NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

COMPUTER AIDED INSTRUCTION IN ENGINEERING

by

Theron S. Rose

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Thesis Advisor: Robert E. Ball

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This thesis presents evidence that computer aided instruction (CAI) is effective and can improve instructional efficiency when it is properly implemented. An overview of CAI in other colleges is presented as a source of ideas. The Department of Aeronautics of the Naval Postgraduate School is used as an example of where CAI can be applied. Procedures for the proper implementation of CAI are presented; and the summary includes specific recommendations for the Aeronautics Department.

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Computer Aided Instruction In Engineering

by

Theron Smith Rose
Lieutenant, United States Navy
B.S., University of Utah, 1978

Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

This thesis presents evidence that computer aided instruction (CAI) is effective and can improve instructional efficiency when it is properly implemented. An overview of CAI in other colleges is presented as a source of ideas. The Department of Aeronautics of the Naval Postgraduate School is used as an example of where CAI can be applied. Procedures for the proper implementation of CAI are presented; and the summary includes specific recommendations for the Aeronautics Department.

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I. INTRODUCTION

Microcomputer proliferation presents colleges and universities with opportunities and challenges that were unimagined fifteen years ago. Modern engineers have been liberated from tedious calculations and analyses by the increasing availability of powerful computers. Educators and students are also beginning to see the wisdom of applying this same technology to higher education. Small, powerful computers are now affordable on an individual basis, and the benefits of exposure to computer aided engineering (CAE), four to six years before entering the job market, are becoming evident. The objective of this thesis is to explore the background of computer-aided-instruction (CAI), and its possible applications in the Department of Aeronautics at the Naval Postgraduate School (NPS).

A. TYPES OF COMPUTER UTILIZATION

Educational use of microcomputers or Computer Aided Instruction (CAI) can be divided into three catagories, the "THREE T's OF CAI"; tool, tutor and teacher.

1. Tool

The microcomputer can reduce the time required for designs or analyses involving repetitive or iterative calculations from hours (days?) to minutes. Examples of the use of the computer as a tool in education already exist in the Aeronautics Department. In the advanced aerodynamics class, AE4501, the FLO 27 wing analysis and the CEBECI boundary laryer programs are used on the mainframe and Series 1 IBM computers. Advanced aircraft construction, AE4103, is enhanced by student written programs that analyze composite materials used in aircraft construction. These student programs are run on whatever computer system the student feels most comfortable with and is capable of handling the computations required. Because the time investment in the analysis was reduced, more possibilities were tried, and engineering principles were less obscured by the paperwork blizzard.

2. <u>Tutor</u>

Use of the computer as a tutor involves the presentation of remedial or supplementary lesson modules that reinforce classical classroom presentations. Many tutorials already exist, on the mainframe IBM and VAX computers, to train or retrain students in the use of these computer systems on campus. This same principle could be applied to NPS undergraduate level courses where basic engineering principles may be rusty from long disuse. A three to five hour module dealing with basic physics, geometry, or heat transfer, could polish these old skills to current usefulness. Modules could also be developed to give a much more detailed explaination and more (better?)

examples than the instructor has time to present in class. The student can receive a high quality graphical or video presentation at a time of his own choosing to clear up difficult points in the lecture presentation or to review prerequisite concepts.

3. Teacher

In this application, the computer takes on the role of the instructor. Courseware, the package of instructional modules that form the curriculum, must be carefully designed to anticipate the questions students may ask or areas where a short extra explanation may be needed by only a few of the students. A human monitor would only need to introduce the class to the computer and distribute the courseware. At the highest level of implementation, the computer would take care of all other functions, such as testing, pacing, grading, roll taking, and motivating. This placement of the education process entirely in the realm of computers is obviously less than desirable. Instead, the presence of a qualified instructor to proctor tests and grade them, answer unforseen questions, and even improve the courseware as deficiencies are found, appears to be the ideal level of computer implementation. Student to instructor ratios could be doubled, as a conservative estimate, without sacrificing the quality of instruction. Questions from the students may actually be more forthcoming than in the peer-pressure environment of the classroom.

B. THE EFFECTIVENESS OF CAI

Examples of computer use in schools and studies conducted to evaluate the results of such use, have shown that students in the computer aided environment achieved, at the least, the same level, and usually better, as the control groups that did not have access to CAI. Research has indicated [Refs. 1-4] that CAI has a positive effect on student achievement in a clear majority of the studies. In one compilation of other studies [Ref. 1], 14 out of 54 studies showed a statistically significant difference between conventional instruction and CAI. CAI was favored in 13 of the studies, while only 1 study favored conventional instruction. The other three studies [Refs. 2-4] were evaluations of the effectivness of newly acquired systems. All of the studies mentioned that both the instructors and the students were somewhat hesitant in their acceptance of CAI. However, as the courseware was tailored to local needs, all parties involved with the courses became enthusiastic about both the improvements in student achievement and the efficient use of instructor time. The improvement in performance was not restricted to the students; instructors were also helped by their "electronic teaching assistants". Time spent in contact with the students was more productive because it was now in a question and answer format rather than a lecture. Administrative tasks such as grading, attendance, tracking student progress, ranking of the students, and record keeping are exactly what the computer is best suited for and thus were the areas most praised in instructor evaluations.

C. WHAT OTHERS HAVE DONE

Several universities and colleges across the country have joined the microcomputer revolution. All examples of specific college applications in this section have been summarized from reference 5. Their approaches to hardware acquisition range from including the price of the required microcomputer in the students tuition to offering substantial discounts on microcomputers at the bookstore without requiring the students to buy. Although this seems to shift the major financial burden of college microcomputing to the student, the universities are supplying campus-wide high speed data networks to interconnect the personal computers and provide a link to the mainframe. School administrations are also devoting time and money to developing more uses for microcomputers in more classes.

