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EVALUATION OF TWO LCC MODELS TO IMPROVE  
LOGAN(LCC)

By

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### **ABSTRACT**

This report analyzes three life cycle costing models LOGAN(LCC), CASA and ACEIT in order to validate and make recommendations for improvements to LOGAN(LCC). It develops recommendations in three area: the elimination of LOGAN(LCC)'s weaknesses, the powerful features of similar softwares, and general software characteristics.

### **RÉSUMÉ**

Ce rapport analyse trois modèles de coût du cycle de vie LOGAN(LCC), CASA et ACEIT de manière à les valider et à recommander des améliorations à LOGAN(LCC). Des recommandations ont été développées dans trois domaines: l'élimination des faiblesses de LOGAN(LCC), les caractéristiques puissantes des logiciels semblables, et les caractéristiques générales du logiciel.



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## EXAMINATION OF TWO LCC MODELS TO IMPROVE LOGAN(LCC)

### I. INTRODUCTION

1. The life cycle of a system is defined as the span of time over which the system is designed, acquired, used and disposed, and the Life Cycle Costing is the process of predicting the total costs of the system over its life cycle (1:9). In order to aggregate the costs across the various phases of the life cycle and calculate the life cycle cost, life cycle costing models are generally employed.

2. The Directorate of Logistics Analysis is responsible for the design, development, and evaluation of a variety of decision support methods required for Canadian Forces equipment life cycle costing. It has developed and put into use a life cycle costing (LCC) model within the shell known as the Logistics Analyzer (LOGAN) which includes a sparing model and a level of repair analysis model as well. The Directorate also has access to some other life cycle costing models, such as CASA and ACEIT.

3. The objective of this study is to conduct a comparative analysis of the three life cycle models LOGAN(LCC), CASA and ACEIT in order to validate and make recommendations for improvements to LOGAN(LCC).

4. The study does not criticize the rationality of the models included in the comparison. It is not aimed at determining the best model. It makes its evaluations and discusses the weaknesses and strengths of the individual models in order to bring light on possible improvements to the LOGAN(LCC) model. All explanations are based upon the interpretations from the applications, the user

manuals and the on-line help systems of the available versions of the models. The study is based on the following versions of the models:

- a. LOGAN Version 1.1 Dated November 16, 1995;
- b. CASA Version 3.00 Dated 1994; and
- c. ACEIT Version 2.3 (Demo) Dated 6 March 1995.

5. Specific issues considered in the study include the purpose and general characteristics of the models, the definition and scope of the life cycle cost in the models, features of their input and output, and the perceived benefits and shortcomings of their operation.

## **II. COST ANALYSIS STRATEGY ASSESSMENT (CASA)**

### **MODEL**

6. Cost Analysis and Strategy Assessment (CASA) model is one of the available LCC models developed for military purposes in the USA. It was developed for the Defence Systems Management College in 1986 and upgraded in 1990 and 1994.

### **PURPOSE OF CASA**

7. The most recent version of CASA was designed as a decision-making tool. It is one of the individual functional modules constituting the Program Manager's Support Systems that are government management tools intended to assist executives and managers in their decision-making processes (2:Foreword). It is claimed that it can be used for the following tasks (2:Sec 1,2):

- a. LCC estimates;
- b. Trade-off analyses;
- c. Repair Level Analyses;
- d. Production Rate and Quantity Analyses;
- e. Warranty Analyses;
- f. Spares Provisioning;
- g. Resource Projections (e.g. manpower, support equipment);
- h. Risk and Uncertainty Analyses;
- i. Cost Driver Sensitivity Analyses;
- j. Reliability Growth Analyses;
- k. Operational Availability Analyses with Automated Sensitivity Analyses;
- l. Spares Optimization; and
- m. Operation and Support Cost Contribution by Individual LRUs.

### SYSTEM REQUIREMENTS OF CASA

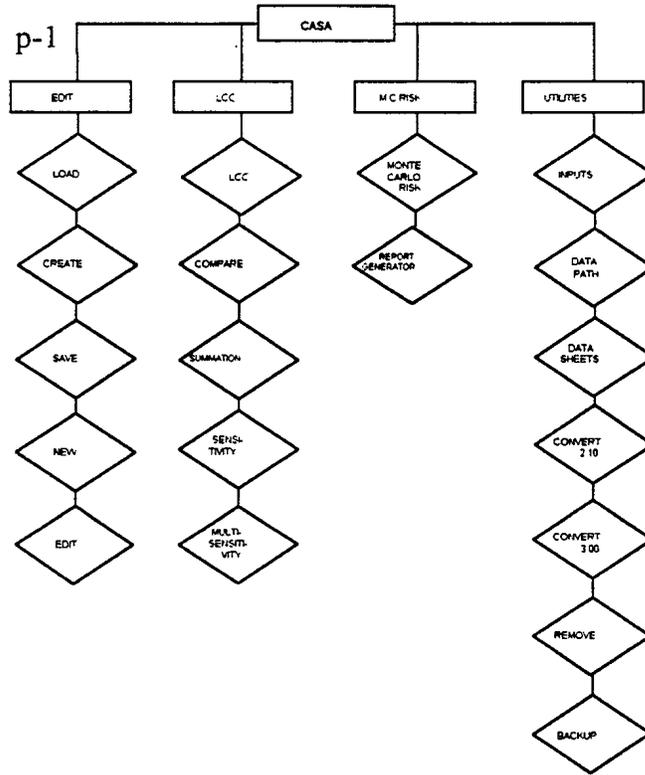
8. The user's manual for Version 3.0 of the CASA model lists, as the minimum, the following hardware requirements as well as the operating system requirements of a version of 3.30 or later of PC-DOS or MS-DOS and a mouse driver (2:Sec 4,1):

- a. IBM PC/XT/AT, PS/2 or compatible;
- b. One floppy disk drive;
- c. One hard drive;
- d. Monochrome monitor;
- e. 580 K RAM; and
- f. Mouse.

9. In addition to these minimum requirements, a color monitor, a 80287/80387 math coprocessor, a printer and extended memory are recommended.

### GENERAL CHARACTERISTICS OF CASA

10. The user's manual for Version 3.0 of the CASA model suggests that CASA "incorporates various analysis tools into one functional unit" (2.Sec 3,1). More specifically, it allows the user to generate data files, perform LCC, sensitivity analysis, risk analysis, compare various LCC runs and summarize the results in tabular and graphical formats. It provides structured data input and edit utilities. In addition, it provides the user with such utilities as data file information output, data work sheets output, and conversion of data files from earlier versions of CASA. Figure 1 illustrates how these programming modules are related.



**Figure 1: CASA System Overview** (2:Sec 3,1)

11. The logical structure of CASA follows the process used by the cost analyst in determining the feasibility of various competing strategies (2.Sec 3,2). The program structure reflects the following general divisions in this process :

- a. File Creation - Identifying the system to be studied and entering basic data.
- b. System Attributes - Entering technical data on the system in order to permit cost runs.

- c. **Cost Analysis** - Calculating the cost of the system described by the above inputs.
- d. **Change Inputs** - Altering basic input data and measuring the effect of changes on the system cost structure.
- e. **Risk Analysis** - Defining risk levels and calculating the probabilities of meeting, exceeding, or falling short of any LCC target value.
- f. **Sensitivity Analysis** - Altering hardware parameters and measuring their influences on spares levels, LCC and other factors.
- g. **Comparison and Summation Analysis** - Output of comparison and summary tables for various LCC runs.
- h. **Multiple Sensitivity Analysis** - Conducting sensitivity analysis on a number of LCC files.

### **USER-FRIENDLINESS OF CASA**

12. CASA provides the user with color displays and easily understandable pop-up menus. Each menu choice and each data item to be input has an explanation shown at the bottom of the screen. Further, it has an extensive on-line help system. The user can reach the help information he/she needs simply by pressing a key. The user is also provided with considerable menu assistance in entering and editing data, and formatting the model output. One can enter and edit data or determine the type and inclusion of the report by selecting from the menus reflecting available alternatives.

13. Contrary to the above-mentioned user-friendliness, the user frequently encounters the message reflected in Figure 2 when a CASA option is selected or left for another choice. This message is from the Phar Lap 286 memory manager that CASA employs, but it is disturbing the user since it comes on the screen immediately after leaving or selecting a program module.

<p style="text-align: center;">Extended-DOS Power by Phar Lap's 286 DOS-Extender(tm) Version 3.0 Copyright 1993 Phar Lap Software Inc. Available Memory = 10981 Kb</p>
--

**Figure 2: Phar Lap 286 Memory Manager Message**

### **CASA LIFE CYCLE COSTING (LCC) MODEL**

#### **DEFINITION AND SCOPE OF LIFE CYCLE COST IN CASA LCC**

14. The user's manual for Version 3.0 of the CASA model assumes that the life cycle of a system consists of three phases: the research, development, testing, and evaluation phase, the acquisition phase and the operation and support phase (2.Sec 2,1). Thus, it develops cost projections for these phases. The following equation reflects its LCC definition:

$$LCC = TRDTE + TACQ + TOS$$

where: LCC = Total Life Cycle Cost,

TRDTE = Total Research, Development, Test and Evaluation Cost,

TACQ = Total Acquisition Cost,

TOS = Total Operation and Support Cost.

15. Naturally, within each of the life cycle phases, are subsidiary cost categories, as well as universal parameters such as labor rates and secondary calculations of operational availability optimization of LRU spares. CASA LCC breaks down these three life cycle phases into the subsidiary cost categories.

