Comparative Cost Analysis of Implementing Computer Assisted Instruction on General Purpose Computers, Minicomputers, or Time-Shared Systems

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COMPARATIVE COST ANALYSIS OF IMPLEMENTING COMPUTER ASSISTED INSTRUCTION ON GENERAL PURPOSE COMPUTERS, MINICOMPUTERS, OR TIME-SHARED SYSTEMS.

William Henderson Truesheart Junior
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IMPLEMENTING COMPUTER ASSISTED INSTRUCTION
ON GENERAL PURPOSE COMPUTERS,
MINICOMPUTERS, OR TIME-SHARED SYSTEMS

by

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Approved by

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[Signatures]

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PREFACE

During the past two years the United States Army Southeastern Signal School has been operating a computer assisted instruction system employing commercially remoted time-shared computer resources. Acquired by means of competitive contract award, this project has enabled this Fort Gordon, Georgia, Army facility to develop classroom material and train the school's staff and faculty. The only major limitation of the program, for proper employment in support of military instruction, as conducted by the Southeastern Signal School, has been the number of student terminals available, three. This limitation was the direct result of fiscal constraints on computer assisted instruction development imposed by the school's higher headquarters.

While the program was most rewarding in developing the techniques and philosophies of computer assisted instruction, it pointed out the lack of understanding both data processors and management have for interactive time-shared
operations and computer assisted instruction concepts. Discussions with public and private school officials time and again homed in on one central theme - That school officials - appointed or elected - are reluctant to commit resources without guarantees that resulting systems would enhance education as publicized. This study is an attempt to provide a cost comparison of the major computer systems available to school systems for developing or supporting a new computer assisted instruction project during its formative period.

Hopefully, use of the data and criteria set forth in the study by educators interested in computer assisted instructional systems may enable them to acquire requisite computer resources at a considerably reduced resource investment than over previous projects.

It is most befitting that the author both thank and recognize those who have contributed in the undertaking and completion of this thesis. First and foremost is the author's wife, Betty Ann, whose moral support, patience, and editorial assistance enabled the project to continually progress. Special
thanks are rendered to Mrs. Carolyn Malin and Carol Contreras who somehow transcribed the author's pen scratches into a finished product. To the members of the select jury who weeded through vendor questionnaires often filled with ambiguous answers and who sorted this data into meaningful terms, my sincerest thanks.

THE AUTHOR
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CHAPTER I
INTRODUCTION

BACKGROUND AND REASONS FOR THE STUDY

The marriage of computer technology and educational techniques has resulted in numerous computer assisted instruction hardware innovations and educational philosophies; each vying for its share of the available resources while maneuvering to be considered as the computer assisted instruction project that should be selected as the standard automated classroom teaching machine or instructional media. Undoubtedly, in no other sphere of education is there greater variance in the approach or concepts of employing a technology than has evolved pertinent to the advantages, capabilities and potentialities of the computer in the classroom (Luskin, 1972).

Historically, digital computers have been classified as either general purpose, primarily business oriented, or special purpose machines, those having a highly scientific orientation. Today sophisticated software techniques allow for each type of computer system used for business or
scientific applications to have its potential effectiveness quantified and measured. Thus, investment for data processing facilities, specialized staff members (computer programmers - analyst - operators), continuing operational requirements, and long range versus short term fiscal returns have all become acceptable risks to the businessman or researcher. Who can now succinctly predict if a system will provide a satisfactory monetary return for that organization's resource investment.

According to Donald D. Rogers, the "concept of applying cost effectiveness techniques to instructional systems is still in its infancy" (1972, p. 3). Pragmatically, the high initial as well as unidentifiable long term investments, when coupled with non-quantifiable results may have been paramount in forcing several computer assisted instruction projects, that commenced their investigations during the early 1960s, to have been terminated because the degree of financial support required could not be justified (Luskin, 1972).

One could conjecture that each of the terminated
projects may not only have contributed significantly to the
development and practicality of computer assisted instruction,
but, more significantly, that these terminated programs may
have been extremely valuable tools in advancing the state-of-
the-art of computer technology by being a major catalytic
force that aided in the development of remote terminal time-
shared operations and concepts.

It now appears that the computer industry of the 1950 -
1960 era was unable to satisfy the educators' requirement to
interconnect student terminals from more than one location
or classroom simultaneously. Admittedly, these terminated
computer assisted instruction projects may not have been
responsible for the eventual marketing of general purpose
mini-computers and the establishment of companies devoted
to a market in remote batch and interactive time-shared
computer support. But, it can be said with some degree of
confidence that these projects did prove that there was a
marketable need to solve a definable educational requirement.

The American computer industry currently markets
some 200 different computer systems and terminals purport-
edly designed for direct on-line interaction and capable
of being employed as adjunctive training systems (Luskin, 1972). In addition, each major or large scale computer manufacturer has developed front end communications or pre-processing devices designed to convert general purpose computer processing systems to remotable time-shared computer systems; each being capable of responding to the demands of the educator and his unique but ubiquitous computer assisted instruction requirements.

Recently a third marketing base has proven itself worthy for serious consideration as a primary candidate to support classroom activities. This latest data processing entrant into the commercial world is the marketing of resource sharing. Where one organization owns and controls the computer hardware and executive software systems, but sells the excess computational power and time available on a computer system. Depending on the mode of operation, remote terminal entry can then either be used to acquire batch processing support or sustain interactive on-line (real-time) operations.

Operationally, the trend towards resource sharing is
just beginning to be recognized as a major means of satisfying computer requirements throughout the entire spectrum of computer operations and management. More and more small and medium scale users are leasing or purchasing computer terminals and obtaining on time and materials contractual agreements computer time to fulfill internal requirements instead of buying or leasing a separate independent computer system (Loehwing, 1973). Some see this trend continuing to where companies may bring the computer, as a utility closer to reality, where, according to Dr. George J. Feeney, General Manager of the Information Services Division, General Electric Company, "Sometime in the next five years a major company president is going to get up at a future American Management Association meeting and proudly announce that his company no longer has any computers." (Loehwing, 1973)

Assuming that a cost analysis could prove the economic feasibility of supporting the development of a new computer assisted instruction project utilizing leased time-shared computer resources, without degradation to lesson material or student learning; it may be plausible to conclude that a
large number of medium and small scale public school systems could become actively engaged in initiating a computer assisted instruction project.

Although the intent of this document is not to pass judgement on the relative educational values or merits of computer assisted instruction, it may be useful to provide the reader with a short discussion of the merits of this subject. Numerous claims and counter-claims have been made pertaining to the dollar savings computer assisted instruction can or cannot provide an academic institution through staff reductions. At present neither side of this discussion appears able to empirically substantiate their position. Time and greater involvement may provide sufficient data for this substantiation.

A savings can be envisioned in the time a student would require to complete a computer assisted instruction segment or lesson when compared to the time required for this student to complete a comparable block of instruction through conventional means.

The United States Army anticipates that as a minimum
a "thirty percent (30\%) reduction per student training hour will be realized for each course of instruction implemented on its Computerized Training System (Task Group Report, 1972).

A United States Navy project for the evaluation of a computer assisted instruction system realized a forty-five percent (45\%) time savings over group instruction (Ford, 1972). When extended to several thousand students over a given period, one can see a tremendous manpower impact in the reduction of the time required for a student to be in a classroom or learning status. In addition, there may be corresponding reductions in training support activities and the amount of facilities ultimately required.

It should be readily apparent to the casual reader that the quality of each lesson segment implemented on a computer system would remain constant for each student each time that lesson was presented. The same degree of quality control cannot be achieved when a presentation is dependent on the physical and mental condition of a human. Empirical data collected by the Army further indicates that the retention level for a given block of instruction presented by computer assisted instruction is markedly above that same instruction
received conventionally (Task Group Report, 1972). Of equal importance, computer assisted instruction will enable the instructor to structure his lesson material so it may be responsive to the individual needs of each student. Ultimately one can foresee the computer expanding on the instructional base to respond in real-time to the needs of a given student.

Computer assisted instruction offers the educator a significant advantage over conventional instruction and other educational techniques as it is the one method or medium capable of satisfying the individuality aspects of self-paced instruction in its orientation towards a target audience and its capacity to present material with minimum external distraction. Despite this academic advantage, a primary constraint in the development and employment of computer assisted instruction has been the dollar resources school boards and other non-professional data processing governing bodies have been willing to allocate for the development of computer assisted instruction programs (Luskin, 1972).