Robert Golden of Rochester Institute of Technology said,"Our business is education, and we shouldn't lose sight of that. Planning for computer use on campus has got to be curriculum driven, not just an afterthought to the selection of some hardware." RIT is one of the schools that decided to leave the microcomputer decision up to the students.

Digital Equipment Corporation (DEC) micros are offered through the bookstore for 30 to 60 percent discounts, with some faculty discounts of up to 82 percent. Application of computer graphics in fine arts courses and an introductory computer science course that is taught primarily by the computer are two of the ways that RIT is integrating micros into the classroom.

Case Western Reserve was faced with an overburdened mainframe that was due to be replaced, but the installation of DEC Pro350s in a computer lab and in clusters around the campus relieved the load on the mainframe. Major users of the lab turned out to be freshman and sophmore students in computer science; while the juniors and seniors move on to the capabilities of the mainframe. The reduction in time purchased from the mainframe will pay for the cost of the lab in two and a half years. Case had rejected, for the present, the idea of a personal computer for every student.

Drew College of Liberal Arts began issuing Epson QX-10 microcomputers to all new freshmen in the fall quarter of 1984, and software was to be available for introductory courses throughout the college. Freshman writing courses will emphasize word processing by faculty demands for rewrites whenever necessary. Richard Detweiler, a psychology professor who is leading Drew's computer initiative, said,"We are a liberal arts institution and we believe that for people to be liberally educated they need to know how to use the computer as a tool."

Reed College, the smallest member of the Apple University Consortium, will provide Macintoshes to all students and is being funded by donations from friends and corporations. Plans include an icon oriented networking system to include the mainframe and Macintoshes. Students will not be required to use the computers, but an Information Resource Center will be established to provide printing and graphics facilities and student contact. "This should reduce some of the isolation that might be caused by many independent terminals," said Richard Crandall, chairman of the Technical Resource Committee.

MIT and Brown University have both initiated joint research and development projects with IBM. MIT's Athena project also includes DEC and involves a $20 million commitment by MIT, half of which will fund software development by the faculty. Athena software will initially use UNIX 4.2 as a base with a printing formatter, editor, mail/file transfer program, numerical analysis and graphics packages, and languages (C, LISP, Pascal, and FORTRAN). Brown has provided a lab with 60 Apollo workstations that are used to present dynamic graphic simulations of algorithms. George Landow, an English professor at Brown, has predicted the eventual use of a scholar's workstation to access the Library of Congress catalog for hands-on research. Both universities have made a commitment to get microcomputers involved in the classroom in a big way.

The approaches to integrating microcomputers in the college classroom are as varied as the types and sizes of the colleges themselves. The small private schools have the financial flexibility and administrative control needed to lead the way; however, large schools have the volume purchase ability needed to gain the interest (and discounts) of the major computer companies. The large universities have a more diverse curriculum leading to the need for separate solutions, with different systems and software, for the different departments within the university. Smaller schools seeking their own solution may find it in a departmental subsystem at the large universities. The University of Michigan has diversified its involvment with microcomputers with Apple Macintoshes and Lisas, IBM PC XTs and Apollo Engineering Workstations and has placed them in varied environments across the campus. Instructors in the technical communications course noticed a significant increase in the use of graphics in reports produced by students on the Lisas. The UM College of Engineering is testing microcomputers for the rest of the university and is sharing the information gained with deans of other colleges. This would be a good place to start when looking for applications and lessons learned.

D. THE FUTURE

Success with a CAI system can either be achieved or avoided by the process that is followed to implement this new technology in the classroom. Buying or shopping for hardware first has proven to be one of the best ways to sabotage the possibilities of the CAI system. Although the first motivation to become involved in CAI may come from a "deal too good to refuse" on the hardware needed for a system, the professional educator must first evaluate the goals of his institution. Some curricula just do not "fit" on the computer screen. Teaching philosophy with a computer appears to be very far in the future. Following the proper steps, described later, will lead to a system that meets the goals of the educator both academically and financially.

The educational software market has come to life in the past year. Both courseware, either the actual modules or the entire curricula needed to teach subjects, and authoring packages, the software that makes creation of the courseware easier, are coming on the market. The authoring packages are intended to directly involve the educator in creating the courseware modules. Construction of the teaching modules is menu or question driven, requiring no programming expertise. The "page-turning" courseware of the past has been replaced by interactive graphics and student tailored examples.

The videodisc player, controlled by the computer and courseware, has made the use of high resolution animated graphics accessible to the average educational budget. Videodiscs with up to 54,000 separate frames of video information, from a simple text screen to a segment of a motion picture, or both overlaid, are sparking the creativity of courseware designers. Several companies are providing authoring software bundled with videodisc control interfaces. With respect to advances in the microcomputer itself, they are now capable of number crunching that was only done on mainframes just five years ago. Memories and processing speeds have increased to the point that total computer animation is now possible, though not yet affordable.

Technologies, talents, and attitudes have coincidentally arrived in the computer education field during the eighties; much the same as they did during the sixties in the field of space exploration. Columnists and editors of several computer magazines, in charting the direction of computing in the coming year, have stated that this will be the year for educational computing as 1983 was the year of the microcomputer price wars. Much is in store, and many developments are yet to be announced, but we can not wait. What will be the cost of one or two years missed experience for the students.

