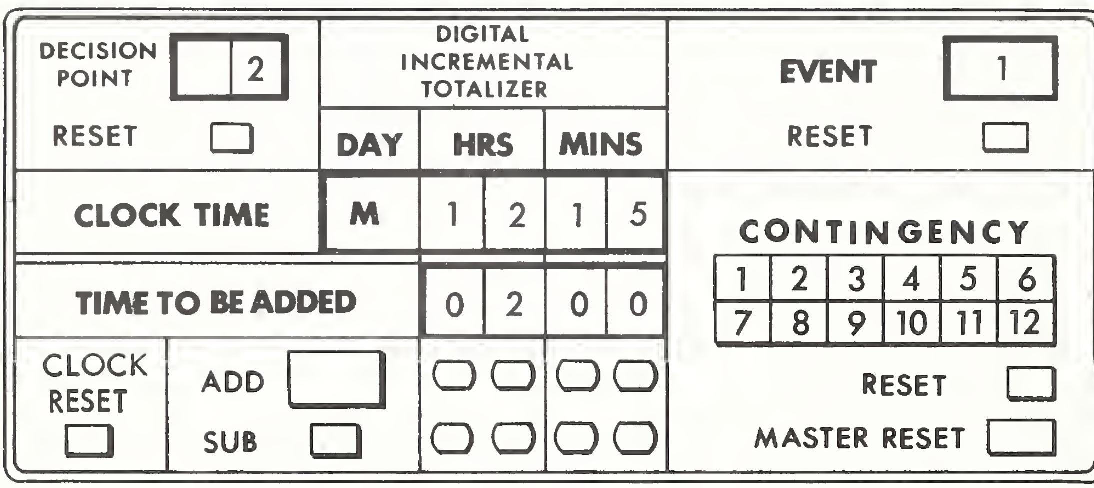

Fig. 3--Digital Timer

Some treatments or tests may affect coming events, either putting them off or bringing them closer, and the clock adjusts for these contingencies. Such decisions will result in the student being directed, generally by the workbook, to punch a specific contingency button, thus affecting the time at which the clock will announce an event.

Danny decides to choose a patient with pleural effusion for a clinical encounter simulation, and out of several pleural effusion cases on the shelf he chooses case No. 75. He takes workbook No. 75 off the carrel shelf, finds the list of adjunct materials on the first page, and checks that all necessary records, x-ray films, 8mm film cartridges, and other materials are available. He is directed to insert tape cassette No. 75 into the digital timer, clear all displays, and enter a day and hour at which he wishes to start the simulation. Now he turns the page and reads the basic admitting information on the patient: a white male, 60 years old, complaining of chest pains and shortness of breath. The next paragraph asks if Danny wants to elicit the history of the patient, or feels that he is sufficiently skilled at this process and wishes to save the time and have the relevant history presented to him. If he chooses to take the history, he is directed to take a history sheet from the supply in the carrel and ask as many questions as he wishes, in whatever order he likes. Since he feels fairly confident about his ability to take histories, Danny elects to skip this exercise. He does not use the sheet illustrated in Fig. 4.

He is directed to a particular page in the workbook that reminds him to tally up 15 min on his clock; then he is presented with the relevant information.

Danny notes that the history brings out only one or two additional pieces of useful information; the patient has had a soreness in his right calf for the last week or so, and he has a history of two packs a day cigarette

HISTORY SHEET Case #_____ Date __________

Where does it hurt?	
How long has it bothered you?	
Do you smoke?	3
Has your weight changed recently?	
Are your parents alive?	No
Various other appropriate questions	8

Some answers are yes or no or short enough to be revealed by the erasures

Others, more lengthy, are to be found in the workbook on the pages specified

Fig. 4--Sample History Sheet

consumption. The timer now shows "2" in the decision-point display window; decision point 2 is entitled on his sheet of directions, "Physical Exam" (Fig. 5). Danny is asked if he wishes to perform the physical workup himself or to skip that exercise. He chooses to do this himself, so he is directed to take a physical examination sheet from the supply in the carrel, enter 15 min on the clock, ask questions, and make whatever tests he wishes. He scans the list of available physical maneuvers and selects palpation. He makes the selection by erasing the black square that follows the word palpation, and turns to the workbook page number that was revealed. Here Danny finds a diagram of a patient with several sites for palpation identified by number. He chooses the sites for palpation by erasing the appropriate boxes, and he is directed to the page that contains the verbal description of palpation of the selected site.

Danny decides to perform auscultation next, so he erases the square opposite this choice. The page to which the erased square directs him contains a diagram of a patient's chest. Associated with the diagram is a matrix that associates all the indicated sites with two or more modes of breathing--sites listed as the lines of the matrix; e.g., modes of breathing as columns. Thus, from a total of eight sites and three modes of breathing, for instance, he has a 24-cell matrix from which to choose the various combinations that he thinks will be most informative. Returning to the physical examination sheet, Danny finds the same matrix with black erasable squares in each cell. He chooses to hear the sounds at a particular site and with a given mode of breathing (say site 3 with mode of breathing A, which is inhalation) so he erases cell 3A, revealing a number that identifies the proper cut on the "case No. 75 auscultation and percussion cassette recording," which he finds filed in his carrel. Donning earphones, Danny mounts the tape cassette, positions the tape to the proper point with the aid of an indexing device, PHYSICAL EXAMINATION SHEET   Case #_____   Date __________

Palpation	17
Pupillary light response	13
Observation of optic fundae	48
Test visual field	43
Auscultation	50

Auscultation

Mode of breathing	Sites 1	2	3	4	5	6
A	[redacted]	51	[redacted]	52	53	[redacted]
B	56	[redacted]	[redacted]	58	[redacted]	[redacted]
C	[redacted]	60	62	[redacted]	68	69

Percussion 10

Sites

1	2	3	4	5	6	7	8	9	10
[redacted]	[redacted]	[redacted]	13	14	[redacted]	[redacted]	21	[redacted]	22
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
30	[redacted]	32	34	[redacted]	[redacted]	[redacted]	39	40	[redacted]

Next test	[redacted]
Various other tests	[redacted]
	[redacted]

Fig. 5--Sample Physical Examination Sheet

and listens to the sound. The tape begins with an announcement giving site number and mode of breathing, followed by approximately 15 sec of breath and heart sounds. He listens to several of these sounds, listening again to one or two before he is satisfied. He notes diminished heart and breath sounds over the lower right lung.

Danny next chooses percussion. He erases the square associated with that name on the physical examination list, and is directed to a workbook page on which he is again given a diagram with several possible sites for percussion, identified by number. Each number is associated with a black square on the examination sheet. Danny chooses the sites at which he wishes to try percussion, and by erasing he determines the proper point on the cassette recording. He pays particular attention to the right lung, and notes a dullness and decreased resonance in that area.

He next picks pupillary light response, and his erasure this time refers him not to the workbook but to an 8mm film cartridge. He inserts the cartridge into the film projector, and watches the patient's pupil respond to light. He may repeat this short loop of film as many times as he wishes.

After choosing to observe the optic fundae, Danny is referred to a high-quality color photographic print mounted on a page in his workbook. In response to choosing the visual-field test, he is given a verbal description accompanied by appropriate diagrams. From these and the other physical examination tests that he chooses to apply, he decides the output is exceedingly unremarkable. His physical examination sheet now contains a record of the tests he has used. He files it on a shelf in his carrel, and turns over several possibilities in his mind.

The clock tells Danny that he is at decision-point 3. He scans the list of possible tests, which is two or three pages long, and decides to begin with "P-A and lateral chest films." He notes a test time of one hour and clocks up an hour's time. He erases the square in column 3 since he is at his third decision point, and he is directed to a numbered package of x-ray films that is stored on a shelf in his carrel. He examines these by laying them over a ground-glass insert that is flush with the carrel work surface and has a light underneath. The films carry a workbook page number where he can find the radiologist's interpretation. The films reveal that the lung fields are clear except for a moderate-sized right pleural effusion.

Now Danny decides to order blood and urine tests. Since every time he clocks up time he is advanced to the next decision point, the clock shows him at decision-point 4. He notes that these tests will take three hours, and he wonders if there is anything that he should be doing in the meantime. He wishes he had saved the hour the x-rays took by ordering the bloods and urines first, but it is too late now. He decides he can do nothing but wait; he must know the results of these tests before he can make any further decisions, so he clocks up three hours and starts to erase the page-number block.

The three added hours trigger the first event: A buzzer sounds and a red number 1 appears in the event window. Danny knows he must deal with this event before he does anything else. He enters the clock time on his decision sheet and erases the square after EVENTS in column 5. He is directed to a page in the workbook where he can learn about the event. He discovers the patient is having trouble breathing and is somewhat distressed. He looks quickly over the two or three dozen treatment options that are listed on the treatment sheet, considers some of the tests that are listed, and looks at the results of the bloods and urines that he has been entitled to read ever since he tallied up the required three hours. No abnormalities were found in either sample.

On the basis of the test results and the present emergency, Danny decides to remove the lung fluid and orders a thoracentesis. The clock reads decision-point 6, so he erases the square in the sixth column and enters the clock time. He is told to tally up another 15 min and then is directed to a page on which a color photograph of a small beaker of fluid is mounted. Danny notes that the fluid appears turbid and blood-tinged. Having forgotten the significance of blood-tinged fluid, he devotes a few minutes to his reference books. From some cursory reading, he gathers that bronchogenic carcinoma may be a possibility, and he decides to make some further tests, which leads him to the test sheet. In the seventh column, he makes five erasures, simultaneously ordering a protein test, gram smears, acid-fast smears, glucose tests of the fluid, and a pleural-needle biopsy. All test times are 2 hr except for the pleural needle biopsy, which is 24 hr. Danny decides to enter two hours on the clock and look at the results of the first four tests; he makes a note of the day and the time his clock will show when he will be able to see the biopsy results. He finds the protein to be 4.1 percent, glucose 60 grams, and the smears negative.

Danny now suspects a bronchogenic carcinoma and decides to order a cytologic examination, which will take 24 hr. He knows that his pleural-needle biopsy is due in 22 hr and decides to do nothing until he has the results of the biopsy. Accordingly, he adds 22 hr to the clock so he can look at these results. The added time trips event 2, and the red light goes on. He turns quickly to event 2 and reads that the patient has expired during the long wait. If he would like to see the autopsy report and end the game, he may turn to the last page of the workbook.