During the past five years significant progress has been made to drastically reduce the cost of developing and
implementing a computer assisted instruction system. It is probable that further cost reductions may still be realized. For example, a developmental program could commence operations by acquiring the required computer support through the award of a service contract with a computer time-shared company. Assuming that a significant cost advantage would be realized, such a concept would assist school systems, industry, or other training institutions in obtaining funding approvals to commence computer assisted instructional programs or allied research efforts.

THE PROBLEM OF THE STUDY

The problem of the study will be to determine if a small scale (ten student terminal) computer assisted instructional system, developed and implemented on a remoted time-shared computer system, can be accomplished with greater cost effectiveness than a comparable computer assisted instructional system implemented on either a general purpose computer system or a minicomputer system leased and installed within the instructional agencies facilities?
THE HYPOTHESIS

The hypothesis of the study is: That a small scale, ten student terminal, computer assisted instructional system that utilized remoted time-shared computer resources would cost significantly less to develop and implement than a comparable computer assisted instructional system implemented on either leased or purchased general purpose computer systems or minicomputer systems that would be installed in the using agency facilities.

BASIC ASSUMPTIONS

The basic assumptions required to support this research were as follows:

1. That the computer assisted instruction author language compiler and its manner of execution will be transparent to either of the alternative methods that could be acquired as a supporting computer system.

2. That the time required to structure the educational strategy and complete the instructor author programming of any given lesson hour would be the same for each supporting computer system.
3. That the operating speed of the student terminals should equal 30 characters per second, equivalent to a 300 baud data transfer rate and will be fully capable of operating over commercial dial telephone lines.

4. That the student terminals could be or may not all be located in the same classroom, building or general campus area.

5. That any one lesson hour may require all ten student terminals on-line at any point in time, or for a given lesson hour that each student terminal must be capable of interacting with a different segment or label of the instructional text under a self-paced mode.

6. That a supporting computer or time-shared system would have to be operational during a normal academic day (0730-1700 hours) Monday through Friday and available for remedial or specialized instruction from 1700 to 2330 hours Monday through Friday and 0800-1300 hours Saturdays.

7. That the developing school system would not have access to a computer capable of being upgraded to a time-shared configuration capable of supporting ten interactive terminals.
8. That the minimum number of terminals that would be required to provide sufficient resources for starting a system would be ten. This is based on the researcher's experience in developing a comparable system at the United States Army Southeastern Signal School, Fort Gordon, Georgia.

LIMITATIONS AND CONTROLS

The limitations and controls established for the conduct of this research effort were designed to insure maximum comparison of candidate computer assisted instruction systems and that each system selected was responsive to the requirements of the representative computer assisted instructional system selected for the study. To insure that the volume of data collected and analyzed could be effectively managed during the conduct of the study, the computer companies selected for this comparative cost analysis were limited to manufacturers and suppliers in the following categories:

a. The three largest manufacturers and suppliers of computer systems in the United States. The selection criteria was based on computer sales for 1972 as reported by Forbes.
The companies selected for the conduct of this study were: The International Business Machines Corporation; Sperry Rand (UNIVAC); and Honeywell.

b. The Digital Equipment Corporation, one of the largest suppliers of minicomputers for educational systems, in the United States, has a specialized staff of data specialists and educators for designing and resolving educational requirements was requested to participate.

c. The third category was time-sharing companies that could not be classified as computer equipment manufacturers or suppliers. Selection of the three top companies in this category was based on financial results published in Barron's National Business and Financial Weekly (1973). The three companies used in this study were: the General Electric Company, Information Services Division, the University Computer Company, and the TYMSHARE Company.

A panel of experts were requested to review the hardware and/or time-shared concepts proposed by each participating vendor to satisfy the computer assisted instruction system developed for this research. Each member of the
panel was asked to rate the hardware or time-shared system proposed to determine the capability and cost of that system to satisfy a theoretical computer assisted instruction system developed by this study. The composition of experts used for this panel were members of the United States Army Southeastern Signal School, Data Systems Branch, knowledgeable in both computer operations and computer assisted instruction techniques.

DEFINITION OF TERMS

The terms and/or special phrases used in this study are presented herewith in alphabetic order:

1. **Author Language** - A specifically refined pseudo coded language which uses defined symbols and letters to express instructional text and educational strategies for meaningful communications between the educator, as a novice programmer, and a computer compiler.

2. **Batch Processing** - A sequential-processing procedure that uses an accumulation or group of units; this is in contrast to on-line processing, during which each unit of data or information is processed immediately at the time of presentation to the top of the processing sequence.
3. **Baud** - A unit of signalling speed equal to the number of code elements per second and for practical purposes used interchangeably with "bits per second," as the unit of data flow.

4. **Bits Per Second** - The rate at which binary digits, or pulses representing them, passes a given point in a communications line or channel.

5. **Central Processor** - The central processor of the computer system. It contains the main storage, arithmetic unit, and special register groups.

6. **Computer Assisted Instruction (CAI)** - An educational concept which places the student in a conversational mode with a computer which has a preprogrammed study plan. The programmed course selects the next topic or phase of study according to previous responses from the student, allowing each student to progress at a pace directly related to his learning capability.

7. **Core** - A configuration of magnetic material that is placed in a spatial relationship to current-carrying conductors, and whose magnetic properties are essential to its use. It is
used to concentrate an induced magnetic field as in a trans-
former, induction coil, or armature, to retain a magnetic
polarization for the purpose of storing data, or for its non-
linear properties as in a logic element. It may be made of
such material as iron, iron oxide, or ferrite, and in such
shapes as wires, tapes, toroids, or thin film.

8. Digital Computer - A computer that processes informa-
tion represented by combinations of discrete or discontinuous
data as compared with an analog computer for continuous data.

9. Executive Software - An integrated collection of service
routines for supervising the sequencing of programs by a
computer.

10. General Purpose Computer - A computer designed to
operate on a program of instructions for the purpose of
solving many types of data processing problems rather than
being designed to fulfill a single function or type of function.

11. Input/Output Device - Any subscriber (user) equipment
which introduces data into or extracts data from a data-com-
munications system.

12. Label - A string of alphanemic information placed at any
location for informational and instructional purposes, as a means of identification.

13. Magnetic Tapes - A tape or ribbon or any material impregnated or coated with magnetic material on which information may be placed in the form of magnetically polarized spots.

14. Minicomputer - A third or fourth generation computer system generally consisting of 32,000 bits of internal core or less, with the central processing system having a physical characteristic of being manufactured in a single unit generally of office desk size. These systems have a capability of being extended by attaching external peripherals for storage, data transfer or input/output activities.

15. Remoted Time-Shared Operations - On-line inquiry stations permit users to interrogate the computer files and receive immediate answers to their inquiries. In industry, the stations can be located at dozens of remote locations such as office, factory, warehouse, and remote branch locations. Such a system permits all levels of industrial management to obtain immediate answers to questions about inventories, work-in-process, sales and other facts.
16. Self-Paced Mode - A special capability of a device or machine such that it can improve its capability in decision-making a program with instruction based on information received, new instruction received, results in calculation or environmental change.

17. Scientific Computer - Scientific problems are characterized by a minimum of input, a maximum of compute, and a maximum of iteration. Management science applications have these attributes, plus the massive data load of the normal commercial applications. The requirements for a computer to handle these special applications are very large memory, extremely high speed arithmetic, and a very large variety of float-point arithmetic commands.

18. Tape Drive - The mechanism that moves magnetic or paper tape past sensing and recording heads and is usually associated with data processing equipment. (Synonymous to tape transport and feed tape, and related to tape unit, magnetic-tape unit, and paper-tape unit.)

19. Transparent - The ability of a software operation developed for a computer or a system to be transferred to a
second computer or system with minimum alteration to the original software.

OVERVIEW OF THE INVESTIGATION

An overview of the Investigative Study is as follows:

The parameters for a small scale theoretical computer assisted instruction system were submitted to selected vendors with a request that each recipient define the technical, cost, and environmental parameters of a computer system or time-shared service that his company would propose to satisfy the study training system; similarly, as if they had received either an actual query for information or a request for a proposal from a customer.