16. CASA LCC model also, optionally, evaluates warranty usage and calculates the number of each type of LRUs needed at the organizational level in order to achieve the highest degree of operational availability given a certain spares budget (2.Sec 3,5-7). Costs and resource quantities are calculated for each cost category for each year of the analysis, and the model permits the number of operating systems to vary from month to month as deployment alterations may occur within a given year (2.Sec 2,1).

17. **Research, Development, Test and Evaluation Cost.** The total research, development, test and evaluation cost (TRDTE) is defined by CASA as the cost attributed to the initial research and development to determine the feasibility of the system to be procured (2.Appendix B,3). TRDTE main cost group includes the following sub-groups of or individual cost items (2.Sec 3,3):

- a. System/Project Management Cost;
- b. System Test and Evaluation Cost;
- c. Training Cost;
- d. Data Cost;
- e. Demonstration and Validation Cost;
- f. Research and Development Cost;
- g. Software Cost; and
- h. Other Cost.

18. **Acquisition Cost.** CASA LCC model defines the total acquisition cost (TACQ) as the initial investment cost to the user (2.Appendix B,4). It identifies the following sub-groups of and/or individual cost items that are generally associated with the designing, developing, and procuring systems and supporting items necessary to make the system operational (2.Sec 3,3-4):

- a. Production Tooling and Test Equipment Cost;
- b. Production Start-Up Cost;
- c. System Acquisition Cost;
- d. System Shipping and Storage Containers Cost;
- e. Pre-production Engineering Non-Recurring Cost;
- f. Pre-production Units Refurbishment Cost;
- g. Installation Cost;
- h. Support Equipment Cost;
- i. Hardware Spares Cost;
- j. Spares Reusable Containers Cost;
- k. Initial Technical Data Cost;
- l. Initial Training Cost;
- m. Training Devices Cost;
- n. New or Modified Facilities Cost;
- o. Initial Item Management Cost;
- p. Initial Software Development Cost;
- q. Miscellaneous Acquisition Cost; and
- r. Warranty Cost.

19. **Operation and Support Cost.** The last life cycle cost category in CASA LCC model is the total operation and support costs (TOS). The model defines this category as the total cost of operating, maintaining, and supporting all systems and support equipment at all maintenance levels over the life cycle of the

equipment (2.Appendix B,40). The sub-groups and individual cost items evaluated within this group are as follows (2.Sec 3,4-5):

- a. Operation Labor Cost;
- b. Repair Labor Cost;
- c. Support Equipment Maintenance Cost;
- d. Recurring Training Cost;
- e. Repair Parts and Materials Cost;
- f. Repair Consumables Cost;
- g. Condemnation Spares Replenishment Cost;
- h. Technical Data Revisions Cost;
- i. Transportation Cost;
- j. Recurring Facilities Cost;
- k. Recurring Item Management Cost;
- l. Software Maintenance Cost;
- m. Contractor Services Cost;
- n. Engineering Changes Cost;
- o. Recurring Warranty Cost; and
- p. Miscellaneous Operation and Support Costs.

### INPUT DATA

20. It is possible to divide the operation of CASA into two main functional parts. One of them is the selection and execution of the analysis of the alternatives, and the other one is the CASA editor, namely EDCASA, that enables the user to perform file operations and to input and edit all data related to the analyses.

21. EDCASA has essentially a fixed data structure. It uses the fixed data categories shown in Table I. All data input and edit functions are realized through

**TABLE I****CASA DATA CATEGORIES**

1. General Input Information
2. Maintenance Level Information
3. System Cost Data
4. System Deployment Data
5. Production Tooling & Test Equipment
6. Production Startup Costs
7. Shipping & Storage Containers
8. Research, Development, Test & Evaluation
9. Pre-Production Engineering Costs
10. Pre-Production Refurbishment Costs
11. Hardware Data
12. Support Equipment Maintenance Data
13. Support Equipment Loading Data
14. Transportation Costs
15. Reusable Spares Containers
16. Initial Technical Documentation
17. Recurring Technical Documentation
18. Initial Training
19. Recurring Training
20. Training Devices
21. New Facilities
22. Recurring Facilities
23. Initial Item Management
24. Recurring Item Management
25. Initial Software Development
26. Software Maintenance
27. Contractor Services
28. Operational Engineering Changes
29. Miscellaneous Acquisition Cost
30. Miscellaneous Operation & Support Cost
31. Warranty Data
32. Individual Item Reliability Growth
33. System Cost Risk Analysis Data
34. Hardware Item Risk Analysis Data
35. Military Pay Grade

this fixed structure. It only allows the user to add and/or delete sub-items to some cost groups in the list. Except for these additions and deletions, it is impossible to modify the data input structure. CASA has an error checking system that checks every input when it is entered within this structure.

22. Category 1 includes the general input information, such as the study (project) life, the default base year in which dollars are expressed, cost and MTBF adjustment factors, monthly operating hours per system, its operator required portion, operator labor rate, support equipment and spares adjustment factor, and the rates of inflation and discount. Category 2 is related to maintenance levels, and contains information about maintenance personnel labor rate, software personnel labor rate, support equipment availability and parts cost and spares confidence levels. Category 11 includes the system hardware data, and establishes the hierarchical structure of the items or the prime equipments.

23. Category 32 contains item reliability growth data, which is used to provide different reliability growth curves for each item. On the other hand, Categories 33 and 34 deal with risk analysis data, and they can be omitted if there is not a need for risk analysis.

24. All the other categories reflect the sub-groups of costs in Research, Development, Test and Evaluation Cost, Acquisition Cost, and Operation and Support Cost, which were explained above in Paragraphs 17, 18, and 19.

25. **Input Limitations.** CASA LCC establishes several limits on the data inputs. Table II identifies the general limits established by the CASA LCC model.

26. CASA LCC assumes that the maximum life cycle of a system is 30 years, and requires the statement of this period in number of months. It also assumes that the study begins in the first month of the first year. Thus, the life cycle of a project in CASA LCC always starts in January.

**TABLE II****GENERAL LIMITS ON DATA INPUTS**

<u>Item</u>	<u>Maximum Allowed</u>
Maintenance Levels	3
Prime Hardware Items (LRU, SRU, etc.)	2000 (limited by available memory)
Items of Support Equipment	20
Study Life (Months)	360
Miscellaneous Acquisition Costs	30
Miscellaneous Operation and Support Costs	30
Initial Technical Documentation	30
Initial Training Courses	30
Training Devices	30
New Facilities	30
Production Tooling and Test Equipment	30
Support Equipment	20
Reusable Spares Containers	30
Max CASA files of same extension per directory	50
The Summation Model allows for a maximum of 10 LCC output files (*.lot) or previous summation output files (*.sum).	
The Comparison Model requires two LCC output files (*.lot).	
The Monte Carlo Risk Model requires a minimum of 50 iterations and a maximum of 1000.	
The Multiple Sensitivity Model allows for a maximum of four Sensitivity output files (*.sen).	

27. **Features of Hardware Item Data.** The maximum number of hardware items that CASA LCC model can work on is 2000 (2.Sec 5,5). CASA requires that items must be entered in top-down fashion, so that each item's next higher assembly is positioned before that item. Items are given numbers between 1 and

9, reflecting their indenture in the hardware breakdown structure. Level 9 is reserved for scheduled maintenance items (2.Appendix B,51).

28. **Features of Cost Data.** As stated earlier, CASA LCC classifies the life cycle costs into three groups: Research, Development, Test and Evaluation Cost, Acquisition Cost, and Operation and Support Cost, and states the contents of these groups. The cost structure is not changeable, and CASA LCC uses mainly this pre-determined cost structure to calculate the life cycle cost of the project. However, it allows the user to make additions or deletions to some cost sub-groups, such as Miscellaneous Acquisition Costs and Miscellaneous Operation and Support Costs.

29. In terms of the time value of money, CASA LCC differentiates between the cost items, and enables the user to define a different base year for each cost item. Each cost is input to CASA LCC in constant dollars of its financial year. Furthermore, the model has the capability of calculating and presenting the results of its LCC calculations in either constant, inflated, or inflated and discounted dollar terms. It allows the user to define the inflation and the discount rates to be used in each year of the analysis.

### **CASA LCC REPORTS**

30. CASA LCC provides the user with the choices designated in Figure 3 when the LCC option is selected from the main menu. It computes the life cycle cost and the other output tables, and determines the contents of the reports in accordance with the user's selections. In other words, through these choices, the user can:

- a. state that a detailed or a summary report is needed;
- b. determine the type of the LCC calculation (constant, inflated, inflated and discounted);

- c. state the types of reports needed;
- d. state whether operational availability analysis and/or optimization of LRU spares is required; and
- e. specify the output environment.

31. The options on the LCC screen in Figure 3 represent at the same time the report types that CASA LCC can produce. It seems that it has a wide range of reports providing a remarkable number of cost estimates related to the system under study.

LCC Options V3.00	
Path/File: C:\CASA\DATA\PROJECT.L30	
<input type="button" value="File Select"/>	
<input type="checkbox"/> CASA <input type="checkbox"/> SVLCCM	<input type="checkbox"/> Complete Life Cycle Cost Data <input type="checkbox"/> Constant Dollar Yearly Cost Table <input type="checkbox"/> Inflated Dollar Yearly Cost Table <input type="checkbox"/> Inflated and Discounted Dollar Yearly Cost Table <input type="checkbox"/> Tables of General Inputs and Hardware Item Inputs <input type="checkbox"/> Deployment Data Tables <input type="checkbox"/> Maintenance Man-hours and Maintenance Personnel Tables <input type="checkbox"/> Maintenance Actions per Location Tables <input type="checkbox"/> Total Spares Requirements Tables <input type="checkbox"/> Total Support Equipment Requirements Tables <input type="checkbox"/> Support Equipment Utilization Tables <input type="checkbox"/> Operational and Support Cost Table Sorted by LRU <input type="checkbox"/> System MTBF by Year Table <input type="checkbox"/> Operational Availability Analysis (OAA) <input type="checkbox"/> OAA plus Optimization of LRU Spares <input type="checkbox"/> All CASA Options
<input type="checkbox"/> (*) Display <input type="checkbox"/> Printer <input type="checkbox"/> Outfile: C:\CASA\DATA\PROJECT.LOT	<input type="button" value="OK"/>  <input type="button" value="Cancel"/>

**Figure 3: CASA LCC Options**

## COMPLEMENTS OF CASA LCC

32. CASA offers some other functions in addition to LCC. These additional functions support and complete the LCC analysis. These are Compare, Summation, Sensitivity, Multi-Sensitivity and Monte Carlo Risk Assessment.

