AN EVALUATION OF THE AUTOMATED COST ESTIMATING INTEGRATED TOOLS (ACEIT) SYSTEM

THESIS

Caroline L. Hanson
Major, USAF

AFIT/GCA/LSQ/89S-5

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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of the
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Master of Science in Cost Analysis

Caroline L. Hanson, B.A., M.B.A.
Major, USAF

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Preface

I wish to thank Dr Roland Kankey, my thesis advisor, for first of all leading me to ACEIT, and then having the patience to answer my endless questions. His guidance, encouragement, and assistance were appreciated throughout this research effort. I would also like to thank Mr Richard Murphy, my reader, who provided many helpful comments. Special thanks is due to Ms Ellen Coakley and Ms Margaret Weech of ESD/ACC. This research effort would not have been possible without their support and assistance. I also wish to thank all the interviewees and the 1989 AFIT Graduate Cost Analysis students, whose comments helped focus this research.

Finally, I dedicate this thesis to my family: Reed, Kelly, and Sarah.

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Abstract

The purpose of this study was to evaluate the Automated Cost Estimating Integrated Tools (ACEIT) System and answer the following investigative questions: (1) How user-friendly is ACEIT and does it require extensive training? (2) Does the proper use of ACEIT require cost estimating expertise or does the system prompt even a novice to generate an accurate estimate? (3) Does the ACEIT Statistics Package give the same estimates and statistics as the Statistical Analysis System? (4) What are some of the potential benefits and problems of successfully implementing ACEIT throughout the Air Force? (5) Can ACEIT be quickly and effectively introduced to AFIT Graduate Cost Analysis students who are unfamiliar with the system?

Review of the existing literature, discussions with ACEIT users, personal experience with the system, and comments of AFIT students were used in answering the first two questions. The determination was that ACEIT is very user-friendly and does not require extensive training. However, even though the system provides excellent prompts, it is designed as a decision support system not an expert system. Thus, some cost estimating expertise is required to generate accurate cost estimates.

Sample data sets run through the ACEIT Statistical Package and the Statistical Analysis System produced

comparable estimates and statistics for learning curves, linear and log-linear regressions.

The ACEIT system's major benefit may also be its major potential pitfall. Since ACEIT is a framework to use in building an estimate, organizations can fill its databases with their own unique work breakdown structures, data, and cost estimating relationships. This benefit can turn into a pitfall if the databases are not accurate. Each organization must ensure quality control of its own unique ACEIT databases.

Results of a brief introduction of ACEIT to AFIT Graduate Cost Analysis students indicate the system can be quickly and effectively introduced. The four one-and-a-quarter-hour periods included a briefing, a hands-on demonstration of the ACEIT tutorial, and a hands-on exercise.

Recommendations of this study include suggested updates to the already excellent User's Guide, suggestions for additional ACEIT capabilities, presenting the ACEIT introduction earlier in the Graduate program and expanding it to five one-and-a-quarter-hour periods. Further research should examine the technicalities of creating the organizational databases and replication of an estimate from scratch.

AN EVALUATION OF THE

AUTOMATED COST ESTIMATING INTEGRATED TOOLS (ACEIT) SYSTEM

I. Introduction

General Issue

This thesis evaluates the Automated Cost Estimating Integrated Tools (ACEIT) System. Tecolote Research, Inc. developed ACEIT for Electronic Systems Division (ESD) under contracts F19628-84-D-0019 and F19628-88-D-0007. It is designed as a user-friendly integrated set of tools to allow one to define the program to be estimated and build and document the cost estimate. Although only received by the Air Force in the spring of 1988, ACEIT generated considerable interest at the April 1988 Air Force Systems Command (AFSC) Cost Symposium (4:2). The following agencies have installed or are in the midst of installing ACEIT (5):

Electronic Systems Division MA

Air Force Cost Center Washington DC

Arnold Engineering Development Center TN

Munitions Systems Division FL

Space Systems Division CA

Ballistic Systems Division CA

Strategic Defense Initiative National Test Facility CO

Air Force Institute of Technology (AFIT) OH

Originally designed to support ESD, ACEIT currently runs on a mainframe (VAX) computer (although a personal computer version for certain portions of the system is under development). It has an extensive database of ESD program-related cost factors; document, source, and cost estimating relationship (CER) equation libraries; cost models; and cost, schedule, and technical information (13:Sec 1,1). ACEIT gives the user the "capability to search for and extract data from the databases and to develop analogies and CERs from the data" (13:Sec 1,1). Prompted by the growing interest in ACEIT throughout the Air Force, this research provides an independent review of ACEIT and an examination of the issues involved in expanding ACEIT's use beyond ESD.

Specific Problem

Since ACEIT is so new, there has been little time to 1) identify errors in its instructions which would lead a user to make an erroneous estimate or 2) identify problems which could occur as ACEIT is implemented Air Force-wide.

Research Objective

The objective of this research is to provide an independent, in-depth evaluation of ACEIT by developing familiarity with the ACEIT system, sampling the system's data, interviewing current and prospective users, and developing an "Introduction to ACEIT" lesson plan for Air

Force Institute of Technology (AFIT) Graduate Cost Analysis students.

Research Investigative Questions

A thorough evaluation of ACEIT requires answers to the following questions.

1. How user-friendly is ACEIT? Does it require extensive training?

2. Does proper use of ACEIT require cost estimating expertise or does it prompt even a novice user to generate accurate estimates?

3. Does the ACEIT Statistics Package give the same estimates and statistics as the Statistical Analysis System (SAS)?

4. What are some of the potential benefits and problems to be avoided in successfully implementing ACEIT in organizations throughout the Air Force?

5. Can ACEIT be quickly and effectively introduced to the AFIT Graduate Cost Analysis students who are unfamiliar with the system?

Assumptions

Since the ACEIT system includes a built-in tutorial program, this research hypothesizes that the tutorial and documentation will provide adequate training to effectively use the system. ESD currently hosts a 5-day training course on ACEIT. However, in real world situations individuals must frequently learn to use systems without attending a training course. Therefore, this research should test the hypothesis, provide some indication of how adequate the

existing tutorial is, and determine whether or not a training course should be considered mandatory.

Definitions

Before discussing the details of the ACEIT system and addressing the research investigative questions, it is necessary to clear up the confusion indicated in various interviews as to exactly what ACEIT is and what it is not. ACEIT is intended to be an effective decision support system; it is not a knowledge based expert system nor is it just a computerized spreadsheet. One concern uncovered during this research was that ACEIT is a dangerous concept because it is an automated cost estimator (or expert system) which takes the individual out of the cost estimating process. At the other extreme, another concern was that ACEIT doesn't give the user anything more than a spreadsheet program does. Both of these concerns are unwarranted. ACEIT will not make a decision for a user, and most certainly it does not take the individual out of the estimating process. However, ACEIT will provide significantly more support to the estimator than a simple spreadsheet program.

Davis and Olson in Management Information Systems define decision support systems as

> a class of systems which support the process of making decisions. The emphasis is on "support" rather than on automation of decisions. Decision support systems allow the decision maker to retrieve data and test

alternative solutions during the process of problem solving. (6:368)

They further define the concept of decision support systems in terms of the role the computer plays in an effective decision making process:

> 1. The computer must support the manager but not replace his or her judgement. It should therefore neither try to provide the "answers" nor impose a predefined sequence of analysis.
>
> 2. The main payoff of computer support is for semistructured problems, where parts of the analysis can be systematized for the computer, but where the decision maker's insight and judgement are needed to control the process.
>
> 3. Effective problem solving is interactive and is enhanced by a dialogue between the user and the system. The user explores the problem situation using the analytic and information-providing capabilities of the system as well as human experience and insights. (6:368-369)

The key comments to be emphasized in the above passage clearly address the concern that ACEIT will automatically make the cost estimate without human intervention. ACEIT does not "replace" the manager's judgement. ACEIT does not impose a predefined sequence of analysis (although it does provide a sequence should the user choose to follow it). ACEIT does systematize the calculations required in a cost analysis (such as applying inflation rates) but the user's "insight and judgment are needed to control the process" (6:368). ACEIT is interactive.

ACEIT is not an expert system. According to Davis and Olson,

> An expert system is a computer application that guides the performance of ill-structured tasks which usually

> require experience and specialized knowledge ... Using an expert system, a non-expert can achieve performance comparable to an expert in that particular problem domain. ... The unique, distinguishing feature of an expert system is the knowledge base, the data and decision rules which represent the expertise. (6:375)

An example of a rule-based expert system would be the medical diagnosis system MYCIN (20:93). With this type of system the user provides a set of symptoms and the system then searches its knowledge base of symptoms and possible causes (6:375). ACEIT is not an expert system; it has no knowledge base or decision rules.

ACEIT clearly fits in the decision support system category. As currently configured, ACEIT consists of eight integrated modules:

Automated Cost Estimator (ACE)

Automated Cost Database (ACDB)

Automated Cost Document Library (ACDL)

Cost Estimating Relationship Library (CERL)

Cost Estimating Models (CEM)

Software Cost Database (SCDB)

Software Size Database (SSDB)

Statistics Package (STATPAK)

ACE is the "heart of ACEIT" being the module from which all the other modules can be accessed (13:Sec 1,1). A discussion of each module will be presented in Chapter II. Suffice it to say at this point that the modules together clearly meet the definition of a decision support system.

Another misconception about ACEIT is that it is a model. As is evident from the list of ACEIT modules above, one module within ACEIT provides access to a variety of models. However, ACEIT itself is not a model. The predictive accuracy of an estimate developed using ACEIT does not reflect on ACEIT's ability to predict. ACEIT does not predict cost, rather the methodology input into the ACEIT framework is predicting the cost. It is that methodology, not ACEIT, which would then be either accurate or inaccurate. In the words of Ms Ellen Coakley, ESD/ACC, Technical Director, "ACEIT is an architecture" (5). ACEIT is a framework to use in building a cost estimate. It provides access to a lot of data, CERs, and models, as well as doing learning curve and inflation calculations, but it is not a model. Therefore, there is really no need to validate ACEIT as an accurate cost estimating model; instead, all of the data, CERs, and models put into any given ACEIT database need to be validated. This thesis will evaluate the STATPAK and learning curve calculation routines within ACEIT. However, it must be made clear that saying an estimate was built using ACEIT is not like saying an estimate was built using RCA PRICE-S or COCOMO for instance. ACEIT is simply a framework which provides access to the tools necessary to make an estimate.

Scope

The size and complexity of the ACEIT system necessitate that the scope of this research effort be limited. Part of this research includes evaluating the STATPAK and learning curve calculations. Since it would be impossible to test every conceivable type of data or equation in the short time allotted for this research, representative data will be used. Additionally, the inflation calculations will not be evaluated at all. The current version of ACEIT does not permit a user access to the inflation indices used in the actual calculations. They are referenced internally and the calculations are transparent to the user. Therefore, it would be somewhat difficult to verify the exact numbers being used. Another consideration (described in Chapter IV) is the fact that Bradley's replication of an existing cost estimate verified that, in that case, the inflation calculations were correct (4:19). Thus, rechecking the inflation calculations is not a priority concern and will not be included in this research.

II. Literature Review

Introduction

Since ACEIT is so new, there are not any published reviews of it. The only published reference to ACEIT is the User's Guide which is used extensively for this research. ACEIT does not show up in any computerized or manual literature search under cost model, automated cost model, cost effectiveness, cost estimating, or automated cost estimating. Therefore, this chapter first provides a thorough description of each of the ACEIT system modules to help the reader unfamiliar with ACEIT to understand the remainder of the thesis. Next, literature on systems which may compare to ACEIT is reviewed. This is followed by an examination of several unpublished reviews of ACEIT. Lastly, literature pertaining to the concepts of user-friendliness, cost estimating expertise, and statistics package accuracy is reviewed.

ACEIT System Description

Automated Cost Estimator (ACE).

ACE is the "heart" of ACEIT, since it is the module from which every other module can be accessed (13:Sec 1,1). "Ace uses a user-friendly spreadsheet architecture employing on-line help and 'Lotus' style command menus" (13:Sec 1,1). ACE currently has two operating modes, one for the novice

estimator and the other for the experienced estimator. The difference in the two modes is the level of prompts automatically provided. "The expert mode provides nominal guidance and assumes that you are an experienced cost estimator, familiar with the ACE system software operation" (4:7). The novice mode includes a set of about 100 tutorial training screens created by Ms Ellen Coakley (ESD/ACC). These screens essentially walk a novice estimator through the estimating process using ACEIT with "tutorials, on-screen prompts, and interactive sample problems" (13:Sec 1,1). Even if a user is in the expert mode, he can access the novice mode screens if desired. These screens cover all the essentials: defining the estimating task; building and defining a work breakdown structure (WBS); planning the cost estimating methodology for each WBS element; including General and Administrative overhead and Fee rate adjustments; addressing learning curve methodology; collecting, evaluating, and normalizing data; addressing risk and potential contract changes; calculating the estimate in base year dollars; time phasing the estimate; escalating the estimate to then-year dollars; and finally documenting the estimate (4:36-110). The screens do not make the novice mode an expert system even though Ms Coakley is an expert and they contain her advice. The screens are instead a computerized version of a cost estimating handbook. They could just as well have been located in an

off-line workbook, but computerizing the text makes the learning an interactive process versus a passive reading process.