He is given another option, however, available only to medical students who treat simulated patients; he may turn back the clock to the beginning, or to any point along the way, and try again.

Danny decides to start again, just after the physical examination. He takes out a fresh set of record sheets, notes the clock time entered on his first decision (which shows on this first test sheet), and enters this time on the new sheet. Then he sets the clock back to that number.

He remembers the patient's pain in the right leg and wonders about the possibility of a thrombophlebitis. This time he begins with a different theory. He now suspects a pulmonary embolism; he scans the test options that are available and chooses to order a lung scan. He tallies up four hours, erases the block in the third column, and turns to the given page. The first heading asks if the pulmonary fluid has been removed. If the answer is yes, the results of the lung scan can be found on the following page. Since he has not removed fluid, he pays closest attention to the next heading, "If the fluid has not been removed," and reads the paragraph below carefully. Danny is warned that the lung scan may be misleading in the presence of fluid; if fluid is present, he is advised to remove the fluid before the lung scan. He is told that if he wishes to do this, he should tally up an additional 15 min and turn to the next page. This done, he finds a photograph of a lung scan on which he can see no abnormalities.

Danny ponders for a moment and suddenly remembers that a lung scan can be negative in spite of a pulmonary embolism; he decides to make sure by ordering a pulmonary angiogram. He tallies up two hours on the clock, enters the clock time, and erases the square in column 4. He is directed to a page where the angiogram is represented. He notes various defects that are consistent with a large pulmonary embolus. Now, for the first time in the process, he has decided on a treatment. Turning to the treatment sheet Danny selects "Anticoagulants and Breathing Assistance." Glancing at the clock he notes that he is now at his fourth decision point, so he erases the block in the fifth column. He is directed to enter "Contingency 6" (which will prevent any events from occurring due to passage of time) and to tally up 12 hr. Turning to the proper page, he reads that after a few hours the patient rested comfortably, and within 12 hr was well on his way to recovery.

At this point, the student is very curious to know if the patient did indeed have a pulmonary embolism, or if the recovery was fortuitous. With a simulated patient, the student can have his cake and eat it too--he can delight in the patient's recovery, while submitting him to an autopsy. He turns with great interest to the back of the book and reads that the official cause of death was a second massive pulmonary embolus.

The student now puts together the decision sheets he has used and their erasures, which now constitute a record of the actions and events of the clinical encounter. The student may file these for later study or use them in reviewing the case with colleagues or professors.

A few years later, Roger wants to manage a patient with a pleural effusion. Roger and a few of his classmates decide to try a case together, using the new model of the simulator recently put into operation. Upon entering the small room, they are struck by the contrast between the old and new simulators. In place of the array of books, papers, 8mm cartridges, and phonograph records, they see only a single television-like screen, a light pen, a speaker, a typewriter input device, and a small-line printer.

Communicating with the scope via the light pen, Roger selects case No. 75 from an indexed, multiple-choice list; the same pleural effusion case study that Danny used in the old simulator. Roger, with prompting from his classmates, proceeds through the history and physical as did Danny, except that all textual material is displayed on the screen under control of a central computer in Massachusetts. The pictorial information on the screen and the audio information emanating from the speaker are stored locally (in

Roger's school), selected under central computer control, and sent via closed circuits to Roger's simulator. However, cost studies under way may show that centrally stored video and audio information, transmitted via satellite communications, will soon be more economical and flexible than this locally-stored information.

One important advantage of the new simulator, which Roger notices immediately, is that the mechanics of the simulation, such as decisions as to what comes next (e.g., a decision, a test result, a wait) are automatically performed by the computer, allowing him to devote his full attention to the clinical encounter. Also, the clocking and contingent events are under automatic control of the computer. Another satisfying characteristic is that he is able to explore a particular area, to any depth desired, quickly and easily. For example, when he discovers the patient's pain in the right calf, he decides to probe deeper and find out answers to such questions as: how long has the pain been noticeable, how frequently does it occur, at what times of day, and the exact location? Most questions are asked and choices made with the light pen and a multiple-choice list. In some cases, Roger is told that he can type in a nonlisted choice or question that the system, if possible, will answer. If the computer system cannot find an answer, it notes the problem for future attempts at updating in the central facility.

Roger continues through the case study, viewing slides, films (sound and silent), and diagrams. At the start of the session, he chose to operate the simulator in the tutorial mode, so the computer acts as a consulting physician, prodding him into developing good clinical habits. For example, upon completion of the physical and history, the computer asks Roger why he left out certain important questions or examinations; it asks for a differential diagnosis and if Roger fails to include the true disease, it probes further. The computer asks him to rethink the decision, to perform certain tests that involve excessive risk or that may not be relevant to the case. Further, it suggests useful tests that he did not consider, and in general supports Roger as an expert clinician might do. If Roger had so chosen, all of this support could have been suppressed.

At a certain point, one member of the group disagrees with Roger's decision, so he marks that point accordingly. At the end of the first try, the computer returns to this point and the dissenter is allowed to try his hand. Also, at the end of each run-through of the case, the line printer provides hard copy of all decisions, test results, and contingent events, in the proper time sequence. At the end of the session, Roger notes with satisfaction that because of computer control and direction of the simulation, he was able to complete the same work as Danny in substantially less time. Another satisfaction to Roger is that he has been able to carry out the management of a patient from beginning to end. Because of his relatively short assignments to the various wards or clinics, he seldom has the opportunity to do more than start the process or to follow up the decisions of those who saw the patient before him.

THE PATIENT-MANAGEMENT DECISION AID

After a number of unsuccessful pleural effusion encounters and a few dead patients (on paper), Roger decides he can use more study on pleural effusion and its related diseases. However, he also realizes that even through he returns to the books in this area, he may never really be proficient in managing pleural effusions if for no other reason than his main interest lies in cardiology. Therefore, he learns to use the Patient Management Decision Aid (PAMDA), a tool recently designed to aid both the student and the practicing physician in efficient management of a broad spectrum of such syndromes as pleural effusion. So Roger returns to the same room in which he has been working with the Clinical Encounter Simulator, but this time he uses the PAMDA.

Since Roger does not have a patient at hand, he requests the computer to supply him with a simulated patient. After receiving the admitting information and color pictures of the patient, the PAMDA asks Roger if he wishes to perform the history and physical examinations. He elects to skip these steps, so the computer presents these examination results to him in the appropriate media (textual, audio, still photographs, movies, etc.) and provides him with a written summary for future reference. The PAMDA then starts presentation of the decision tree for pleural effusion, requesting that Roger prune the tree whenever desirable. The first display is a list of the alternative acts (diagnostic tests or treatments) that one might reasonably expect to perform in an arbitrary case of pleural effusion. The PAMDA explains that pruning the decision tree is not absolutely necessary; however, it is more efficient to do so. Though Roger is not sure what this patient's problems are, he immediately sees some actions that can be justifiably omitted from consideration at the first stage of the decision process. For example, since his patient has neither fever nor a recent history of purulent sputum, Roger feels that the sputum-gram smears and bacterial cultures are not serious contenders at this stage. He also notes that the computer has automatically pruned the pelvic pneumogram alternative from all stages since the patient is a male. He proceeds in this manner through four decision sets, and then decides it is time to continue to the next step.

The system then computes the probabilities of the possible etiologies for this pleural effusion based on the results of the history, the physical examination, and the incidence of the disease in the general population. These probabilities are displayed to Roger, and he is given the option of adjusting them, based on his observations of this patient.

Next, Roger is given the option of examining the possibilities supplied by the PAMDA and changing them if he wishes. These possibilities are associated with the various diagnostic tests and the prognoses of the diseases. For example, if the patient is currently taking a steroid drug, Roger may wish to decrease the probability of a positive reaction to the tuberculosis skin test. If the patient is old and sick, Roger may increase the probabilities of the complications associated with a thoracotomy. Roger satisfies himself that the probabilities used by the PAMDA are consistent with the particular patient, the local laboratory, and his beliefs in general.

The computer then proceeds to compute the sequential decision strategy that, if followed, will result in the least expected utility loss (i.e., best balance between costs and medical effectiveness). Thus, the computer recommends that Roger first do a pleural tap. He agrees and so orders. The result, 400cc of a clear fluid, is presented pictorially and in hard copy. The PAMDA then advises him to ask for the protein and glucose determinations and smears of the fluid. He does so, gets the results, and continues the management process until a terminal outcome (e.g., cure, or death). Whenever he desires, Roger can request the system to show him the second or third best action, and he is free to choose any action he wishes at each stage. If he chooses an action other than the best, the PAMDA recalculates its recommended strategy from that point on. Also, Roger is free to ask the system to compute the consequences of the recommended strategy changes that he makes in the probability and utility estimates.

At the completion of the exercise, Roger is given hard copy that describes the events of his session so that he can study it at his leisure, or discuss it with colleagues and teachers.

Roger returns home, musing about the medical curricula: he realizes that for students 10 or so years hence, it is likely to be substantially different as a result of such concepts as those evidenced by the PAMDA and the Clinical Encounter Simulator.

III. OBJECTIVES OF APPLYING TECHNOLOGY

The ultimate objective of research concerned with any facet of "health care" must obviously be its improvement. Improvement through research in medical education may be effected through eventual increase in both the *quantity* and the *quality* of health manpower. Both are, to a large extent, goals having unanimous support both within and external to the biomedical community.

Thus, this section develops a series of goals and objectives, beginning with consideration of the demand for health care, and translating these general goals into operational objectives for further research and development. Furthermore, it will show how the programs and devices described in the scenario can support these objectives in various ways.

Although Sec. IV discusses most questions raised by the scenario, one paramount question is discussed throughout this section. What is the purpose of applying technology to medical (or any other) education?

QUANTITY

Table 1 reflects the MD population from 1950 to the present, and calculates the number necessary for a continuation of the present physician-patient ratio. These physicians are in private practice, on hospital staffs, or in residency or internship. The ratio may be understood as the "intensity" of patient care. Though many factors or future occurrences might well increase or decrease the desirable intensity of patient care, this ratio is used as a constant basis for projection.

Table 2 shows *total* active MDs as recorded in 1950 and 1965, and as projected for 1975.