### COMPARISON

33. The Compare option enables the user to compare the results of two LCC runs, and thus, to compare various "what if" scenarios to determine the effects of cost changes by inflation, deployment schedules, and maintenance configurations (2.Sec 6,33). It reports the amount and percent differences for cost categories over all years and for the complete set of runs.

### SUMMATION

34. The Summation option performs the cost summations of the yearly cost tables of 2 to 10 LCC runs (2:Sec 3, 7-8). The resulting summation output file is evaluated as the output of a LCC run. Thus, the Summation option allows the user to determine life cycle costs of various subsystems and combine them to develop a overall life cycle cost (2:Sec 6,35). This capability makes it possible to carry out LCC analysis on very large projects.

### SENSITIVITY

35. Sensitivity module of CASA permits the user to measure the impact of changes in the key parameters of LCC and operational availability (2.Sec 6,37). It performs sensitivity analysis on 17 input parameters (2.Sec 3,8-9).

- a. Hardware item related sensitivity analysis includes:

- (1) Condemnation rate;
- (2) Material cost per repair;
- (3) Mean time between failures ;
- (4) Mean time to repair;
- (5) Not repairable this station;
- (6) Re-test OK;
- (7) Spares turnaround time; and
- (8) Unit cost.

b. Maintenance level related sensitivity analysis includes:

- (1) Available support equipment hours;
- (2) Maintenance labor rate;
- (3) Maintenance person turnover rate;
- (4) Shipping cost per pound ; and
- (5) Spares confidence level.

c. Other sensitivity analysis possibilities are:

- (1) Percent labor for Re-test OK;
- (2) Production quantity slope;
- (3) Production rate slope; and
- (4) System operating hours/month.

36. Multi-Sensitivity option, on the other hand, can be used to output the results of two to four sensitivity analyses at one time, and thus, it allows the comparison of the effect of different sensitivity parameters (2.Sec 6,39).

### **MONTE CARLO RISK ASSESSMENT MODEL**

37. CASA LCC model is deterministic in nature and uses discrete values in its LCC calculations. However, CASA employs Monte Carlo Risk Assessment

model as a complement to the LCC model, which allows the user to quantify and measure the impact of uncertainty on the key parameters of the LCC model - unit cost, mean time between failures, and mean time to repair (2.Appendix B,84). This uncertainty is presented in the form of a probability distribution, and the user is able to choose from four probability distributions: normal, triangular, uniform and constant. The Monte Carlo Risk Model requires a minimum of 50 iterations and a maximum of 1000.

## EVALUATION OF CASA LCC

### DEFICIENCIES OF CASA LCC

38. First of all, CASA LCC has a user-friendly environment. Nevertheless, as stated earlier, the user frequently encounters the message given in Figure 2 from the memory manager that CASA employs. This message has a disturbing effect on the user in an otherwise user-friendly model.

39. The life cycle definition of CASA LCC is not as comprehensive as it should be. It does not include all phases of the life cycle of an equipment. It disregards the last phase, namely the disposal phase. As a result, the LCC value it reports is exclusive of the disposal cost of the system under study, which may be misleading in terms of decision making.

40. CASA LCC, on the other hand, has fairly extensive input data requirements. As stated previously, it requires input data within the context of 35 data categories. All of these categories include cost and resource information. System hardware data must be entered according to the hierarchical structure of the items. This means that the analyst must have detailed information on the hardware breakdown structure, every type of cost, economical indicators, and manpower requirements.

41. CASA LCC uses the pre-determined cost groups and cost items. Thus, it channels the user to adapt life cycle costing problems to this fixed cost structure. Such a standardization may be helpful for some problems, and facilitate the calculations. However, it is a fact that it is impossible to uniquely structure all life cycle costing problems. In particular, it is very difficult to find data about the life cycle of a new equipment or a new weapon system during the early stages of research and development, and is almost impossible unless there is an analogous equipment on which to base the estimate. For example, CASA LCC calculates most of the operation and support costs as a function of component reliability parameters, such as average operating hours per system, mean time to repair, mean time between failures and average material cost per repair. It also uses some other cost data related to support equipment, software and warranty. It is very difficult to use CASA LCC in such a situation. The result is some doubt about the universality of the model.

42. Furthermore, CASA LCC disregards the echelons in the logistics support. The operational availability sub-model of CASA LCC does not consider indentured spares below the LRU level and deals only with the system and LRUs whose spares are considered only at the organizational level (2.Sec 2,2). This assumption may, in turn, result in incorrect estimates about the operational availability.

43. Related to this shortcoming is the computation of the transportation cost. CASA LCC differentiates between three levels of maintenance, the organizational level, the intermediate level and the depot level, and requires the transportation costs per pound between the levels of maintenance be entered by the user or the analyst. It calculates the transportation cost by multiplying the shipping weight of the equipment in pounds by the transportation cost per pound between the two

levels of maintenance. The distances between the maintenance levels are not taken into account.

44. As mentioned earlier, CASA LCC assumes that the study begins in the first month of the initial year of the study, and as a result, the life cycle of a project always starts from January. This may cause unacceptable deviations in estimates that require precision.

### **STRENGTHS OF CASA LCC**

45. CASA is a user-friendly program. It provides the user with color displays and easily understandable pop-up menus in addition to an extensive on-line help system. Besides that, the user is provided with considerable menu assistance in entering and editing data, and formatting the model output. It also has a well-structured and clearly-explained user's manual.

46. CASA is a versatile tool. The range of functions it offers allows it to be used for a number of other types of analyses in addition to LCC. The user can perform LCC, sensitivity analysis, risk analysis, compare and sum various LCC runs and get the results in tabular and graphical formats.

47. CASA LCC provides a comprehensive coverage of the life cycle of a system within the context of its LCC definition. It tries to cover all possible costs within the three phases of the life cycle of the system. It has the capability of calculating and presenting the results of its LCC calculations in either constant, inflated, or inflated and discounted dollar terms. Furthermore, it can evaluate warranty usage and perform operational availability analysis.

48. CASA LCC permits the user to determine the type and inclusion of features in the output report. CASA presents its output in an easily understandable format with well-defined cost categories.

### **III. AUTOMATED COST ESTIMATING INTEGRATED TOOLS (ACEIT) AUTOMATED COST ESTIMATING (ACE) MODEL**

49. Automated Cost Estimating Integrated Tools (ACEIT) is a shell that is a collection of special-purpose spreadsheets specifically developed for cost analyses conducted by the US Air Force, and Army (3:86). It is currently being updated to meet the needs of the US Navy as well. The original version of ACEIT was designed for use on a VAX system, and VAX-based ACEIT is still in use. It includes more cost databases and more cost estimating relationships than PC-based ACEIT. The PC version includes some functions facilitating accessing to the VAX version. Since the version examined in this study is the PC demo version, VAX-based ACEIT and the related subjects are outside the scope of this study.

#### **PURPOSE OF ACEIT**

50. ACEIT has been designed to assist cost analysts in conducting analyses such as cost estimates, what-if studies, cost proposals and evaluations, risk and uncertainty analyses, and cost estimating relationship development (4:Sec 1,1).

51. Promotional brochures on ACEIT state that it can be used:

- a. to develop and document:
  - (1) Cost estimates;
  - (2) Cost estimating relationships;
  - (3) Cost and operational effectiveness analyses;
  - (4) Time-phased financial analyses;
  - (5) Learning/rate curves;

- (6) Risk/Uncertainty analyses;
  - (7) Sensitivity/What-if analyses;
  - (8) Cost Engineering Studies; and
  - (9) Economic Analyses.
- b. to find and use:
- (1) Cost/Schedule/Technical/Program data;
  - (2) Estimating methodologies and models; and
  - (3) Cost and technical sources.

### **SYSTEM REQUIREMENTS OF ACEIT**

52. ACEIT requires a version of 3.22 or later of PC-DOS or MS-DOS. The minimum hardware requirements are as follows (4:Sec 2,1):

- a. IBM PC AT or compatibles;
- b. 2.5 MB RAM;
- c. 10 MB hard disk space; and
- d. A monitor with a graphics adapter.

53. However, 386 or a higher model processor, a math coprocessor, 4 MB or more RAM, 28 MB or more free hard disk space, and a VGA card are highly recommended. A printer is needed to get printouts.

### **GENERAL CHARACTERISTICS OF ACE**

54. ACEIT has been designed specifically for the US Air Force, and the US Army. The US Navy was added to the users' list within the last few years. ACEIT has been developed in accordance with the rules and regulations stated by the USA

Authorities. It includes and uses the pre-defined work breakdown structures (WBS), cost estimating structures (CES) and cost estimating models that are specific to the US Army, Air Force and Navy, and the appropriation codes and terms assigned by the US Treasury Department, that reflect the annual authorizations by Congress.