Whichever mode is used, ACE will allow a user to create an estimate. ACE includes built-in WBSs consistent with Military Standard 881A (13:Sec 2,21); these include separate WBSs for aircraft, electronics, missile, ordnance, ship, space, and surface vehicle systems (4:42). However, the user has the capability to tailor any system WBS to his specific requirements. ACE's system WBS elements are linked to ACE built-in libraries of CERS, models, and sources (people, places, documents, and databases) of data/knowledge (13:Sec 1,2). The link allows ACE to present the estimator with only those CERs, models, and sources applicable to that particular WBS element instead of the entire library (although the entire library can still be accessed). Additionally, the linkage will carry information on fee, G&A rate, learning curve etc. throughout the estimate. The CER library within ACE is not the Cost Estimating Relationship Library (CERL) which will be described later. The ACE CERs are a separate library of CERs. ESD has chosen to include only those CERs which have been "identified/developed and reviewed for ESD use by ESD/ACC" in the ACE built-in library (4:63). The CERs in the built-in library also include comments on the parameters, definitions, data ranges, statistics, and recommended uses (13:Sec 1,2). Any selected

CERs can be electronically transferred to the ACE workscreen to be used in building an estimate. ACE also allows a user to run a model from ACE's built-in library and transfer the answer to the worksheet (13:Sec 1,2). Additionally, ACE lets a user search on-line databases to find an analogy, or transfer data to the STATPAK module to create a new CER (13:Sec 1,2).

Before calculating an estimate, ACE checks the methodology for missing appropriations, equations, parameter input values, and proper format as well as prompting the user for learning curve information (13:Sec 1,2). Following the completion of the estimating methodology, ACE moves the user to a calculation workscreen where inputs can be varied to run multiple simultaneous sensitivity/what-if analyses (13:Sec 1,2). ACE uses built-in learning, inflation, and summing routines to translate figures into the units and base year specified by the user (13:Sec 1,2). ACE also time phases the estimate and then translates it into then-year dollars based on the user's direction (13:Sec 1,3).

Finally, ACE will print out any of the following documentation requested by the user:

1. Summary Costs (Base-Year and Then-Year) by Appropriation by Fiscal Year
2. Time Phased Dollars (Base-Year and Then-Year)
3. Estimates in Base-Year Dollars
4. Estimating Methodology
5. Time Phasing Methodology

6. WBS Definitions

7. CER/Source/Model Definitions

8. ACE Notepad Comments

A key aspect of the ACE module which makes it so flexible is the fact that the system manager has a set of utilities available to tailor system training screens, WBSs, definitions, expansions, and built-in libraries (13:Sec 1,3). As mentioned earlier, ACEIT can be considered a framework for building an estimate. The ability to tailor training screens, WBSs, CER libraries, etc. to meet an organization's unique requirements is what will make it possible for units Air Force-wide to effectively use ACEIT. This subject will be addressed further in Chapter IV.

Automated Cost Database (ACDB).

The Automated Cost Database currently contains cost, schedule, technical, and programmatic data on over 130 ESD system acquisition contracts (13:Sec 1,3). Monthly data was extracted from CPRs, C/SSRs, and CFSRs. Following ESD/ACC's approval of a mapping scheme, this data was then mapped into a standard WBS for electronic systems (13:Sec 1,3). This data can be queried to find an analogous program, system contractor, or contract (13:Sec 1,3). Reports by WBS, in then-year or base-year dollars, can be obtained which include any of the following: actual or cumulative cost by month, percent spent by month, percent spent by schedule milestones, cost-to-cost factors, durations, lag times, and

cumulative beta curve parameters (13:Sec 1,3). An important feature of the ACDB which makes a cost estimator's work a lot easier is that data selected from the ACDB can be electronically transferred to the STATPAK module for analysis. This is a fast, error-free (no typos) way to create CERs from analogous programs. However, as in any estimate whether computerized or not, the estimator must make sure the programs used are truly analogous. ACEIT will not do this for a user, it only provides easy access to the data from the computer terminal.

Automated Cost Document Library (ACDL).

The Automated Cost Document Library contains abstracts on over 1200 ESD technical and cost related source documents (13:Sec 1,4). The ACDL can be searched by Title, Author, Subject, Abstract Text, Publication Date, and/or Originating Organization (13:Sec 1,4). The ACDL is simply a computerized card catalog of the ESD Cost Library. The benefit of having the ACDL module is that it simplifies the estimator's search for documents related to his program. Although many libraries now have computerized card catalogs (Wright State University in Dayton, Ohio for instance), it is a nice feature for the cost estimator to be able to quickly search from his terminal while doing an estimate. ACDL is not a substitute for reading a document, it just points the user in the right direction.

Cost Estimating Relationship Library (CERL).

The Cost Estimating Relationship Library contains over 1150 CERs extracted from more than 380 cost studies performed for the Army, Air Force, and Navy (13:Sec 1,4). The library is adapted from the MICOM Automated Database System (MIDAS) developed by the Huntsville, Alabama office of Tecolote Research, Inc. for the U.S. Army Missile Command Comptroller (13:Sec 5,i). In other words, the library was already available and only had to modified to be included in ACEIT. An important point to mention here is that the CERs contained in the library have not been evaluated by ESD, they have only been compiled. Included in the library extracts are summary documentation for each CER such as source data and relevant descriptive statistics (13:Sec 1,4). However, an estimator would be wise to consult the original source document on any CER under consideration.

Cost Estimating Models (CEM). (13:Sec 1,4-5)

Cost Estimating Models is a large module consisting of a set of Tecolote-developed and commercially available cost estimating models including BBEST, COCOMO, WICOMO, RADARDEV, and access to the RCA PRICE Family. BBEST is a family of twelve electronics hardware cost models. COCOMO and WICOMO estimate software cost and schedule. RADARDEV is an automated set of CERs for estimating the complete development costs of radar/C^3 equipment at the system or subsystem level. The RCA PRICE family of models are

applicable for a variety of electronic hardware, circuit cards, software, etc. Although the PRICE models can interface with ACEIT, this feature was not available on the ACEIT system as it was configured at AFIT.

Software Cost Database (SCDB). (13:Sec 1,6)

The Software Cost Database currently is not integrated into ACEIT (a future version will be) but instead is installed as a stand alone system on the ESD base VAX. Similar to the Automated Cost Database and the Software Size Database, SCDB contains detailed cost, schedule, and technical data for 28 software development projects, containing 177 computer software configuration items (CSCIs).

Software Size Database (SSDB). (13:Sec 1,6)

The Software Size Database contains software size, functions, and technical information for 1,458 computer software configuration items. Since the SSDB is integrated into ACEIT, the user can search and retrieve data for reports or to be moved into STATPAK for analysis.

Statistics Package (STATPAK).

STATPAK is a statistical package for analysis of data extracted from ACEIT and transferred into STATPAK or data from other sources (13:Sec 1,6). The ACEIT User's Guide states

> The main purpose of this software is to run regression analysis for both linear (or log-linear) and nonlinear models in a user-friendly fashion. Learning curve (unit and cumulative average) theories are also incorporated. Another option provides "descriptive

> statistics." The basic descriptive statistics are the measures of central tendency (location) and the measures of dispersion (scatter) of the data set. These statistics are used to describe, graphically and numerically, the characteristic behaviors of sets of data. (13:App A,1)

STATPAK allows the user to edit data, review histograms and scatterplots and perform basic statistical analysis, regression, and learning curves (13:Sec 1,6).

Other Systems

There is very little literature identified on any systems which are comparable to ACEIT. Although there are numerous automated cost estimating models, none allow a user to both access a variety of models and actually create CERs. ACEIT appears to be a truly innovative idea.

A good example of the automated models which are available is the Army system described in "Beyond the DCA-P-92(R) Structure Costing at a New Level of Detail" (24). This paper described "an automated cost estimating tool" which uses existing models to generate a "baseline cost estimate" (24:1). The baseline cost estimate "represents an operational, integrated cost estimating process for both the acquisition and the Planning, Programming, Budgeting and Execution cycles" (24:2). However, this tool does not generate CERs and it does not provide the flexibility that ACEIT does.

The system which most closely resembles ACEIT is the Air Force Cost Center's (AFCSTC) Cost Estimating System

(CES) developed by Delta Research Corporation. In the user's guide cover letter, LeRoy Baseman, Technical Director AFCSTC, states CES "can be used by analysts to develop and test cost estimating relationships" (8). Unlike the current version of ACEIT, CES runs on the Zenith 248 or any IBM-PC/XT/AT compatible microcomputer with 640K of RAM. The CES uses a separate off-line Aircraft Cost Handbook to supplement the databases stored on diskette. While ACEIT provides a tutorial especially designed for the novice estimator, the CES appears to be geared toward the more experienced analyst.

Unpublished ACEIT Reviews

Although no published reviews of ACEIT were identified, several unpublished papers were obtained.

The Air Force Institute of Technology (AFIT) Graduate Cost Analysis Class 88S prepared a "Preliminary Evaluation of the Automated Cost Estimating Integrated Tools (ACEIT) System." Their review focused on the "user-software integration of ACEIT ... using a cost estimating case study provided by Electronics Systems Division" (1:1). The class determined ACEIT to be "a very powerful package with great potential" and offered some minor recommendations not to change the architecture of ACEIT but to "make the system less cumbersome" and "to ease working within the architecture" (1:5). Since their report was completed, an updated version of ACEIT was installed on the AFIT computer.

This, plus some changes made by the AFIT Database Administrator and a reconfiguration of some of the AFIT terminals, significantly improved user-system interaction. The system installed at AFIT is now much easier to access, and updating and printing of files is also very straightforward.

Two other reports were prepared by Aeronautical Systems Division (ASD) cost personnel. In the first, Kenneth L. Birkofer, ASD/ACCR, in "A Review of the ESD ACEIT Model" briefly described the features of the eight ACEIT modules, their ease of use, and their potential "usefulness to the ASD cost estimating community" (3:1). Randall S. Bradley prepared the second report to fulfill the research project requirement within the ASD/AC Comptroller Training Program (4:3). He basically evaluated the spreadsheet computational features and ease of use of the ACE module by replicating the ASD cost estimate for the Light Detecting and Ranging (LIDAR) System. He did not evaluate any of the database, CER library, model library, learning curve, or STATPAK capabilities. A further analysis of both of these reports is included in Chapter IV.

User-Friendliness

Literature pertaining to the concept of user-friendliness was reviewed to establish guidelines in evaluating ACEIT's user-friendliness. Unfortunately, the review has indicated that user-friendly is hard to define.

Webster's Dictionary does not even provide a definition. However, Henry Simpson wrote a whole book for small computer programers to help them write user-friendly programs. His comments also apply to large mainframe computer programs like ACEIT. In Design of User-Friendly Programs for Small Computers, Simpson defines a user-friendly program as "one with features that acknowledge human factors" and one which is in general "easy to use, tolerant of operator errors, easy to learn, and acknowledges that human beings are imperfect creatures" (21:2). Simpson also addresses the importance of user documentation, stating "It is accurate to say that user documentation will make the difference between whether your program can be used effectively or not" (21:184). Simpson further breaks down his analysis of user documentation into "internal" documentation consisting of comments or help screens that can be accessed from within the program and "external" documentation such as a user's guide or video tape (21:193). The documentation provided must also serve as both a tutorial and a reference guide:

> as people use a program, they gain skill and their needs change. New operators need a step-by-step tutorial that they can use to work through the program and that will help them to develop skill and confidence. Experienced operators no longer need this but they do need quick access to important reference information for using the program. In sum, the user's guide should serve the needs of all members of its audience and should accommodate itself to growth in skill. (21:193)

William J. Raduchel approached user-friendliness from a completely different perspective than Simpson. In a Byte

magazine article, Raduchel presented a mathematical formula for determining user-friendliness (19:103-104). Before developing the formula, he made several comments about the concept of user-friendliness in general such as "nobody can define what user-friendly means, although many claim to know it when they see it" and "since every piece of software is presumably friendly to its author, every piece of software can be described as user-friendly" (19:101). In another comment he presents a simple definition of user-friendly: "30 minutes (or less) of training is required for the software to be usefully applied" (19:103).

The main focus of Raduchel's article is his formula based on the premise that "no system can be user-friendly except in the context of specific problems for specific users" (19:103). Raduchel's logic is that "A system is user-friendly if it solves problems reliably" and that the probability of solution, F, is the result of

> P_o - the probability that the user will find the set of steps to solve the problem
>
> p - the probability that the user can successfully execute each step
>
> n - the minimum possible number of steps in the solution. (19:103-104)

Raduchel uses the above variables to generate the following equation for the probability of solution:

$$F = (P_o) * (p^n) \qquad (1)$$

His requirement for being user-friendly is "that F be at or above some threshold probability value F_o, determined by the characteristics of the alternative systems" (19:104).