The vendor-developed data was then submitted to a select jury for evaluation and rating of the technical responsiveness of each of the proposed configurations. Within the limitations of the cost data provided, the panel then conducted a cost analysis of each computer system or service and ranked them accordingly. The researcher then computed a weighted mean for each jurist's technical and cost analysis findings to determine the responsiveness of each proposal to test the project hypothesis.
CHAPTER II

REVIEW OF RELATED LITERATURE

INTRODUCTION

A selected data processing technical and educational review of computer assisted instruction background literature germane to the concept of extending the computer to students is presented in this chapter. The researcher primarily used the facilities of the U. S. Army, Fort Gordon Woodworth and Conrad Libraries, and the Augusta College Library during this phase of the study. As anticipated, this review disclosed that there is a significant amount of research material and general publications that are related to Computer Assisted Instruction. However, the relevance of the material reviewed was primarily oriented toward the development of computer assisted instruction educational strategies, classroom material, subject presentations and the acceptance of the use of this technology by educators and students as opposed to hardware systems research.

This phase of the project then concludes that considerable research had been performed citing the numerous difficulties
brought about by high resource investments required to implement computer assisted instruction. But, as brought forth by Luskin (1972), although the monies made available for this teaching medium have been spent, to date it has yet to be proven what return the investor has received for these expenditures.

STUDIES OF SIMILAR NATURE AND DESIGN

A paper written by Duncan N. Hansen (1970) provides a concept by which the educational functions of an organization can be conceptually integrated within an organization's computer system during the nineteen seventies. The single computer concept presented envisions the sharing of the system to support administrative information retrieval, scientific computing, and computer supported instruction. The author, the director of the Computer Assisted Instruction Center, Florida State University, provides an economic analysis on computer hardware alternatives for support of instruction.

Duncan N. Hansen, Paul F. Merrill, H. Dewey Kribs, and David B. Thomas (1972) wrote a report which describes
the detailed processes utilized by Florida State University in the preparation of functional specifications for the United States Air Force Advanced Instructional System. The work was performed under the terms and conditions of Air Force contract number F33615-71-C-1686 which principally conveys the planning methodology that was employed in developing functional characteristics for the Advanced Instructional System concept to include management functions, course planning, course evaluation, training research, and systems evaluation.

A draft report made to the Presidents of Universities of Ontario by a Joint Ad Hoc Subcommittee on Regional Computer Centers (1969) set forth a tentative recommendation that the implementation and development of an university regional computing center be held in abeyance pending further study, as a large scale system may not be financially supportable in view of the marketing advanced by time-shared companies.

Warren J. Kock (1972) completed a study, sponsored by the National Association of Secondary Principals, which
presents the results of research obtained by surveying 454 schools throughout the United States. Presented are the results of an unique effort, which sets forth an annotated digest of how computers can be used in instruction. In his opening remarks the author outlines six means by which a school can obtain computer support. Of importance to this research effort was Mr. Koch's presentation on time-sharing, which he notes is fast becoming one of the most popular means for a school system to acquire computer support. Mr. Koch further felt that time-sharing has brought the availability of the computer for starting an educational project within the economic means of a school system.

An extensive review by David A. Loehwing (1973) outlines the history of remote batch processing and the major business growth this concept of extending the power of the computer has sustained since 1970. Mr. Loehwing presents a comparative analysis of the decision made in 1970 by the Chairman of the General Electric Board, Fred Borch, to sell the company's computer manufacturing business to Honeywell, while retaining its Information Services Division for marketing computer time-shared activities.
In 1972 the United States Navy conducted an indepth staff study at its Training Equipment Center, Orlando, Florida, on cost and training effectiveness of Proposed Training Systems entitled Training Analysis and Evaluation Group Report 1 (1972). The objective of the staff report was oriented on two aspects of training systems design not previously emphasized in training devices design. The integration of cost effectiveness and training effectiveness measurement, and prediction of the cost and effectiveness of proposed training systems. Although not specifically designed for computer systems, the philosophy developed sets forth definable objectives for determining device cost and predicted effectiveness.

OTHER RELATED LITERATURE

John D. Ford, Jr., Dewey A. Slough, Richard E. Hurllock (1972) completed an indepth technical report on the development and evaluation of computer assisted instruction techniques employing an International Business Machines (IBM) Corporation 1500 Instructional System for the Basic Electricity/Electronics (BE/E) Curriculum at the United States Navy Personnel and Training Research Laboratory, San Diego,
California. Two major conclusions of this effort being that computer assisted instruction required thirty-nine to fifty-four percent less training time than conventional training time and that students preferred to have seventy to eighty percent of their training via computer assisted instruction. The study further indicated that additional savings could be realized by the employment of larger and more powerful computer systems.

A comprehensive review of the development of computer assisted instruction throughout the United States was conducted by Dr. Bernard J. Luskin (1972) whereby he establishes the background for a descriptive research effort that examined obstacles to the development of computer assisted instruction. The researcher, based on the findings of a select jury, orders 23 obstacles by rank under the headings of critical, considerable, minor, and not an obstacle based on their cruciality. Although the criticality of local funds established an obstacle, Dr. Luskin did not search out hardware and related costs as applied to computer assisted instruction.

The United States Continental Army Command school system conducted an indepth study entitled Task Group Report
on Computer Assisted Instruction (1972). This study pertained to the large scale application of computer assisted instruction and technical training conducted throughout the United States Army educational system. The study presents a detailed analysis of some fifteen military computer assisted instructional systems and set forth a significant recommendation that the United States Army develop a multiprocessor mini-computer system to be responsive to technical training requirements. The follow-on system, composed of one hundred twenty-eight student terminals is being developed and installed at the United States Army Southeastern Signal School.

Under the auspices of the United States National Bureau of Standards, Siegried Treu's (1972) research project had the intent of designing, implementing and testing a terminal network that enabled "Transparent Stimulation" during interaction with a computer system. The overall concept being to provide a base upon which unidentified or non-experimentally verified human factors research could be researched. Mr. Treu's study provided an overview of the hardware and software features employed and their interactions for the studied network.
CHAPTER III
THE INVESTIGATION

DESIGN OF THE EXPERIMENT

The research was proposed to be conducted as a descriptive investigation in that the problem was viewed as practical in nature, requiring judgement as to the interpretation and analysis of the data collected. The research hypothesis is presented at this time to assist the reader as he proceeds with the investigation: That a small scale, ten student terminal computer assisted instructional system that utilized remoted time-shared computer resources, would cost significantly less to develop and implement than a comparable computer assisted instructional system implemented on either leased or purchased general purpose computer systems or mini-computer systems that would be installed in the using agency's facilities.

To test the project hypothesis, a theoretical computer assisted instructional requirement, Appendix B, developed as the base element for a technical and cost comparative analysis, was forwarded to selected computer manufacturers.
or time-shared system support companies. The theoretical requirement forwarded as an inclosure to a letter of transmittal, set forth at Appendix A, solicited assistance from nine vendors. Each participating company being requested to complete a questionnaire (Appendix C) detailing either the computer system or remote time-shared support they would propose to satisfy the theoretical study requirement. A questionnaire was employed for this research effort instead of asking each vendor to develop a cost and technical proposal, in that proposals are both time consuming to develop and expensive to publish.

THE THEORETICAL REQUIREMENT

To provide a base to test the study hypothesis (in determining if a remoted time system would cost significantly less than leased or owned computer systems), a theoretical computer assisted instruction requirement was developed. The theoretical requirement formed the primary element of the technical and cost requirement forwarded to selected computer manufacturers or appropriate computer support companies to assist in their completion of a questionnaire. A copy of the
Theoretical computer assisted instruction system is at Appendix B.

The requirement was formatted as a Statement of Work, similar in scope to the means a school system or other government or private institutions would forward a request for support to manufacturers. The letter proposed at Appendix A forwarded the Statement of Work and solicited support from the selected companies.

The overall requirement makeup was based on the three terminal computer assisted instruction system initiated in October 1971 at the United States Army Southeastern Signal School, Fort Gordon, Georgia. Although this undocumented effort proved the feasibility of using time-shared support to initiate a computer assisted instruction system, the number of terminals acquired were insufficient to provide the instructional force the requisite tools to implement the concept on the scale either required or desired.

VENDOR QUESTIONNAIRE

Each participating vendor was requested to complete a questionnaire and submit his proposed equipment or support.
concept. The format and content of the questionnaire is set forth at Appendix C.

The questionnaire was forwarded as an inclosure to the proposed letter of transmittal to be used by the companies and develop technical and cost data. The questionnaire was being used for two reasons: First, technical and cost proposals are expensive projects for most companies in developing a response to a request for a proposal or contract. The researcher also believes that the selected vendors would not participate in the study had they been requested to expend funds for a proposal. Second, a questionnaire provided a set format for recording and capturing data during the analysis phase of the study.