Table 1

PHYSICIANS IN PATIENT PRACTICE 1950-1975 [1]

	1950	1965	1975
1. U.S. population (millions)	154	196	225
2. MDs per 100,000 (patient practice)	109	97	97
3. MDs (patient practice)	168,089	190,748	238,250[a]

[a]Necessary for continuation of above ratio.

Table 2

ALL PHYSICIANS 1950-1975[a]

	1950	1965	1975
1. MDs (actual and forecast)	232,697	305,115	360,000
2. Percent in patient practice	72.2	62.5	62.5
3. Total MD population in patient practice (expected)	168,089	190,748	225,000

[a]*Report of the National Advisory Commission on Health Manpower*, U.S. Government Printing Office, Vol. 11, Washington, D.C., 1967, p. 235.

Comparing total versus patient-practice figures shows a decrease in the percentage of the total physician population involved in the practice of medicine. A variety of technical and social reasons may explain this phenomenon; at any rate, it may be expected to continue. In light of this, the *total* medical population expected to provide health care (in the ratio mentioned above) is depicted on the bottom line of Table 2.

Once the necessary physician population is forecast, the disparity between demand and expected supply is clearly demonstrated. Table 3 illustrates this calculation.

Table 3

PHYSICIAN SHORTAGE

	1975
Necessary supply (patient practice)	238,250
Expected supply (patient practice)	225,000

The table shows that an increase of about eight percent is necessary to maintain even the current intensity of care. Several other factors (such as a further decline in the ratio of practicing to non-practicing physicians) might further aggravate this situation. Additionally, there is an increasing influx of foreign physicians into the United States. The Report of the National Advisory Commission on Health Manpower (NACHM) Panel on Foreign Medical Graduates warns of the dangers to quality of care under the present system of supervision and visa requirements. The Panel unanimously recommended as a national goal for the U.S. medical education system that it "provide a sufficient number of well-trained physicians and other health personnel to meet the health needs of the United States and to assist other countries, particularly less-developed countries, to improve their systems of medical education and their levels of medical practice and public health."†

It is doubtful that the shortage described can be remedied through massive enlargement of the present system, primarily because of fiscal constraints. In assessing the consequences of continuing the current system, many other aspects are worthy of consideration. Budgeting for expansion of medical education is considered in the NACHM Report on Foreign Medical Graduates. Program costs for the projections in this report are derived at 1961 costs of $200,000 per starting student space for construction of facilities and $32,000 per starting space per year for operation. To these figures could be added $50,000 per space to build teaching hospitals, $50,000 per space per year for the research expenses of active faculty, and a 10-percent annual increase in operating expenses.

This forecast calls for an immediate expenditure of from $3.12 billion to $6.63 billion to support the increase necessary for 1965 to 2000, at 1961 cost levels, without associated teaching hospitals, without faculty research, and at constant 1961 operating costs.

The report of the NACHM suggests care in planning expansion of medical education:

> In the short run at least, the dominant constraint will be the capacity of medical schools to expand without lowering the quality of their educational programs or incurring unreasonably high costs.‡
>
> Curriculum review aimed at reducing both the length of formal medical education and the length of specialty training should be considered as an integral part of any expansion plan.††

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†*Report of the National Advisory Commission*, p. 72.

‡*Report of the National Advisory Commission*, p. 39.

††*Report of the National Advisory Commission*, p. 42.

The above quotations represent articulate statements of measures that might be taken through technology. The next necessary step is the translation of these measures into specific operational objectives, accompanied by the discussion of concepts through which these might be achieved.

Operational Objectives Addressing Quantity

Two possibilities immediately present themselves as regards an increase in the quantity of physicians through manipulation of the educational process. The first, to increase the number of students that may attend a given institution at any time, might come through enlargement of physical and faculty resources, reduction of resources necessary to train and educate a given number of students, or some combination of these alternatives. The second possibility is to decrease the time required for a medical education through curriculum changes.

Decrease in Student-Faculty Ratio

The current faculty-student ratio in undergraduate medical institutions is approximately 1:1; that is, every student "space" within a school indicates the existence of a similar faculty space. Although in many cases the faculty member is simultaneously a practicing physician, his contribution to health care is not what it would be if fully dedicated. Therefore, an increase in the number of students through enlargement of facilities is not really effective as a means of increasing the numbers of health care personnel; for every physician trained to enter the population, one must first be removed to train him. Thus, it seems that primary effort should be directed at "significantly" *reducing the number of trained personnel necessary to educate a given quantity of students*. This is a paramount operational objective.

A decrease in the student faculty ratio may occur in a variety of ways. An extreme case involves simply doing it; that is, increasing class size, decreasing student-faculty contact, and eliminating the close personal relationships involved in the cohort method. This philosophy is rejected out of hand as unacceptable. A more viable plan accomplishing the same objective reduces the faculty (or holds faculty constant and increases student population) and accompanies this decrease with a substantial increase in supplemental educational programs and teaching assistants.

The computer-assisted instruction system, clinical encounter simulator, and the "PAMDA" are designed for use by individual students. Each system addresses a different area of medical education, and a broad application of each device within that area should substantially lessen required faculty. Instead of functioning at the elbow of a faculty member, or under his direct tutelage in a classroom, the student is more responsible for his progress through the curriculum. The faculty continues to be available, as they must be when the student body is involved in learning. But *one* available instructor may replace a considerably larger number of faculty who might be tied up in the teaching of actual classes, particularly true when study normally associated with the pre-clinical years is involved.

<u>Decrease in Time Required through Curriculum</u>

Quantity of available professionals may be increased (over time) by reducing the time period necessary to produce a competent physician; perhaps accomplished by structuring the premedical education in a different manner. This might shorten the normal medical school education process by one or two years. This methodology, however, might work a considerable hardship on students not having ideal preparation. A more feasible means appears to be the establishment of an environment in which the student could prescribe his own pace, instead of the "lock-step" currently demanded. Thus, a second operational objective, which should reflect in the quantity of medical school graduates, is to *make available the means for the student to govern the speed of his progress through the curriculum.*

An objective of self-pacing implies a corollary objective of *self-evaluation.* In a truly free-form environment, the mechanics of the education process might be facilitated through removal of the testing burden from the faculty. The student should have available various aids for measuring his progress, and can be expected to assume responsibility for his own competence, the implications of which are more fully explored in later discussion of objectives concerned with quality.

Almost all scenario items relate in some way to these objectives. On the whole, the scenario sketches an environment in which instruction has been individualized, and learning self-paced. The student in a fully self-paced environment might well complete the required curriculum in a much shorter time. This statement mainly applies to the CAI system described for the teaching of the pre-clinical sciences.

The "clinical" portions of the scenario also describe devices that might serve to decrease time spent in formal education. The student can supplement (not replace) his actual clinical encounters with simulated experience, which will allow encounters with even the rarest of maladies. This situation might markedly accelerate the students progress, as his education and the time allocated to it is in no way subject to random patient admissions. In addition, the student can perceive relationships between various clinical states that might otherwise be difficult to form. The addition of this planned curriculum might well compress the total time necessary to reach a desired state of knowledge (and "wisdom" as well).

QUALITY

It is difficult if not impossible to satisfactorily express the quality of health care in numeric terms. One can only abstract a multitude of conflicting opinions, and there are as many of these as there are voices. Nevertheless, it is possible to make one judgment; the quality of health care may be improved, regardless of its present status. No implication that current practitioners are not capable is intended; it seems clear, however, that physicians lack the services that might provide the information and education necessary to maintain the currency desirable in their practice.

Whether this lack of knowledge is best remediable through undergraduate and graduate education is unclear. It seems feasible, however, that certain measures can be instituted in these areas to insure that this information deficiency will be minimized in the future practice of the student. In addition, attitudes and skills can be developed that will allow the future practitioner to make effective use of the services currently available to him, as well as those services that might be expected to become available, given the current high level of interest in the information plight of the physician.

Certain broad operational objectives, two of which are discussed below, may be formulated for improving the quality of health care through alteration of the medical education process.

Information Currency

A constantly expressed notion is that the practicing physician is not as "up to date" with new techniques and treatments as he should be. It is unclear to what extent this is the fault of the physician; it seems true, however, that information deficiencies must be remedied by the man who feels them.

The alteration of undergraduate and graduate medical education can affect this problem only to a limited degree. All that might be done, and thus stated as an objective, is *to inculcate the prospective practitioner with attitudes of self-reliance and a feeling of individual responsibility toward his continuing education.* A corollary in the general area is the development of skills--and more importantly, attitudes--that will allow the physician to effectively utilize whatever information and education resources should become available to him. This seems most important in view of the highly publicized aversion of medical practitioners toward computers; although this aversion is, in all likelihood, illusory, every possible measure should be taken to insure a smooth interface between man and machine.

The Structure of Medical Knowledge

Medical schools currently provide each student with education in most aspects of practicing medicine. The student is given a broad background in the basic sciences, and instructed rather exhaustively in the nature of the various diseases that he might encounter, the multitude of tests used in their identification, and the steps taken to return a patient to a "healthy" state. A cursory examination of various medical school curricula reveals great disparity in the pacing, emphasis, and time of first encounter (by the student) with any of the subject areas. Constant throughout most medical curricula, however, is the lack (or irrelevance) of structure to the studies. What structure medical education has may be characterized as *disease-oriented*; the medical student is instructed in the whole of medicine as it relates to maladies that may be encountered.

This contrasts sharply with the patient-management process of the actual practice of medicine. The patient does not appear on the scene with a disease, but rather with signs, symptoms, syndromes; complaints about a change from "normal." These initial indications are further complemented by facts elicited by the physician in the history-taking and physical examination processes. The practicing physician is expected to apply the unrelated knowledge and unrelated facts gained in one structure (medical education) to a problem having an entirely different structure (actual diagnosis and treatment). He then must assimilate all pertinent facts about the particular patient, formulate the problem, select the therapy course, and then apply his factual knowledge to this markedly different structure, an inefficient and needlessly difficult way to practice medicine; perhaps needlessly expensive.

The above is not intended to imply that medical students receive no education in the diagnosis of disease. It appears, however, that too seldom is that diagnostic training logically linked to any of the more formal course work demanded.