Raduchel also discusses the tradeoffs implied in the equation. For instance, if the number of steps is low the probability of finding the correct set of steps will be high but then only simple problems can be solved. If more complex problems are to be solved n will increase and P_o will decrease. The result is "the ease of use and ease of learning conflict". However, with training and experience, the user "will consider a system with fewer, but ... more complex steps to be more user-friendly". Then, as also mentioned by Simpson, to be user-friendly the system must grow with the user, being easy to learn and use in the beginning yet have the flexibility to skip novice steps and solve complex problems as the user gains expertise. (19:104)

Cost Estimating Expertise

A.D. Kazanowski, wrote an interesting article "Cost-Effectiveness Fallacies and Misconceptions Revisited," which tied the experience of a cost estimator to the quality of his estimates. He comments that the worth of a cost-effectiveness evaluation is

> closely correlated with the experience of the analyst. The validity of many evaluations was not constrained by the limitations of cost-effectiveness per se as much as by the ability of the analyst to avoid various pitfalls

> that tended to invalidate or at least bias the conclusions. (12:151)

He presents about two dozen problem areas including criteria selection, assuming all pertinent criteria can be quantified, using criteria because they are quantifiable or ignoring criteria because they are not quantifiable, and extrapolating the results of the evaluation beyond the relevant range (12). Since the ACEIT system is specifically designed for both novice and expert estimators, it will be interesting to discover if the documentation and structure of the system encourages a novice to either make or avoid the pitfalls noted above.

Statistics Package Accuracy

James W. Longley's article, "An Appraisal of Least Squares Programs for the Electronic Computer From the Point of View of the User", written in 1967, is still applicable today. The article illustrates that the procedures used by computers as they carry through their calculations can result in very large errors which may only be evident with certain data (14). Therefore, data which challenges the regression program will highlight programs which are not effective for all data even though they seem to be producing reasonable regression solutions for some data. Since the time constraints imposed on this research prevent every conceivable type of data from being tested on the ACEIT

STATPAK module, Longley's data should provide insight as to how well STATPAK handles a challenging data set.

Longley ran economic data (some of which is extracted in Appendix G) on a series of available programs on various computers (14:827). The data used was interesting:

> ... the means of the vectors of X and the mean of the total Y-variable end in round numbers, but also the elements in the product moments matrix ... ended in either a five or zero within nine decimals. ... While the determinant of the 6x6 product moments matrix was 5.7 septillions (25 digits to the left of the decimal), the determinant of the correlation matrix was 0.000 000 015 796 154 862, which proves that neither matrix is singular. (14:820)

If the matrix was singular, its inverse would not exist (due to the determinant equalling zero) and the regression equation could not be computed. However, regression equations could be computed for Longley's data, although the very small determinant helps highlight program and computer weaknesses. The fact that the product moments matrix ended in either a five or zero accentuated the differences produced by either rounding or truncating in the calculations.

Even more interesting than the characteristics of the data, were the results obtained from running that data on different computers with different programs:

> Many programs tested with identical inputs produced results which differed from each other in every digit for all multivariate equations run. In some instances the sign of the net regression coefficients were wrong. (14:827)

Although the same data inputs were being used, the differences in how the computations were actually accomplished (how digits were carried in the calculations, and whether rounding or truncating was used) produced a variety of resulting regression coefficients.

Longley compared his test program results against "values for some 165 equations carefully worked out on a desk calculator" which agreed with an available matrix inversion program for an IBM 1401 computer modified to carry matrix calculations to 40 digits (14:821-822).

It is the intent of this research to run Longley's data set through the ACEIT STATPAK program and compare the results to Longley's calculated values.

Comments on the Literature Reviewed

The unpublished reports of ACEIT along with the definitions of a decision support system and user-friendliness provide the background needed to evaluate the ACEIT system. It would be convenient to use Raduchel's simple "30 minutes (or less) of training" definition of user-friendliness. However, ACEIT is too involved to be usefully applied after only 30 minutes of training. The next choice would be Raduchel's quantitative measure. Unfortunately, for a program of ACEIT's size, it would be too difficult to collect the data needed to solve his equation, so Simpson's definition of user-friendliness, such as ease of use and documentation, will be used.

III. Methodology

Introduction

This chapter will review the steps taken to answer the investigative questions. Each section of the chapter is devoted to explaining the methodology used in answering a particular investigative question.

How User-Friendly is ACEIT?

The first research investigative question is:

> How user-friendly is ACEIT? Does it require extensive training?

The information provided in Chapter I and Chapter II will be used as the background against which to evaluate ACEIT's user-friendliness. This will include evaluating both the internal and external documentation of the program. Additionally, other users will be consulted for their opinions. As a further test of user-friendliness and the requirement for extensive training, this researcher will not attend the ESD training course. Therefore, this researcher will receive only the limited training offered by the ACEIT tutorial, the User's Guide, and discussions with other users. A one day trip to ESD/ACC will include some time for training if needed.

Part of the answer to this question will also be provided by the AFIT Graduate Cost Analysis students who will be briefly introduced to the system through a lesson

plan developed in support of question #5. If they can "quickly and effectively" be introduced to ACEIT, that will support the concept that the system is user-friendly and does not require extensive training.

Is Cost Estimating Expertise Required?

The second research investigative question is:

> Does proper use of ACEIT require cost estimating expertise or does it prompt even a novice user to generate accurate estimates?

The answer to this question was partially answered by Randall Bradley in his evaluation of the ACE module and recreation of an historical estimate (4). However, he used data available off-line which was simply input and calculated by ACEIT. In other words, he did verify that the ACEIT calculation routines work properly, but he did not verify that a novice would be correctly prompted by the system to make effective choices using the entire integrated system (the databases, the CERs, and STATPAK). Therefore, it is hoped that an historical ESD estimate can be replicated which allows/requires this novice estimator to use the entire system. If this is not possible, ESD and AFIT personnel knowledgeable about ACEIT will be interviewed as to their opinions on this question.

Is STATPAK Accurate and Reliable?

The third research investigative question is:

> Does the ACEIT Statistics Package give the same estimates and statistics as the Statistical Analysis System (SAS)?

This question will be answered by running data provided as samples in the ACEIT User's Guide as well as AFIT Graduate Cost Analysis courses through both STATPAK and SAS. Another test of STATPAK's accuracy will be to run the Longley Data Set through STATPAK and compare the results to Longley's answers. Since the results should be 99.9% the same, any differences will be investigated for cause.

As an expansion of this question, learning curve data will also be run through Captain Larry D. Hutchison's Microcomputer Program for the Solution of Learning Curve Computations (10). This program, written as a thesis project for the AFIT Master of Science in Systems Management, is now used regularly in AFIT courses.

Answering this question requires a working knowledge of STATPAK, SAS, and the microcomputer learning curve program.

Benefits and Problems of Air Force Implementation

The fourth research investigative question is:

> What are some of the potential benefits and problems to be avoided in successfully implementing ACEIT in organizations throughout the Air Force?

This question requires a working knowledge of ACEIT as well as some exposure to problems that may occur in implementation. This researcher will base an answer to this

question on interviews with ESD personnel who initiated ACEIT, and with AFIT, SSD, and BSD individuals who have either already implemented ACEIT or are considering it.

Is a Quick and Effective Introduction Possible?

The last research investigative question is

> Can ACEIT be quickly and effectively introduced to the AFIT Graduate Cost Analysis students who are unfamiliar with the system?

This question will be addressed by developing a lesson plan to introduce the 1989S AFIT Graduate Cost Analysis Class to ACEIT as part of their Cost Seminar. Following development of the lesson plan, it will be taught and feedback sought from the students. The objective of this introduction is not to make ACEIT experts of the students but rather to familiarize them with the system: to make them aware of ACEIT and its capabilities, and to give them some limited hands-on experience. The goal is that should the students encounter ACEIT at their next assignment (a likely scenario) they will be familiar with it.

IV. Findings

Introduction

This chapter details the result of the research regarding each investigative question. Each question is addressed in its own separate section. Conclusions and recommendations follow in Chapter V.

Question 1: How user-friendly is ACEIT ...

ACEIT is very user-friendly and it does not require extensive training, although training should be available to those who desire or need it.

The above conclusion is based not just on the personal experience of this researcher, but also on the opinions expressed in the unpublished reviews of ACEIT and on how well ACEIT met Simpson's definition of user-friendliness as outlined in Chapter II.

Personal Experience.

As mentioned earlier, this researcher did not attend a formal ACEIT training course but instead learned the system through the built-in tutorial, novice learning screens, and exercises provided by someone who had attended the course. This "training" proved sufficient to gain a working knowledge of the system. Although a brief 1-day visit with ESD ACEIT experts definitely refined the skills needed to fully utilize ACEIT, a working knowledge of ACEIT is

certainly obtainable from the system itself. An extensive training course should not be mandatory.

One can learn ACEIT on his own because it is very user-friendly. It would be nearly impossible to obtain a working knowledge of a system as involved as ACEIT on your own if it were not user-friendly. Throughout the process of building an estimate, ACEIT will prompt the user, even in the expert mode, if certain elements are missing or incorrectly entered. One can exit the system at any time or go to a help screen for further guidance. The system allows a user to easily correct mistakes and proceed on with the estimate. All in all, it was very easy to use.

Other Opinions.

Birkofer (3) and Bradley (4) confirmed this researcher's diagnosis that ACEIT was very user-friendly. Birkofer briefly reviewed each module of ACEIT and concluded that each was either "easy" or "very easy" to use (3). Bradley limited his review to the ACE module. Unfortunately, he had some difficulties initially using the system (4:23). However, these difficulties were not really with ACEIT but instead with its configuration at AFIT. The difficulties Bradley experienced in accessing the system were the same as those documented and experienced by the 1988S AFIT Graduate Cost Analysis Class. These problems, largely due to the use of a Z-248 microcomputer as a terminal, have been eliminated by the addition of numerous

VT-100 terminals (the preferred terminal to use with ACEIT) as well as a new release of ACEIT (and the User's Guide) which has improved documentation for using the system with a different terminal (such as a Zenith PC). Although the system could always be used with different terminals, different keystrokes were required and the initial documentation was hard to follow if a VT-100 was not being used. This created a frustrating environment where mistakes were made, not because they were actual estimating mistakes but because the incorrect key was being used. Even with the difficulties Bradley experienced, he concluded that ACEIT "on the whole, is fairly easy to use" (4:25).

One other comment Bradley made regarding the system should also be addressed here. In his recommendations, Bradley stated that ACEIT was "suited mainly for one person accomplishing an entire systems estimate. Although it could be possible to incorporate this model in a team estimating environment" (4:25). In contrast to Bradley's conclusion that ACEIT is mainly suited for one estimator, is evidence that ACEIT works very nicely with team estimates. According to Ms Margaret Weech, ESD/ACC ACEIT Program Manager, ESD has recently completely an Independent Cost Estimate (ICE) on the Cheyenne Mountain Upgrade using ACEIT (23). This large estimate was definitely a team estimate. Although the current version of ACEIT does not permit merging ACE files (as a future version will), ESD gave the estimators access

to an account holding only the Cheyenne estimate. This allowed estimators to work on the estimate within that account or copy it into their own account and then manually input final calculations into the main account. The ability to support team, as well as individual, estimates is more evidence of ACEIT's user-friendliness.

The 1989 AFIT Graduate Cost Analysis Class was able to experience ACEIT from the beginning without the frustrating terminal difficulties experienced by the previous class and Bradley. This class was an interesting test group because they came from varied cost and computer backgrounds. Some individuals were extremely computer literate, others had almost no computer experience. The same was true for their cost estimating experience. Some individuals entire cost estimating background was limited to their recent academic courses, others were considered experienced estimators before attending the AFIT program.

This difference in background as well as the briefness of the ACEIT introduction was definitely a test of ACEIT's user-friendliness. Evidence of ACEIT's user-friendliness is that with very little instruction the students were able to complete an entire full scale engineering development cost estimate. However, computer problems during the initial hands-on lesson, long delays caused by a heavy load on the time-shared computer (not necessarily the ACEIT class), and the depth of the estimating exercise made the time available

really inadequate. Based on the survey of the class (Appendix E) several students requested the introduction be lengthened. Others requested a review of the novice mode before doing the estimate (although this was available to them to review on their own). The students did not have a chance to experiment with the system in class before attempting the estimate. Even with these drawbacks, the overall consensus was that ACEIT was somewhat user-friendly. Additionally, several students commented they felt the system was very user-friendly and easier to use than they had originally thought it would be.

<u>According to Simpson ...</u>

ACEIT definitely meets Simpson's requirements for being user-friendly. As already detailed above, ACEIT is "easy to use, tolerant of operator errors, easy to learn, and acknowledges that human beings are imperfect creatures" (21:2).

The exceptionally clear and easy to understand ACEIT internal and external documentation also meets Simpson's requirements. The current release (version 2.5) and current User's Guide are excellent examples of what Simpson considers user-friendly. The system is designed to grow with the user by providing novice and expert modes. The internal documentation prompts respond according to the mode being used. The User's Guide is designed with several sections for the novice user. The ACEIT Introduction, the

ACE Tutorial, and STATPAK appendix are specifically geared toward the novice user and probably would not be referenced by an expert user at all. However, the guide is still valuable for those with a lot of estimating and/or ACEIT experience.