E. SCOPE OF THIS THESIS

This thesis will now discuss the present situation in the Department of Aeronautics, at the Naval Postgraduate School, and a possible solution to the problems now faced. A description of the proper steps to follow in setting up a CAI system will be presented, followed by sections dedicated to software and hardware considerations. Recommendations to improve the instructional efficiency in the Department of Aeronautics at NPS will close out this thesis.

II. CURRENT SITUATION

Statements made in the Introduction apply to a broad base of institutions. The remainder of this thesis will be placed in the setting of the Naval Postgraduate School (NPS), and specifically the Department of Aeronautics. Recommendations will apply to the situation at NPS and may or may not apply when taken outside this setting. However, the general procedure followed to arrive at the specific recommendations should be just as broadly applicable as the Introduction.

A. NPS PERSONNEL AND FUNDS SHORTAGE

The needs of the Navy and changes in curricular emphasis have led to a widely varying enrollment in the Department of Aeronautics over the past fifteen years. An interesting fact is that the current student count (about 100) is now almost exactly the same as it was fifteen years ago, having dropped to less than half this number (36) during this time. The number of faculty members also dropped off (from 22 civilian plus 3 active navy to 13 civilian plus 1 active navy) with the decline in student population, but as the students came back, the number of professors did not increase. Currently, the number of permanent faculty is approximately half of what it was fifteen years ago when the enrollment was the same.

Local and national economic conditions, coupled with restrictions in government pay scales, have resulted in professor recruitment being a fine art that barely keeps up with attrition. Campus conditions and student attitudes are the major selling points that NPS has to offer, but neither of these will pay the rent nor feed the family.

The same conditions that have depleted the faculty ranks were also working even more effectively on the support staff. Secretaries, lab technicians, and active navy technicians numbered 2, 23, and 4 respectively fifteen years ago. Currently, the numbers are 3, 8, and 0 for the same respective staff positions; slightly more than one-third of their strength fifteen years ago. Three visiting research faculty and nine contract research associates also call on the services of the lab technicians. Laboratory facilities are sadly underused, and only minimum maintenance is done due to the lack of technicians. New funds that have been earmarked for lab improvements will enhance conditions in the labs and, with better instrumentation, yield better labs with the same workload. However, the amount of research work that was conducted in the past cannot be supported by the present staff; thus reducing the amount of contract research funds for lab operation.

B. INCREASE IN CURRICULAR CONTENT

Engineering practices in industry have undergone a major change in the last ten years. Computers are used to design everything from wing structures to the microchips that will be used in the fly-by-wire control systems. Physical prototypes are only used in the final stages of simulation and testing. Thousands of hours of computer simulation and refinment of the initial design have already taken place before the near-finished design encounters reality beyond the terminal screen. Many of the principles and equations governing these simulations were not even known ten years ago, but room for them must now be found in the curriculum without sacrificing what is now there. There has been a dramatic increase in the amount of knowledge that must be presented, and hopefully absorbed, during the two years of graduate education.

Furthermore, microcomputers are replacing calculators for practicing engineers, just as calculators replaced the slide-rule. Prediction and analysis programs that used to take weeks of iteration on a calculator, or by hand, or waiting overnight for a printout to return from the mainframe, can now be done in an afternoon on the engineer's own personal computer. The engineer who does not know how to use this tool efficiently will be left in the drafting room as his collegues leave to enjoy their weekend.

Computer proficiency--not just computer literacy--is required of anyone involved in modern engineering.

C. THE PROBLEM AND A SOLUTION

Because personnel and funding shortages are overloading the research and teaching talents that are still available, and because additional areas of knowledge and new techniques that need to be taught are compounding the problem, improved efficiency in the educational process is obviously called for. Microcomputers utilized as teaching assistants in all three phases of the "Three T's of CAI" can contribute to this needed efficiency. Careful evaluation of the goals of the curriculum, using the computers for topics that are not naturally alien to computer presentation and adapting courseware to meet local needs, can bring great benefits to both students and instructors.

As a consequence of the potential educational benefits to be gained by student use of microcomputers as tools, the Department of Aeronautics is currently in the process of acquiring twenty-one new IBM PC AT microcomputers. All but four of these computers will be equiped with excellent color graphics packages and some with superior capablities in this area. Dot matrix printers will be dedicated to fourteen of the systems and seven Hewlett-Packard Laser Jet printers will be available on network. Five of the computers are part of the lab upgrade project and will be dedicated to instrumentation and data reduction in the laboratories. The other sixteen were proposed for use in the instructional program. Word processing, simulation and analysis programs, such as Bode plot programs used in the Controls classes (AE 4301 and AE 4342), are currently available to support the use of the computer as a tool for conventional classes in the curriculum. Extension of these assets to cover the other two T's of CAI should be considered and given equal priority in view of the problems stated above.

III. SETTING UP THE CAI SYSTEM WITHOUT SETTING OURSELVES UP

The rising tide of microcomputers in education is here, and the professional educator will attempt to channel these innovations to the maximum benefit of his students. Diving into the hardware/software buying mode could result in wasting time, effort and money until the rescue squad does some careful evaluation of educational goals [Refs. 4,6,7]. Looking at what other schools have done, then comparing the results obtained with the goals set, will result in a system closely tailored to the needs of the local institution. It may even be found that CAI cannot be effectively applied to meet all of the established goals. Evaluating courseware or authoring packages should only be attempted after goals have been set to prevent being led astray by technological dazzle.