SELECT JURY

The makeup of the panel used to review the technical and cost proposals was established as follows:

Permanent party personnel with the requisite academic and professional data processing expertise, employed at the United States Army Southeastern Signal School were invited to participate as members of the select jury to conduct the study and analysis.
It must be recognized that the composition of the select jury could not be accomplished by random selection, as the participants must have had more than a generalized working knowledge of computer assisted instruction principles and concepts to insure that each vendor was responsive to the technical elements of the study.

The population of the panel was limited to five members. Each member worked independently in the development of his determinations and findings. No member of the panel was appointed to act as recorder or president of the panel as is generally the custom in most contract proposal evaluation teams. This alteration was considered necessary to provide independent data for further manipulation by the researcher.

THE TECHNICAL PROPOSAL EVALUATION

The technical proposal evaluation as proposed was accomplished in three phases:

Phase one - This phase of the evaluation was accomplished by the select jury. Each jurist conducted a technical review of the contractor's proposed systems configurations to determine the adequacy of each proposal in satisfying the
requirement set forth in the Statement of Work. Each panelist computed an observed value, based on his individual technical competence, of the ability of the unranked proposals to satisfy the technical requirements of the Statement of Work. This rating was accomplished by awarding a point value, on a scale of 1 - 10, for the lettered paragraphs, part II of the Vendor's Questionnaire form (Appendix C). The parameters and calculations for the award of point values is set forth at Appendix E.

In Phase two, each member of the jury then computed cost factors based on the data submitted by the participating companies to determine the developmental and operating cost for the 36 month period proposed in the Statement of Work. The mathematical representation of the cost analysis is:

\[ CR_X = C_{ACQI} + C_{PETN} + C_{OPMT} \]

where \( CR_X \) = The cost relationship of a proposed system.

\( C_{ACQI} \) = Cost of systems acquisition or lease.

\( C_{PETN} \) = Cost of personnel salaries and training factors for the evaluation period.

\( C_{OPMT} \) = Cost for operations and maintenance for the evaluation period.
A detailed explanation of the cost analysis formula is at Appendix D. Each member of the select jury was provided a copy of Appendix D for his review and accomplishment of this phase of the evaluation.

Phase three - This phase of the project evaluation was performed by the researcher. As proposed, a weighted mean for each proposed system was computed from the observed values resulting from the panel technical evaluations in phase one, above. The weighted mean was calculated by assigning a weight to the lettered subparagraphs, part II of the Vendor Questionnaire, proportional to its relative importance. A detailed description of assigned weights and accompanying rationale is at Appendix F. The weighted mean was then found by dividing the sum of the products of the values and their weights by the sum of the weights; that is: \[ Y = \frac{\sum WiYi}{\sum Wi} \]

The researcher then compared the results of the three phases of this evaluation to test the project hypothesis.

SUMMARY

A theoretical Statement of Work for a computer assisted instructional system was developed by the researcher as the
primary vehicle to analyze vendor-proposed supporting concepts. To insure that the vendor-furnished data would be technically compatible with the cost relationship equation devised for the experiment, an unique study questionnaire was provided each company. The use of a questionnaire was considered to be more reliable for the research effort than being dependent on the development or writing of technical proposals. A select jury conducted individual reviews of the vendor data as the basic ingredient for the computation of a weighted mean for each questionnaire and an indepth cost analysis to test the study hypothesis.
CHAPTER IV
ANALYSIS OF THE DATA

INTRODUCTION

A technical ordering of the returned questionnaires was completed by each jurist prior to the jury's computing of cost factors for use by the researcher to test the study hypothesis. The study hypothesis is re-presented at this time to assist the reader in reviewing the investigation: That a small scale, ten student terminal computer assisted instructional system that utilized time-shared computer resources would cost significantly less to develop and implement than a comparable computer assisted instructional system implemented on either leased or purchased general purpose computer systems or mini-computer systems that would be installed in the using agency's facilities.

PRE-JURY PREPARATION OF DATA

Six of the seven companies requested to participate in the survey returned completed questionnaires. The researcher assigned each vendor questionnaire an alphabetic designation
in the order in which they were received via United States mail. The lettered designations, as indicated below, were the only identification each jurist was provided with regards to the participating companies. To preclude prejudiced judgement of the participating vendors, the researcher has limited all further reference to the participants to the assigned letter designations:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Vendor Proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>General purpose computer system leased.</td>
</tr>
<tr>
<td>B</td>
<td>Time-Shared company.</td>
</tr>
<tr>
<td>C</td>
<td>Time-Shared company.</td>
</tr>
<tr>
<td>D</td>
<td>Mini-computer system leased.</td>
</tr>
<tr>
<td>E</td>
<td>Mini-computer system purchased.</td>
</tr>
<tr>
<td>F</td>
<td>Time-Shared system.</td>
</tr>
</tbody>
</table>

One vendor, when initially contacted by the researcher and as listed in the study limitations and controls, page 12, proposed responding with a large scale computer system. Upon submittal of his questionnaire, his proposal was for a mini-computer system. Telephonically, the respondent informed the
researcher that his company did not believe they could be competitive without altering the system category and this change was acceptable to the researcher.

Select Jury Technical Evaluation Work Sheets, Appendix G, and Cost Analysis Work Sheets, Appendix H, were prepared by the researcher to assist the jury in their two phases of the evaluation.

SELECT JURY TECHNICAL EVALUATION - PHASE I

Allowing for each jurist's technical and managerial competence, the six returned questionnaires were awarded an observed value based on the criteria set forth in Appendix E. The observed values were recorded on the Select Jury Technical Evaluation Work Sheet, Appendix G, and provided the researcher to compute the weighted mean for each proposed system.

SELECT JURY COST ANALYSIS - PHASE II

The Select Jury was then directed to compute cost factors employing the criteria set forth in Appendix D. The data was recorded on the Select Jury Cost Analysis Work Sheet, Appendix H, and provided the researcher to test the study hypothesis.
The variances in costs computed for each proposed system by the jury was predicated on their subjective considerations of the staffing, administrative support, and training that would be required along with the objective cost data for equipment or services as supplied by each vendor.

Within the criteria established, the individual estimated cost findings for each vendor are provided in Appendix I.

WEIGHTED MEAN COMPUTATIONS - PHASE III

The researcher computed a weighted mean for each proposed system based on the observed values resulting from the panel's technical evaluations. The weighted mean was calculated based on the assigned weights (Appendix E) for each lettered subparagraph of Part II of the questionnaire (Appendix C). Chart one, page 39, was developed to graphically illustrate and compare the weighted technical evaluations on the same grid. The weighted mean was found by dividing the sum of the products of the values and their weights by the sum of the weights; that is \( \bar{Y} = \sum \frac{W_i Y_i}{Y_i} \).

Analytically the weighted mean, as illustrated on page 38 reveals that five of the six vendors responding to the study
CHART 1

VENDOR TECHNICAL EVALUATIONS' WEIGHTED SCORES

Vendor Designations

Weighted Scores

A  B  C  D  E  F

45.4  46.1  47.4  46.0  43.2

43.86
statement of work (Appendix B) could be considered technically responsive. Subjectively, the cost data provided by five of the vendors could then be considered viable for technical and cost negotiations if a contract were to be entered into and to satisfy the study requirements. Conversely, the low technical evaluation and rating assigned vendor B by the select jury indicated to the researcher that the cost data provided by that company was suspect and should be disregarded when testing the research hypothesis.

**TEST FOR HYPOTHESIS**

To enable the researcher to reach a conclusion with regards to the study hypothesis, an in-depth review was made of the cost data provided by each vendor and as analyzed by the select jury. In that the problem of the study was considered practical in nature, requiring judgement as to data interpretation, the researcher also performed a cost analysis.

Chart two, on page 41, graphically displays the averaged cost per type system (vendor) as computed by both the select jury and the researcher. Although vendor B was judged not technically responsive, the cost data provided and as analyzed
CHART 2

AVERAGED AMORTIZED COSTS

Dollars (in millions)

Vendor Designations

--- Select Jury's Findings

--- Researcher's Findings

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by the jury and researcher are portrayed for the reader's information.

A comparison of the data from the two analyses indicated that the primary differences between the jury's findings and the researcher's determinations were concentrated in those areas requiring the greatest subjective consideration. Specifically, personnel, facilities, and environmental requirements. For example, the researcher considered the personnel staffing requirements for the two time-shared systems as being the same; in that the data processing and instructional functions would be identical - four people ($170,000). The select jury determined that system C would require four people ($161,800) and system F a five man staff ($175,300). The researcher also concluded that the staffing requirements for systems A, D and E would be similar enough to be considered equal, or ten people. In contrast, individual members of the jury in their considerations for these systems had personnel staffing from a low of four to a high of fourteen people.