In summary, ACEIT appears to have been designed from the very beginning to be user-friendly by having various modes with appropriate documentation provided for users of different levels. An intermediate mode is planned but not currently available. Additionally, based on discussions with ESD ACEIT personnel, Tecolote Research, Inc has been very responsive to making requested (and funded) user-friendly improvements to the system (5).

Question 2 - Is Cost Estimating Expertise Required ...

Some cost estimating experience is necessary to be able to effectively use ACEIT, understand the User's Guide, and correctly select the appropriate models or cost factors for each WBS item. However, it is this researcher's opinion that extensive expertise is not required because the system does an excellent job of prompting a novice user.

An initial goal in attempting to answer this question was for this novice estimator to replicate an existing cost estimate from scratch using the ACEIT system. However, discussions with ESD Cost personnel quickly revealed that this was not possible (5). Time constraints, a lack of knowledge of ESD programs, a lack of knowledge of ESD

engineering personnel, physical distance from ESD, and changes in data over time all contributed to making this initial goal unattainable (5).

However, while this researcher was unable to replicate an estimate from scratch, as mentioned earlier Randall Bradley was able to accomplish a replication of ASD LIDAR by using available LIDAR cost data. This was different from replicating the estimate from scratch. Bradley did not search ACEIT's databases for analogous programs or use ACEIT's models. He simply input appropriate costs indicated from LIDAR data or off-line runs, or throughput equations such as ASD/RW Factors (4:117). The end result was that he validated the computational capabilities of the ACE module of ACEIT. When the same numbers were input into ACEIT the same estimate was generated. Referring to the estimate in base year dollars Bradley stated

> The cost estimate produced by ACE matched (WBS element by WBS element) the estimate I used as input. It should be noted that this was an expected outcome since all of my inputs were either direct throughputs or equations set up to produce specific answers. (4:16)

An interesting result of Bradley's estimate was that he validated the inflation calculations by identifying an error made in the original LIDAR then year dollar estimate.

> The Then Year estimate which ACE calculated did not match the ASD/AE LIDAR estimate that I had used as input. I traced the steps used in computing the ASD/AE estimate and concluded that his methodology was incorrect. After contacting the LIDAR estimator, he confirmed that his methodology was in error and that ACE computed the Then Year estimate correctly. (4:19)

So it can be concluded that given all the appropriate methodology a novice estimator can certainly use ACEIT to create an effective estimate. However, the question remains of whether a novice estimator can use ACEIT to create an estimate from scratch (where the estimator would have to determine the appropriate methodology to use).

ESD Cost personnel indicated the system was not intended to be used by individuals with no cost expertise, but instead that some expertise was required (5, 22). The ACEIT User's Guide does not specifically mention cost expertise but does comment

> Though tailored specifically to the ESD/ACC requirements, it is intended that this software be used by trained Program Office personnel to develop and maintain Program Office cost estimates in a manner totally consistent with accepted cost analysis standards, procedures, and formats. (13:Sec 2,1)

The guide does not define what exactly is meant by "trained" personnel (whether they are trained to operate ACEIT or trained in the area of cost estimation). AFIT faculty indicated that ACEIT could be dangerous if used by totally inexperienced personnel and that some cost estimating expertise was required (15). Captain Chris Voss (SSD) even commented that more then "some" cost estimating expertise was required (22).

The reason some cost expertise is required can be traced back to the fact that ACEIT is not an expert system. As mentioned in Chapter I, ACEIT will not tell a user what methodology to use. It may suggest alternatives, but the

user must determine which methodology is appropriate. ACEIT does not prevent an inexperienced estimator from making the mistakes noted in Kazanowski's article described in Chapter II (12). An estimator can still miss, misuse, or ignore pertinent criteria. Additionally, the system will not prevent an estimator from extrapolating beyond the relevant range. The system does provide comments as to what the relevant range is but the estimator can choose to ignore those comments.

ACEIT will provide support to an estimator. The CERs linked to specific WBS items, the definitions provided and the checks within ACEIT which identify missing variables all are geared to guide an analyst. However, the information provided within ACEIT is not complete, it is more like an executive summary. Before including a model or CER in an estimate, the estimator should first check the source documentation to ensure the model or CER is appropriate. Estimating with or without ACEIT, the same rule applies: an estimator must ensure his methodology fits the situation.

For a novice estimator, this can be confusing. ACEIT's sometimes brief documentation may not be sufficient to alert an inexperienced estimator to a potential problem. For instance, ACEIT includes two software cost estimating models: COCOMO and WICOMO. If the same data is input into both, different answers will result. Neither the ACEIT User's Guide nor the internal documentation make clear that

the Tecolote COCOMO program is an uncalibrated version of the intermediate COCOMO equations and the Wang WICOMO program is an uncalibrated version of the detailed COCOMO equations. This novice estimator originally assumed the two programs would provide the same estimates as REVIC (another COCOMO program - a calibrated version of the intermediate version) taught at AFIT. It was only after discussions with Capt Joe Dean of ESD/ACC that the differences between the programs were clarified (7). This type of mistake could easily be made by a novice estimator given the current internal and external documentation in ACEIT. However, if a novice estimator takes it upon himself to investigate everything he uses and not wait for the system to alert him, ACEIT can be a great guide. A novice must always remember that ACEIT will not provide all the answers.

Therefore in conclusion, ACEIT is designed to prompt novice estimators to help them make accurate estimates. However, some cost estimating expertise is required since ACEIT is not an expert system. It will aid an estimator, but the estimator still must make the critical choice of using the most appropriate estimating methodology.

Question 3 - Is STATPAK Accurate and Reliable?

The ACEIT statistical analysis module, STATPAK, appears to be just as accurate and reliable as SAS or the Hutchison Learning Curve program. Additionally, although not as powerful as SAS, STATPAK is definitely easier to use and

appears to have all the essential computational capabilities.

Four different sets of data were used to compare the statistical analysis capabilities of STATPAK and SAS. The first set was the practice data used as an example in the STATPAK section of the ACEIT User's Guide (Appendix G). The second set contained actual helicopter engine performance data but the engine cost data was modified to maintain proprietary data rights (Appendix G). The third set contained actual rocket engine performance data but again the cost data was modified to maintain proprietary data rights (Appendix G). Both the second and third data sets were provided by AFIT faculty and are used in AFIT cost classes. The last data set run was the Longley data set. This data was run on both STATPAK and SAS and the answers were compared to Longley's results.

The same linear and log linear regression equations and statistics were calculated by both SAS and STATPAK for the first three data sets; nonlinear regressions were not investigated. Sample outputs are provided at Appendices A and B. However, STATPAK rounds all figures to four decimal places while SAS carries the equations to eight decimal places. In some cases the STATPAK figures differed in the fourth decimal place, or for very large (eight digit) numbers in the units column. These differences are negligible. Since the figures were 99.9% the same (except

as noted below), the programs produce essentially identical answers.

STD RES on the STATPAK output appears to be the only confusing statistic. According to the User's Guide, this is the standardized residual and it is described as the residual divided by its standard deviation (13:App A,17). Neter, Wasserman, and Kutner, in Applied Linear Regression Models, define a standardized residual as the residual divided by the square root of the mean square error; while they define a studentized residual as the residual divided by its standard deviation (18:404-405). SAS produces figures for its studentized residual which are at least 97.4% the same as STATPAK produces for its standardized residual. It appears that the figures aren't 99.9% the same due to the fact that the SAS figures are carried to four decimal places versus only two for STATPAK. If the SAS figures were rounded to two decimal points, the figures would be 100% the same. Since the abbreviation STD could be for standardized or studentized, the STATPAK documentation and printouts should clarify what STD RES stands for and use a conventional name for the residual.

Another confusing characteristic of STD RES is how it handles an undefined value. Observation 6 on the sample SAS and STATPAK outputs has a residual value of zero as well as a standard error of the residual value of zero. Therefore, the STD RES calculation (dividing by zero) is undefined.

SAS simply prints a dot out, but STATPAK prints out 10,000. This is not explained in the ACEIT User's Guide, but 10,000 appears to be a default value. A more conventional notation such as a dot or an asterisk should probably be used.

An interesting result developed when the Longley data was run: neither SAS nor STATPAK gave the identical results that Longley calculated. The comparison of results is presented in Table 1. In contrast to the parameter estimates Longley developed when testing the data on various programs, at least both SAS and STATPAK always had the correct sign and at least were the right magnitude. In other words they were both in the ball park. Since an in-depth analysis of the calculations used by SAS and STATPAK in computing the least squares regression equations is beyond the scope of this research, the only conclusion that can be made is that SAS and STATPAK produce comparable results.

Table 1

Regression Parameters Estimated Using Longley Data

VARIABLE	LONGLEY (14:832)	SAS	STATPAK
INTERCEPT	-3482258.6330	-3493388.	-3423916.0000
X1	15.06187227	25.87507008	14.4961
X2	-0.03581917	-0.0389083	-0.0343
X3	-2.02022980	-2.05617	-1.9971
X4	-1.03322686	-1.04138	-1.0264
X5	-0.05110410	-0.0269874	-0.0557
X6	1829.15146461	1833.45774	1801.8125

STATPAK was much easier to use than SAS. The user does not have to remember specific commands and their peculiar formats or create a program to produce an output. STATPAK asks the user in english what output he desires and it is simply produced.

The only capability STATPAK lacked which might be desirable is that of running correlation matrices on a set of variables. STATPAK will however, provide scatterplots of the variables specified.

STATPAK also produced learning curve results comparable to those produced by the Hutchison program. Two different data sets provided by AFIT faculty were used to compare the two programs (Appendix G). Both weighted and unweighted unit curve calculations were made. Sample outputs are provided at Appendices C and D. Again, the last digit was different in some cases but this could be due to one program running on a microcomputer and one running on a mainframe computer which may result in different rounding of the calculations. An example is Data Set 2: 1) STATPAK generated a learning curve with Unit 1 cost of 1783.923 and slope of 82.73%, while 2) Hutchison generated a learning curve with Unit 1 cost of 1784.13 and slope of 82.72%. These figures are 99.9% the same. Even with the slight difference in unit one cost and slope the two programs resulted in comparable predicted costs for a future lot. Using their respective parameters to predict a new lot for

units 252-311: 1) ACE using STATPAK parameters predicted a lot cost of 22900.2, 2) Hutchison predicted a lot cost of 22889.54, with 95% confidence interval limits of 21590.00 - 24267.30 (again the figures are 99.9% the same).

It should be noted that for doing a lot of learning curve analysis (working with deletions, additions, or breaks in production) the Hutchison program is more flexible than STATPAK. The Hutchison program contains a Calculator option which allows the user to easily vary first unit value, slope, given unit/lot, or to change from unit to cumulative average formulation (or vice-versa) (10:61).

Question 4 - Benefits/Pitfalls of Air Force Implementation

This researcher believes that overall the Air Force-wide implementation of ACEIT will be good. It should be made clear that at this point in time the term "Air Force-wide implementation" refers only to research and development organizations. It is not this researcher's intent to infer ACEIT should be implemented at every base in the Air Force. However, even though there are specific benefits to be gained from this implementation there are also pitfalls to be avoided or the implementation will be a failure.

Benefits.

Air Force-wide implementation of ACEIT has numerous benefits which should make it very helpful to cost estimators.

As discussed in Chapter I, ACEIT is essentially an architecture and as such can be tailored to fit specific organizational requirements. This is the beauty of the ACEIT system. Even though the system was originally designed for ESD. It's databases, WBSs, CERs, and models can be exchanged for those of interest at any organization. For instance, Space Systems Division (SSD) has already included its own WBS with links to CERs "blessed" by SSD/ACC for use in estimating (22). In addition, a Space Systems Division specific model has been added with plans to add additional models in the future (22).

As far as databases are concerned, efforts are underway to standardize the format of data which may be of use to several organizations (22). This would mean that common data could be collected in one location and yet be usable by numerous organizations.

With many organizations using the same ACEIT program, organizations could also share data. Since the data formats would be the same, data collected and normally used at one location, could easily be transferred to another organization and used on their ACEIT system.

Another benefit of organizations using a common program is that personnel transferring between different organizations will not have to learn a new system. Personnel will already be familiar with the system. The ACEIT output may also be a benefit. With the common ACEIT

output, estimators should have an easier time understanding each other's work. Additionally, the ACEIT output format helps to provide a clear history of the estimate with ample room for references and notepad comments.

Pitfalls.

Unfortunately the beauty of the ACEIT system (being able to fill the system with organization specific data) may also be its major potential pitfall. The data input at each location must be carefully screened in terms of its appropriateness and in terms of measurement and typographical errors. In this case, "data" includes data, CERs, and models. For instance, the unique WBS and corresponding CERs linked to those WBS items must be very carefully examined (5,2). At ESD, the Technical Director of Cost Analysis personally reviewed each CER linked to a WBS item as well as the text describing each CER (5). Only CERs or factors agreed upon by the senior analysts in ACC were included as WBS linked CERs (5). BSD is also carefully screening their CERs (9). Although ESD plans to maintain configuration control of the ACEIT program itself, they cannot possibly maintain configuration control of the unique data input into the system at each location (5). This will be the responsibility (most likely) of ACC at each location. To maintain high quality estimates with ACEIT, requires that the data initially input into ACEIT be high quality and that the data be continuously updated to avoid obsolescence.