A. DEFINE THE EDUCATIONAL GOALS

Educational goals should be established while constantly considering the three T's of CAI. Microcomputers are already in extensive use as tools in engineering curricula across the country [Ref. 7]. The utilization of computers in this manner teaches the student how to use the computer, how to evaluate computer generated data, and mainly to realize that sometimes computers spit out the most rediculous drivel. Students learn to properly format input data and to program short routines that will allow iteration of the input data. Learning efficiency is increased for the student, but the instructor must still teach all of the conventional material plus the use of the computer tool. This teaches use of the computer, but will not solve the problem in the situation at the Naval Postgraduate School because the instructors are already overloaded.

Incorporating tutorial modules to supplement the presentation of the basic principles of the course can relieve the instructor of some of this load. The instructor will now have more class time to present the more difficult concepts that have confused students in the past. Knowledge of the tutorial modules is a new requirement for the professor so that he can answer questions that come up or detect bugs in the tutorials. Courseware already exists that can be applied in a tutorial fashion (see the list of applicable courseware in the appendix); reducing the time needed to incorporate this into the curriculum.

Teaching all or a majority of the course from the computer takes much more preparation than the two previous options. A competent instructor is still needed to answer questions that the courseware did not anticipate. This instructor can, however, accomodate two or three times the number of students as he could in a conventional class. Testing and administrative record keeping can be left to the computer or handled by the teacher. Courseware that fits the exact range and depth of an existing conventional course may be difficult if not impossible to find. The choice must be made to either spend the time creating or adapting software to the course or to change the standards of the course to meet the available software. Creating or adapting the courseware for undergraduate level courses could be an opportunity for projects assigned to students as thesis topics.

Using the preceding information, based on the three T's of CAI, and considering the subject matter of the course, funding available, and instructor attitudes, a decision can be made for the type of computer involvement in the class. Care should be exercised not to try and mold every class to a computer curriculum. Some classes, such as philosophically based classes or introductory/overview classes or higher level math theory classes, may be best presented by an instructor and text. Examples of classes from the Aeronautics curriculum that would not profit from CAE are: System Safety--part of the course would be aided by statistical computer tools, but the majority of the course is meant to establish the philosophy of system safety design. Aircraft Survivability--again there are some quantitative analyses that can be done and there are computer program tools in existence, but the qualitative evaluation of historical developments in aircraft survivability forms the majority of the class.

Ordinary/Partial Differential Equations--this course is based on memorizing algorithms (few), techniques (some), and tricks (many) for solving differential equations.

B. DETERMINE IF/HOW CAI CAN MEET THE EDUCATIONAL GOALS

The most difficult and most often ignored step has already been discussed; defining the audience and educational goals of the curriculum. Goal setting is tough wherever it is encountered, but the rewards are always worth the effort expended. By defining the destination, the trail leading to it is often exposed. As previously stated, philosophical or historical courses do not easily lend themselves to CAI, and since engineering curricula are seldom overburdened with such courses they offer a wealth of areas in which to apply CAI. At this point I will become specific and draw candidates from the Department of Aeronautics of the Naval Postgraduate School.

Undergraduate level courses reviewing the basic engineering disciplines are usually considered to be the best candidates for CAI introduction. The courses were offered in pairs in alternating quarters and every enrolled student must take all four classes: Flight Structures, Thermo-Gas Dynamics, Engineering Dynamics, and Basic Aerodynamics. Each of the courses requires completion of many practice problems in order to become proficient in recognizing, organizing and solving engineering problems in an efficient manner. They also depend heavily on visual aids, mostly in the form of instructor drawn diagrams on the blackboard, but several good films are presented to illustrate dynamic principles. Most instructors are adequatly talented in the graphic arts to represent a three dimensional object on the blackboard. A few are highly skilled, and others are less than satisfactory, but a considerable amount of time is required for any of them to get a usable diagram on the board. Computer graphics offer an obvious solution to this inefficient use of time. A skilled instructor need only draw the diagram once; then copy, rotate, mirror, or expand, under computer command, to best illustrate points throughout the lesson. Films or segments of films could be put on interactive videodiscs controlled by the courseware to repeat important sequences or freeze particularly enlightening frames for a period of time determined by the student.

Some students in the undergraduate level classes have no engineering background, while a few have postgraduate work in aeronautics. This diversity of backgrounds complicates the instructor's task of keeping the class interesting while not leaving the inexperienced student behind. By using microcomputer based CAI for these courses, in the "teacher" mode, the instructor would be released from teaching the same class twice each day. The resulting improvement in instructor morale would improve response to student questions that were not anticipated by the courseware. Instructor time could now be dedicated to research, improving or developing new courseware for other courses, or more time to council assigned thesis students. The goals of these basic courses can be met by CAI.

C. EVALUATE EXISTING COURSEWARE

Even the best courseware, if it was developed more than three years ago, lacks the necessary graphics to make them more than a tool or poor tutorial. Most of them operate in the question and answer or page-turner format. If this format must be used, it is best left in a book; the pages are cheaper and easier to turn. The most recently released courseware incorporates not only high resolution graphics, but the ability to overlay this onto pictures or movies from a videodisc or videotape. Color is used effectively in most of the modern software to either differentiate entries or just to make the lessons less boring.

However, courseware designed for a course at one university can be found lacking in some areas when applied to the same course in a different school. Students may have different backgrounds, or the courses may cover significantly different ranges of the same subject. For example, the undergraduate courses in the Department of Aeronautics present material in one quarter that is sometimes covered in most undergraduate curricula in two or three quarters. A new program of courses, instituted in October 1984, has relieved some of this course content overload. The classes are taught to people of varying undergraduate backgrounds, but all are college graduates, and all have been out of college for at least five years. Adapting outside courseware to meet the needs of the local classes may turn out to be more time consuming and expensive than building the courseware in-house. One comment that surfaced in several studies of the effectiveness of CAI was that locally generated courseware was more effective, better received and more easily debugged or updated than outside purchased courseware [Refs. 1-4,6].