Using the average cost data computed by the researcher, per vendor or system, an in-depth examination of Chart two
then discloses that the general purpose system (A) averaged $610,000 more than the time-shared systems proposed to support the study computer assisted instructional system. Combined, the mini-computer systems (D and E) computed to cost $60,000 less than the averaged cost for the two time-shared systems. Specifically, mini-computer system D was $10,000 more and system E $130,000 less than the average cost for the two technically acceptable time-shared systems (C and F).

Factored on a monthly basis for the thirty-six month period established for the proposed systems validation, the general purpose computer system would cost an estimated $38,000 per month. The computed averaged cost for both mini-computer systems (D and E) for the same period equaled $17,500 per month and the averaged cost for time-shared support (vendors C and F less vendor B) to satisfy the study statement of work was estimated at $19,000 per month for the thirty-six month period.

SUMMARY

Based on the data collected, collated, and reviewed by the select jury and the researcher, the study hypothesis was
examined in detail. Although the data supplied by one of the vendors was technically suspect and disregarded by the researcher, the data provided by the five technically acceptable proposals was considered to be sufficient to reach conclusions concerning the study hypothesis.
CHAPTER V
SUMMARY AND RECOMMENDATIONS

INTRODUCTION

The test of the project hypothesis was focused on the technical and cost data collected, evaluated, and analyzed by the select jury and the researcher. The research hypothesis is: That a small scale, ten student terminal computer assisted instructional system that utilized remoted time-shared computer resources, would cost significantly less to develop and implement than a comparable computer assisted instructional system implemented on either leased or purchased general purpose computer systems or mini-computer systems that would be installed in the using agency's facilities.

FINDINGS AND CONCLUSIONS

Within the technical constraints of the study Statement of Work (Appendix B), the design of the experiment set forth in Chapter III and the data obtained and analyzed by the select jury and the researcher (Chapter IV), the study hypothesis could not be supported. Although the proposed general purpose
system (Vendor A) would cost significantly more than the averaged cost for time-shared systems, Vendors C and F, the combined mean cost for the mini-computer systems would be $60,000 less than the averaged cost for time-shared support. The $60,000 difference actually represents approximately an eight point seven percent reduction in cost for the mini-computer systems over the time-shared concept and is not the anticipated cost savings projected by the study hypothesis.

OBSERVATIONS

Based on the study findings and the requirements of a computer assisted instructional system, training institutions apparently have two concepts, financially competitive, which they could evaluate in developing or designing an academic data processing system and facility. One area that an institution would have to seriously consider when reviewing contract solicitation proposals would be the value in-house batch processing support a mini-computer system could provide over a time-shared system. It should be noted that this enhancement would increase the equipment cost of a mini-computer system
approximately $60,000 for the three year period. The additional programmers and operators that would be required would raise the staffing to 16 or 18 people, depending on the nature of the effort to be automated.

Within the constraints imposed by the study hypothesis, limitations and controls, basic assumptions, and the test of the hypothesis, one area or observation has been excluded; initial investment. Although long-term, thirty-six month, amortization of time-shared and mini-computer systems are for all practical purposes equal, the initial investments for facilities, personnel, and equipment are not. All systems would require, from the outset, the training of the full staff, ten people for systems D and E (mini-computer) and four people for the time-shared systems. Initial facility preparation would cost an estimated $38,000 for the mini-computer concept as compared to $1,000 for the time-shared services.

A second major area that management would have to consider would be the initial equipment investments required to support a project. This could be a significant factor if an academic institution was attempting to determine the value of
computer assisted instruction and compare the benefits versus costs of a pilot project. For example, the leased mini-computer system would incur a cost of $7,000 per month concurrent with equipment installation and acceptance. The purchased system commence operations with a $121,000 debt regardless of how little it would initially be utilized for staff training, instructional material development, or classroom (student) activities.

In comparison, initial and recurring costs for time-share support would be directly related to the total use or demand one would make on a system. This would offer a manager (school headmaster or project leader) a distinct advantage in that he could directly control and limit costs as they are incurred or potentially reduce his costs in proportion to financial limitations that might be imposed by governing bodies. Further, during the initial stages when project goals, training strategies, educational philosophies, or even academic acceptance is being most solicitously sought, project investments and initial cost could be kept minimal.
SUMMARY

A ten-student terminal computer assisted instructional system, developed on either commercially acquired time-shared or leased/purchased mini-computer systems, when amortized over a three year project span, are economically and technically comparable. As determined in the test of the study hypothesis, both systems offer distinct advantages and disadvantages that a project leader would have to subjectively consider in his final analysis and determination as to which system to employ for his project. The time-shared approach would require the least amount of resources to initiate a new effort and be potentially easier to inaugurate. However, mini-computer systems potentially afford long-term dollar savings and additional processing support over the time-shared concept.

RECOMMENDATIONS FOR FURTHER STUDY

During the conduct of the study, several affiliated areas have come to the attention of the researcher that warrant further research. These areas were not included in this study in that they would have significantly enlarge the research effort and report.
Based on the experiences of the researcher, the immediate study was a limited effort to provide secondary school officials some concept of the cost factors and technical requirements necessary to establish a computer assisted instruction program. Additional research should be attempted to catalog, define, and evaluate the numerous computer assisted instructional author languages that would be available to support a program. Specifically helpful would be a determination as to the impact each author language would have on this study's technical analysis and weighted mean findings.

A second area for consideration would be the optimum number of student terminals that a new project should employ in the formative stages. The number of terminals employed for this effort again was based on this researcher's experiences at the United States Army Southeastern Signal School. A further determination as to the impact the results such a research project would have on this study's findings is considered appropriate by the researcher.

The future impact of computer assisted instruction can only be a matter of individual conjecture given the current
state-of-the-art. Despite the do not fold-spindle-or-mutilate syndrome, computer assisted instruction is a reality and in all probability will be incorporated into the classroom beyond today's experimentation. Yet, unlike the engineering field, there is no evidence that teachers' colleges have incorporated the subject of data processing, or even more specifically computer assisted instruction, into their degree programs. It is urgently recommended that a detailed study be inaugurated to determine how and when the philosophy, techniques, and concepts of computer assisted instruction should be incorporated into undergraduate and graduate studies of those institutions that develop and accredit the teachers of tomorrow.
APPENDIX A

Proposed Cover Letter to Participating Vendors

TO: 

Dear Sir:

The purpose of this communication is to solicit your assistance to complete a research project pertaining to an analysis of the costs involved in initiating Computer Assisted Instruction projects at the elementary and secondary educational levels.

The research effort is being conducted in conjunction with my graduate studies, in Industrial Technology at Georgia Southern College, Statesboro, Georgia. For your information my qualifications for conducting this research project are:

a. Undergraduate major - Secondary Education.

b. Fourteen (14) years of my 17 years of commissioned military service is in data processing.

c. Present assignment is the Chief of an Educational Data Systems Center and Command project officer for
implementation and evaluation of the Army's Computerized Training System at Fort Gordon, Georgia.

Your assistance is requested to complete the attached questionnaire (Inclosure 1) on an equipment or service configuration your company would submit to a perspective customer should you receive a Computer Assisted Instruction project similar to the one attached as Inclosure 2. The data provided will be used in a cost analysis formula for comparison purposes, which has as its primary purpose to determine the type and cost of support activities required to initiate a Computer Assisted Instruction project utilizing your company's equipment.

Please be advised that there is no correlation between this activity and any effort within the United States Army or Georgia Southern College for the acquisition or development of a project.

I wish to thank you in advance for your cooperation and kind assistance in completing this phase of the research.

Sincerely,

MAJ WILLIAM H. TRUEHEART, JR.
126 Gardner's Mill Road
Augusta, Georgia 30907
APPENDIX B

STATEMENT OF WORK FOR A THEORETICAL COMPUTER ASSISTED INSTRUCTION SYSTEM

1.0 Objective: The objective of this specification is to outline the requirements for a theoretical computer assisted instruction system and to collect data relative to the cost required for the initiation of a project.

2.0 Scope: To encompass the necessary contractor interactions which could lead to the development of a computer assisted instruction system at the secondary or elementary school level.