Training is another potential pitfall for ACEIT. Although the system is user-friendly and it is not difficult to gain a working knowledge of ACEIT, some individuals may desire or require additional training. ESD currently hosts 5-day training workshops taught by ESD personnel (5). SSD on the other hand has contracted out to have Tecolote Research Inc provide a training workshop (22). Whatever the situation, some training should be available to those who need it or the ACEIT system will not be used effectively.

An area which may also be a pitfall if not carefully controlled is that of proprietary data. User access to the various data sets or models which ACEIT includes must be carefully controlled so that only authorized personnel have access to proprietary data. The proprietary data issue must be considered if contractors are to have access to the ACEIT system. For instance, TRW works closely with BSD personnel. According to Mr David Hanson, Chief of Cost, BSD/ACC, TRW has a nondisclosure clause in their contract (9). Additionally, BSD is only including data in their database which TRW may access (9). At ESD, task order contractors may not access other contractor's proprietary CERs (23).

Question 5 - Is a Quick and Effective Introduction Possible?

It is possible to quickly and effectively introduce ACEIT to AFIT Graduate Cost Analysis students.

In contrast to the five-day course being offered at ESD and the two and a half day course being offered at SSD, this

brief introduction only included four one-and-a-quarter-hour periods. The introduction was not intended to accomplish the same level of detail presented in longer courses, but it was still a challenge to introduce the subject in the significantly reduced time-frame. The goal of the introduction was to familiarize the students with ACEIT. Although a simple briefing could have informed them of ACEIT's capabilities, this researcher considered some hands-on experience mandatory. Therefore, only one out of four periods were in the lecture format. The first period was used to brief the students on ACEIT, its capabilities, and what to expect in the next three periods. The second, third, and fourth periods provided hands-on training and guidance. Each student was to follow through the well documented Tutorial in the ACEIT User's Guide. Unfortunately, computer problems during the first period resulted in only two students being able to use their terminal while the other seven students watched. This resulted in very little learning. However, during the next two class periods, students were able to work through an estimate based on an ESD training exercise (Appendix F).

Several lessons were learned from this experience. First, the ACEIT Tutorial is an excellent learning tool. However, the size and diversity of the tools available with ACEIT make it very difficult to cover the Tutorial in one classroom period. Additionally, as evident from the

students' answers to the questionnaire (Appendix E), computer background and cost estimating experience play a part in how quickly the ACEIT system is grasped. Although the hands-on experience reinforces what ACEIT does, it also requires the students to become adept at moving around ACEIT. Just learning to use the ACEIT commands takes some time and is more difficult for students with little computer expertise. Before covering the Tutorial, some time should be devoted to just explaining some of the basic ACEIT commands. This would also help students learn how to recover if they hit the wrong command. Also a reference card with basic commands for moving around ACEIT should probably be distributed. The cost estimating experience helped students understand the flow of steps needed to complete the estimate with ACEIT. Those with less cost estimating experience needed more time and more direction to accomplish the estimating exercise. These students probably could have worked through the estimate themselves using the novice mode, but the pace of the brief introduction did not allow enough time to work through the novice mode in class.

Although the students were introduced to ACEIT, if an estimate is going to be accomplished, more time must be allotted to ensure adequate understanding of the many facets of this complex system. Additionally, even with an expanded schedule it is recommended that the exercise be shortened somewhat. The exercise used and a recommended shortened

version are included in Appendix F. A suggested expanded lesson schedule is:

Lesson 1 - Briefing with computer demonstration.

Lesson 2 - Hands-on. Basic ACEIT commands and Tutorial through the WBS.

Lesson 3 - Hands-on. Finish Tutorial.

Lesson 4 - Hands-on. Start exercise.

Lesson 5 - Hands-on. Finish exercise.

Another lesson learned, is to have alternate plans if the computer equipment fails to work properly. The hands-on experience is essential, but since classes cannot just be canceled due to computer malfunctions, backup plans should be available.

A last lesson learned would be to introduce the ACEIT system earlier in the graduate program. The timing of this particular introduction unfortunately coincided with thesis preparation (which definitely took priority in the students' minds). With a heavy thesis load, students are unlikely to spend significant time on ACEIT outside of class. To be really effective during the class, the students should at least read through the Tutorial and exercise ahead of time. Another benefit of introducing the system earlier in the program is that students could then use it in support of some of their other classes and become even more familiar with it as they did.

V. Conclusions and Recommendations

Introduction

This chapter summarizes the conclusions identified in Chapter IV and makes some recommendations regarding further research and ACEIT documentation.

Conclusions

The ACEIT system is very user-friendly. Both the internal and external documentation are easy to follow. The availability of both an expert and a novice mode tailors the system's prompts to the user's ability. The documentation is so good that it enables a user to obtain a basic working knowledge of the system without extensive training. However, to fully utilize all of ACEIT's capabilities quickly, training should be available for those that desire or need it.

Although the system is user-friendly, it still requires some cost estimating expertise. ACEIT is not an expert system. It does not make decisions for the cost estimator; it only provides support. A user must have some background in cost estimating to fully utilize ACEIT's capabilities and to be able to wisely select from any options ACEIT may provide. Even the novice screens will only support an estimator who already has some experience.

The STATPAK module appears to be at least as accurate as SAS and the Hutchison Learning Curve Program.

Essentially the same estimates and statistics were produced by STATPAK and the other programs. When the Longley data set was used STATPAK and SAS produced essentially the same parameter estimates although neither matched the results identified by Longley.

The major benefit of ACEIT may also be it's major potential pitfall in implementing the system throughout the Air Force research and development community. The fact that ACEIT is a framework which can be filled with organization unique data puts a great responsibility on organizations to quality control that data. ESD will maintain quality control of the ACEIT program itself. However, each organization must ensure the work breakdown structures, data, and cost estimating relationships put into ACEIT's databank are initially accurate and accurately documented, as well as being accurately updated on a continual basis.

Results of the brief introduction of AFIT Graduate Cost Analysis students to ACEIT indicate that ACEIT can be quickly and effectively introduced. This does not mean that the AFIT students are now ACEIT experts, they have only been introduced to the system. The introduction was a combination of a briefing and hands-on experience using ACEIT to complete the Tutorial and an estimating exercise. However, the short four-period introduction was too fast paced for those with little computer experience or little cost estimating experience. An expanded introduction would

provide more time to explore ACEIT's capabilities. However, even an expansion to five periods could not provide the level of detail currently offered in the ESD five-day course. The five-period introduction would still be an introduction.

Recommendations

Following from the discussion of the ACEIT introduction to the AFIT students, the first recommendation is to expand the number of lessons from four to five, and reduce the complexity of the estimating exercise. This will give the students more time to work with ACEIT. It is not recommended that the introduction go to a briefing format only. The hands-on experience is essential if the students are to fully grasp the potential of the ACEIT system.

Throughout this research a few recommendations surfaced for improvements to ACEIT and to the User's Guide. One additional computational capability desired is to be able to input the inflation indices used in calculating the then year estimates. Implementing this suggestion would also include printing the indices out as part of the ACE documentation. For large estimates, it would be helpful to be able to merge files. For example, one estimator might be working on WBS items 1-25 while another estimator works on 26-50. It would be nice to be able to merge their files for a final product. In addition to using a more conventional notation for undefined values, suggested STATPAK

enhancements include an option to calculate a correlation matrix on the variables in a data set as well as a connection to a graphics capability. The graphics interface could be resident within ACEIT or simply be a capability to format an output file to be used with an existing offline graphics package such as Harvard Graphics.

The most asked for improvement to the User's Guide was an index. Although the chapter table of contents are quite thorough, an index would be very helpful for the novice ACEIT user. Another convenient reference feature might be a keystroke template to lay over the keyboard. Additional information should be provided on the models connected to ACE (for example source references). Some are well commented, others are not. Further explanation of the sequential/disjoint learning curve routine would also be helpful (again including a source reference). Lastly, the confusing residual notation mentioned in the findings section of this thesis should be clarified.

Further research with ACEIT should investigate the technicalities involved with creating the organization specific databases. Several concerns surfaced during this research as to the benefit of ACEIT without the organization-specific databases if the cost of obtaining and maintaining those databases becomes prohibitive. Additional research should also attempt to replicate an estimate from scratch using ACEIT to determine if the internal linkages to

CERs, models, and factors can accidentally hurt instead of help an estimator. For instance, one could compare the results of two equally qualified analysts accomplishing the same estimate, one using ACEIT and one not using ACEIT.

Appendix A: Sample SAS Regression Output

DEP VARIABLE: A

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	59654620.98	29827310.49	6.996	0.0494
ERROR	4	17054746.45	4263686.61		
C TOTAL	6	76709367.43			

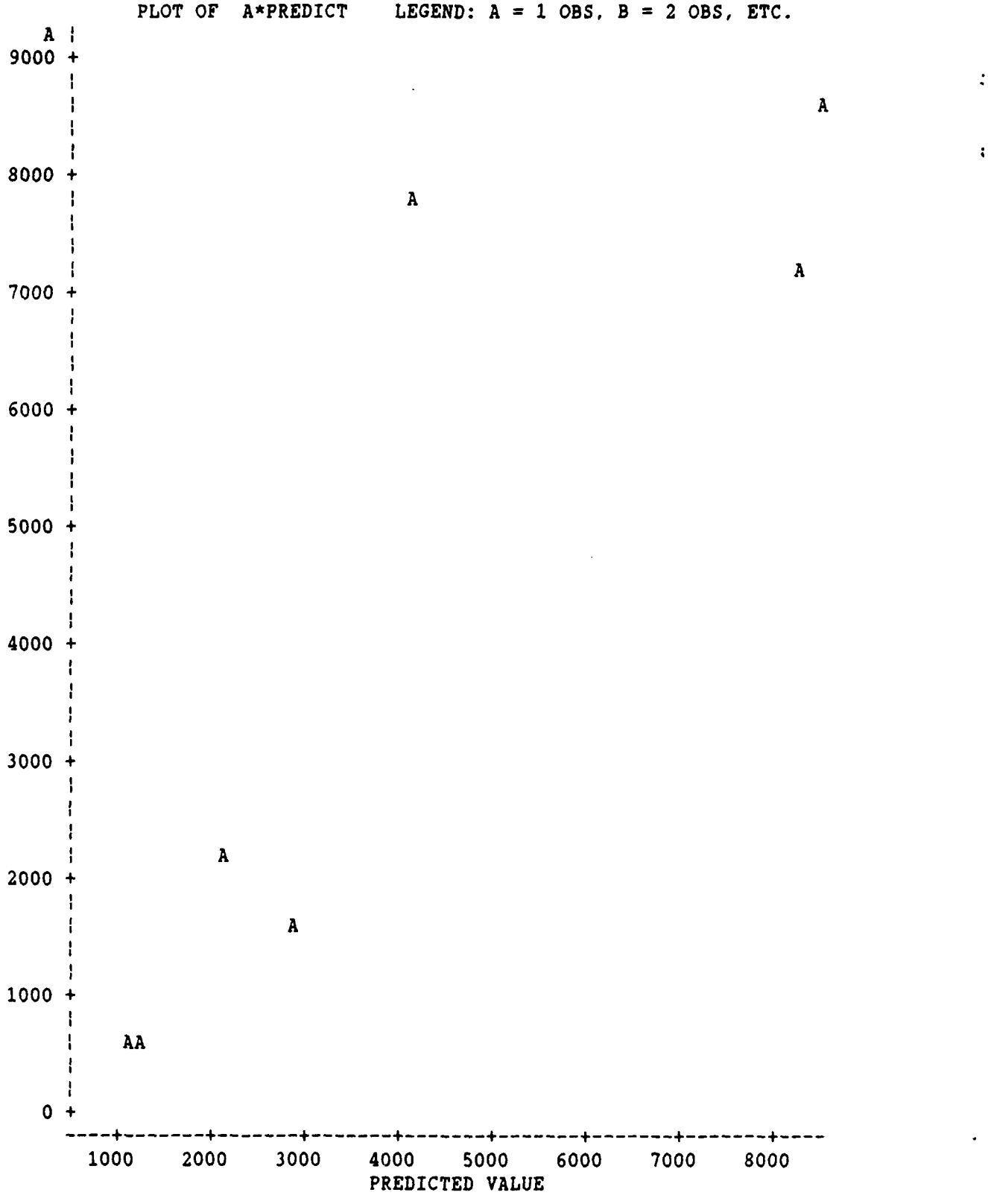
ROOT MSE	2064.87	R-SQUARE	0.7777
DEP MEAN	4063.714	ADJ R-SQ	0.6665
C.V.	50.81237		