D. DEVELOP NEW COURSEWARE

If the choice is made to produce the courseware in-house, the authoring system used to produce it must be selected. Authoring packages that do not offer control of videodiscs as an option are passing up one of the best tools available to the teacher. This would be equivalent to saying "no thanks" when offered a random access, variable speed film projector (assuming such an animal existed). This subject will be covered more thoroughly later. Videodisc units are an added expense, but they do not need to be used from the start. Most authoring packages offer excellent graphics, usually in color, and all of the management and security features necessary to administer and protect the courseware. Several good authoring packages are available [Refs. 8-11], but care should be taken to ensure that the software/hardware of the package is compatable with any hardware that the school already has or is locked into purchasing. Some of the packages are only compatible with outdated systems and thus only appear to be a bargain. Any system that is not compatible with current 16 bit machines (IBM or compatibles) should not be considered due to lack of speed and graphics quality.

IV. COURSEWARE AND DEVELOPMENT CONSIDERATIONS

All computer hardware advertisements should carry a warning like the cigarette ads. "Computers without software are just hi-tech junk." Without good courseware, the major purpose of the best CAI system will be to gather dust. Some time has already been devoted to basic software evaluation; this section will deal with the same topic in more detail.

A. HAS SOMEBODY DONE THIS BEFORE?

Thousands of educational courseware programs have been written for microcomputers. Hundreds have been written that apply to some form of engineering on a college level. The Plato system was started at least fifteen years ago at the University of Illinois. Plato is a mainframe (Cyber 70, 170, or 6000) based instructional system, accessed from specially designed terminals built by Control Data Corporation and sold or leased to schools. The catalog of courses offered on Plato is two inches thick, but these courses are getting old and, being designed for presentation on a terminal, offer only medium resolution line graphics. Software was released in early 1983 that allows an IBM PC to access the Plato system, but no engineering programs were offered or planned at that time. Only a small portion of the Plato courseware was available to microcomputer access;

probably due to the slow transfer of graphics over a telephone line, even at 1200 baud.

This seems like a vast arena in which to start a search for just the right software to present a specific course. A big chunk can be knocked out by discarding all those programs written more than five years ago, unless they are just to be used as tools. Major engineering firms in the same specialty as the curriculum will often donate analysis or simulation programs to be used as tools; or they can be obtained from other universities for a copying charge. Tutorials and full course teaching packages are a little harder to find, depending on the course topic.

The Basic Aircraft Structures course, AE 2025, was selected from the Department of Aeronautics undergraduate level sequence as a topic to see how many programs were available to replace all or portions of the course. Topics covered in the course range from definitions of force, moment, and torque, to buckling in plates and beams. A surprising scarcity of courseware was found on this topic. Only three related entries were found on the Plato instruction network, and they covered only part of the course. However, several entries and even a complete curriculum for thermodynamics is available on Plato, and, if Chemistry were selected as a topic, the available software is overwhelming. This proves that, even if a course is one of the basics that everybody takes, there isn't necessarily a lot of courseware to choose from. From the Aeronautics undergraduate curriculum described earlier, the only supported topics are Thermodynamics and Gas/Fluid Flow. This is a good place to refer to the list of applicable courseware in the appendix.

Adapting the programs to suit local needs is still a problem, even if the topic is adequately supported by outside software. The authoring system that was used to design the course would need to be obtained or licensed and learned before any adaptation could begin. Once the authoring system is available, the manpower must be found with the talent, time and desire to complete the job and a system must be dedicated to the task.

B. VIDEODISC POSIBILITIES

Think back about four years and remember the big news in the video market. The videodisc or laserdisc was going to take over the home video market. It fizzled out. But wait; the same things that made it good at home, worked to its favor in the classroom without the disadvantage of not being able to record. Teachers discovered the ultimate visual aid machine. Imagine a film projector capable of infinitely variable speeds from three times normal to still frames, then add random access to any frame of a 30 minute movie in less than a second; it can go in reverse too, of course. The videodisc player is all of this and more.

Images are carried deep within a plastic disk in digital form and read by a low power laser beam. No contact is made on the rotating disk by a needle or film shuttle so the image will not be scraped off. It is almost silent in operation. The accessing of frames and all other functions of the player can be computer controlled on most industrial models. Here is where the software comes in. Several new authoring packages offer videodisc control and integration into the lessons. Some offer the capability to overlay computer generated graphics on the picture from the videodisc depending somewhat on the hardware in the system. The combination of computer control of the operation of the videodisc player and the ability to mask out video "noise" or highlight important areas of the videodisc image, has expanded the applications and effectiveness of CAI by a factor of two. These advantage do not come cheap.

Industrial grade videodisc players with computer interfacing capability cost about $1000. The authoring package to write the courseware or modify existing courseware to use the videodisc will cost another $800 to $1000. Controller and mixer boxes to interface the computer, monitor and disc player also cost about $1000 if the overlay capability is wanted, about $600 if not. Each student station in a learning lab would require an individual control box and disc player for independent teaching. If group teaching were considered viable, up to four stations could share one video system. Only one or two authoring packages would be needed for each department. For example, a ten station lab set up for independent instruction would cost about $21,000 extra to include the videodisc capability.

Most universities have the capability to produce the videotapes from which the instructional videodiscs could be mastered. First copies of videodiscs from the 3M company cost about $500, with additional copies at $30 to $50. This adds about $1000 to the cost of video in the lab for each disc to be used. The Naval Postgraduate School has an advantage at this point by being able to get the videodisc masters done by the U.S. Army Instructional Command in Georgia for mailing costs. Now it must be decided if the advantages of videodisc presentations are worth the extra price.