One possible remedy is the revision of the medical curriculum toward the presentation of information as it appears in clinical practice. This problem-orientation of the curriculum might allow a more efficient utilization of information by the physician in his treatment of a given subject. Problem-orientation would require that the student be taught the principles of patient management through problem-solving situations, constructed in the same manner in which he will encounter problems in the practice of medicine. The physician can thus be instructed to be an information analyst and problem-solver.†

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†A compelling benefit of problem-orientation may be glimpsed when the concept is viewed with regard to automated medical services. From initial experimentation carried out by Weed [2] and others, it can be seen that the problem-orientation lends itself to the automation of the patient-management process. The use of problem-orientation is one efficacious way of *systematizing* medical practice; experience

In viewing medical knowledge as a resource that the physician brings to bear upon the patients' problem, it is likely that the tailoring of this resource to fit the problem will result in a more efficient application. The practicing physician is not forced to perform mental translations; instead, he is able to follow the total treatment in the manner in which he has been trained.

From the above discussion, yet another primary objective emerges: *to promote a valid, systematic framework that might better aid the physician's difficult transition from education to practice.*

RELATIONSHIP OF THE SCENARIO ITEMS TO THE OBJECTIVES

Information Currency

The core of this problem is attacked by the scenario items because the devices described manipulate an information base. This base is highly volatile, and the use of electronic and microform storage allows the rapid update necessary to maintain currency of the files. In addition, most of the systems described have only a limited number of information repositories; thus, each student's store of reference materials may be changed by a small alteration to one or several central repositories.

The scenario item having the greatest impact upon information currency is the portable "med-file." Although sketched as a system for the undergraduate-medical student,

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has shown that it is impossible to automate a non-system. Thus, in order to apply the tremendous power of computers to patient management, it first will be necessary to define the structure and nature of that practice. Problem-orientation allows that definition and may thereby open the way for broad application of computing machinery. Because the use of this orientation allows the physician to effectively structure, manage, and analyze data, there is every possibility that the more "library like" functions of the physician might be easily assumed by machines.

it is obvious that this device has greater applicability as an aid to the practicing or research physician. As evident in the scenario, the Med-File provides a "pipeline" from the physician to a central information source that is constantly stocked with the latest information, in the form of monographs, journals, and special releases to physicians.

Attitudes and Skills for Continuing Education

Tomorrow's medical practitioner will have available a wide variety of technological assistants. Such devices will probably gain initial acceptance in hospitals, where they already perform an increasing number of administrative and record-keeping functions. The role of the computer and communications system should continue to broaden, as more of the lower level tasks are supplemented. It is not unlikely that in a few years the computer will play a major (though subservient) role in medical diagnosis and prescription of treatment.

Ideally, the medical practitioner should be able to make immediate and effective use of such assistants. He should develop the skill for use in this environment during his years of undergraduate and graduate education. Moreover, he should develop, along with requisite skills, a "fluency"; a familiarity and ease with and around mechanized assistants. One of the greatest benefits of the environment described might be the acquisition of these skills and attitudes.

Along similar lines, the responsibility incumbent upon the student in a self-paced, self-evaluated environment might change attitudes toward continuing education. The physician, responsible for his own knowledge, should be substantially more aware of deficiencies; he should be more capable of dealing with them, having developed a large measure of self-reliance in undergraduate training. In summary, the student is not sent unprepared into a situation where he alone is charged with his educational responsibility; the transition is gradual and logical, from pre-medical training to graduate education.

Restructuring of Medical Information

The two devices described in the scenario most concerned with this objective are the Clinical Encounter Simulator and the PAMDA. The "restructuring" chosen involves a shift toward problem orientation, or viewing the patient as having a "problem" that must be resolved as opposed to the patient having some unknown disease that first must be diagnosed then treated.

The scenario devices mentioned work from this structure, and are intended to promulgate it as an approach to patient management. As mentioned earlier, a large measure of structure is necessary before certain types of technology may be brought to bear upon medical education. Thus, to a considerable degree, both the systems described and problem-orientation are mutually supportive. It must be pointed out that structures other than "problem-orientation" might be used to the ends described; "problem-orientation" is used primarily because of its success in several experimental situations.

IV. AREAS OF NECESSARY RESEARCH

The scenario was written as an exploratory device, designed to sketch a broad framework of areas for further research. In addition, each scenario raises a multitude of implicit and explicit questions; questions addressing effectiveness, economic feasibility, implementation modes, and other areas of concern.

These questions must be answered prior to implementation. A premature installation of any of the systems described, no matter how superficially attractive, could be extremely costly and offer little in the way of educational assistance. It is obvious, however, that effectiveness cannot be finally determined until the system is operational. Thus, one must design a research program that is satisfactory yet avoids "studying the problem to death."

For purposes of discussion, the questions elicited throughout the scenario are divided into six categories. Within these categories, an attempt is made to articulate pertinent questions, followed by an initial judgment of the situation and a detailing of research that might be performed in pursuance of a more satisfactory answer. In most cases, the questions raised apply (to some degree) to all of the systems described. Where this is not the case, it is so indicated.

BENEFITS

The questions relating to "benefits," or effectiveness of the scenario items, are restatements of the goals described earlier:

1) *Will "problem-orientation" improve the quality of health care?*
2) *Will reduction of the faculty-student ratio have deleterious effects upon the educational system (regardless of the employment of technology)?*

3) *What will a "self-paced" environment mean in terms of physician supply?*

These and other questions of effectiveness can only be answered through testing in real situations of the systems described. Certain gross judgments may be made prior to systems testing. These judgments will determine the best direction for contemplated research.

In most discussions of self-pacing, it is assumed *a priori* that nearly all students will progress faster. This assumption comes from a belief that present curriculum is necessarily geared to the slowest learner in the class. It must be remembered, however, that one is dealing with a population (students) that is constantly changing and about whom little is known. Early subjective indications from a series of informal interviews with medical students point towards a pessimistic answer to question three. Students unanimously agree they would take more than four years to complete medical school; they were considerably more interested in the "quality of life" during these years than in economic considerations.

Some answers to these questions might be found through continued interviewing of a larger, statistically valid sample. In addition, testing situations must be established in order to determine if an average student will progress faster or slower in the environment with which we are concerned. Such experimentation could be done at a minimum expense using as course material the PAMDA programs currently under development at Rand (once the equivalency of these programs to some specified curriculum had been established).

The quality of health care is extremely difficult to measure. More indirect measures of physician performance, such as National Boards, might be used. A more effective approach could be through faculty and peer-group evaluation, systematically elicited and evaluated by the experimenters concerned.

TECHNOLOGY

Primary questions to be answered are:

1) *Is available, "off-the-shelf" technology sufficient to support the items described?*
2) *What technological advances can be expected that would significantly increase capability or decrease expected cost?*

The first question is easily answered; with one exception (the widespread use of color display in the scenario items); all of the systems described may be implemented through use of existing hardware. In some cases, implementation would entail purchase of an entire system; in others, such as the Clinical Encounter Simulator, it would require an engineering effort of some magnitude to piece together components into a working configuration.

The second question is more difficult. An answer might be gained through the "ear to the ground" approach, sifting literature and maintaining close contact with firms who appear to be working in promising directions. An obvious extension of this thinking leads to consideration of what the Lister Hill Center might do to spur new and necessary technological developments. These situations must be examined as they arise.

A major part of any research effort must be directed towards exploring what benefits different technologies might offer, particularly in the area of communications systems. Nationwide programs aimed at providing medical information and education can be expected to employ a wide variety of transmission systems. Detailed exploration of the possibilities and potentialities of communications satellites, cable television, and leased-lines systems are necessary. It is highly likely that some mix of these systems represent the ideal service system. This combination will largely be determined through cost-benefit analyses of the type described in *Implementation Strategies and Costs*.

FEASIBILITY

"Feasibility" concerns both cost and acceptance by the medical community. Although a detailed determination of implementation expenditures is considered below, a gross treatment of cost is necessary early in the system design phase to insure that effort will not be expended in consideration of systems that, due to excessively high cost, have no chance for near-term implementation.[†]

The question of "acceptance" is not easily dealt with. The success of any implemented system is, in the final analysis, dependent upon the attitudes of faculty and students, a cause more for optimism than pessimism. Physicians appear to be an extremely pragmatic group; they are quick to accept that which promises benefit, and equally rapid to condemn the opposite effect. If a truly beneficial system is designed, problems of acceptance can be minimized by proper explanation and demonstration. In addition, the full coordination and approval of such organizations as the Association of American Medical Colleges and the AMA's Council on Medical Education should be sought, and should be of considerable value in determining the efficacy and consequent acceptance of technological assistance to medical education.

TESTING PROCEDURES

Following system design and an initial determination of feasibility and effectiveness, the device or program must be tested under actual conditions to provide firm answers to the questions raised above. The primary area of uncertainty is where to test; what type of comparative testing should be undertaken; and what strategies of further testing or implementation should attend various test results?

[†] Cost, of course, may not be considered without regard for attendant benefits. Many systems that appear excessively expensive might not appear so in light of the benefits they offer.

Again, organizations such as the AAMC and the Council on Medical Education can provide considerable assistance. "Test beds" must be chosen on the basis of available facilities and receptivity, in order to minimize cost. In addition, these organizations can help determine test and evaluation procedures. The most difficult testing area will be not *how* but *what*--What are indicators of future performance and past achievement? The active participation of a group fully conversant with these questions is a necessity.

IMPLEMENTATION STRATEGIES AND COSTS

A number of questions concern themselves with implementation:

1) *What is the preferred role of the Lister Hill Center in implementation and support of various systems?*
2) *What are effective modes of implementation, in that each program may be provided with varying degrees of centralization?*
3) *How should systems be implemented in order to allow for future expansion or alteration?*

Especially important for future investigation is the type of administrative support necessary to maintain ongoing programs and services. Validation and testing must be continued, and an administrative structure must exist that guarantees the feedback necessary to the maintaining agency. The most effective and economical role of a national center can be best determined (short of actual experimentation) by mathematical or computer modeling of the systems under consideration, and altering these models to determine the levels of service and cost provided by various configurations.

Such modeling is an inexpensive method of "trying" different modes of dissemination and assessing the resultant posture. Accompanying this effort must be a determination of how costs may be shared among the involved schools and the national center.

Further expansion may be planned for thorough extension of the models described. In addition, various alternative systems may be modeled on future technological possibilities, such as the use of satellite technology in supplementing other communications methods. This approach also allows services to be combined. It is possible, for instance, that the Computer-Assisted Instruction and the Med-File systems can share the same computer and, consequently, the cost. Modeling offers a highly attractive means of judging the feasibility of such combinations.