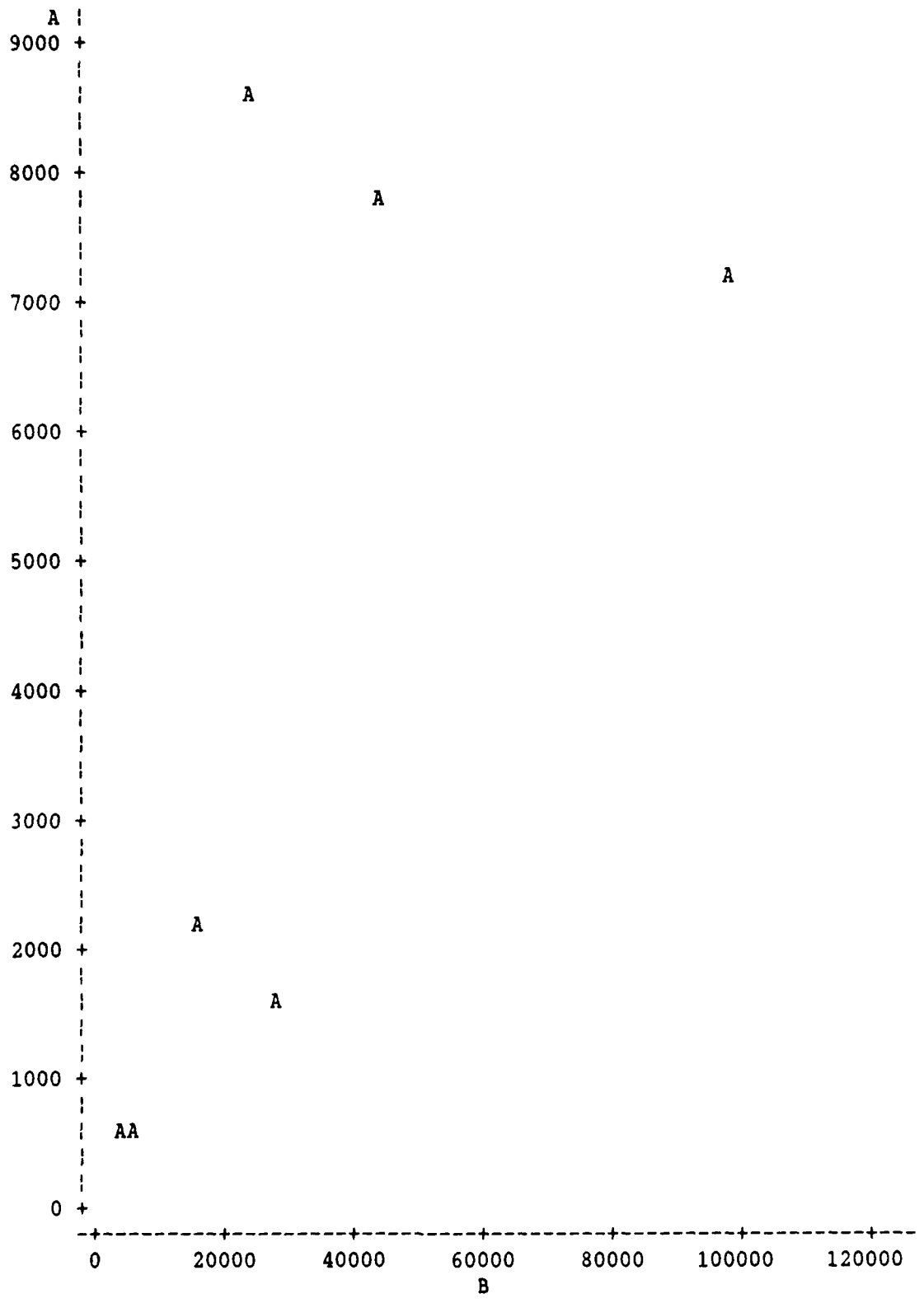
PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	849.33440483	1195.12748	0.711	0.5165
B	1	0.07576375	0.02602999	2.911	0.0437
C	1	5918.77755	2242.47918	2.639	0.0576

VARIABLE	DF	STANDARDIZED ESTIMATE
INTERCEP	1	0
B	1	0.68995102
C	1	0.62565428

OBS	A	RESID	PREDICT	STUDENT
1	7119	-1190.3	8309.26	-1.5251
2	642	-592.7	1234.74	-0.3398
3	542	-631.8	1173.75	-0.3640
4	7755	3614.3	4140.66	1.9395
5	2267	143.4	2123.60	0.0779
6	8555	0.0	8555.00	.
7	1566	-1343.0	2908.97	-0.7144


PLOT OF A*PREDICT LEGEND: A = 1 OBS, B = 2 OBS, ETC.
A
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
AA
1000 2000 3000 4000 5000 6000 7000 8000
PREDICTED VALUE


PLOT OF A*B LEGEND: A = 1 OBS, B = 2 OBS, ETC.
A
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
AA
0
20000
40000
60000
80000
100000
120000
B

Appendix B: Sample STATPAK Regression Output

***** Linear Model *****
***** With Intercept *****

THE REGRESSION EQUATION IS:
A=849.334+0.076*B+5918.777*C

VARIABLE	COEFFICIENT	STD DEV OF COEF	T-STATISTIC (COEF/S D)	COEF NOT 0 (95% PROB)
INTERCEPT	849.3342	1195.1274	0.71	2.776
B	0.0758	0.0260	2.91	2.776
C	5918.7773	2242.4790	2.64	2.776

STD ERROR (SE) = SQRT(MSE) = 2064.9

R-SQUARE = 77.77 %
R-SQUARE = 66.65 %, ADJUSTED FOR DEGREES OF FREEDOM (DF)

ANALYSIS OF VARIANCE (IN FIT SPACE)

DUE TO	DF	SUM OF SQUARES(SS)	MEAN SQ = SS/DF	F-STAT	COEF NOT 0 (95% PROB)
REGRESSION	2	59654624.000	29827312.000	7.00	6.94
RESIDUAL(ERROR)	4	17054746.000	4263686.500		
TOTAL	6	76709368.000			

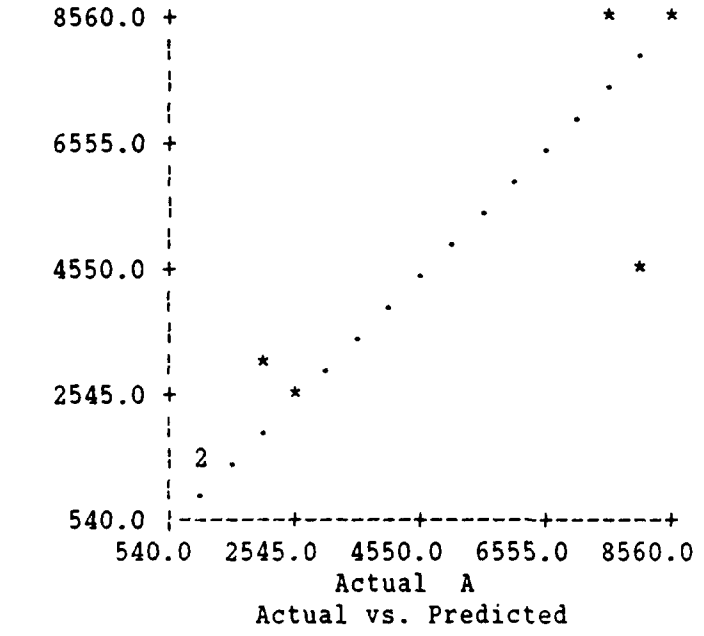
FURTHER ANALYSIS OF VARIANCE (IN FIT SPACE)
SS EXPLAINED BY EACH VARIABLE WHEN ENTERED IN THE ORDER GIVEN

DUE TO	DF	SEQUENTIAL SS
REGRESSION	2	59654624.000
B	1	29952156.000
C	1	29702466.000

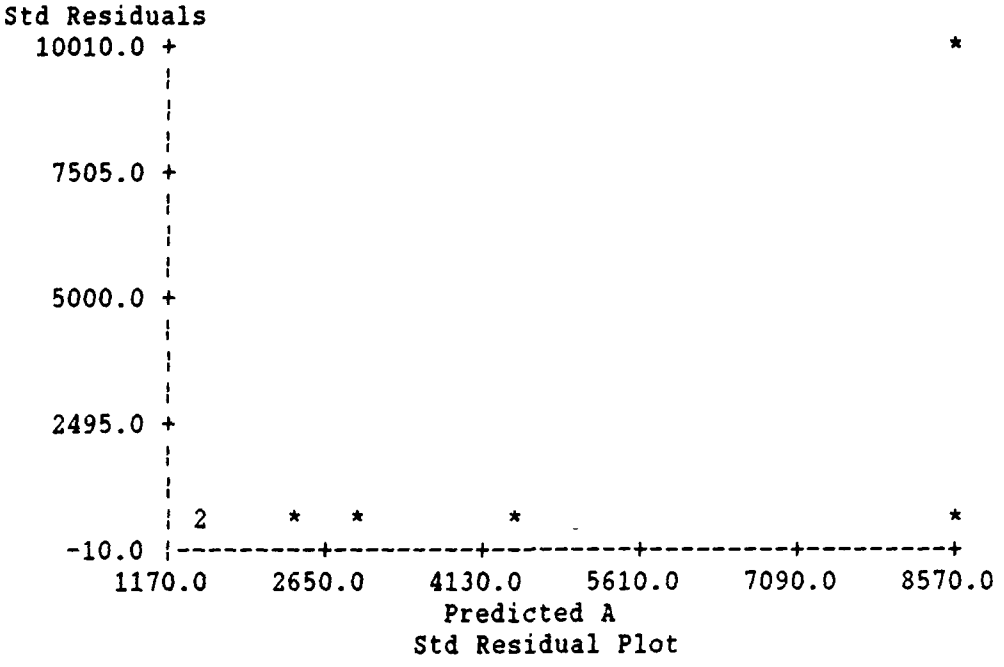
OBS	Y VALUES B	A	PREDICTED Y VALUE	STD DEV PRED Y	RESIDUAL	STD RES	
1	98463.00	7119.00	8309.262	1911.706	-1190.262	-1.53	
2	5087.00	642.00	1234.744	1105.217	-592.744	-0.34	
3	4282.00	542.00	1173.755	1118.883	-631.755	-0.36	
4	43442.00	7755.00	4140.664	889.411	3614.336	1.94	
5	16819.00	2267.00	2123.605	937.128	143.395	0.08	
6	23585.00	8555.00	8555.000	2064.870	0.000	10000.00	R
7	27185.00	1566.00	2908.972	854.453	-1342.972	-0.71	

SE = 2064.870, MEAN = 4063.71, COEF OF VAR = 50.81% IN UNIT SPACE
R DENOTES AN OBSV WITH A LARGE STD RESIDUAL

DURBIN-WATSON STATISTIC = 1.89



Actual vs. Predicted



********** Percentage Error Table **********

Observations	Actuals	Predicted	Residuals	% Errors
1	7119.00	8309.26	-1190.26	16.72
2	642.00	1234.74	-592.74	92.33
3	542.00	1173.75	-631.75	116.56
4	7755.00	4140.66	3614.34	-46.61
5	2267.00	2123.60	143.40	-6.33
6	8555.00	8555.00	0.00	0.00
7	1566.00	2908.97	-1342.97	85.76
Avg (Arith)	4063.71	4063.71	0.00	36.92%
Avg (Absolute)			1073.64	52.04%

Average Actual (Avg Act) in Unit Space.....	4063.71
Standard Error (SE) in Unit Space.....	2064.87
Root Mean Square (RMS) of % Errors.....	67.6%
Mean Absolute Deviation (MAD) of % Errors.....	52.0%
Coef of Variation based on Std Error(SE/Avg Act).....	50.8%
Coef of Variation based on MAD Res (MAD Res/Avg Act)..	26.4%

Appendix C: Sample Hutchison Program Learning Curve Output

File Name = hmwk1
Total number of lots = 7

Lot	First Unit	Last Unit	Total Lot Cost
1	1	8	2312.00
2	9	24	2672.00
3	25	50	3120.00
4	51	82	3040.00
5	83	122	3000.00
6	123	172	3500.00
7	173	232	3660.00

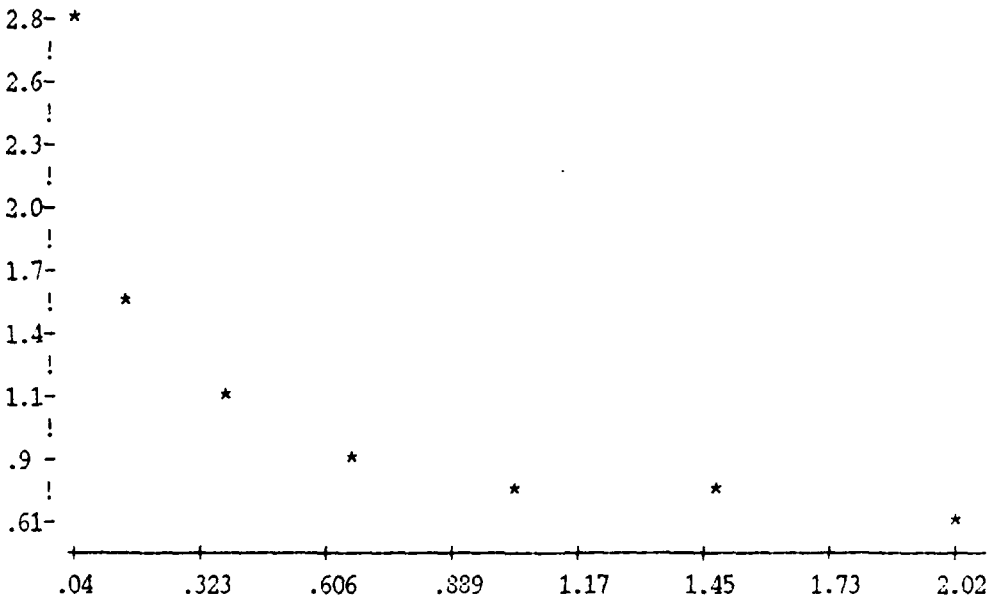
File name = hmwk1
Total number of lots = 7