C. AUTHORING PACKAGES

Construction of courseware and control of videodiscs can be accomplished using almost any resident programming language in a computer, however, the person doing it is either a skilled programmer or soon will be. Authoring packages claim and are designed to insulate the educator from the complications of programming. The packages are intended to allow a professional educator with moderate computer literacy to sit down and produce a lesson module from a lesson plan or outline and storyboard sketches of the desired presentation formats. At least as much time should be planned to convert a conventional lesson plan to CAI as was used to produce the original lesson plan. This is a minimum; if graphics are needed or videodisc controlling is involved, the ratio of preparation time to presentation time can reach 50:1 easily. This needs to be weighed against the quality of instruction and the fact that the instructor need only answer questions and possibly give and grade tests now. The quality of questions should definitely improve, and test performance should also display an upward trend if past studies are any indicator [Refs. 1-4]. Correlation between a successful CAI program and local production of the courseware was mentioned repeatedly.

Quest, an authoring package produced by Allen Communications of Salt Lake City, Utah, is currently on loan to the Department of Aeronautics from the Department of Continuing Education. This package, aided by an industrial grade videodisc (Pioneer) and interface/controller (Allen Communications), demonstrates most of the capabilities of current technology in CAI. Full control of the videodisc is offered with complete graphics construction commands, in menu form, for computer graphics. Administration of courseware production is handled through a multiple layered, password accessed structure. A senior programmer has access to all levels, the courseware designers can access all but the highest, and so on through instructors, and aides, to the students who have access to only their own files. Students would not normally have access or write capability to change courseware or alter records generated for administrative purposes.

V. HARDWARE CONSIDERATIONS

Compatability is the keyword to selection of hardware for current microcomputer aided education. Software, chosen because of unique features that are new to the market, may not be compatible with older computer systems. Hardware advances have been so rapid in the last five years that new capabilities are introduced before software is written to take full advantage of the latest developments. Many different operating systems exist due to copyright restrictions, and even updates of an operating system for the same computer from the same company, may not run software written for the old system. During my testing of programs on two different, but supposedly identical, IBM PC's, programs that ran without problems on the older one would not get beyond the first menu selection on the new computer. The only difference between the two computers was PCDOS 2.0 for the older one and PCDOS 2.2 for the new one.

A. PROCESSING CAPABILITIES

One of the most important features of the hardware is the graphics capability. Speed is important when doing graphics manipulations determined by student inputs or responses. The older eight bit machines, such as the Apple II series, operate at a clock rate of one or two megahertz;

IBM PC's and their compatibles operate at four or eight megahertz, and the new micros, like Apple's Macintosh, operate at twelve megahertz. However, clock rate does not serve as the best basis for comparison; instructions per second serves much better to judge a computer's true speed. Older eight bit machines have an eight bit parallel data bus with an eight bit microprocessor. IBM PCs, and compatibles are 8/16 bit machines; meaning that, all have sixteen bit microprocessors, but most have only eight bit data buses. This requires two memory fetch instructions to get the sixteen bits for the microprocessor to operate on. Some of the IBM compatibles have sixteen bit data buses and, during memory intensive operations, appear to operate twice as fast. The Apple Macintosh is designated as a 16/32 bit machine using the same rationale. Atari has announced a full thirty-two bit, 32/32, microcomputer but it is not on the market yet.

Typical operating systems allow overlap of instructions so that each instruction only appears to take three clock cycles rather than the five to seven it would take without the overlap. Newer machines with wider data buses, sixteen bits compared to the older eight bit buses, can transfer twice as much information per instruction. Thus, older machines will handle about one or two hundred thousand instructions per second, while the 16/32 bit machines will handle the same information at two or three million instructions per second. These numbers look great until compared to the thirty million instructions per second required for animated graphics on a 1000x1000 pixel screen. This is based on thirty frames per second to give smooth motion and one million pixels per frame.

Addition of a hardware math co-processor can speed up operations involving many calculations by a factor of ten in some cases. Usually the average increase is about double the normal speed for typical programs. This speed may be greatly appreciated by the student waiting for the computer to draw a picture. For a standard IBM high resolution (320x200) sixteen color screen, up to sixty four thousand nibbles of four bits each need to be defined in the screen memory to make the picture appear. The standard resolution just mentioned should be considered a minimum for all but crude symbolic representations. Resolution of 1000x1000 produces a very nice picture approaching high quality television video, but this obviously requires a very large amount of memory and very fast processors.

B. PROGRAMMING LANGUAGES

Programming languages may seem out of place in a discussion of hardware, but the applicability of a language can be determined by the hardware chosen. High level languages such as Pascal, or FORTRAN may not fit in a microcomputer without stripping many useful functions from the language. BASIC, even though it is small and easily learned, lacks the power and functions needed for applications at the graduate engineering level. Masterson [Ref. 12] presents a good comparison of languages used in education and industry. His choice of languages can be debatable, but his criteria for choosing them are valuable. Masterson wants the ideal language to have six features:

1. interactive, interpreted code
2. powerful primitives for creating and altering whole data structures
3. functional notation that often emphasizes the hierarchical structure of a computation
4. dynamic memory allocation
5. stored workspaces containing variables and function definitions
6. user access to system variables

The source language of a system may not be important if a good authoring package is available, but eventually someone will want to modify the authoring package or need functions not offered in the package. They will need to fall back on the language that the package was written in or a compatible language that has been adapted to the hardware in use.