3.0 Background: A preliminary analysis of the educational benefits available to the professional educator, through the employment of computer assisted instructional techniques, indicates that a ten student terminal system would provide an appropriate amount of data for evaluation by school officials to determine if a larger system would prove justifiable and should be acquired. Within that context, project initiation is to commence using software to train the institution's staff and faculty in data processing concepts and

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instructional strategies necessary to develop computer assisted instruction curriculum. Based on the results achieved after an initial operating period of 36 months, the school's administration will prepare an evaluation for the governing board, recommending project termination or expansion as can be empirically supported.

4.0 Technical Requirements:

4.1 The contractor shall prepare and identify an equipment configuration or computer service capable of satisfying the following parameters:

4.1.1 A ten terminal time-shared processing system or support capable of simultaneous interconnecting ten 300 baud student positions (terminals). Each terminal must be capable of working independent of other terminals and be fully capable of allowing a student to interact with a different lesson segment of the same computer program to which the nine other student positions could be interconnected. The operating configuration must also provide for the student positions to be
executing 10 separate lessons (computer programs) simultaneously.

4.1.2 The maximum wait time for the computer system to respond to a student query under either condition with all student positions on-line is 2-3 seconds.

4.1.3 On-line storage, capable of being accessed from any student terminal position, is estimated at 12 million characters of on-line storage. Off-line storage will be required, estimated at 25 tapes.

4.1.4 System proposed must have both a FORTRAN IV and BASIC compiler, capable of being executed from any on-line student terminal.

4.1.5 Student terminals should be able to be connected to the system via the local dial telephone system.

4.1.6 If a batch processing capability is to be provided, the input/output functions should provide for card, paper tape, and page printing (600 lines per minute).
4.1.7 System configuration proposed should be capable of satisfying educational requirements 5 days a week, 0700-2100 hours daily. This equates to the following on-line projections of 20 hours per terminal per week for a total annual requirement of 12,000 terminal connect hours.

4.2 The contract shall propose a cathode ray tube device for use as a student terminal. The device will be capable of 30 characters per second display, foreground and background display, keyboard entry for student responses, and be able to be connected to the central processor via an accoustical coupler or equivalent by dial telephone.

4.3 The contractor shall provide systems and operations training to 5 members of the school's system. Instruction shall be oriented toward entry level training and is estimated to be for 2 systems personnel for 3 weeks and 3 operators for 2 weeks.

5.0 System Support Requirement: The contractor is requested to provide detailed information, at the time the contract is
awarded which will be used by the school's engineering element to prepare the operating facility and environmental control features.

6.0 Delivery Schedule: The contractor shall indicate in his proposal how long after contract award before the system will be installed and made available to school staff for training and operations.

7.0 Systems Maintenance: The contractor is requested to forecast monthly maintenance costs and the total number of hours the system will not be available annually for scheduled maintenance.
APPENDIX C

VENDOR QUESTIONNAIRE
ON THE
STUDY STATEMENT OF WORK
FOR A
COMPUTER ASSISTED INSTRUCTION SYSTEM

I. Background Supporting Data:

A. Date questionnaire was completed

B. Please indicate by checking the appropriate block if you felt that the draft Statement of Work would have been adequate for use by a school to forward its requirement to your company to commence contract proposal, negotiations and configuration design: ______ adequate, ______ inadequate.

The proposal was inadequate for the following reasons:

C. Please indicate an estimated number of computer assisted instruction systems your company has installed or supports as of 1 January 1974.

D. Based on the classification indicated below, please indicate in what single category your proposed configuration
could be classified:

1. _______ Large Scale  
   2. _______ Medium/Small scale
3. _______ Minicomputer  
   4. _______ Time-shared Service

E. Would you propose that the equipment acquired for this Statement of Work be purchased or leased? Please indicate by checking the appropriate block:

1. Leased _______; by the ____ month, ____ hour, ____ year.
2. Purchased _______.
3. Other ________, please clarify______________________________

II. What equipment configuration or system support do you propose to satisfy the requirements of the Statement of Work:

A. In the area provided, please indicate the equipment configuration your company would propose if a formal response to the Statement of Work had been solicited and the appropriate leased or purchased price based on your response to question I. E. above.

1. ________________________ $ ________________________
2. ________________________ $ ________________________
B. What student terminal do you propose to satisfy this requirement?

1. The Cathode Ray Tube recommended for this requirement is: _________________________________.

2. The estimate cost to lease or purchase this item of equipment based on your response to question I.E. is $______________.

3. The maintenance charges will be approximately $______________ per maintenance period, which is ________ (Month, Week, Year, etc.).
C. Based on your knowledge of the proposed configuration please indicate a degree of confidence of the capability of the system to meet the 2-3 second maximum delay per student terminal query, with ten terminals on-line.

1. 100% confidence
2. High degree of confidence (70-95%)
3. An average degree of confidence (40-65%)
4. Low degree of confidence (20-35%)

D. Please check, as appropriate, the compilers that will be available to the customer on your system. If there is a cost beyond that specified with the equipment per compiler, please indicate.

1. FORTRAN IV (requested), $__________
2. BASIC Language (requested), $__________
3. Extended BASIC, $__________
4. COBOL, $__________
5. Assembler, $__________
6. FORTRAN II, $__________
7. FORTRAN V, $__________
8. Report Program Generator (RPG), $__________
9. QUIKTRAN $ $

10. JOSS $ $

11. CAL $ $

12. Machine Language $ $

E. The Type of data set or telephone modem proposed to satisfy the requirement:

1. Data set nomenclature: __________________________.

2. Manufactured by: ________________________________.

3. The cost to ______ lease or purchase this equipment is estimated as $ ___________ (per ______ period if leased).

F. What batch processing input/output equipment would you recommend a new system include in its configuration? (Based on the purchase/lease response to question I. E., please also indicate the rental period to be considered, i.e., month, week, hour, or year).

1. ______________________$, __________, per ______.

2. ______________________$, __________, per ______.

3. ______________________$, __________, per ______.

4. ______________________$, __________, per ______.

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G. Does your company charge for extra shift operations? Please indicate the applicability of this question to the operating schedule of paragraph 4.1.7 of the Statement of Work.

1. Not applicable
2. Yes, we do charge for 2d and 3d shift operations,
3. The operating cost for 2d shift is $per
4. The operating cost for 3d shift is $per
5. Extra maintenance cost to support 2d shift operation is $per

H. Does your company have a provision within its operating base to extend an educational discount to educational institutions?

1. Applicable, and is equal to
2. Not applicable

I. Can your company provide the training cited in paragraph 4.3 of the Statement of Work?
1. Yes_______, estimated cost $______________.

2. No________.

J. Please indicate the estimated number of square feet of system operational and support space, not including that required for academic areas to include student terminals, that would be required to support the proposed configuration:

1. Operating space ______________ sq.ft.

2. Support space ______________ sq.ft.

K. Please rate the degree of sophistication in environmental support required for your equipment based on the following - 70° Fahrenheit and 50% relative humidity; is your system able to tolerate fluctuations of ± 4° F or 10% relative humidity? Do you consider the support proposed to be:

1. Satisfactory ________.

2. Too stringent ________.

3. Not stringent enough ________.

4. Not applicable ________.

L. Will a raised floor be required?

1. Yes ________.

2. No ________.
M. Please indicate an estimated power requirement required to support the configuration proposed:

1. Voltage - 110 _______ or 220 _______.

2. A.C. _______ or D.C. _______.

3. Estimated amperage _______.

4. Will an independent feeder line to the transformer be required? _______.

N. Please indicate in weeks the time after receipt of an order that is required to complete the acquisition cycle, install, test, and accept the system; _______ weeks.

O. Will the customer be responsible for transportation charges?

1. Yes and the F.O.B. point is _______.

2. Not applicable as the contractor is responsible for transportation costs. _______.

P. Will there be special charges for the installation, testing and/or acceptance of the system on and above those previously noted as either equipment lease or purchase costs?

1. Not applicable _______.

2. Yes, and these costs are estimated to be $ _______.

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III. Contractor Comments: Please indicate in the space provided or on the reverse, other pertinent data a perspective customer should consider in the development of a computer assisted instruction system that the researcher has failed to include. Thank you!
APPENDIX D

CALCULATION OF COST FACTORS

1. The acquisition cost relationship given in equation form is as follows:

\[ C_{ACQI} = C_{HD} + C_{TM} + C_{DS} + C_{BT} + C_{FC} + C_{FE} + C_{FF} + C_{FP} + C_{OA}. \]

Where:

- \( C_{ACQI} \) = Cost for the acquisition (or lease) of system.
- \( C_{HD} \) = Hardware purchase cost
  
  or
  
  Hardware 3 year lease cost
  
  or
  
  Cost of time-shared system for 36,000 connect hours (3 year equivalency).