55. ACEIT is a shell. It contains and integrates a variety of tools. These are Automated Cost Estimator (ACE), Cost Estimating Models (CEM), Cost Analysis Statistics (COSTAT), Risk Analysis Model (RISK), and some utilities.

56. ACE is the heart of ACEIT set. It is a special-purpose spreadsheet explicitly developed for cost analysis. It has pre-defined column headings. It has been organized and structured to follow the steps or phases used in developing a cost estimate, ranging from defining what is being estimated, through time-phasing and final documentation.

57. ACE includes some built-in cost estimating methodology libraries containing a great number of cost estimating relationships (CER), factors, and models. Besides, it has the following features (4:Sec 1,1-2):

- a. Automatic checking of variables, variable names, mathematical expressions, and missing values.
- b. Automated summation of work breakdown structure indentures and some related data.
- c. Normalization of inputs that have different fiscal years, dollar units, quantities, burden rates, and contract tiering levels.
- d. Capability to conduct rapid side-by-side sensitivity/ what-if analyses.
- e. All-inclusive Department of Defence inflation indices.

- f. Twelve different time-phasing methods.
- g. Flexible and comprehensive automated documentation system.
- h. Utilities to transfer data between ACE and external spreadsheets and databases.

### **USER-FRIENDLINESS OF ACE**

58. ACE and the other functional modules in the ACEIT shell are special spreadsheets. They provide the user with colored displays, and spreadsheet-style command menus with pull-down windows. Each menu choice is shown together with a summary information placed at the bottom of the screen. Besides, they have an integrated full-feature on-line help system. The user is directly provided with the information concerning the highlighted menu choice or a specific spreadsheet column when desired. The help system also offers subject-related information.

### **MODELLING IN ACE**

59. ACE itself is a spreadsheet specifically designed for cost estimating purposes. It is not an LCC model. Instead, it is a special environment to be employed in order to develop or use any type of cost estimating models including LCC. It has built-in cost estimating methodology libraries including a considerable number of CERs, factors and models, and links to the CEM module that contains some cost estimating models. Hence, the user can develop an LCC model with any content in terms of features, phases, boundaries and estimation methodologies, with or without the help of the built-in facilities that ACE offers.

### **DEFINITION AND SCOPE OF LIFE CYCLE COST IN ACE**

60. In ACE, the user is in control of the scope of the life cycle cost. However,

ACE permits and defines five life cycle phases in its on-line help system:

- a. Conceptual;
- b. Validation;
- c. Engineering and Manufacturing Development (EMD);
- d. Production (PROD); and
- e. Operating and Support (O&S).

61. Though ACE does not use the term "Research and Development" clearly in this taxonomy, the first three of these phases constitute the Research and Development phase of a system.

62. The conceptual phase is the initial sub-phase in the research and development phase of a system. It refers to the development of an idea. The validation phase is the test of the idea in terms of its general feasibility. ACE and most of the cost estimating models it offers disregard the conceptual and the validation phases.

63. EMD is defined as the phase that includes engineering design, development, and testing. The EMD phase is the last of the development phases and occurs before production approval and after validation or concept definition development phases. The objective of EMD is to prepare a pre-production system that closely approximates the final product, document the steps necessary to continue with production, and demonstrate that the product will meet the stated requirement.

64. The production phase is the phase of the life cycle of the weapon system, where the hardware is manufactured and delivered. It occurs after the full scale development phase and before the O&S phase.

65. O&S is the phase in the life cycle of the weapon system during which the product is being used. The phase starts when the product is accepted and includes all operations, maintenance, and modification activities.

66. ACE mainly uses the last three phases in its built-in models, but it allows the user to estimate the costs of the conceptual and/or the validation phases via the modification of the EMD phase. Most of the built-in work breakdown structures (WBS) or cost estimating structures (CES) it includes contain EMD, PROD and O&S phases.

### INPUT DATA AND COST CALCULATIONS

67. ACE has been organized and structured to follow the phases used in developing a cost estimate. These phases are (4:Sec 3,1):

- a. Defining the estimate;
- b. Developing the estimate;
- c. Conducting sensitivity and what-if analyses;
- d. Time-phasing and inflating the estimate; and
- e. Structuring the estimate documentation.

68. ACE is actually a collection of interrelated special spreadsheets, namely “workscreens”, where estimates are made. These workscreens are structured in such a way that they reflect the above-mentioned logical steps in building a cost estimate. They are Adjustment, Beta phasing, Keywords, Learning, Methodology, Sensitivity, WBS/CES, and Yearly phasing workscreens. The All Columns Workscreen that includes all of the columns of all the workscreens facilitates viewing and manipulating the input. These workscreens are actually spreadsheets with pre-defined column names. The user is allowed to rearrange the structure of these workscreens.

69. The estimation problem and all related data are entered into these workscreens, except for some general parameters related to the base year, financial year, and inflation index which are defined separately at the beginning. The maximum

number of rows in the workscreens that ACE allows is 8000. However, this amount depends upon the amount of free RAM. The amount of input data depends upon the size of the WBS/CES, the methodologies employed, the degree of utilization of ACE libraries, and the methods selected. However, the first four phases of the cost estimate require a large amount of data.

70. ACE requires the user to structure the WBS/CES of the project. It prompts the user to select one or more systems from the options list to construct the WBS/CES when the user builds a new session. The user may select at least one of the built-in systems that ACE gives as defaults, or start with a blank workscreen and design the WBS/CES. The selection of a system does not limit the user. It only establishes some links between the estimate and the ACE libraries. The user is free to develop the WBS/CES and the related methodologies. The built-in WBS/CESs that ACE offers are shown in Table III.

71. In fact, the system selection creates a three-line WBS that only shows the names of the ACE life cycle phases. The user can modify the created WBS, add some items manually, or use ACE's WBS/CES Expansion feature to expand this three-item structure. This feature offers four types of expansion: functional, non-recurring/recurring, resource, and system. The last type of expansion depends upon the system selected. It provides the built-in WBS/CES of the system if the user selects. The other types of expansion have standard inclusions. Table IV shows the standard inclusions for the first three types of expansion.

72. The ACE expansion types are independent from each other, and none of them has any priority over the others. The selection of a standard expansion type simply adds the items it includes together with their appropriation codes to the WBS/CES, but does not bring any methodology or any other data. The user can select these standard expansion modes in any order to expand the WBS/CES of every life cycle phase.

**TABLE III****ACE Built-in WBS/CES Systems**

ESC ELECTRONIC SYSTEMS
AIRCRAFT SYSTEM
ARMY CES (AIRCRAFT)
ARMY CES (AIS)
ARMY CES (ELECTRONICS)
ARMY CES (GENERIC)
ARMY CES (MISSILE)
ARMY CES (ORDNANCE)
ARMY CES (SPACE)
ARMY CES (SURFACE VEHICLES)
ASC SMALL MISSILE/MUNITION SYSTEM
ASC/RW EW SYSTEMS
ASC/SM AERONAUTICAL SYSTEMS
ELECTRONIC/AUTO S/W SYS WBS
ENVIRONMENTAL WBS
GENERIC SYSTEM
HSC HUMAN SYSTEM
MISSILES SYSTEM WBS
ORDNANCE SYSTEM WBS
OSD AUTOMATED INFO SYSTEM
SHIP SYSTEM
SMC PEACEKEEPER ICBM SYSTEM
SMC SPACE SYSTEM
UPA - SHIP SYSTEM

Legend: ESC : Air Force Electronics System Center  
 CES : Cost Estimating Structure  
 ASC : Air Force Aeronautical Systems Center  
 EW : Electronic Warfare  
 AUTO S/W SYS : Automated Software System  
 WBS : Work Breakdown Structure  
 HSC : Human System Center  
 OSD : Office of Secretary of Defence  
 SMC : Space and Missile Center  
 ICBM : Inter Continental Ballistic Missile  
 UPA : Unit Price Analysis

**TABLE IV****ACE STANDARD EXPANSION TYPES**

<b>FUNCTIONAL</b>	<b>NON-REC/RECURRING</b>	<b>RESOURCE</b>
Program Management	Non-Recurring	Direct Labor
Development	Recurring	Direct Material
Engineering		Computer Time
Manufacturing		Travel Costs
Quality Control		Other Direct Costs
Tooling		Interdivisional Spt
Subcontract		Material Handling
Other		Overhead
		General and Administrative
		Cost of Money
		Fee

73. On the grounds that most of the ACE's built-in WBS/CESs contain the EMD, PROD and O&S phases of the life cycle, the user usually has to modify the structure given. At first, the EMD phase should be modified if the conceptual and/or the validation phases are needed. Some additions to the given WBS/CES and/or deletions from it can be made in order to tailor the cost structure provided to the actual system being estimated. Though ACE does not recognize the disposal phase of the life cycle of a project, it can be added easily to the structure if desired.

74. In structuring the WBS/CES of the estimate, the user must obey some rules. One of them is that the items must be entered in such a way that their indenture reflects the parent-child relationship. ACE allows 8 levels of indenture (5: Sec 3,12).

75. After defining the WBS/CES, the user defines the estimating methodologies of the cost items in the WBS/CES, and then, inputs the values of variables utilized in these methodologies to calculate the results. The maximum number of characters to define the methodology equations is 240.

76. The user has three alternatives for defining the estimating methodology of an item: entering the cost directly, entering his/her own equation, or bringing a pre-defined cost estimating relationship (CER) from the ACE library. The imported CERs are not rigid or inflexible expressions. They can be modified easily according to the user's needs. Further, ACE allows the user to develop his/her own CERs. The estimating Methodology Library that ACE's demo version offers is given in Annex A.