A SAMPLE RESEARCH PROGRAM

The above discussion points out the questions raised by innovations proposed in the scenario. In order to demonstrate the research necessary to answer these questions, we will select one of the innovations, the PAMDA, and present one possible research plan.

SYSTEM DESIGN AND TESTING

With the PAMDA, the main questions of technological feasibility and medical-community acceptance can best be addressed by experiments with a prototype system. The first step is development of the decision-analytic model and concepts, and the methods for establishing the data base for a specific syndrome. This work, which has essentially been completed, will be fully documented in forthcoming Rand publications. The syndrome of pleural effusion was chosen because of its prominence in many disease processes and the difficulties it often presents in decisionmaking.

Choosing the hardware and developing the software is next. Because of its wide availability, the IBM 360/50 computer and 2250 graphics units were chosen as implementation vehicle for the prototype system. However, extensive cost-effectiveness evaluations of other existing and proposed hardware devices will subsequently be carried out. Consideration of centralized versus decentralized implementation is crucial to these calculations. The development of the software and preferred modes of man-computer interactions, which has been partially completed, is expected to answer questions about the feasibility of presenting large amounts of quantitative and qualitative data to the student in reasonable time. Initial indications are that current hardware and software developments are capable of performing this task.

Once the prototype system with the pleural effusion example is operational, expert physicians would be able to make suggestions for improving both the medical and teaching aspects of the system. They also could provide answers to a formal set of questions and make comments aimed at evaluating the system as a clinical teaching aid.

In order to test student reaction to the PAMDA, and its efficacy as a teaching device, a pilot implementation in at least two medical schools should be attempted. Design of the experiment, the conduct of the experiment, and the evaluation of results should be carried out in cooperation with the AAMC. One possible stumbling block might be the lack of understanding of decision-analysis techniques on the part of the typical medical student. Use of the CAI techniques discussed in the scenario could conceivably overcome this problem.

One interesting way of conducting the experiment is to use the PAMDA on a voluntary basis in one school and on a selective *required* basis in another. Measurement techniques to evaluate such parameters as student interest, student attitude, and improvement in clinical problem-solving ability would have to be carefully designed. The latter might be accomplished by presenting test cases to two groups of students. The group of students who had never used the PAMDA would manage the test cases using only their unaided judgment. Part of the group having used the PAMDA a certain minimum number of times also would use only unaided judgment, and the remainder would be asked to use the PAMDA in managing cases. Evaluation by a panel of experts of the student protocol in these test cases could serve as a measure of the usefulness of the concept in teaching clinical problem solving. Clearly many questions of proper control of such an experiment need examination.

IMPLEMENTATION AND COSTS

At this point, the system may be considered tested and ready for implementation. Prior to this, research must be carried out to determine:

1) The demand for such a service;
2) The system configuration (telecommunications, computers) to meet this demand;
3) The degree of centralization most cost-effective;
4) Effective methods of program production and maintenance;
5) A feasible implementation schedule (in view of human and fiscal resources).

This analysis of demand will draw heavily upon the preliminary testing described above. In that situation, two different service postures (voluntary versus required) were tried. Data from this should provide an indication of each student's demand upon system resources. The larger demand consideration (number of schools to be serviced) should be easier to derive depending upon institutional interest and resource availability.

This calculated demand and system configuration provide input to a modeling effort. In this case, a computer simulation model of the PAMDA system would be built, using various communication technologies--microwave, lease-line, satellite--to provide the services described. The simulation would be "run" using each alternative, and would give an indication of the feasibility and level of service of each alternative. In addition, the simulation would be performed using varying degrees of centralization--single national computer, ten regional computers, and a dedicated system to every school--to again determine the benefits of each.

A detailed costing of every simulated alternative also would be done. Then, based upon some prescribed criterion, the levels of service would be evaluated in terms of their benefits (as judged by the simulation) versus the resource implications (as judged by the costing of the alternatives).

The above is a selected research plan. The work described would be supplemented by other efforts. It is expected, for instance, that the system's instructional software would require a great deal of study, establishing standards, procedures for review and evaluation, and describing methods of effective and rapid feedback to the implementing agency. In the main, however, the work should provide a general picture of the types, variety, and magnitude of the requisite research.

V. EXAMPLES OF IMPLEMENTATION

The study plan developed in Sec. IV presupposes that a thorough system design activity will precede the research effort. The two cases described below are the result of such analysis. These cases present an impression of the final conception of the devices described in the scenario; how system implementation might be accomplished; and what costs might attend this implementation. Note that this final conception differs (in minor ways) from the devices in the scenario. Detailed research might similarly alter any or all of the remaining systems as more effective means are discovered of providing the services described.

THE MED-FILE

In basic concept, the Med-File is a microform medical library system with equipment for the search, retrieval, and use of information. In operation, the devices are supported by a central indexing and abstracting service that provides and maintains the data base for the system.

The Med-File hardware and its support system may be designed in one of four different forms, depending upon the combination or separation of functions. The four alternatives are:

1) Search function combined with retrieval-and-use in one device, library-based (occurring physically within the library);
2) Search function divorced from retrieval-and-use; two devices, both library-based;
3) Search function combined with retrieval-and-use in one device, portable;
4) Search function divorced from retrieval-and-use--search device library-based; retrieval-and-use device, portable.

The first possibility would require a dual-screen display system similar to that manufactured by Microform Data Systems of Palo Alto, California. In this device, one screen is a CRT, the other a rear projection screen for ultrafiche.† This system wastes the complex CRT display console and character generator, as those components would be used only for search, and would be idle while the user is viewing ultrafiche displayed upon the optical display screen. As the two functional units are physically combined, no one else could use the search equipment. The Med-File also would be an expensive system for a medical school library since every study position would have to be equipped with a CRT interactive terminal. Because the interactive search system will represent the larger of the two costs, such a combined function appears needlessly expensive.

The second possibility is to divide the two functions, but keep both library-based. If search accounts for 20 percent of study time, and study proper accounts for 80 percent, one search terminal would be required for each four ultrafiche display units. Thus, a library might have 20 search terminals and 80 ultrafiche display units (med-file carrels) rather than 100 of each.

The third possibility is to divorce both search and use from the library, which would require a portable, interactive, graphic terminal associated with each Med-File ultrafiche display device. It also would require a wired or other live interconnection with the central computer. It is likely that this interconnection would be through voice-grade telephone lines. The limited bandwidth of these lines would preclude the degree of sophistication necessary in the search support system.

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†"Ultrafiche" is a variety of strip- or sheet-microform having a reduction ratio greater than 40 to 1, and repositing several page images upon a single strip (or "fiche").

The fourth configuration leaves the search system in the library along with a number of Med-File carrels, as in the second alternative, but adds a briefcase size ultrafiche reader. This device can be used at home, or any other location where a telephone is present. The following discussion is based on this configuration (Fig. 6).

System Functions

The student searches at a library-based console supported by a computer program that operates on a time-shared central computer. The search process is interactive; the computer helps him define his need by displaying titles and abstract materials. But in order to make use of this expensive console as short as possible, he does no studying here.

Once information is located, this location and pertinent indexing information is recorded on a secondary storage of the central computer reserved for the student. Before he leaves the search console, the student will display the references he has located and order those he wants to study by punching an "order" button. This transmits the number of the cartridge on which the desired information is recorded to a check-out desk, along with his student ID number. As he leaves the library he passes by the "magazine" loader and picks up the ultrafiche magazines that hold cartridges containing the text of the articles ordered.

Study is performed either at home on the portable Med-File or at the library Med-File carrel into which the magazine of ultrafiche is placed. The magazine holds a large number of cartridges, each containing about 1900 page images. In using the Med-File, the student first insures that the correctly numbered ultrafiche cartridge is in place. He then places the telephone receiver upon the Med-File, and dials the number of the central computer. After entering the proper information, the first article desired is displayed before him (this action is keyed by the computer's