C. EXPANDABILITY AND PERIPHERALS

As the system becomes accepted and used by more students and faculty, more capabilities will be wanted. Memory expansion is usually the first requirement. More use of graphics and the writing of longer programs or the need to manipulate larger masses of data will all drive the need for more memory. Current 8/16 bit machines can address a full megabyte of memory, but they are seldom expandable to this point. The 16/32 bit micros exceed this capability by two orders of magnitude.

An alternative to gigantic internal memory is the use of mass storage devices such as hard or floppy disc drives or tape transports. Software that uses the storage space of the disc drives during calculations is naturally slower, but is not restricted to the space available in memory. The hard disc drives are the best for this application because of speed and storage capacity. Multiple megabytes of storage with fast access times can be obtained for the same price as one megabyte of floppy disc storage that has a much slower access rate. Tape storage is best used as a backup for a hard disc in case of a head crash or system failure causing data loss. Compatibility must again be considered with the purchase of mass storage.

Several microcomputers are usually purchased to form a computer lab or learning center. Linking these computers together and sharing input and output devices decreases the cost of the system and can also enhance the capabilities of the system. Every unit of the system need not store all programs or data necessary to complete a problem if an effective data communications network is available between the units (distributed processing). IBM has announced a local area network, for the PC, XT, AT family, that will be available in April 1985. Elements of the network system that are not duplicated at each PC station include a translator, base expander (if more than eight, up to seventy-two, units are to be networked), short distance converter, and the reference manual, and are commercially priced at $888.00. Equipment needed for each PC station includes an adaptor card, network software, DOS 3.1, and a twenty-five foot connector cable; having a total commercial price of $861.00. Purchasing through GSA contracts will reduce these prices by about thirty percent. If less than eight PCs are to be networked, the central equipment price can be reduced by $59.00.

Interfacing with the human world has generated a parallel technology race with microcomputers. Different devices include the keyboard, joysticks, lightpens, touch-screens, digitizing pads, and of course, our little long tailed friend, the mouse. Each of these devices has advantages in different situations. The keyboard is best suited for text entry and, if equiped with a convenient numerical keypad, for data entry. Trackballs and the mouse (an upside-down trackball is a good description) have overtaken the joystick as a graphics input device, but cost significantly more. A lightpen or touchscreen interface seems like the most natural method to communicate with a computer, but strong shoulders are needed for long sessions unless the display screen is mounted in a desk top. The touch screen is also not a high resolution device. A digitizing pad offers high resolution, convenient use, and correct spatial orientation, but it comes at a high price. Overall, the mouse seems to be the most economical and adaptable of these devices. It is capable of high resolution and does not suffer from spatial orientation problems like the joystick.

VI. SUMMARY AND CONCLUSIONS

CAI has been shown to be effective, sometimes even more effective than conventional instruction. Comparison of the costs of conventional and computer instruction will be left to the administrators, but they should consider the current lack of professors and compare the government pay scales to the costs of a computer learning center. CAE stations can be obtained for $4000 to $6000 each depending on the capabilities desired, and courseware will run about $300 per station per course. Remember that initial costs such as the authoring package, the initial investment of faculty time, and shared peripherals can be spread over the number of stations and time that a CAI curriculum is used. A student to computer ratio of 1:1 would be ideal but under used; a ratio of 2:1 would be realistic. Successful systems have operated with a ratio of up to 4:1.

The question could be asked, "Can we meet our educational goals faster, better or cheaper with CAI?". Given the shortage of professors and support personnel, I must change this question to, "Can we meet our educational goals without CAI?". Professional engineers are using the computer as a tool today like they used the slide rule in 1950. If the student engineer is not familiar with this tool before he enters the job market he starts out behind.

The same studies that substantiate the premise that CAI is as good or better than traditional instruction, when applied to the right topics in interesting ways, also indicate that students will absorb the course material faster from the computer.

Based on the available experience of others and the present situation in the Department of Aeronautics as presented here, the following recommendations are presented:

1. The purchase of the IBM microcomputers should go ahead as planned and they should be used as tools to aid the instruction in the traditional courses wherever appropriate.

2. Introduce instructors and thesis students, if available, to the Quest authoring system for in-house development of courseware. This recommendation is based on the current availability of this system and is not meant to preclude evaluation of other systems as this young and fast changing technology develops.

3. Obtain, on approval if possible, copies of the best tool, tutor, and teacher software listed in the appendix. Very little courseware currently exists that utilizes the videodisc capabilities, but this may change drastically in the next year. Several groups, also listed in the appendix, are currently in the process of developing such courseware, but had none available when contacted in late 1984. If no suitable courseware is found, expand development of in-house courseware to teach the major portion of the four undergraduate courses (Structures, Dynamics, Gas-Thermo Dynamics, Basic Aerodynamics).

4. Obtain more microcomputer systems as needs require and funds allow to the point of a student to computer ratio of 5:1 for the whole curriculum. (About 20 stations available as learning stations.)

Faculty acceptance of teaching aids developed by other professors, even in the same department, has typically been low. Each professor has an individual teaching style that may or may not accommodate different visual aids. Therefore, participation by all concerned faculty members in the development of courseware is essential. If each professor can feel that his ideas were considered during the preparation of a course, the course will be more likely to be accepted and, more importantly, to be used.

Man is separated from the animals by his use of complex tools. We have available now a tool that is adaptable to almost all phases of modern life, and it is being adapted by modern engineers. CAI is just another adaptation of this tool that will help expand the frontiers of human knowledge by making it easier to aquire the existing knowledge base from which to build.