77. ACE permits the utilization of Learning curve theory in the estimate. The user can specify either the unit cost theory or the cumulative average cost theory be used in the estimation of the cost of the WBS/CES item.

78. ACE takes into consideration the time value of money. It includes the official inflation indexes for all RDT&E, Procurement, Operation and Maintenance, Military Personnel, and Military Construction appropriations, that are special to the units of the US Armed Forces. It allows the user to input the cost values with different fiscal years. It uses the appropriation codes or terms that tell ACE which inflation indices to use, and these are assigned to each cost item by the user to convert input values from different fiscal years' dollars into the base year of the estimate. ACE permits the user to build and use his/her own inflation indices.

79. ACE calculates the base year estimate that includes the methodology results in base year's dollars. ACE can make three types of estimates for each cost item: Cumulative Average Cost, Lot Average Cost, and Lot Total Cost. The cumulative average cost is calculated by summing the cumulative cost for all the units produced to a point in time and dividing this sum by the cumulative number of units produced to that same point in time. The lot average cost is the total cost of the production lot divided by the number of units produced in the lot. The lot total cost, on the other hand, is the sum of all costs incurred in the production of a specified number of units of some item.

80. Following the base year calculation, the user has to time-phase and inflate the base year costs to Then Year (the year when the expenditures were or will be made) dollars (3:Sec 4,13). ACE permits the utilization of 12 different phasing methods exclusively for each item, that are shown together with their features in Table V.

81. ACE automatically escalates the time-phased base year estimates of the cost items with an appropriation code or term into the Then Year dollars. It also normalizes throughputs and CER results to the base year.

**TABLE V**

**ACE YEARLY PHASING METHODS**

<b>Method</b>	<b>Feature</b>
Percent	Costs are allocated according to the yearly percentages input by the user.
Quantity Buy	Costs are allocated according to the yearly authorized buy-quantities input by the user.
Quantity with Rate	Costs are allocated according to the yearly authorized buy-quantities adjusted by a rate reflecting the difference between the actual and the planned production rates.
Input Variables	Costs are allocated according to the input variable values that vary by financial year.
Input Variables with Sums	Costs are allocated according to the input variable values that vary by financial year and then summed.
Variable Factors	Costs are allocated according to the methodology equation and then summed.
Average	Costs are allocated and total is found according to the methodology equation.
Constant	Costs are assumed as constant and not phased.
Same Year Throughput	Costs are assumed in financial year dollars.
Base Year Throughput	Costs are assumed in base year dollars.
Then Year Throughput	Costs are assumed in obligated or budgeted then year dollars.
Beta Curve	Costs are allocated according to the cumulative beta curves.

### **BUILT-IN COST ESTIMATING MODELS**

82. CEM is a collection of cost estimating models that can be accessed from and used with ACE. The following sub-sections includes the explanations about CEM models, that are available in the ACEIT on-line help system. The models that CEM includes are as follows:

- a. Black Box Estimators (BBEST);
- b. Constructive Cost Model (COCOMO);
- c. ESC Software Cost and Schedule Model (ESCASM);
- d. Missile Development Cost Model (MISLDEV);
- e. Radar RDT&E Cost Model (RADARDEV); and
- f. Reduced Constructive Cost Model (REDUCOMO).

### **BLACK BOX ESTIMATOR (BBEST)**

83. Black Box Estimator (BBEST) is a family of thirteen electronics hardware cost models that are aimed at calculating the cost of a generic type of equipment that is called "box". The BBEST models provide the user with the CERs, data ranges, statistics, recommended uses, estimates of hardware production and development costs, and estimates of missing technical parameters. They are as follows:

- a. Box Level Development;
- b. System Development;
- c. Digital Electronics;
- d. Digital Interface Electronics;
- e. Power Supply;
- f. Low Power Radio Frequency;
- g. High Power Radio Frequency-Tube Type;
- h. Phased Array Antenna;

- i. Ground Based Antennas;
- j. Airborne Antennas;
- k. Analog Electronics;
- l. Display and Control Electronics; and
- m. Hardware System Integration and Shelter.

84. **BBEST: Box Level Development.** The Box Level Development (BOX\_DEV) model estimates the development cost of individual boxes as well as the development cost of system or large subsystem integration. A total system cost can be obtained by summing the estimates for each box, plus the estimate for the development cost of integration. The model estimates costs in thousands of FY86 dollars including overhead and the general and administrative (G&A) costs, but excluding fee (an agreed-to amount beyond the initial estimate of costs in cost-reimbursement pricing arrangements), software, non-Prime Mission Equipment (PME), and tooling.

85. The BOX\_DEV model estimates the hardware development total lot cost, including recurring and non-recurring costs, as a function of the number of prototype units in the lot, the production cost of the 100th unit (PME) for the box (UC100), the manufacturer's experience, level of hardware design definition, and the type of the equipment (power supply or other).

86. This model assumes all boxes are 100% new development items. Costs of partial developments (e.g., only half the box is new) will be over-estimated by the model.

87. This model can also be run backwards. Given development cost and quantity, it can estimate unit production cost. Given development cost and unit production cost, it can estimate development quantity.

88. The BOX\_DEV model is based on data from 54 items: all are ground based, and nine are power supplies. All the data comes from seven systems, two of which are radars. No missiles are included in the data set. The data reflects mid 1980s production hardware.

89. **BBEST: System Development.** The System Development (SYS\_DEV) model estimates the development costs of radar, communication, and C3 systems hardware. It estimates total hardware development lot cost, including recurring and non-recurring costs, in millions of FY 1986 dollars including G&A, but excluding fee, non-PME, and software. Costs are estimated as a function of the number of prototype units in the lot, the number of prior units developed, UC100 for the system hardware, system type (radar or other), contractor's experience, level of design definition, joint service effort, the percent of the UC100 which is newly developed hardware, and the time duration between contract award and critical design review. The model assumes all systems are at least 5% new developments.

90. SYS\_DEV also estimates the cost to upgrade or modify existing hardware. Given UC100 and the percent of the UC100 that is new, the model prorates the unit cost and estimates new and existing hardware recurring costs separately. It then uses the new hardware recurring cost to drive non-recurring prototype design costs.

91. This model can also be run backwards. Given development cost and UC100, it can estimate development quantity. Given development cost and quantity, it can estimate UC100.

92. The SYS\_DEV model is based on data from 20 systems: 14 are radars and six are communications or C3 systems. Most of the data reflects mid-1970's to early 1980's hardware developments.

93. **BBEST: Digital Electronics.** The Digital Electronics (DIGI) boxes generally have more than 25% of their circuitry devoted to memory and digital processing, such as digital processors, digital signal processors, data bus controllers, memory controllers, radar controllers, and beam steering units. The DIGI model estimates UC100 of digital boxes whose primary function is processing digital information in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. The model estimates costs as a function of weight, volume, power consumption, number of printed circuit boards (PCB), total PCB area, and type of platform.

94. The DIGI model is based on data from 51 items: 28 radar, 13 missile seeker, and 10 communications boxes; 25 are for airborne systems, and 26 are for ground systems. The data reflects early 1970's to mid-1980's production hardware.

95. **BBEST: Digital Interface Electronics.** The Digital Interface (DIF) Electronics model estimates the cost of hardware used to interface electronic boxes using digital information. Some interface boxes contain memory and digital processing circuitry, but not in as high a percentage as found in digital processors. DIF boxes generally have less than 25% of their circuitry devoted to memory and digital processing. Examples of digital interface boxes include multiplexers, modems, bit synchronizers, timing devices, A/D converters, and D/A converters.

96. DIF estimates UC100 of digital interface hardware in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. It estimates cost as a function of weight, power consumption, volume, and number of printed circuit boards.

97. The DIF model is based on data from 26 boxes. All are for ground based communications systems. The data reflects 1980's production hardware.

98. **BBEST: Power Supply.** The Power Supply (POWSUP) model estimates the cost of power supplies and power conditioner hardware. A typical box accepts one or more AC or DC inputs, and outputs one or more DC voltages. Both high voltage and low voltage power supplies are included in this model. This model specifically excludes power distribution units.

99. POWSUP estimates UC100 in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Cost is estimated as a function of weight, volume, input power, output power, and type of platform.

100. The POWSUP model is based on data from 42 items: 17 are for radars, 13 are for missiles, and 12 are for communications systems. The data reflects mid 1970's to mid 1980's production hardware.

101. **BBEST: Low Power Radio Frequency.** The Low Power Radio Frequency (LPRF) model estimates the cost of hardware used to receive or excite electrical signals below frequencies of about 17 GHz. LPRF hardware may contain some signal processing, or A/D converters, but the hardware items in the data set are predominantly analog devices. Examples include all types of receivers, excitors, signal generators, synthesizers, mixers, LNAs, and beamformers.

102. LPRF estimates UC100 in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Cost is estimated as a function of weight, power consumption, volume, and type of platform.

103. The LPRF model is based on data from 48 items: 24 are airborne and 25 are receiver/exciter combinations. The data reflects mid-1970's to mid-1980's production hardware.

104. **BBEST: High Power Radio Frequency, Tube Type.** The High Power Radio Frequency, Tube Type (HPRF\_TUBE) model estimates the cost of transmitters using the most common types of high power amplifiers: tubes. Tube type amplifiers include klystrons, traveling wave tubes, and cross-field amplifiers. Examples of HPRF\_TUBE hardware include radio/communications/radar transmitters and transmit subsystems with up-converters and amplifiers. Transmitters and HPAs using solid state technologies are not treated in this model.

105. The model estimates UC100 in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Cost is estimated as a function of weight, total output power, volume, and type of platform.

106. The HPRF\_TUBE model is based on data from 15 items, eight are airborne and seven are ground based. The data reflects early 1970's to mid-1980's production hardware.