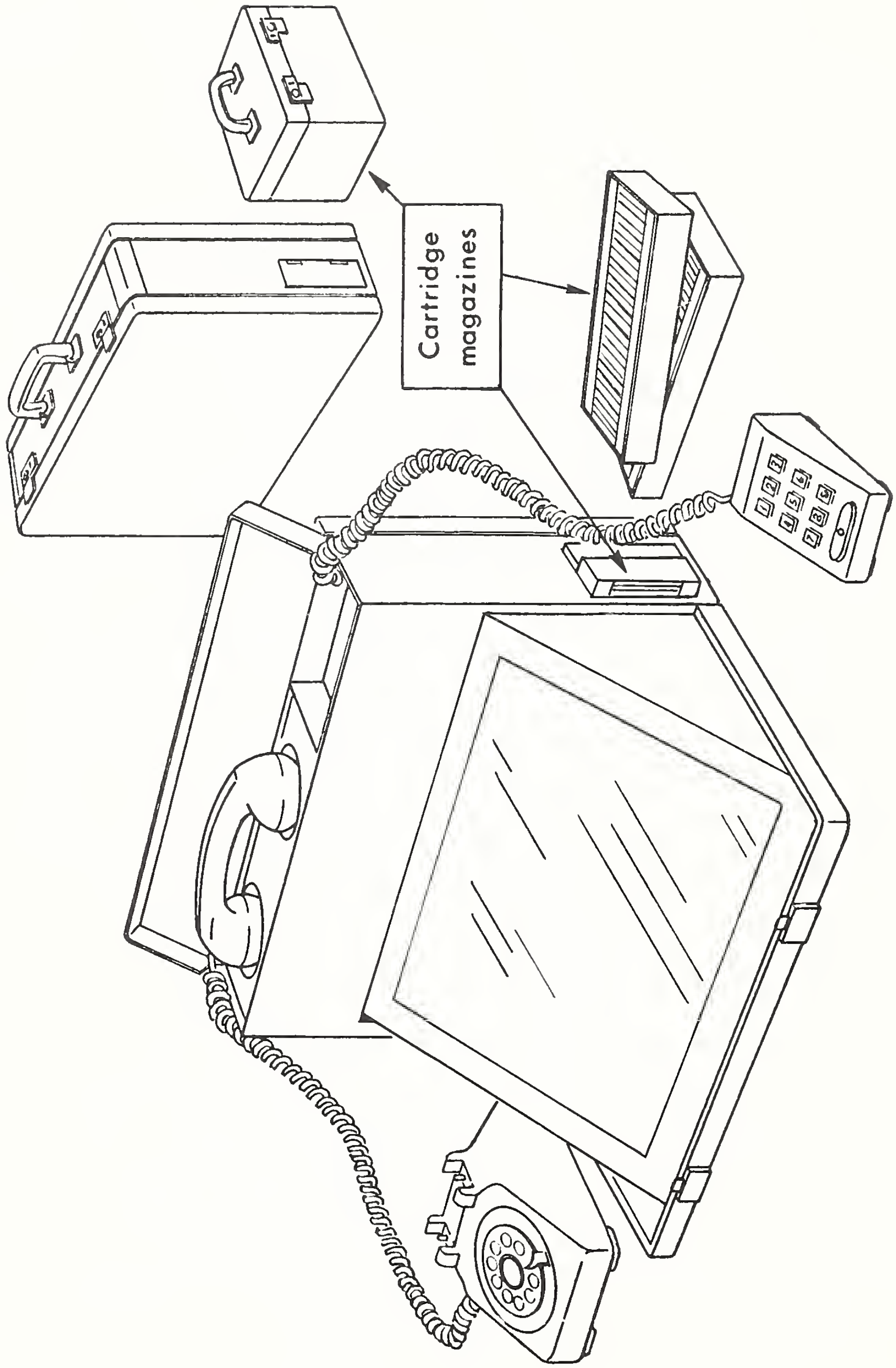

Fig. 6--Portable Med-File

reference to the student's "file"). From that point, the student may advance one page at a time by pressing the "single page" button, or skip more rapidly forward or back by pressing other appropriate buttons. At any time, he may automatically return to the index pages of the cartridge by pressing the "display" button. The existence of index pages offers the student some remote search capability. Were index pages not present, additional search would require a return trip to the library.

The Med-File Data Base

The ultrafiche cartridge is 1-1/2 x 6 in. and 1/4 in. thick. Sixty cartridges may fit into a tray 15 in. long. The usable area within such a cartridge is about 7/8 x 5-1/2 in., or a total of 4.8 sq in. At a density of 400 images per square inch, this would provide for approximately 2000 images (pages) per cartridge. A magazine of 60 cartridges would carry 120,000 pages or the equivalent of 234 500-page books. In terms of journal issues, at 65 pages apiece, this would amount to over 1800.

The amount of medical literature that must be included in the Med-File library is open to question. It is assumed that about 10,000 books will be sufficient, as will the inclusion of 2400 journal issues per year. The system configuration is not sensitive to change in these assumptions. However, the cost of such a system is highly sensitive to such change.

System Implementation

The computer system shown in the Appendix will support a single medical school. The system is configured to provide 24 search stations, and can simultaneously support 130 remote Med-Files. In this treatment, the computer is pictured as *dedicated*, i.e., used only for support of the Med-File and search systems. In reality, it will be capable of handling other data processing tasks, and later cost figures should be considered with this in mind.

The individual school system is supported by a national center that performs all indexing, abstracting, and microfilming services. In addition, the center provides all computer software to the individual schools, preserving a certain economy of scale. Each school could use the same basic ultrafiche library and might have similar computer systems.

System Cost

The cost figures displayed in Table 4 were calculated by a small computer program representing a "cost model." In such a program, one need only enter certain parameters, describing the configuration to be costed. The computer calculates the cost of the system under consideration, an especially effective technique in that minor system changes and reformulated assumptions do not require laborious recalculation of system costs.

The following assumptions are used in the costing of the Med-File system:

1) The basic library includes 10,000 volumes, and 150 new books are added annually. Twenty percent of book holdings will be automated, and processing of the backlog will be spread over four years.
2) Twenty-four hundred journal issues are received each year. Ten years of back issues are included in holdings, and 25 percent of journal holdings will be automated, with processing of backlog again spread over four years.
3) Twenty-four hundred journal articles will be microfilmed each year. In addition, the two years previous to system implementation will be microfilmed and added to the basic library.

Table 4

MED-FILE COSTS

SYSTEM ASSUMPTIONS

Number of Books in Library:	10000
New Books Published per Year:	150
Pages per Book:	500
Fraction to be Automated:	0.2
Journal Issues per Year:	2400
Pages per Issue:	65
Articles per Issue:	10
Years of Back Issues:	10
Fraction to be Automated:	.25
Years to Eliminate Backlog:	4
Number of Schools:	100
Users per School:	800
Unit Cost of Med-Files:	1000
Monthly Rental per KCRT:	200
MEDLARS Indexing to be Used (true or false):	false

Table 4--Continued

ANNUAL WORKLOAD

YEAR ->	1	2	3	4	5
BACKLOG ELIMINATION:					
Books:	500	500	500	500	0
Pages:	250000	250000	250000	250000	0
Journal Issues:	1500	1500	1500	1500	0
Pages:	97500	97500	97500	97500	0
CURRENT MATERIAL:					
Books:	30	30	30	30	30
Pages:	15000	15000	15000	15000	15000
Journal Issues:	600	600	600	600	600
Pages:	39000	39000	39000	39000	39000
TOTAL OPERATION:					
Books:	530	530	530	530	30
Pages:	265000	265000	265000	265000	15000
Journal Issues:	2100	2100	2100	2100	600
Pages:	136500	136500	136500	136500	39000
Journal Articles:	21000	21000	21000	21000	6000
Total Pages:	401500	401500	401500	401500	54000
Microform Masters:	201	201	201	201	27

Table 4--Continued

PERSONNEL REQUIREMENTS

YEAR =>	1	2	3	4	5
NATIONAL CENTER:					
Administrative					
Director:	1	1	1	1	1
Deputy:	1	1	1	1	1
Secretary:	1	1	1	1	1
Clerical:	2	2	2	2	2
Literature Processing					
Abstracters:	12	12	12	12	3
Indexers:	12	12	12	12	3
Clerical:	6	6	6	6	2
Input Preparation:	3	3	3	3	1
Total:	38	38	38	38	14
LOCAL DEPOSITORIES:					
Administrative					
Librarians:	25	50	75	100	100
Total:	25	50	75	100	100

Table 4--Continued

A N N U A L   C O S T (T H O U S A N D S)

YEAR ->	1	2	3	4	5
NATIONAL CENTER:					
Administrative					
Director:	20	20	20	20	20
Deputy:	18	18	18	18	18
Secretary:	8	8	8	8	8
Clerical:	12	12	12	12	12
Supplies:	6	6	6	6	6
Literature Processing					
Abstracters:	180	180	180	180	4,
Indexers:	180	180	180	180	45
Clerical:	42	42	42	42	14
Input Preparation:	21	21	21	21	7
Microform Masters:	73	73	73	73	10
Supplies:	42	42	42	42	11
Postage and Handling:	1	1	2	2	2
Facilities					
Space Rental:	26	26	26	26	9
Equipment Purchase:	7	7	7	7	0
Total:	635	636	636	637	208
($/Page:	1.58	1.58	1.59	1.59	3.84)
LOCAL DEPOSITORIES:					
Administrative					
Librarians:	225	450	675	900	900
Other					
KCRT Rental:	500	1000	1500	2000	2000
Med-File Purchase:	6111	6667	7222	7778	2222
Microform Copies:	368	1138	1974	2877	733
Total:	7204	9254	11371	13555	5856

* * * * * * *

	1	2	3	4	5
Schools:	25	50	75	100	100
Cost per School:	288	185	152	136	59

Thus, Table 4 describes the five-year cost of implementing the national center described, and the cost of equipping a single school with the Med-File system described (exclusive of hardware costs other than Med-Files and KCRTs). The Appendix contains the assumptions and calculations that produced these results.

THE CLINICAL ENCOUNTER SIMULATOR

The concept of an almost totally automated Clinical Encounter Simulator involves the remote presentation of all visual, audible, and textual material. The only materials not on-line will be visual materials in which a realistic reproduction of natural colors is required.

It is expected that eventually such a system will incorporate the presentation of visual materials in full and natural color. However, since color television techniques today are not capable of consistently realistic color reproduction, color is being deferred for five years or more when, it is assumed, more reliable color equipment will be available. It can be noted that wherever in medical diagnosis color plays an important role, as in examination of the optic fundae, the recognition of subtle nuances of color is necessary. Although slightly unrealistic and inconsistent color is no detriment to entertainment television, it could be worse than no color at all in medical diagnosis.

Data Base

To estimate the resources required for these electronically presented simulations when their full potential is realized, a total of 100 local simulation centers is assumed (at medical schools), each of which contains 40 student carrels in which any one of 1000 simulations may be encountered. Each simulation is assumed to require about 45 min of the student's time, but will contain three times this much prepared material to provide for the various routes through the diagnosis therapy process. The estimated amounts of data (audio, still-video, motion video, and text) are listed in Table 5.

It is assumed that 80 percent of information presentation will be provided by text (alphanumeric characters displayed on a CRT), which means 100 min of text presentation will be prepared, of which the average student will use 35. The ratio of 3 to 1 in materials prepared to materials actually used reflects the branching nature of the simulations. Although all students will receive the same data at the beginning of each simulation, they will tend to branch out as they choose to make different tests and different treatments.

Data stored in the Central Data Base will include the basic test presentation that will convey most of the information, and audio data that will include spoken answers to history--taking questions in the "patient's" own voice, recordings of heart and breath sounds and other such natural sounds. These audio materials will be transferred quickly (many times normal rate) from the Central Data Base to a local audio disc recording that will have sufficient capacity to hold the 600 min of audio required for a total of 40 simulations. Forty students may use audio from this buffer source, if necessary, since this device, as all buffers in the total system, will be equipped with 40 heads. Pictorial material will not be stored centrally because of the relatively high cost or slow speed of long-line transmission of video. Instead, motion and still pictures will be stored locally.

Still picture materials will be stored in microfilm form. Since an average of only 18 still pictures will be required for each simulation, it will be possible for the 18,000 stills required in all 100 simulations to be stored locally. Retrieval and display microfilm equipment now available makes

Table 5

CAPACITY REQUIRED OF VARIOUS FILES

	Central Data Base	Local Data Base or Sub-file	Local Buffers	Per Simulation	Used by Average Student in One Simulation
Text	(1000 sims) 30,000 pp. 6×10^6 characters	(40 sims) 1200 pp. 2.4×10^5 characters	40 pp. 8×10^4 characters	100 min[a] 30 pp. 6×10^4 characters	10 pp. 2×10^4 characters
Audio	(1000 sims) 15,000 min (250 hr)		(40 sims) 600 min	15 min	5 min
Still-Video		(1000 sims) 18,000 stills	40 stills	18 stills	6 stills
Motion Video		(1000 sims) 2000 min (33 hr)	26 min	2 min	40 sec

[a]Pages and characters are calculated on a reading rate of 100 wpm and 2000 characters per page (6 characters = 1 word).

access possible to any one of 18,000 documents in three or four seconds.