Unit curve - ordinary least squares

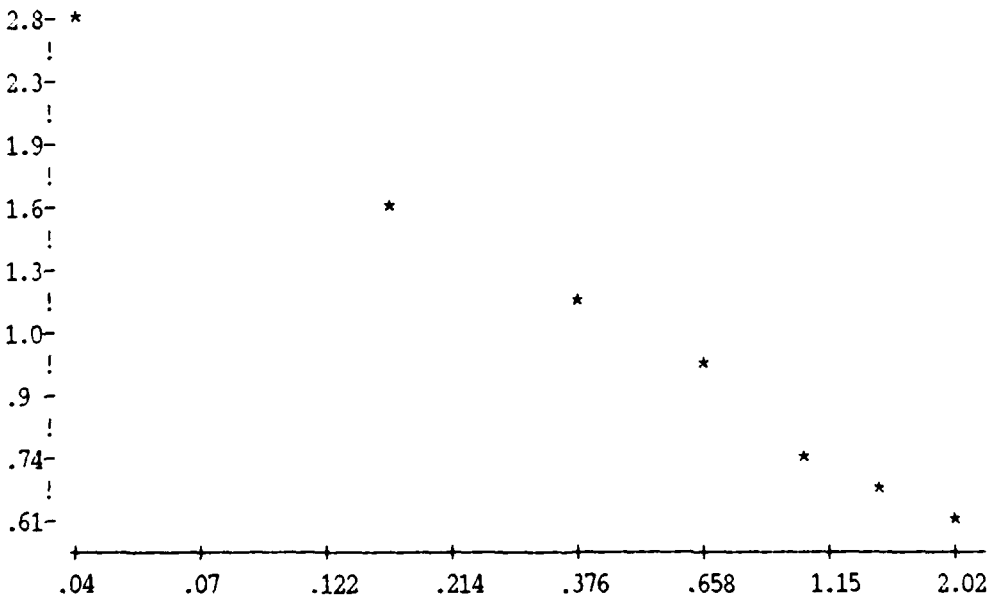
First unit value = 473.45
Slope coefficient = -.386817
Learning curve slope = 76.48
Coefficient of correlation = -0.998788
Coefficient of determination = 0.997578

File Name = hmwk1
Total number of lots = 7

Lot	Actual Total Cost of the lot	Predicted Total Cost of the lot	Difference	Percentage Difference
1	2312.00	2347.64	-35.64	-1.5
2	2672.00	2620.67	51.33	2.0
3	3120.00	3063.77	56.23	1.8
4	3040.00	3003.42	36.58	1.2
5	3000.00	3169.91	-169.91	-5.4
6	3500.00	3439.08	60.92	1.8
7	3660.00	3648.52	11.48	0.3



LEARNING CURVE - ARITHMETIC PLOT - COSTS = 1 * 100 UNITS = 1 * 100



LEARNING CURVE - LOG LOG PLOT - COSTS = 1 * 100 UNITS = 1 * 100

Appendix D: Sample STATPAK Learning Curve Output

*****Learning Curve Unit Theory*****

THE REGRESSION EQUATION IS:
UNIT COST=473.324*(CUM QTY^-0.387)
(T1 = 473.324, Slope = 76.48%)

VARIABLE	COEFFICIENT	STD DEV OF COEF	T-STATISTIC (COEF/S D)	COEF NOT 0 (95% PROB)
INTERCEPT	6.1598	0.0344	179.04	2.015
CUM QTY	-0.3868	0.0085	-45.34	2.015

Note: A 5% cut-off point is listed for using one-sided test in learning curve applications.

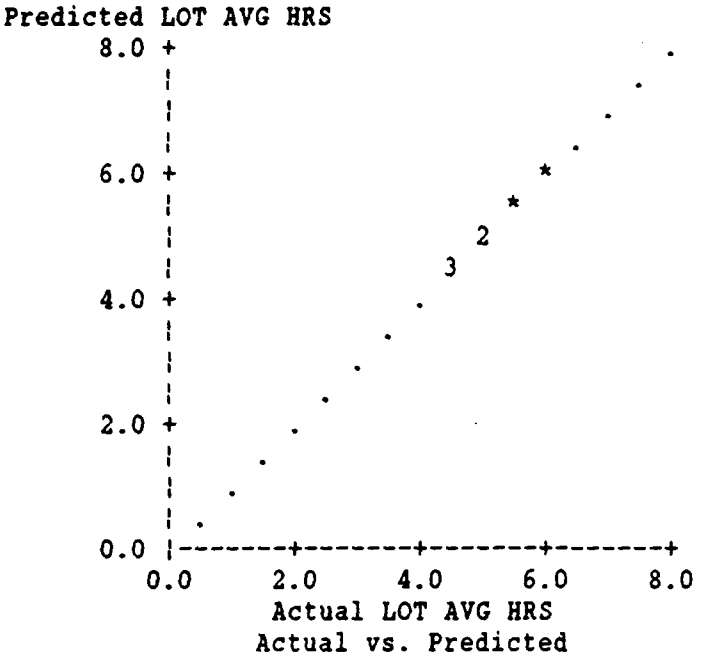
STD ERROR (SE) = SQRT(MSE) = 0.0298

R-SQUARE = 99.76 %
R-SQUARE = 99.71 %, ADJUSTED FOR DEGREES OF FREEDOM (DF)

ANALYSIS OF VARIANCE (IN FIT SPACE)

DUE TO	DF	SUM OF SQUARES(SS)	MEAN SQ = SS/DF	F-STAT	COEF NOT 0 (95% PROB)
REGRESSION	1	1.829	1.829	2055.58	6.61
RESIDUAL(ERROR)	5	0.004	0.001		
TOTAL	6	1.834			

SE = 0.030, MEAN = 4.69, COEF OF VAR = 0.64% IN LOG SPACE
Warning: Observation(s) with large std residual(s)
found in your data set, Check input data!!



********** Percentage Error Table **********

Observations	Actuals	Predicted	Residuals	% Errors
lot 1	289.00	293.48	-4.48	1.55
lot 2	167.00	163.78	3.22	-1.93
lot 3	120.00	117.83	2.17	-1.81
lot 4	95.00	93.86	1.14	-1.20
lot 5	75.00	79.25	-4.25	5.66
lot 6	70.00	68.78	1.22	-1.74
lot 7	61.00	60.81	0.19	-0.31
Avg (Arith)	125.29	125.40	-0.11	0.03%
Avg (Absolute)			2.38	2.03%

Average Actual (Avg Act) in Unit Space.....	125.29
Standard Error (SE) in Unit Space.....	3.35
Root Mean Square (RMS) of % Errors.....	2.6%
Mean Absolute Deviation (MAD) of % Errors.....	2.0%
Coef of Variation based on Std Error(SE/Avg Act).....	2.7%
Coef of Variation based on MAD Res (MAD Res/Avg Act)..	1.9%

Appendix E: ACEIT Questionnaire

1. Prior to this lesson did you have any experience using ACEIT? If so, how much?

2. What is your cost estimating experience other than this AFIT Graduate Program?
   None ____ Some ____ Moderate _____ Extensive _____

3. What is your level of computer expertise?
   None _____ Some ____ Moderate _____ Extensive _____

4. Did you feel this introduction to ACEIT was
   Too Brief _____ About Right _____ Too Long _____

5. Would you have felt comfortable doing the tutorial exercise on your own (without classroom assistance)?
   Yes _____ No _____

6. Is ACEIT's external documentation (check all that apply)
   Readable ___ Helpful ___ Adequate ____ Excellent ____
   Difficult _____ A Waste _____ Well organized _____
   Thorough _____ Not broad enough _____ Confusing ___

7. Is ACEIT's internal documentation (check all that apply)
   Helpful ____ Confusing _____ Thorough _____
   Adequate _____ Inadequate _____ Excellent _____

8. How user-friendly do you feel ACEIT is?
   Not at all _____ Somewhat _____ Very _____

9. Will this brief intro help at your next assignment?
   Yes _____ No _____ Don't Know _____

10. What would you like to have added/deleted from this introduction?

11. What features do you think should be added to ACEIT?

12. Other Comments

Appendix F: ACEIT Lesson Plan

PERIOD 1:

Briefing with slides which covers ACEIT background, each of the various ACEIT modules, and an introduction to the Tutorial (including the configuration of the system at AFIT and assigning user codes to provide access to the system).

Handouts include: ACEIT User's Guide and a printout of the Tutorial documentation as an example.

PERIOD 2:

Hands-on experience. Walk the students through the Tutorial (with each student on their own terminal). Point out some features of the system not illustrated by the tutorial exercise (importance of indenture in building the WBS, defining a WBS item, commenting on the notepad, examining the definition provided for a CER in the ACE CER library). Highlight things which might be different in the WHIZBANG exercise.

Handouts include: ACEIT Tutorial Notes on how to access the system and receive a printout with the current AFIT configuration, the WHIZBANG exercise for the following periods, and the ACEIT Questionnaire.

PERIOD 3:

Hands-on experience. Assist students in completing the attached WHIZBANG exercise. Work up to the first ACDB search in the ACE methodology screen.

PERIOD 4:

Hands-on experience. Continue assisting students in completing the WHIZBANG exercise. Work through obtaining a printout of the complete documentation. Collect the questionnaires.

WHIZBANG EXERCISE

The WHIZBANG is a ground radar system being procured for the Air Force. Only Full Scale Development is being considered. The plan is to buy two prototypes.

The Prime Mission Product includes:

A. Radar Hardware

B. Operational Software
   CSCI #1 - Tracking
   CSCI #2 - Display

DO NOT include:
Operational site Activation;
Common Support Equipment;
Industrial Facilities;
Warranty;
Training;
or Software Engineering/Project Mgmt (already included in COCOMO)

OTHER INFORMATION

The estimate should be developed in BY$89 ($M).

Use 15% as the default G&A.

Use 12% as the default fee.

Development planned for 1 Feb 89 - 30 Sep 91.

METHODOLOGY

For the Radar Hardware:

Use the BBEST System Development Cost Model. Watch the units.
The inputs are:
UC100 Production cost: 1107 ($86 in K)
contractor experience: high
system definition: good
NOT a joint service effort

For the Operational Software:

Use COCOMO. Assume all new code.
The inputs are:
Average rate/manmonth is $10000 ($87)
for Tracking:
19500 DSI
embedded
all nominal except -
RELY - very high
Database Size - high
Complexity - high
Execution Time - very high
Schedule - low

for Display:
14700 DSI
embedded
all nominal except -
RELY - very high
Database Size - high
Complexity - high
Execution Time - high
Schedule - low

For Software Integration & Checkout - 20% of all CSCI costs. DO NOT include dollar units or year as this will be calculated in Base Year dollars.

Use Kanter Factors for PMP I&A and Peculiar Support Equipment.

A throughput from the Program Office tells us that SPO Support will be $4.7M ($89).

An engineering assessment for Engineering Change Orders (ECOs) indicates using 10% of the FSED WHIZBANG system cost.

Develop a CER for System Test and Evaluation using ACDB cost information for FSED radar programs except programs 3, 6, 8, 9, 12, 13. Search by Name, not Text. If you choose a Log - Log regression include the following conversion factor (this will not be required in the SEP 89 release of ACEIT):
PMP = (PMP_F * 1000) / 1.1364

Manload System Engineering/Project Management. Use user defined variables to make sensitivity analysis easier. (Include these variables in your equations, then do a methodology check and let ACEIT add them to the bottom of the WBS where you can then put in numerical values). An engineering assessment indicates:
people - 24
months - 32
rate/person/month - $2K ($89)

Data costs are analogous to the Berlin Radar (Templehof) program.

ADJUSTMENTS

Check the Adjustments workscreen to ensure all appropriate G&A and fees have been included. ie. Do BBEST and COCOMO include G&A and fees? Does Software Integration & Checkout need G&A and fees added or are they already included?

PHASING

Use a 65/45 (65% spent at 45% complete) Beta curve at the total program line. Medium peakness is appropriate and the start and end dates are the same as the FSED dates. The only exception to this is that ECO's and SPO support should be phased using percent obligated as follows:

	89	90	91
ECOs	10	50	40
SPO Support	25	40	35

SHORTENED WHIZBANG EXERCISE

The WHIZBANG is a ground radar system being procured for the Air Force. Only Full Scale Development is being considered. The plan is to buy two prototypes.