107. **BBEST: Phased Array Antenna.** The Phased Array Antenna (ANTENNA\_PHSD) model estimates the cost of phased array antennas, including both phased array and phase scanned waveguide arrays. Any pedestal costs are included with the antenna.

108. ANTENNA\_PHSD estimates UC100 in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Cost is estimated as a function of aperture, number of phase shifters, total output power, and type of antenna.

109. The ANTENNA\_PHSD model is based on eight systems: one airborne and seven ground. The data reflects late 1970's to mid-1980's production hardware.

110. **BBEST: Ground Based Antennas.** The Ground Based Antennas (ANTENNA\_GND) model estimates UC100 of non-phased array, ground based

antennas (with their pedestals and feeds). It estimates costs in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Costs are estimated as a function of antenna type and aperture.

111. The ANTENNA\_GND model is based on data from 9 systems: six are dish antennas, physically the largest items in the data set, and three are non-dish systems such as horn arrays. The data reflects mid-1970's to early 1980's production hardware.

112. **BBEST: Airborne Antennas.** The Airborne Antennas (ANTENNA\_AIR) model estimates UC100 of non-phased array, airborne antennas (with their pedestals and feeds) such as dishes and other mechanically scanned systems, including small slotted arrays. The model estimates costs in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Costs are estimated as a function of antenna type, aperture, and weight.

113. The ANTENNA\_AIR model is based on data from 13 systems: one is a dish antenna, and 12 are non-dish systems, mostly small slotted array, mechanically scanned antennas used for airborne fire control. The data reflects mid 1970's to early 1980's production hardware.

114. **BBEST: Analog.** The Analog (ANALOG) model estimates UC100 of certain analog electronic boxes as a function of weight, volume, and platform (airborne or not). Costs are estimated in thousands of FY 1986 dollars with G&A, but excluding fee and Non-PME.

115. ANALOG boxes process or output analog signals for use in other boxes or subsystems. Examples of analog devices include such boxes as servo controllers for wings and fins, inertial navigation devices, autopilots, motor drivers, analog processors, analog test facilities, limiters, and motor controllers.

116. ANALOG is based on data from 27 systems: 15 are airborne items. The data represents mid 1970's to early 1980's production hardware.

117. **BBEST: Display and Control Electronics.** The Display and Control Electronics (DISP\_CONT) model estimates UC100 of display and control hardware such as officer's consoles, operator's consoles, and operator's displays in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. The model estimates cost as a function of weight, volume, type of platform, and type of display.

118. The DISP\_CONT model is based on data from 20 boxes: six are airborne, and 14 are ground based. The data reflects early 1970's to mid-1980's production hardware.

119 **BBEST: Hardware System Integration and Shelter.** The Hardware System Integration and Shelter (INTEG) model estimates the cost to integrate many boxes together into a system or large subsystem. This includes the costs of labor, cabling, racking, assembly, checkout, and test at the system level, as well as the costs of a shelter for ground based items. The model assumes that lower level items are fully integrated and tested at the box level such that only the combining of boxes or subsystems is required.

120. INTEG estimates UC100 of integration hardware and labor in thousands of FY 1986 dollars including G&A, but excluding fee and non-PME. Cost is estimated as a function of unintegrated hardware costs at unit 100, platform (airborne or ground), and the requirement for a shelter.

121. The INTEG model is based on data from 16 systems: four are airborne systems, five are ground based systems without shelters, and seven are ground based

systems with shelters. The data represents early 1970's to mid-1980's production hardware.

### **CONSTRUCTIVE COST MODEL**

122. The Constructive Cost Model (COCOMO) estimates the effort and duration required to develop a software project. This model is based on 63 software development programs completed prior to 1980. It estimates costs at the project level, i.e., an integrated set of CSCIs (Computer Software Configuration Items). Costs are estimated from project design through test and evaluation. Requirements analysis, prior costs, security requirements, volatility, and implementation & maintenance costs are excluded.

### **ESC SOFTWARE COST AND SCHEDULE MODEL**

123. The ESC Software Cost and Schedule Model (ESCASM) is a CSCI effort model, predicting software development effort from the availability of an allocated baseline at the completion of the system design review, through the functional qualification test, when the CSCI is promoted to software-to-software integration. System design, requirements analysis, system tests and audits, independent verification and validation by outside contractors, and government program office costs are excluded. The model makes very little use of effort adjustment factors.

### **MISSILE RESEARCH, DEVELOPMENT, TEST AND EVALUATION COST MODEL**

124. The Missile RDT&E Cost Model (MISLDEV) estimates the complete costs of tactical missile development contracts for the EMD phase only. It is based on 13 tactical missile EMD programs and uses a production-to-prototype

relationship to estimate missile subsystem design and fabrication costs. Other WBS line items are estimated by parametric equations or factored from the missile subsystem design and fabrication costs.

### **RADAR RESEARCH, DEVELOPMENT, TEST AND EVALUATION COST MODEL**

125. The Radar RDT&E Cost Model (RADARDEV) is a cost model that estimates the complete costs of radar development contracts. The model is based on data from 16 modern radar systems (8 airborne and 8 surface) and contains a prototype-to-production cost equation.

### **REDUCED CONSTRUCTIVE COST MODEL**

126. The Reduced Constructive Cost Model (REDUCOMO) estimates the effort and duration required to develop a software project. It is a modified version of the COCOMO model. It excludes some statistically insignificant COCOMO effort adjustment factors.

### **ACE REPORTS**

127. ACE has extensive reporting capability. Each workscreen has Default Print and Tailored Print options. The Default Print option produces hardcopies of workscreens with pre-determined structures. In the tailored printing, the user can arrange the columns to be included, their order of appearance, and their column width.

128. ACE also has an Output option that provides a comprehensive documentation package. ACE offers the report options depicted in Table VI. As

it appears on this table, ACE includes a special output option to create US Army reports in required designs and contexts.

129. The report options reflected in Table VI reflect the parts of a whole. The user can select more than one output option. Most of these options offer secondary design options when the user makes the selections. Within this context, the user can specify his/her preferences in terms of summary or detailed reports, the structure of the reports, groupings, tables to be included, escalation, and sensitivity, and add his/her own narrative explanations to these reports.

130. ACE produces the desired reports as DOS text files, and provides the user with a Print option for hardcopies.

#### TABLE VI

#### ACE REPORT OPTIONS

Phased Results
Methodology Tables
Sensitivity Comparison
Narrative
Appendices
Budgetary Phased Matrices
Cost Category Matrices
Table of Contents
Army Report Generator Files
Export Delimited ASCII

## COMPLEMENTS OF ACE

131. As mentioned previously, ACEIT is a shell that contains some other modules in addition to ACE and CEM. These are COSTAT, RISK, LIBRARIES, and some utilities.

### COSTAT

132. COSTAT is a statistics package designed expressly with the cost analyst in mind (6:Sec 1,1). It includes the methods and techniques used in the day-to-day work of cost analysis. It is not an extensive statistical package. It includes the following statistical analysis routines:

- a. Univariate analysis of single variable data:
  - (1) measures of central tendency;
  - (2) measures of dispersion;
  - (3) measures of shape (skewness of the distribution);
  - (4) confidence interval for the sample mean; and
  - (5) histogram.
  
- b. Multi-variate regression analysis:
  - (1) linear;
  - (2) log linear; and
  - (3) non-linear.
  
- c. Learning curve analysis:
  - (1) cumulative average theory;
  - (2) unit cost theory; and
  - (3) weighted or unweighted method of least squares.

133. COSTAT gives the results of the analyses in tabular and graphical formats.

## RISK

134. The RISK model is designed to assist cost analysts in quantifying the risk in their cost estimates. It is structured around the WBS specified during the development of the cost estimate with the assumption that an estimating methodology is applied to each of the lowest level cost elements of the WBS to generate the point estimate (7:Sec 3,1). It offers two approaches for the risk assessment: a Monte Carlo Simulation and an Analytic Approach. The latter assumes that the distributions at the aggregate levels of cost indenture can be adequately described by beta distributions, and tries to fit a beta curve to the aggregate levels. The former tries to develop an approximation of each aggregate element's distribution by repeating random draws for each lowest level cost element (For more information, see Ref. 7).

135. RISK also assumes that the lowest level cost elements fall into one of four categories: CER, Log-linear CER, Cost-to-cost factor, and an analog or engineering buildup. Since each method naturally gives different degrees and characteristics about the uncertainty of its estimate, RISK provides five distribution forms to model the different uncertainty characteristics. These are Normal, Lognormal, Triangular, Beta, and Uniform distributions.

## LIBRARIES

136. ACE includes some methodology libraries that are collections of CERs, factors, models, and sources that can be used to develop and support the user's estimating methodology. The user can access the available libraries and import the one desired. Then, it can easily be modified to suit the user's needs. The methodology libraries included in the ACEIT Demo Version are indicated in Annex A.

## UTILITIES

137. ACEIT contains some utilities regarding the ACEIT hardware configuration, file conversion and transfers, and creating inflation indexes.

## EVALUATION OF ACE

### DEFICIENCIES OF ACE

138. The first shortcoming of ACE is that it is not an LCC model. It is only a special spreadsheet that can be used for cost estimating purposes. The user may use ACE's cost estimating models, CERs, and factors, or he/she may not. It is no more than a spreadsheet with pre-defined columns. It performs the calculations expressed as described in the methodology in a specific column.

139. Another disadvantage of ACE is its limited use for non-US users. ACE has been developed and designed especially for US users. All the cost models it includes are related to US Army, Air Force, or Navy. All CERs and factors it offers are based upon US data. It uses a number of abbreviations for some specific US organizations. Hence, they are mainly valid only for the US users. However, the non-US users may obtain valuable benefits by using ACEIT's models, CERs, and factors especially when they do very rough estimates, and/or when they can adopt these information resources to the research case under study.