- \( C_{TM} \) = Student terminal cost for 10 terminals for 36 months.

- \( C_{DS} \) = Cost for leasing 20 data sets for 36 months.

- \( C_{BT} \) = Cost of leasing (for 36 months) or purchasing batch processing input/output equipment.
C_{FC} = \text{Cost for facility construction modifications, estimated at $35 per square foot.}

C_{FE} = \text{Cost for environmental control based on one of the following factors:}

(a) if satisfactory $20,000
(b) exceeds needs 60\% of $20,000
(c) insufficient $20,000 + 60\% of $20,000
(d) Not applicable - use of factor of 1.

C_{FF} = \text{Cost for raised floor ($16,000).}

C_{FP} = \text{Cost for power installation if 220 volts is required use $5,000, if 110 volts and 50 amps use $2,000.}

C_{OA} = \text{Cost of other acquisitions not previously identified.}

2. The personnel cost relationship given in equation form is as follows: \[ \text{PETN} = \text{C_{PS}} + \text{C_{PT}} + \text{C_{OP}} \]

Where:

\text{C_{PETN}} = \text{Cost of personnel salaries and training for initial systems development and implementation.}
\[ C_{PS} = \text{Direct and indirect personnel salary cost for 36 month period.} \]

\[ C_{PT} = \text{Direct personnel training cost.} \]

\[ C_{OP} = \text{Other personnel cost not previously identified.} \]

3. The relationship of cost categories for operation and maintenance are as follows:

\[ C_{OPMT} = C_{PU} + C_{CM} + C_{TM} + C_{SM} + C_{SS} \]

Where:

\[ C_{OPMT} = \text{Cost of operations and maintenance for the 36 months evaluation period.} \]

\[ C_{PU} = \text{Estimated electrical power consumption cost for the 36 months evaluation period.} \]

\[ C_{CM} = \text{Operations and maintenance cost associated with preventative and on-call maintenance of the computer system for the 36 month period.} \]

\[ C_{TM} = \text{Maintenance cost associated with scheduled and on-call maintenance of the IO Cathode Ray Tube Terminals for the 36 month period.} \]
\(C_{SM} = \) Maintenance cost associated with second shift operations for a computer system.

\(C_{SS} = \) Cost associated with second shift operations for a computer system.

\(C_{OO} = \) Other cost for operations and maintenance not previously defined.

4. The cost relationship, for comparative purposes, will be based on the internal relationships and specified elements for each cost element set forth above, to determine the implementation cost of any given system are:

\[ CR_1 = C_{ACQ} + C_{PETN} + C_{OPMT} \]
APPENDIX E

SELECT JURY

CALCULATION OF QUESTIONNAIRE POINT VALUES

1. The select jury's evaluation of the technical parameters of the vendor questionnaire accomplished two objectives:

   a. The assignment of a point value based on a scale of 5-10 for each lettered question in part II of the completed vendor questionnaires. The lowest score assigned having a value of 5 points if, in the judgment of the observer, that specific response did not satisfy the requirements of the Statement of Work. Conversely, assignment of 10 points indicated that the observer judged that specific response to be fully responsive to the Statement of Work.

   b. Wherein each element of the questionnaire was not applicable to each vendor solicited to participate in the study, the select jury was instructed to assign a point value to each unanswered question. The point value affixed for unanswered questions was on a sliding scale of 1 to 2 as follows:

      (1) A point value of 1 to those unanswered questions which the vendor could have or should have made a response in the judgement of the observer.
(2) A point value of 2 for those unanswered questions that were not applicable to the specific system proposed.

2. Within the point value system outlined above, the minimum score a given questionnaire could be assigned was 16 points per observer. Conversely, the maximum was a score of 160 points.
APPENDIX F

VENDOR QUESTIONNAIRE WEIGHTED MEAN FACTORS

1. The weighted mean for each proposed system was computed from the observed values resulting from the panel technical evaluation in phase II. The observed values were assigned in accordance with the criteria contained in Appendix E. To calculate the weighted mean the researcher assigned a weight to the lettered subparagraphs, part II of the vendor questionnaire, proportioned to relative importance of a specific question to satisfying the intent of the Statement of Work. The weighted mean was found by dividing the sum of the products of the values and their weights by the sum of the weights:

\[ \bar{Y} = \frac{\sum W_i Y_i}{\sum W_i} \]

2. The assigned weight for each lettered subparagraph of part II of the vendor questionnaire, Appendix C, was:

a. Equipment - weight 10. Rationale: The configuration proposed is most significant to determine technical adequacy and determine cost to test the hypothesis.

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b. Student Terminal - weight 5. Rationale: Cost variations for different end items of equipment although having an impact on the study should not vary significantly and would have to be responsive to the technical specifications of the contract.

c. Delay per student terminal query - weight 9. Rationale: The importance of this question cannot be over-emphasized. A system with a slower responsive time would be detrimental to the purpose and concept of computer assisted instruction and the premise of this research effort.

d. Compilers - weight 6. Rationale: The unavailability of the requested compilers capable of executing on a remoted time-share system would hinder instructional authoring. Although some cost could be involved, it would be minimal to the overall research effort.

e. Data Set - weight 2. Rationale: Although the cost of these items could have a significant impact on a computer assisted instruction program, their importance is insignificant in that they would not technically affect the study observed values.
f. Batch Processing Equipment - weight 1. Rationale:
Batch processing equipment is not required to support computer assisted instruction concepts or operations to include the gathering of student academic and biographical data.

g. Cost for Extra Shift Operations - weight 1. Rationale:
Question has minor impact on cost and negligible impact on the technical capabilities of a system to satisfy the statement of work.

h. Educational Discount - weight 6. Rationale: The percent of discount allowed for a given system could have a significant impact on cost data used to test the study hypothesis.

i. Training - weight 8. Rationale: The cost of training a novice staff would be significant depending on the specific computer system configuration proposed.

j. Square feet of Operational Space - weight 9. Rationale:
The amount of floor space required is a significant factor that would have a high risk element for the designing and establishment of any computer system. Depending on the total square footage required for a given computer system, this could be a substantial initial cost.
k. Environmental Support - weight 9. Rationale: In combination with the operating site, the initial investment for environmental control would significantly impact on this research effort.

l. Raised Floor - weight 9. Rationale: The initial investment for a raised floor, if required, would be a significant cost factor.

m. Power - weight 6. Rationale: Power requirements, while critical to equipment performance, and must be considered, their initial cost would not constitute a significant cost element of the study.

n. Acquisition Time - weight 1. Rationale: Generally, the length of the acquisition cycle becomes more emotional in value than critical to either equipment installation or system operation.

o. Transportation Charges - weight 2. Rationale: Transportation cost while required as an input for fiscal planning would generally be insignificant to the overall cost associated with the implementation of a new data system.

p. Special or Other Charges - weight 8. Rationale: This
item is deemed significant in that charges or seemingly unimportant items not previously identified by the researcher could influence the study in testing the hypothesis results.
APPENDIX G

Select Jury Technical Evaluation

Work Sheet

Questionnaire #___
Date___________

1. System Classification ____________ (question D, part I)

2. Vendor Recommended: Leasing______ (question E, part I)
   Purchase_____
   Other_____

3. Based on your background and experience with computer assisted instruction concepts and techniques, rate each of the letter paragraphs of Section II of the questionnaire using the following scales:
   a. Award a point value between 5 and 10 for each question answered. Awarding a low score of 5 points should indicate that the vendor's response does not satisfactorily respond to the statement of work. A score of 10 points should indicate that the response was technically responsive.
   b. Award points for unanswered questions as follows:
(1) Point value of 1 if answered question could have been completed.

(2) Point value of 2 if unanswered question was not applicable to that vendor.