Configuration

A diagram of the operating system is shown in Fig. 7. Although there will be 18 stills associated with the average simulation, the average student will only use 6 (since he will not follow up all possible branches), which means that 40 students working for 15 min will access only 240 stills or a total of 5 or 6 per min. There should be no queueing problem on a single microform access device, and no need for a master video disc recorder at this slow rate. The system will simply cue the access of a still a few seconds before it is actually required; it will be picked up from the microform file by means of a flying-spot scanner or similar device, transferred into a video signal, and recorded on the still-video buffer.

Motion video will be the smallest component of each simulation. Of 2 min of motion available, the average student will access only about 40-sec worth in the average simulation. Motion pictorial materials will be stored locally in a motion video source, probably on one-hour reels of two-inch standard broadcast video tape.

Motion segments need not be transferred to the motion buffer until they are needed. Motion buffering would be cued by the student action that initiates a response, and its display would be delayed for as long as its actual running length because it could only be transferred at normal running speed. Thus, if the student selects to test the patient's motor coordination, and the response to this selection involves a 30-sec motion segment, the system must first present test and/or still pictures for 30 sec while the motion segment is being transferred into the buffer. By the same token, if the motion segment is a minute in length, a minute of non-motion material will precede it, which is not an impossible constraint upon the writer.

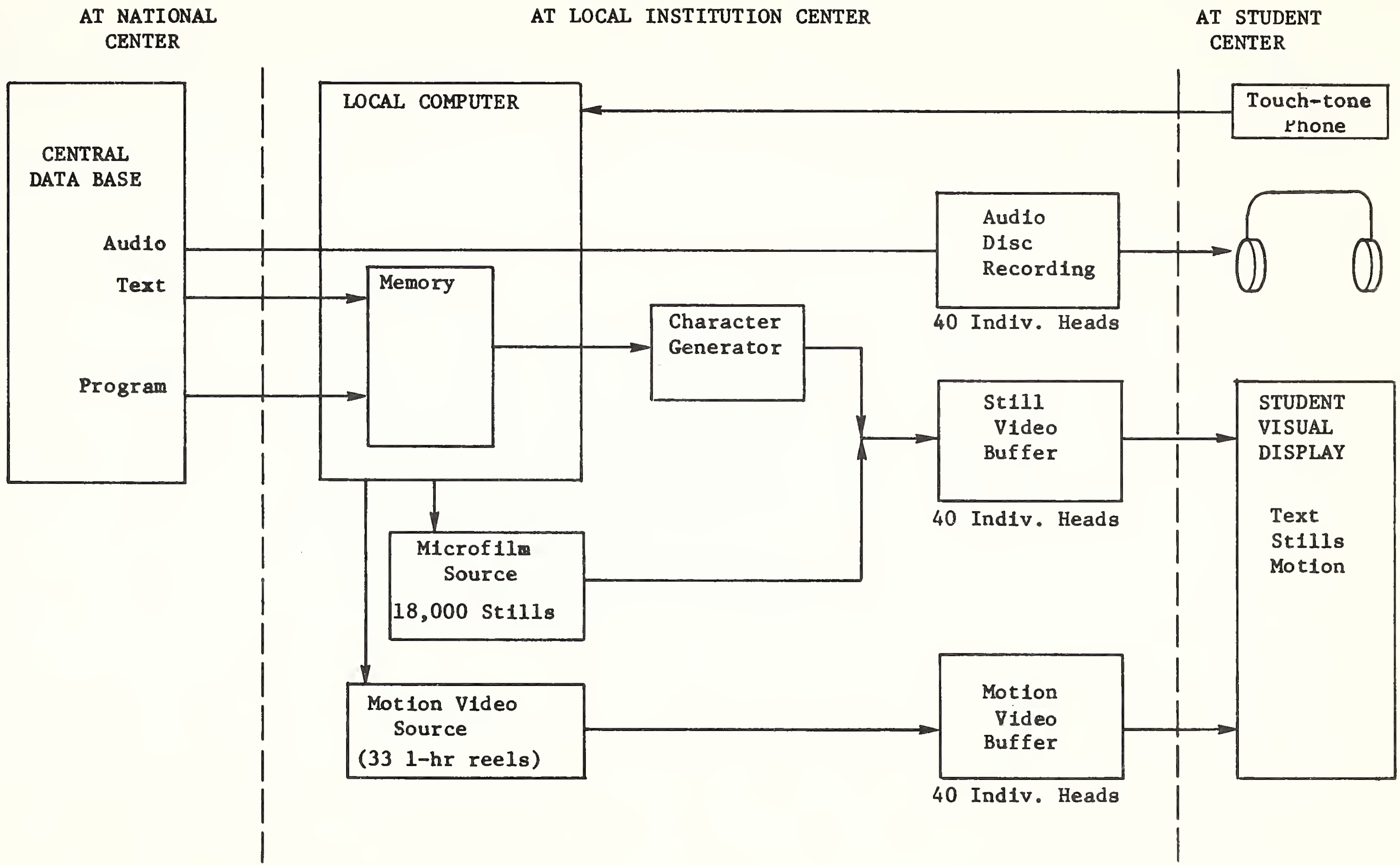

Fig. 7--Clinical Encounter Simulator System

The motion-video buffer planned for this system is designed along the same lines as the motion buffer built by Earl Morrison at the University of Texas Dental School in Houston.

The motion-video source, a standard broadcast quality video tape machine, can hold 30 two-minute segments on a one-hour tape. Thus, it can handle the motion-video requirements for 30 simulations. Two such machines might be threaded with the 60 scheduled simulations. Another two machines could be threaded by an operator during work hours and be used for retrieving the motion video segments of the other 940 simulations.

In the case of the operator-tended machines, a reel of tape would not be left on the machine during an entire 45-min period. Instead, the motion segments required for a particular simulation would be transferred into the motion buffer at the start of the period. In this way, the machine could be released for the use of the next student whose simulation segments might be shown on another reel. These additional 940 simulations would require 31 one-hour reels of video tape for their storage.

Thus, another constraint would be placed on the simulation writer--he could not plan the use of motion video within the first two minutes and fifteen seconds of a simulation. (Two minutes for the average total amount of motion video, fifteen seconds for the average retrieval time.) The two tended machines could provide motion-video for an unscheduled simulation every 67 sec. If the demands came more frequently, a queueing problem could develop that might be alleviated by assigning higher priorities to simulations in which the motion segments came earlier, and empowering the computer to recognize these priorities.

Student Actions

The student will be presented two kinds of material in the visual simulation: 1) lists from which to make choices and 2) responses to actions that result from the choice. The lists will consist of questions he could ask in taking a patient's history, observations he might make during a physical examination, laboratory texts he might order, or relevant treatments he might prescribe. He will activate his choices by "dialing" the proper numbers on a touch-tone phone.

The unit of presentation in the Clinical Encounter Simulator System will then be the system *response* to the student's action. These responses may be 30 sec to two and a half minutes in length; they may consist only of a sentence or paragraph on the screen, or of a sequence presented via multiple media. Each simulation will have its own computer program whose purpose will be to coordinate response to action and to integrate the various media components.

The computer at each learning center will contain its own subfile, which will be loaded at the start of each simulation encounter with the materials required for that particular simulation. Materials for a maximum of 40 simulations can be loaded in the subfile at any one time.

Control and management of the presentation of information will be performed by a local computer. Through long line interconnection, this computer will select the required information from the Central Data Base, which will be drawn upon in this manner by a maximum of 100 learning centers. To avoid queueing problems, it may be necessary to store data required for the most popular simulations in duplicate or triplicate.

System Functions

The program that directs the computer in responding to student actions will be stored in the Central Data Base and transferred (along with the text and audio material) to the local computer subfile as soon as a simulation is ordered. In determining which response the system will give, the program will base its determinations not only on the student action, but on the time within the simulation when the action is taken, and on the student's prior action or lack of action. Because the simulator is keeping a register of elapsed time (simulated time, not actual), the program can present unexpected events, such as a patient's turn for the worse, with which the student must cope. Simulated time will bear a relation to day of the week or time of day, since many tests and treatments take longer when ordered after hours. The student may specify a day and time at the start of a simulation, or he may be given an arbitrary time by the computer. A record of all student decisions and events will be kept by the computer and made available in display or print-out form as needed by the student or his instructor.

Implementation Plan

Implementation of the automated Clinical Encounter Simulator might be accomplished in several phases. Obviously the cost per student position for equipment and operation will be highest in the first phase, and gradually reduced as economies of scale are realized. Implementation might be effected in the manner detailed below:

Phase I--Experimental Stage

Local Centers: 1 Total Simulations: 10
Student Stations: 10
Purpose: To obtain performance and acceptance data on the simulator equipment and the simulations themselves. These tests should provide information on the amount of branching necessary, the time required for preparation, and the level of professional people required.

Phase II--Cluster Stage

Local Centers: 1 (serving 3 schools) Total Simulations: 40

Student Stations: 10

Purpose: A first step in development of the system. Three medical schools within a 20-mi radius will be interconnected with microwave equipment (private or common carrier) so that one computer and set of buffers can serve the 40 student stations in the three schools. Forty simulations will be developed and evaluated.

Phase III--Regional Stage

Local Centers: 20 Total Simulations: 100

Student Stations: 800

Purpose: The continuing development of the system based on experience gained in Phases I and II. In this stage, since student stations exceed 40, a Central Data Base will be introduced. Phase III is conceived as a "regional" stage where all local centers are within a few hours travel time of each other to facilitate the administration of the system. Except for this factor, however, local centers for this phase could be spread nationwide.

Phase IV--Full Installation

Local Centers: 100 Total Simulations: 300

Student Stations: 4000

Purpose: The fulfillment of the installation outlined for Phase IV may take many years, especially if financed locally. Only 300 simulations are specified; another 700 will be added at a rate of 100 per year.