140. Though the user is free in terms of scope of the life cycle model, ACE's life cycle definition in its on-line help system is inadequate. It does not cover all the life cycle phases. ACE covers the R&D phase partially, and disregards the disposal phase completely. The cost estimating models it includes in its library are

related to specific life cycle phases. ACE does not contain a cost estimating model that encloses all the life cycle phases.

141. Further, each cost model ACE offers requires some assumptions. ACE itself states that these models should be used in cases that are in harmony with these assumptions. It is also stated that each model should be used within the range of its data set. Otherwise, ACE will produce estimates with high deviations.

142. Furthermore, ACE and the built-in cost estimating models do not clearly distinguish maintenance levels.

143. Estimating with models based on data from the existing systems is called "analogy". The possibility of obtaining correct estimates with pre-structured models depends upon how much of the system being estimated is analogous to the model used. Since most of the CEM models are based on the data that reflect mid-1970's to early 1980's production hardware, and since it is very clear that there are great differences even between 1980's and today's technologies, the estimations based on such an amount of analogy will always carry some doubt.

144. ACE assumes that the user is an expert in cost estimation. It requires the user to structure the WBS/CES, to define the methodology of the each cost item, and to apply the learning theory. If the user employs at least one of the CEM models, he/she has some hints about the WBS/CES and the related methodologies. Using these, he/she can develop a model. On the other hand, if the user starts with a blank screen, he/she must structure the whole model. The success of the modelling depends upon the knowledge level of the user.

145. Another shortcoming of ACE, possibly the least important, is that it does not have mouse support. The user must use the keyboard for every interaction.

### **STRENGTHS OF ACE**

146. ACEIT as a whole, and ACE as a part of ACEIT are user-friendly programs. The user is provided with colored displays, and spreadsheet-style command menus with pull-down windows. Each menu choice is shown together with a summary information placed at the bottom of the screen. Besides, they have an integrated full-feature on-line help system. Further, ACE has well-designed user manuals.

147. ACE is a flexible cost estimating spreadsheet. The user is free in terms of the cost estimating model to be applied. Therefore, it can be used to estimate any type of cost on condition that the estimation methodology is specified.

148. ACE has built-in cost estimating methodology libraries containing hundreds of CERs, factors, and models. The user can select whichever he/she wants to use. Choices from these libraries are brought directly into the estimate along with appropriate descriptive documentation. It includes a considerable number of mathematical, financial and statistical functions, and allows the user to create special purpose functions. It also has built-in WBSs and definitions that can be expanded and edited to suit the specific estimate at hand. As mentioned above, even the non-US users may obtain valuable benefits by using ACEIT's models, CERs, and factors especially if they are developing very rough estimates.

149. ACE automatically checks variables, variable names, mathematical expressions, and missing values. It can normalize the values for different monetary units, fiscal years, and burden (fee, G&A and overhead) rates. It includes built-in inflation indices. It has the capability of applying the learning theory. It also has the built-in capability to handle simultaneous sensitivity/what-if analyses including production quantity changes.

150. ACE has a flexible and comprehensive documentation capability. The user can arrange the types, structures, and coverage of reports, specify the escalation and sensitivity conditions, and add his/her narrative explanations. He/she can design categories, and therefore can obtain grouped information in reports.

#### **IV. LOGISTICS ANALYZER LIFE CYCLE COSTING** **(LOGAN(LCC)) MODEL**

151. The Logistics Analyzer Life Cycle Costing Model (LOGAN(LCC)), previously called the Department of National Defence Life Cycle Costing model (DND LCC), is the specific LCC model developed to meet the needs of the Canadian Forces. It was developed in 1978 by Bell Northern Research Ltd. under contract for the Directorate of Engineering and Maintenance Planning and Support (DEMPS) to be run on a mainframe (8:Annex A). The Directorate of Logistics Analysis (D Log A) developed its first PC version in 1988. D Log A has upgraded the model several times since then.

152. The most recent version of DND LCC is a subsystem of the computer model known as the Logistics Analyzer (LOGAN) (9:1). Thus, the DND LCC model is now referred as LOGAN(LCC). LOGAN includes two other modules: a sparing module known as LOGAN(SPARING), and a level of repair analysis module known as LOGAN(LORA).

#### **PURPOSE OF LOGAN(LCC)**

153. LOGAN is intended especially for Project Management Office and Life Cycle Materiel Management staffs (8:Abstract), performing logistics support analysis (LSA) tasks (9:1). Thus, it is aimed at enabling these decision makers to achieve sound integrated decisions. LOGAN(LCC), as a module in the shell, enables users to conduct engineering-oriented life cycle cost studies (8:5), and at the end, provides life-cycle-related cost information to managers to assist in their decision-making processes.

154. The LOGAN(LCC) model can be used for (1:ii-iii):

- a. Maintenance Manning Requirements Determinations;
- b. Discard Part Requirements Determinations;
- c. Failure-centred Maintenance Cost Analysis;
- d. LCC Analysis; and
- e. Uncertainty (Cost Risk) Analysis.

### **SYSTEM REQUIREMENTS OF LOGAN(LCC)**

155. LOGAN requires a version of 3.30 or later of PC-DOS or MS-DOS and a mouse driver. Minimum hardware requirements are as follows (9:4-5):

- a. IBM PC AT, PS/2 or compatibles;
- b. 475 K RAM;
- c. 1024 K of expanded memory;
- d. 3 MB hard disk space; and
- e. Mouse.

156. One floppy disk drive, one hard drive and a monitor are necessary. A math coprocessor is highly recommended. A printer is needed for printouts.

### **GENERAL CHARACTERISTICS OF LOGAN(LCC)**

157. The LOGAN (LCC) model is a computer-based analysis package that is aimed at conducting LCC analysis. It is a general model that is capable of dealing with systems consisting of one or more prime equipments that are situated at one or more locations supported by a maintenance and supply organization (8:5).

158. LOGAN(LCC) calculates the life cycle cost of the fixed asset under study. All the costs during the Research and Development, Procurement, In-Service and Disposal phases of the equipment are considered in these calculations, with a special emphasis on the costs of Maintenance and Supply Support activity during its Operational Stage.

159. LOGAN(LCC) has three calculation methods: Complete LCC, No Spares LCC, and Quick Cost. The Complete LCC option is extensive in coverage. It considers all potential costs during a life cycle, including the cost of initial spares and their transportation. In order to obtain this data, it requires LOGAN(SPARING) to be run first. LOGAN(SPARING) assesses the system's operational readiness implied by the level of spare parts inventory in the maintenance system, and produces the spares distribution required by LOGAN(LCC).

160. The No Spares LCC mode of LOGAN(LCC) excludes the cost of initial spares and their transportation. This is why it has no link to LOGAN(SPARING). The Quick Cost option, on the other hand, aggregates the operating and support costs, and gives preliminary estimates of life cycle costs by employing considerably less data.

161. The following operations are performed with LOGAN(LCC) (8:9) :

- a. activates the creation of a costing and logistics support database for analysis;
- b. validates the consistency of this data;
- c. permits on-line revision or correction of this data;
- d. performs an extensive number of cost, maintenance policy and risk

- analysis functions on this data;
- e. allows the performance of several layers of sensitivity analysis;
  - f. permits the performance of sparing analysis; and
  - g. generates reports on the results of each calculation method.

### **USER-FRIENDLINESS OF LOGAN(LCC)**

162. LOGAN has user-friendly input/output capabilities. It provides the user with a coloured working environment, and horizontal menus reflecting the main and sub-functions of the model. The user needs only click the desired function or data input choice. The data are entered into well-designed screens, inclusion of which is adjusted automatically according to the indenture level of item or line of maintenance. It facilitates entering data by including previous item or echelon records, by providing default values, or by providing menus representing possible choices.

### **LOGAN(LCC) MODEL**

#### **DEFINITION AND SCOPE OF LIFE CYCLE COST IN LOGAN(LCC)**

163. LOGAN (LCC) defines the LCC as the study of all the costs of an equipment or system arising over its entire life (10:1), and assumes that the life cycle of a system consists of four phases: research and development, procurement, operations and maintenance, and disposal (11:1). The following formula reflects its LCC definition:

$$LCC = TR\&D + TACQ + TOS + TDIS$$

where: LCC = Total Life Cycle Cost,

TR&D = Total Research and Development Cost,

TACQ = Total Acquisition Cost,

TOS = Total Operations and Maintenance Cost,

TDIS = Total Disposal Cost.

164. The model uses a pre-defined cost class structure in order to group the costs and to calculate the LCC of the system. The cost classes it uses are indicated in Table VII. Thus, the LCC of a system is equal to the sum of the costs of that system within these cost classes. In other words, the LCC equation above can be rewritten as follows:

**TABLE VII**

**LOGAN(LCC) Cost Classes**

-Research and Development
- Acquisition
- Disposal
- Operation
- Maintenance
- Supply Support
- Other

$$\text{LCC} = \text{TR\&D} + \text{TACQ} + \text{TDIS} + \text{TOP} + \text{TMNT} + \text{TSS} + \text{TOT}$$

where: LCC = Total Life Cycle Cost,

TR&D = Total Research and Development Cost,

TACQ = Total Acquisition Cost ,

TDIS = Total Disposal Cost,

TOP = Total Operation Cost,

TMNT = Total Maintenance Cost,

TSS = Total Supply and Support Cost,

TOT = Total Other Cost.