APPENDIX

LIST OF APPLICABLE SOFTWARE

SOFTWARE AND SOURCE	3Ts TYPE AND COURSE	
1. General Physics	tool/tutor	AE 2015
Cross Educational Software		AE 2025
1802 N. Trenton Street		AE 2045
P.O. Box 1536		
Ruston, LA 71270		
(318)-255-8921		

There are 11 disks in the set, of which the first six have applications in the classes noted. Statics (v. 2) is available in the micro lab for evaluation. About $20.00 per disk or the set for $200.00.

2. Unprintable Physics	tool/tutor	AE 2015
Prentice-Hall Inc.		AE 2025
Book Distribution Center		
Route 59 at Brook Hill Drive		
West Nyack, NY 10995		

This is currently available for the Apple II, but may soon be released for the IBM PC. $30.00 one disk

3. Micro-CAE Software	tool	AE 2015
Dr. William Comfort III (L-390)		AE 2025
Lawrence Livermore National Laboratory		AE 2045
P.O. Box 808		
Livermore, CA 94550		
(415)-422-4908		

A series of more than 20 design and analysis programs developed by university personnel working summers at LLNL. The whole set was ordered early in February 1985, at no cost, for the Aeronautics Department.

4. Technical Software	tool	AE 2015
3981 Lancaster Rd.		AE 2025
Cleveland, OH 44121		
(216)-486-8535		

Several design and analysis programs are available in the $100 to $500 range with some packages up to $1500. More titles will probably be added in the future with possible applications in other classes or curricula.

5. Aircraft Stability — tool — AE 2036

Dr. P.R. Smith
Faculty of Engineering, CAT Unit
Queen Mary College, Mile End Road
London, E1, England

The AIRSTB ESP22 program is written in FORTRAN 4, but might be adaptable to the IBM PC if a FORTRAN compiler is acquired. This program was included merely to represent the Basic Aerodynamics course.

6. Dr. A.D. Gosman — tool — AE 2045

Imperial College
Exhibition Road
London, SW7 2BX, England

Dr. Gosman has produced the "TEACH" series of 12 programs, written in FORTRAN 4. Again, these would to be translated to the IBM and they are about five years old as is the AIRSTB program.

7. Plato — tool/tutor/teacher

Control Cata Corp. — AE 2015
A.L. (Nita) Marmouget — AE 2025
1190 Borregas Avenue — AE 2036
Sunnyvale, CA 94089 — AE 2045
(408)-744-5045

CDC is advertising the availability of selected courses for personal microcomputers. No engineering courseware was available as of this writing, but the Plato system contains 16 lessons (14 hours) applicable to AE 2015, 2 lessons (2.25 hours) for AE 2025, a 17 lesson curriculum (13 hours) for AE 2045, and even some problem solving games in Aerospace Engineering that could apply to AE 2036. However, this all depends on CDC's commitment to getting this software adapted to microcomputers and on the market. Scant hope is indicated here.

AUTHORING SYSTEMS THAT USE INTERACTIVE VIDEODISCS

1. Quest
   Allen Communications
   140 Lakeside Plaza II
   5225 Wiley Post Way
   Salt Lake City, UT 84116
   (801)-537-7800

   The Department of Aeronautics currently has a copy of Quest available, in the micro lab, on loan from the Departmant of Continuing Education. Price: $600

2. Micro Visual Authoring (MVA)
   Bell & Howell
   7100 McCormick Rd.
   Chicago, IL 60645
   (312)-673-3300 Price: $250

3. InsightPC
   Whitney Educational Services
   1777 Borel Place #416
   San Mateo, CA 94402
   (415)-341-5818 Price: $990

4. Interactive Authoring System (IAS)
   McGraw-Hill Book Co.
   Microcomputer Software Unit
   1221 Avenue of the Americas
   New York, NY 10020
   (212)-512-6584 Price: $1500

5. PILOTplus
   Online Computer Systems, Inc.
   20251 Century Blvd.
   Germantown, MD 20874
   (301)-428-3700 Price: $500 license for each developed program
   $50 run-time fee for each licensed computer

6. PC Pilot
   Washington Computer Services
   3028 Silvern Ln.
   Bellingham, WA 98226
   (206)-734-8248 Price: $550 multi-use
   $100 single computer

7. The Educator
Spectrum Training Corp.
18 Brown St.
Salem, MA 01970
(617)-741-1150 Price: $3500 annual license

8. Video-computer Courseware Implementation System (VCIS)
VCIS Research Group
University of Utah
Salt Lake City, UT

A copy of this system was obtained by the Department of Continuing Education for testing and evaluation. Although it shows great potential, it is still in development and not really suitable for the present situation in the Aeronautics Department.

Note: Items 2-7 from PC World, p. 101, October 1984

VIDEODISC SOURCES

1. Videodisc Publishing Inc.
381 Park Avenue South
New York, NY 10016
(212)-685-5522

2. Nebraska Videodisc Group
University of Nebraska-Lincoln
P.O. Box 83111
Lincoln, NE 68501
(402)-472-3611

3. Systems Impact
2084 N. 1200 E.
Logan, UT 84321
(801)-753-7973

4. (For D.O.D. agencies only)
U.S. Army Training Command
Fort Gordon, GA

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11. Parker W., "Interactive Video:Calling the Shots", PC World, pp.99-108, October 1984.

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4.	Dr. Robert E. Ball, Code 67Bp Naval Postgraduate School Monterey, California 93943	3
5.	Dr. Max F. Platzer, Code 67Pl Chairman, Aeronautics Department Naval Postgraduate School Monterey, California 93943	1