The Prime Mission Product includes:

A. Radar Hardware

B. Operational Software
   CSCI #1 - Tracking (expand to get this)
   Software Integr/Checkout

DO NOT include:
Operational site Activation;
Common Support Equipment;
Industrial Facilities;
Warranty;
Training;
or Software Engineering/Project Mgmt (already included in COCOMO)

OTHER INFORMATION

The estimate should be developed in BY$89 ($M).

Use 15% as the default G&A.

Use 12% as the default fee.

Development planned for 1 Feb 89 - 30 Sep 91.

METHODOLOGY

For the Radar Hardware:

Use the BBEST System Development Cost Model. Watch the units.
The inputs are:
UC100 Production cost: 1107 ($86 in K)
contractor experience: high
system definition: good
NOT a joint service effort
Note above - 2 prototypes.

For the Operational Software:

Use COCOMO. Assume all new code.
The inputs are:
Average rate/manmonth is $10000 ($87)
for Tracking:
19500 DSI
embedded
all nominal except -
RELY - very high
Database Size - high
Complexity - high
Execution Time - very high
Schedule - low

For Software Integration & Checkout - 20% of CSCI costs (you need to give a variable name to CSCI and then create an equation in the methodology portion of the software integration and checkout line item). DO NOT include dollar units or year as they are already associated with the variable you are using.

Use Kanter Factors for PMP I&A and Peculiar Support Equipment (NOT the Kanter Model).

A throughput from the Program Office tells us that SPO Support will be $4.7M ($89).

An engineering assessment for Engineering Change Orders (ECOs) indicates using 10% of the FSED WHIZBANG system cost (again assign a variable name and create an equation).

Develop a CER for System Test and Evaluation. Use ACDB to retrieve cost information for FSED radar programs (search by program/project/task name for radar and only search FSED contracts). Retrieve all except programs 3, 6, 8, 9, 12, 13. Transfer the data to STATPAK to do regressions. If you choose a Log - Log regression include the following conversion factor (this will not be required in the SEP 89 release of ACEIT):
PMP = (PMP_F * 1000) / 1.1364

System Engineering/Project Management. Create an equation to project cost (manpower x time x rate). Use user defined variables to make sensitivity analysis easier. (Include these variables in your equations, then do a methodology check and let ACEIT add them to the bottom of the WBS where you can then put in numerical values). An engineering assessment indicates:
people - 24
months - 32
rate/person/month - $2K ($89)

Data costs are analogous to the Berlin Radar (Templehof) program. Search ACDB by program/project/task name, move the data to STATPAK and retrieve only the data costs.

ADJUSTMENTS

Check the Adjustments workscreen to ensure all appropriate G&A and fees have been included. ie. Do BBEST and COCOMO include G&A and fees? Does Software Integration & Checkout need G&A and fees added or are they already included?

PHASING

Use Beta curve phasing for the total system and use percent obligated for ECOs and SPO Support.

Use a 65/45 (65% spent at 45% complete) Beta curve at the total program line. Medium peak is is appropriate and the start and end dates are the same as the FSED dates. ECO's and SPO support should be phased using percent obligated as follows:

	89	90	91
ECOs	10	50	40
SPO Support	25	40	35

That's all ....

Congratulations! You have finished your first ACEIT estimate. Now, print out a complete copy of all the documentation and relax - - - until someone asks for a what-if analysis!

Appendix G: Data Sets Used

Extracted From ACEIT STATPAK Practice Data Set (13:Sec 9,8)

System	A	B	C
1	7119	98463	0
2	642	5087	0
3	542	4282	0
4	7755	43442	0
5	2267	16819	0
6	8555	23585	1
7	1566	27185	0

Note: C is a dummy variable where Yes=1, No=0.

Helicopter Turboshaft Engine Data Set (16)

Engine Model	Cost	Air Flow	Pressure Ratio	Horsepower	Weight
T63	42.28	3.20	6.25	317	138
T53	51.96	10.45	5.80	860	480
T55	136.45	21.50	6.60	2200	570
T58	139.76	12.60	8.15	1250	295
T56	157.91	32.50	9.10	3755	1833
T64	185.37	25.50	12.20	2690	717
T700	193.55	9.50	17.10	1560	415
T73	286.46	52.20	6.80	4050	713

Engine Model	Horsepower/Weight
T63	2.29710
T53	1.79167
T55	3.85965
T58	4.23729
T56	2.04855
T64	3.75174
T700	3.75904
T73	5.68022

Solid Propellant Rocket Motor Data Set (17)

Motor	Cost (150th unit)	Propellant Weight (lb)	Inert Weight (lb)	Total Weight (lb)	Burn Time (sec)
1	2097	6.8	10.8	16.9	1.35
2	8542	5.7	7.3	13.0	1.50
3		* data omitted from calculations			
4	8019	60.0	24.0	84.0	2.29
5	8607	65.0	38.0	103.0	4.14
6	14660	60.0	39.0	99.0	5.21
7	13310	90.8	71.5	162.3	3.04
8	25269	243.0	274.0	517.0	1.52
9		* data omitted from calculations			
10	80796	361.0	78.0	439.0	27.40
11	55520	605.0	245.0	850.0	31.50
12	47805	562.0	228.0	790.0	22.40
13	46452	725.0	416.0	1141.0	18.00
14		* data omitted from calculations			
15	94594	2785.0	463.0	3248.0	39.00
16	556548	3665.0	640.0	4305.0	56.00
17	380124	3657.0	592.0	4249.0	56.40
18	90743	4451.0	553.0	5004.0	38.30
19	169916	5900.0	1010.0	6910.0	23.80
20	198930	6562.0	1257.0	7819.0	32.20
21		* data omitted from calculations			
22	418033	7301.0	740.0	8047.0	59.60
23	687441	8872.0	617.0	9489.0	75.80
24	1125507	10371.0	1028.0	11399.0	60.10
25	636064	10249.0	1408.0	11657.0	59.30
26	780611	19270.0	2892.0	22162.0	50.60
27		* data omitted from calculations			
28	1359457	20778.0	3133.0	23911.0	59.50
29	804248	38813.0	3040.0	41853.0	66.00
30	1235237	45350.0	4650.0	50000.0	59.40

* data omitted to validate predictive accuracy of model

Learning Curve Unit Data Sets (11)

Set 1

Lot	Lot Average Hours	Cumulative Quantity
1	289	8
2	167	24
3	120	50
4	95	82
5	75	122
6	70	172
7	61	232

Set 2

Lot	Lot Average Cost	Cumulative Quantity
1	1068.75	16
2	745.00	36
3	630.00	61
4	545.16	86
5	493.63	121
6	463.77	1560

Longley Data Set (14:832)

YEAR	X1	X2	X3	X4	X5	X6	Y
1947	83.0	234289	2356	1590	107608	1947	60323
1948	88.5	259426	2325	1456	108632	1948	61122
1949	88.2	258054	3682	1616	109773	1949	60171
1950	89.5	284599	3351	1650	110929	1950	61187
1951	96.2	328975	2099	3099	112075	1951	63221
1952	98.1	346999	1932	3594	113270	1952	63639
1953	99.0	365385	1870	3547	115094	1953	64989
1954	100.0	363112	3578	3350	116219	1954	63761
1955	101.2	397469	2904	3048	117388	1955	66019
1956	104.6	419180	2822	2857	118734	1956	67857
1957	108.4	442769	2936	2798	120445	1957	68169
1958	110.8	444546	4681	2637	121950	1958	66513
1959	112.6	482704	3813	2552	123366	1959	68655
1960	114.2	502601	3931	2514	125368	1960	69564
1961	115.7	518173	4806	2572	127852	1961	69331
1962	116.9	554894	4007	2827	130081	1962	70551

Bibliography

1. AFIT GCA 88S. "Preliminary Evaluation of the Automated Cost Estimating Integrated Tools (ACEIT) System." Unpublished study. Air Force Institute of Technology, Wright-Patterson AFB OH, 1988.

2. Albee, Cliff. Operations Research Analyst. Telephone interview. BSD/ACC, Norton AFB CA, 22 May 1989.

3. Birkofer, Kenneth L. A Review of the ESD ACE-IT (Automatic Cost Estimator) Model. Unpublished report. ASD/ACCR, Wright-Patterson AFB OH, February 1989.

4. Bradley, Randall S. Evaluation of the Automated Cost Estimating Integrated Tools (ACEIT) System. Research Project presented to ASD/ACC in partial fulfillment of the requirements for the journeyperson level in Financial Management. ASD/ACC, Wright-Patterson AFB OH, May 1989.

5. Coakley, Ellen, Technical Director of Cost Analysis. Personal interviews. ESD/ACC, Hanscom AFB MA, 4-5 May 1989.

6. Davis, Gordon B. and Margrethe H. Olson. Management Information Systems (Second Edition). New York: McGraw-Hill Book Company, 1985.

7. Dean, Captain Joe, Senior Software Cost Analyst. Telephone interview. ESD/ACC, Hanscom AFB MA, 12 July 1989.

8. Delta Research Corporation. Cost Estimating System, Volume 1, Automated Cost Estimating System, November 1987. Contract F08635-85-C-0230. Arlington VA.

9. Hanson, David, Director of Cost. Telephone interview. BSD/ACC, Norton AFB CA, 31 July 1989.

10. Hutchison, Capt Larry D. A Microcomputer Program for the Solution of Learning Curve Computations. MS thesis, AFIT/GSM/LSQ/85S-18. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1985.

11. Kankey, Roland D. Class handout distributed in COST 673, Cost Estimating for Weapon System Production. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, May 1989.

12. Kazanowski, A. D. "Cost-Effectiveness Fallacies and Misconceptions Revisited," Cost-Effectiveness: The Economic Evaluation of Engineered Systems, edited by J. Morely English. New York: John Wiley & Sons, Inc., 1968.

13. Kielpinski, T. J. and others. CR-0300/2 Automated Cost Estimating Integrated Tools (ACEIT) User's Guide, Version 2.5, January 1989. Contract F19628-88-D-0007. Santa Barbara CA: Tecolote Research, Inc.

14. Longley, James W. "An Appraisal of Least Squares Programs for the Electronic Computer from the Point of View of the User," Journal of the American Statistical Association, 62: 819-841 (1967).

15. Murphy, Richard L. Assistant Professor. Personal interviews. AFIT/LSQ, Wright-Patterson AFB OH, January - August 1989.

16. Murphy, Richard L. Class handout distributed in COST 671, Cost Modeling. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1988.

17. Murphy, Richard L. Class handout distributed in COST 672, Model Diagnostics and Software Management. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 1989.

18. Netter, John and others. Applied Linear Regression Models. Homewood IL: Irwin, 1983.

19. Raduchel, William J. "A Professional's Perspective on User-Friendliness," Byte, 9: 101-106 (May 1984).

20. Sheil, Beau. "Thinking About Artificial Intelligence," Harvard Business Review, 65: 91-97 (July-August 1987).

21. Simpson, Henry. Design of User-Friendly Programs for Small Computers. New York: McGraw-Hill, 1985.

22. Voss, Captain Chis, Cost Analyst. Telephone interview. SSD/ACC, Los Angeles AFB CA, 12 July 1989.

23. Weech, Margaret, ACEIT Program Manager. Personal and telephone interviews. ESD/ACC, Hanscom AFB MA, May - July 1989.

24. Williams, Dorothy D. and Roger A. Dietrich. "Beyond the DCA-P-92(r) Structure Costing at a New Level of Detail." US Army Communications-Electronics Command, Fort Monmouth NJ.

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The purpose of this study was to evaluate the Automated Cost Estimating Integrated Tools (ACEIT) System and answer ~~the following~~ investigative questions in reference to the systems effectiveness.
(1) How user-friendly is ACEIT and does it require extensive training?
(2) Does the proper use of ACEIT require cost estimating expertise or does the system prompt even a novice to generate an accurate estimate?
(3) Does the ACEIT Statistics Package give the same estimates and statistics as the Statistical Analysis System (SAS)?
(4) What are some of the potential benefits and problems of successfully implementing ACEIT throughout the Air Force?
(5) How can ACEIT be quickly and effectively introduced to AFIT Graduate Cost Analysis students who are unfamiliar with the system?

A literature review, discussions with ACEIT users and AFIT students, personal experience with the system, and test data sets were used to answer the questions. The results were:

(1) ACEIT is very user-friendly and does not require extensive training although training should be available for those that desire or need it.
(2) Since ACEIT is not an expert system, some cost estimating expertise is required to generate accurate cost estimates.
(3) Sample data sets run through the ACEIT Statistical Package and SAS produced comparable estimates and statistics for learning curve, linear and log-linear regressions.
(4) ACEIT's major benefit, being able to fill its databanks with organization specific work breakdown structures, data, and cost estimating relationships, may also be its major potential pitfall. Each organization using ACEIT must ensure quality control of its own unique databank.
(5) A brief ACEIT introduction given to AFIT students indicated the system can be quickly and effectively introduced. Theses. (AW)