<table>
<thead>
<tr>
<th>Part II</th>
<th>Question #</th>
<th>5-10 Point Value</th>
<th>1-2 Point Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>F</td>
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<td></td>
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<tr>
<td>G</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
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<td></td>
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<td>L</td>
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<tr>
<td>M</td>
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<td></td>
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<td>N</td>
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<tr>
<td>O</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H

Select Jury

Cost Analysis Work Sheet

Questionnaire #

Date

1. System Classification (question D, part I)

2. Recommended procurement procedure (question E, part I)
   a. Leased
   b. Purchase
   c. Other

3. Acquisition Cost (C\text{ACQI}): Part II

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Total Cost</th>
<th>Question #</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Hardware (CHD)</td>
<td>$_________</td>
<td>A, 1-12</td>
</tr>
<tr>
<td>b. Terminals (CTM)</td>
<td>$_________</td>
<td>B, 1</td>
</tr>
<tr>
<td>c. Data Sets (CDS)</td>
<td>$_________</td>
<td>E, 3</td>
</tr>
<tr>
<td>d. Batch Processing</td>
<td>$_________</td>
<td>F, 1-6</td>
</tr>
<tr>
<td>e. Facility (CF)</td>
<td>$_________</td>
<td>J, 1 &amp; 2</td>
</tr>
</tbody>
</table>
   (Sq Ft x $35.)
<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Total Cost</th>
<th>Question #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Conditioning</td>
<td>$__________</td>
<td>K</td>
</tr>
<tr>
<td><strong>(CFE)</strong>(1 = $20,000; 2 = 60% of $20,000; 3 = $20,000 + 60% of $20,000; 4 = 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raised Floor (CFF)</td>
<td>$__________</td>
<td>L</td>
</tr>
<tr>
<td>Power (CFP)</td>
<td>$__________</td>
<td>M</td>
</tr>
<tr>
<td>(If voltage is 220, use $5,000; other use $2,000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other acquisition</td>
<td>$__________</td>
<td>All</td>
</tr>
<tr>
<td><strong>(CFA)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Personnel Cost (CPTN)

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Total Cost</th>
<th>Question #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel Salaries</td>
<td>$__________</td>
<td></td>
</tr>
<tr>
<td>(Senior Operators #__@ $1000/ per mo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Operators #__@ $800/ per mo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Asst Operators #__@ $600/ per mo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Programmers #__@ $1300/ per mo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(System Analysts #__@ $1500/ per mo)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on vendor response - what size staff would be required.

Base salaries on monthly average.
<table>
<thead>
<tr>
<th>Subject Areas</th>
<th>Total Cost</th>
<th>Question #</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Instr Programmers #@ $950/per mo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Management #@ $1600/per mo)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Training (cpt)</td>
<td>$__________</td>
<td>I</td>
</tr>
<tr>
<td>c. Other Personnel</td>
<td>$__________</td>
<td>All</td>
</tr>
</tbody>
</table>

5. Operations and Maintenance Cost (cOPMT)

<table>
<thead>
<tr>
<th>Subject Areas</th>
<th>Total Cost</th>
<th>Question #</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Power/Utility</td>
<td>$__________x 36 G.</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>(1 shift $300)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2d shift $450)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3d shift $600)</td>
<td></td>
</tr>
<tr>
<td>b. Preventative/On Call Maint (cCM)(Single Shift Operation)</td>
<td>$__________x 36 G.</td>
<td></td>
</tr>
<tr>
<td>c. Maintenance Cost</td>
<td>$__________x 36 G, 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for 2 or 3 shift operations (cSM)</td>
<td></td>
</tr>
<tr>
<td>d. Terminal Maintenance (cTM)</td>
<td>$__________x 36 B, 3</td>
<td></td>
</tr>
<tr>
<td>e. Operations Cost for</td>
<td>$__________</td>
<td>G, 3 or 4</td>
</tr>
<tr>
<td></td>
<td>2d or 3d shift (cSS)</td>
<td></td>
</tr>
</tbody>
</table>
6. Impact on cost data of vendor comments to Part III of questionnaire.

7. Is an education discount provided for? (question H)

8. Summary Data

<table>
<thead>
<tr>
<th>Subject Areas</th>
<th>Total Cost</th>
<th>Question #</th>
</tr>
</thead>
<tbody>
<tr>
<td>f. Other Operations</td>
<td>$_________</td>
<td>All</td>
</tr>
</tbody>
</table>

Cost ($COO)

| 1. Acquisition Cost ($ACQ1)  | $_____     | (3 above)  |
| 2. Personnel Cost ($PETN)    | $_____     | (4 above)  |
| 3. Operations & Maintenance ($OPMT) | $_____ | (5 above)  |
| 4. Other factors             | $_____     | (6 above)  |

Sub Total $_____

Less Education Discount $_____ (7 above)

Total Cost This System Cr $_____
## APPENDIX I

Select Jury Cost Findings

### Vendor A

<table>
<thead>
<tr>
<th>Independent Jurist Findings</th>
<th>Jury Average Cost</th>
<th>Researcher's Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,400,000</td>
<td>$1,300,000</td>
<td>$1,400,000</td>
</tr>
<tr>
<td>$1,500,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1,200,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1,200,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1,200,000</td>
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</table>

### Vendor B

<table>
<thead>
<tr>
<th>Independent Jurist Findings</th>
<th>Jury Average Cost</th>
<th>Researcher's Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,000,000</td>
<td>$869,000</td>
<td>$720,000</td>
</tr>
<tr>
<td>$610,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1,130,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$860,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$745,000</td>
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<td></td>
</tr>
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</table>
### Vendor C

<table>
<thead>
<tr>
<th>Independent Jurist Findings</th>
<th>Jury Average Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 735,000</td>
<td>$ 708,000</td>
</tr>
<tr>
<td>$ 815,000</td>
<td></td>
</tr>
<tr>
<td>$ 685,000</td>
<td></td>
</tr>
<tr>
<td>$ 660,000</td>
<td></td>
</tr>
<tr>
<td>$ 645,000</td>
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</table>

<table>
<thead>
<tr>
<th>Researcher's Estimated Cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 700,000</td>
<td></td>
</tr>
</tbody>
</table>

### Vendor D

<table>
<thead>
<tr>
<th>Independent Jurist Findings</th>
<th>Jury Average Cost</th>
</tr>
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<tbody>
<tr>
<td>$ 445,000</td>
<td>$ 513,000</td>
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<tr>
<td>$ 700,000</td>
<td></td>
</tr>
<tr>
<td>$ 460,000</td>
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<tr>
<td>$ 417,000</td>
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<table>
<thead>
<tr>
<th>Researcher's Estimated Cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 700,000</td>
<td></td>
</tr>
<tr>
<td>Vendor E</td>
<td>Independent Jurist Findings</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------</td>
</tr>
<tr>
<td></td>
<td>$ 380,000</td>
</tr>
<tr>
<td></td>
<td>$1,303,000</td>
</tr>
<tr>
<td></td>
<td>$ 443,000</td>
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<tr>
<td></td>
<td>$ 344,000</td>
</tr>
<tr>
<td></td>
<td>$ 560,000</td>
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</table>

<table>
<thead>
<tr>
<th>Vendor F</th>
<th>Independent Jurist Findings</th>
<th>Jury Average Cost</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$ 588,140</td>
<td>$ 550,000</td>
</tr>
<tr>
<td></td>
<td>$ 647,540</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 438,940</td>
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<tr>
<td></td>
<td>$ 472,640</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$ 616,280</td>
<td>$ 680,000</td>
</tr>
</tbody>
</table>
LIST OF REFERENCES

The literature cited and reviewed in the conduct of this research effort are presented alphabetically by surnames of authors.


VITA

William Trueheart was commissioned in the United States Army Signal Corps upon graduation from Northeastern University, Boston, Massachusetts, with a Bachelor of Science in Education. Currently holding the rank of Major, his experience includes assignments in communications and data processing system design, procurement, installation and operations, with assignments in the Far East, Europe, Middle East, and Continental United States.

As a data processing specialist he was the project officer for the first high speed transmission of data over high frequency radio; the project officer for the design and implementation of the first command and control data system employed in a combat theater; and special staff officer to the Chief of the Defense Intelligence Agency Data Processing Facility for the contractual effort to develop a machine independent Data Management System.

His current assignment is as Chief of the Data Systems Branch, United States Army Southeastern Signal School, Fort
Gordon, Georgia. Here he has been responsible for the development of a Computer Assisted Instruction System developed and implemented on a commercial time-shared system. During his tenure at the Signal School he designed an Army Standard 1000 Terminal Multiprocessor Minicomputer Training System, which will be installed and tested at Fort Gordon, and the largest academic and management data processing facility in the Army's School System.

He is a graduate of the Signal Officer Advance Course, the Automatic Data Processing Plans and Operations Officer Course, the United States Army Command and General Staff College, the Army Project Managers School and numerous commercial courses in data processing analysis, programming, and management.