Appendix

MED-FILE--ASSUMPTIONS AND CALCULATIONS

INPUTS

For the sample calculations, we have assumed that a typical medical library contains 10,000 books, and that 150 new books are received each year. An average book has 500 pages, and 20 percent of the library's book holdings will be automated.

For journals, we have assumed 2400 issues per year, with an average of 65 pages (10 articles) per issue. We include 10 years of back issues, and automate 25 percent of journal holdings.

Phase-in is assumed to require four years during which time the backlog of books and journals will be eliminated, and medical schools phased into the system at a uniform rate. Current acquisitions will also be automated as they are received.

In this example, there are 100 medical schools and 800 *users* (not restricted to students) at each school.

The unit cost of a Med-File is estimated at $1000, based on information obtained from Microform Data Systems of Palo Alto, California. Monthly rental for each Keyboard Cathode Ray Tube (KCRT) display unit, including the display control and multiplexor, is $200, the only hardware cost included in the estimates. Other hardware costs are discussed below. All hardware costs, with the exception of the Med-File itself, are based on an IBM 360/50 configuration.

Existing MEDLARS indexing is not used, and both books and journals require indexing. If MEDLARS indexing is used for the journals, a cost saving can be realized as the number of indexers is reduced, which in turn reduces clerical, supply, space, and equipment costs. The total saving is about $200,000 per year during the phase-in period,

period, and about $60,000 per year thereafter. The reduction in cost per page is about 30 percent in all years.

ANNUAL WORKLOAD

Book backlog is 20 percent of 10,000, phased over four years, or 500 per year at 500 pages each = 250,000 pages per year to be processed (abstracted, indexed, and microformed).

Journal backlog is 25 percent of 10 years of 2400 issues per year, phased over four years, or 1500 issues per year at 65 pages per issue = 97,500 pages per year.

Current book processing is 20 percent of 150 per year, at 500 pages each, for 15,000 pages annually.

Current journal processing is 25 percent of 2400 issues per year, or 600 issues at 65 pages each for 39,000 pages annually.

Figures for the total operation are the sum of backlog elimination and current material. Total pages are the sum of book and journal pages, and the number of microform master strips required is the total number of pages divided by 2000 pages per strip (a density of about 400 pages per square inch).

PERSONNEL REQUIREMENTS

National Center

All literature processing and production of microform master strips is assumed to be done at the national center. The administrative level consists of a director, a deputy, one secretary, and two clerk-typists. This manning level is assumed invariant with the processing workload.

We estimate that an abstracter can handle 1 book or 10 journal articles each working day (220 books or 2200 articles per year, assuming a 4-week month and an 11-month working year). The number of abstracters required in the first year is then 530/220 + 21,000/2200 = 12 (rounded off to the nearest whole number). Indexers and "key-worders" are estimated to work at the same rates, and we are not using MEDLARS indexing, so 12 indexers also are required. Clerical support is estimated at one typist for every four abstracters and indexers, or a total of six. Input preparation (retyping, keypunching, etc. in a format suitable for computer input) is estimated to require a 50 percent increment to the clerical staff, adding another three secretaries. This gives a total National Center staff of 38 for the first year. Personnel for microform processing are not included, since we assume this is done under contract at rates obtained from Microform Data Systems.

Local Depositories

We assume that one additional librarian at each school will be required to control ultrafilm cartridges, check Med-Files in and out, etc. This requires 25 librarians the first year (1/4 of the schools), phasing up to 100 (all schools) in the fourth year.

ANNUAL COST

National Center

National Center salary levels are estimated to be: Director, $20,000; Deputy, $18,000; Secretary, $8000; Clerk-typist, $6000; Abstracter/Indexer, $15,000; Typists, $7000. For the administrative section, this gives a total of $58,000 per year, to which we add 10 percent ($5800, rounded off to $6000 in the printout) for supplies.

Literature processing requires $180,000 for abstracting (12 x $15,000), $180,000 for indexing (12 x $15,000),

$42,000 for clerical support (6 x $7000), and $21,000 for input preparation (3 x $7000), for a total of $423,000 in salaries. Again, we add 10 percent for supplies ($42,300, rounded off to $42,000 in the printout).

Microform masters can be produced at the rate of about 400 pages per hour or 64,000 pages per month, assuming an 8-hr day, 5-day week and 4-week month to allow for some service interruptions. Charges are a flat rate of $10,000 per month, plus $50 for each 2000-page master produced, giving a total cost per page microformed of $0.18125 (= 10,000/64 + 50/2000). (This is for the master only; we assume that the schools bear the cost of producing copies.)

The first-year microforming cost to the National Center is then .18125 x 401,500 pages = $72,772, rounded to $73,000 in the printout.

For postage and handling, we estimate that the National Center will make one mailing per month per school in the system, and that each such mailing will cost $2. Cost in the first year is then $24 x 25 schools = $600, rounded to $1000 in the printout. (NOTE: Although values are rounded off in the printout, totals are based on unrounded values.)

Space rental and equipment purchase are based on GSA schedules. Rental is 150 sq ft per employee at $4.50 per sq ft, or $675 x 38 = $25,650 for the first year. Equipment purchase is a one-time cost of $750 per person, which we assume is phased over four years, or $750 x 38/4 + $7100 per year for the first four years.

Total cost for the National Center is the sum of the above, rounded to $635,000 for the first year, or a cost per page of $635,000/401,500 = $1.58.

<u>Local Depositories</u>

Librarian salary is $9000, for a total of $9000 x 25 = $225,000 for the first year (25 schools in the system).

For KCRTs, we assume that each user uses a KCRT for 1 hr per week, and that the KCRT is accessible 16 hr per day, 6 days per week. The number of KCRTs required in the first year is then:

$$\frac{800 \text{ users}}{\text{school}} \times 25 \text{ schools} \times \frac{1 \text{ hr/wk}}{\text{user}} \times \frac{\text{KCRT}}{96 \text{ hr/wk}} = \frac{800(25)}{96} ,$$

and the yearly rental is:

$$\frac{12(\$200)(800)(25)}{96} = \$500{,}000$$

for the 25 schools.

For Med-Files, we estimate that each user has 10 hr per day available for study, that 50 percent of this (5 hr) will be spent in proximity to the Med-File, and that the computer will be usable 18 hr per day. The number of Med-Files purchased in the first year is then:

$$\frac{800 \text{ users}}{\text{school}} \times 25 \text{ schools} \times \frac{5 \text{ hr/day}}{\text{user}} \times \frac{\text{Med-File}}{18 \text{ hr/day}} = \frac{800(25)(5)}{18} ;$$

adding 10 percent annually for maintenance and spares gives a cost in the first year of

$$\frac{\$1000(1.1)(800)(25)(5)}{18} = \$6{,}111{,}111$$

for the 25 schools. In the second through fourth years, the cost is \$6,111,111 for each 25 schools added, plus 10 percent maintenance on the Med-Files previously purchased. Thus, in the second year the cost is:

$$1.1 \times \$6{,}111{,}111 = \$6{,}722{,}722 \quad .$$

In the fifth year, all the initial stock of Med-Files has been purchased, and the only expenditure is the 10 percent for maintenance, or

$$\frac{800\ \text{users}}{\text{school}} \times 100\ \text{schools} \times \frac{5\ \text{hr/day}}{\text{user}} \times \frac{\text{Med-File}}{18\ \text{hr/day}} \times \$1000$$

$$\times\ 10\% = \$2{,}222{,}222 \text{ for the 100 schools.}$$

We assume that each school will buy one set of microform cartridges for each "non-spare" Med-File it owns. While this may seem extravagant, the low cost of microform copies ($0.30 per strip) makes this more than competitive with purchase of hard copies. One microform strip equals 2000 pages, or about 30 journal issues (2-1/2 years of a monthly periodical). For 800 users, the typical school will have:

$$800\ \text{users} \times \frac{5\ \text{hr/day}}{\text{user}} \times \frac{\text{Med-File}}{18\ \text{hr/day}} = 222\ \text{Med-Files.}$$

Buying one strip for each Med-File costs about $67 and makes these 30 issues potentially accessible to 222 users simultaneously. If an annual subscription to a typical monthly journal costs only $5, then 30 issues will cost $12.50 for one copy alone, and only 5 or 6 copies could be obtained for the $67 microform cost, severely restricting possible usage. Buying one set of cartridges for each Med-File thus seems a reasonable assumption. Each school then buys (under our previous assumptions) 222 copies of each cartridge, plus 10 percent for annual replacement, or 244 copies. Schools phasing into the system after the first year must also buy copies of the microfiche produced in preceding years.

Total cost per school per year ranges from $136,000 to $288,000 during the phase-in period, but falls to $59,000 per year during normal operation. National Center cost is about $636,000 per year during phase-in, and $208,000 per year thereafter, under the assumptions used in the sample case.

SOFTWARE

Development of the software necessary to support the Med-File system is estimated as a one-time cost of $200,000. The National Center would probably absorb this, although some of it might be pro-rated among the members of the system.

HARDWARE

The only hardware costs included in the sample calculations are those unique to the Med-File system: the Med-Files themselves, KCRT rental, and rental of the display controls and multiplexors for the KCRTs (Table 6). The additional hardware necessary to support the system is listed below. Because the *incremental* hardware cost will be unique to each school, depending on the computer facility it now has, we have not attempted to estimate incremental hardware costs.

Table 6

HARDWARE COSTS

Qty	Unit	Model	Description	Unit Rental	Total Monthly Rental
1	2050	I	C.P.U.	$20,550	$20,550
1	#6980		Selector ch 1	720	720
1	#6981		Selector ch 2	720	720
1	#6982		Selector ch 3	720	720
1	#7920		1052 adapter	232	232
1	2803	1	Tape control	670	670
4	2401	1	Magnetic tape	335	1,340
1	2821	1	Printer control	1,000	1,000
	#3615		1100 lines/min adapter	77	77
1	2540	1	Card Rd/punch	660	660
1	1403	N1	1100 lines/min printer	900	900
1	1416		Print train	100	100
1	2841	1	Storage control	525	525
1	#8079		2321 ATCH	175	175
1	2321	1	Data cell drive	2,885	2,885
1	2314	1	Disk facility (9 drives)	5,250	5,250
1	2703		Trans control	1,495	1,495
			Features	1,495	1,495
			Total monthly rental:		$39,514

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