165. LOGAN(LCC) requires the identification of costs as fixed or recurring, and it has pre-determined twelve cost items in the Maintenance and the Supply Support cost classes. Table VIII designates these cost items with their types.

166. The pre-determined Maintenance and Supply Support cost items are the minimum requirements for these classes. The user can not delete or change them. Only their values can be altered. However, it is possible to add new cost items to all of the cost classes, and alterations and/or deletions can be made with these added items.

167. The LOGAN(LCC) model has definitions for only the Maintenance and the Supply Support cost classes. It has no pre-defined cost breakdown structure for the other cost groups. In fact, it requires the creation of a project-based cost structure by determining and classifying the cost items associated with the life cycle of the equipment as fixed or recurring, and in turn, dividing these fixed or recurring costs into the areas of global interest to the decision

**TABLE VIII**  
**LOGAN(LCC) Pre-determined Cost Items**

<b>Cost Item</b>	<b>Cost Type</b>
<b><i>Maintenance Cost</i></b>	
Scheduled Maintenance Labour Rate	Recurring
Labour Rate at Prime Equipment Site	Recurring
Labour Rate at 1st Line Site	Recurring
Labour Rate at 2nd Line Site	Recurring
Labour Rate at 3rd Line Site	Recurring
Original Maintenance Document	Fixed
Translation Cost per Page	Fixed
Maintenance Software Cost per Line	Fixed
Document Update Cost per Page	Recurring
Reproduction and Distribution Cost per Page	Recurring
<b><i>Supply Support Cost</i></b>	
Initial Supply Document	Fixed
Recurring Supply Administration	Recurring

maker, on condition that its pre-determined cost classes and the twelve cost items within the specified cost classes are used.

168. In addition to the cost data, LOGAN(LCC) employs a considerable number of parameters to make the necessary projections, calculations and analysis.

### **INPUT DATA**

169. LOGAN(LCC) requires the user to input data associated with the following areas:

- a. Echelon;
- b. Item;

- c. Cost;
- d. Inflation;
- e. Constants;
- f. Test Equipment; and
- g. Sensitivity.

170. **Features of Echelon Data.** The echelon data group specifies the hierarchy of support sites, and designates the place of each support site within this structure. The maximum number of support sites that LOGAN(LCC) allows is 40 (12:9). Support sites must be entered in such a way that the echelon reflects the hierarchy, but it is not necessary to enter the sites sequentially. Further, the model permits the utilization of four levels of maintenance. The echelon data also include the distances between the support sites, and the related shipping cost data, that are required for the calculation of transportation costs.

171. **Features of Hardware Item Data.** The Item data group, similar to the echelon data, specifies the hardware breakdown structure, and indicates the place of the item being entered within that structure. It includes some cost-related data that are used in the calculations of acquisition and operation and support costs. Included within this group are the item's likely replacement cost, shipping weight, documentation, software, mean time between failures, procurement lead time, training times, repair times and the capabilities of the lines of maintenance. In addition, the repair material cost, the contractor repair cost and the scheduled maintenance cost as percentages of the item cost are defined.

172. Items must be entered in such a way that their indenture codes reflect the relationship of an item to the next higher assembly in a top-down breakdown of the prime equipment, but it is not necessary to enter them sequentially. The maximum number of items with the LRU indenture is 1000, and each LRU may have up to 75 subcomponents including all SRUs and modules (12:9).

173. **Features of Cost Data.** As mentioned above, the LOGAN(LCC) model offers a flexible cost definition system even though it has some pre-determined cost elements that are to be utilized for the calculation of the LCC of the system. Except to identify fixed and recurring costs within summary level cost classes, no other pre-defined project cost structure is imposed. Thus, the user may establish the cost structure of the project.

174. The LOGAN(LCC) model requires cost relevant data on the name of the cost, the likely amount, the cost type, the cost measure, the cost class, and the inflation category. The cost type defines whether the cost is fixed or recurring. The cost class specifies the class of the cost item such as Research and Development, Acquisition, Disposal, Operation, Maintenance, Supply, and Other. The cost measure indicates the unit of cost measurement. The model allows the utilization of the measures shown in Table IX. The inflation category, on the other hand, addresses the rate utilized in the calculation of the inflated value of this cost item. The following non-changeable default inflation categories are given by the model, but the user can add new categories and delete these added categories, and of course, modify the rates:

- a. Consumables;
- b. Manpower;
- c. Maintenance;
- d. Transport;
- e. Administration; and
- f. No Escalation.

175. The Constant data are the global cost data related to such areas as life cycle data, acquisition profile, scheduled maintenance, prime equipment maintenance, and operations.

**TABLE IX****LOGAN(LCC) Cost Measures**

1. Prime Equipment
2. 1st Line
3. 2nd Line
4. 3rd Line
5. Operating Hours
6. LRU
7. New Item
8. Scheduled Manhour
9. Prime Equipment Manhour
10. 1st Line Manhour
11. 2nd Line Manhour
12. 3rd Line Manhour
13. Page (Original)
14. Program Line
15. Page (Distributed)
16. Straight(No Factor Used)

176. The Test Equipment data is required to calculate the costs related to the external test equipment.

**LIFE CYCLE COST CALCULATIONS OF LOGAN(LCC)**

177. LOGAN(LCC) has three calculation methods: Complete LCC, No Spares LCC and Quick Cost. The Complete LCC option is extensive in coverage. It takes the whole life of the weapon system into consideration. It calculates the

project's life cycle cost as the sum of total research and development cost, total acquisition cost, total disposal cost, total operation cost, total maintenance cost, total supply and support cost, and total other cost.

178. The LOGAN(LCC) model first differentiates between the fixed and the recurring costs of the project. It uses the following fixed cost categories (13:Annex A,1), the sum of which yields the total fixed cost:

- a. Research and Development;
- b. Acquisition;
- c. Disposal;
- d. Operation;
- e. Maintenance;
- f. Supply Support; and
- g. Other.

179. The model employs the following recurring cost categories (13:Annex B,1), the sum of which yields the total recurring cost:

- a. Operation;
- b. Maintenance;
- c. Supply Support; and
- d. Other.

180. The system's life cycle cost is the total of the total fixed cost and the total recurring cost.

181. LOGAN(LCC) employs the stochastic and the "fuzzy" arithmetic approaches to estimate the life cycle cost distributions, and to see how uncertainties impact on the system's life cycle cost.

182. The No Spares LCC option of LOGAN(LCC) excludes the cost of initial spares and their transportation. The Quick Cost option disregards most of the operating and detailed support costs. It uses very general information.

### **LOGAN(LCC) REPORTS**

183. In the Complete LCC and No Spares LCC options, LOGAN(LCC) provides the user with the choices shown in Figure 4 when the Reports option is clicked or at the end of the LCC calculation process. The user can cancel the undesired report types since all have been selected by the program itself, and can select the cost graphs to be displayed, which present the results of the uncertainty analyses in a graphical form. Then, LOGAN(LCC) arranges the output in accordance with the user's choices and produces the cost, the manpower and the recurring maintenance reports.

184. The Quick Cost option produces only a cost report.

185. In addition to these reporting capabilities, each LOGAN(LCC) input screen has a "Print" option that enables the user to get the printout of the input data appearing on the screen.

186. Unfortunately, LOGAN(LCC) reports to the screen as default, and sends the output to files instead of the printer. The user must get out of the program to print out these files.

### **COMPLEMENTS OF LOGAN(LCC)**

187. LOGAN includes two analysis subsystems in addition to life cycle costing: Sparing and Level of Repair Analysis.

<input checked="" type="checkbox"/>	Manpower Summary Report	[ file .RLM ]
<input checked="" type="checkbox"/>	Recurring Maintenance Report	[ file .RLR ]
<input checked="" type="checkbox"/>	Costs Report	[ file .RLC ]
<input type="checkbox"/>	Life Cycle Cost Graph	[file .CLS/F]
<input type="checkbox"/>	Fixed Cost Graph	[file .CFS/F]
<input type="checkbox"/>	Annual Cost Graph	[file .CAS/F]
<input checked="" type="checkbox"/>	Preview on Screen	
Output File Name	<input type="text" value="MRSISSPA"/>	

**Figure 4: LOGAN(LCC) Report Screen**

### **SPARING**

188. LOGAN has a Sparing option that initializes the Recursive Optimal Spares Allocation Model (ROSAM). The objective of this model is to optimally allocate the spares needed to support a given weapon system (12:1). It optimally selects the numbers and types of spare items to purchase, and the placement of these parts among the repair facilities of the Logistics Support Organization in accordance with a measure of effectiveness selected by the user.

189. There is a link between the LCC model and the Sparing model. The output of the latter is a prerequisite for the functioning of the former in its

Complete LCC mode. The LCC module uses the spares file created by the Sparing module.

### **LEVEL OF REPAIR ANALYSIS**

190. LOGAN's L.O.R.A. option initiates the Automated Level of Repair Analysis (ALORA) module. ALORA gives the most cost-effective repair and maintenance policy for the prime equipment .

### **SENSITIVITY ANALYSIS**

191. LOGAN(LCC) and the other modules of LOGAN have sensitivity options to measure the impact of changes in the key parameters. LOGAN(LCC) carries out sensitivity analysis on the following parameters:

- a. Mean time between failures;
- b. Shipping weight;
- c. Procurement lead time;
- d. Labour rates;
- e. Inflation rate;
- f. Shipping cost;
- g. Training times;
- h. Replacement cost;
- i. Repair cycle time;
- j. Order and ship time;
- k. Operational hours per month;
- l. Repair manhours;
- m. Repair material cost;
- n. Contractor repair cost;
- o. Scheduled maintenance cost; and

- p. Work hours per month per technician.

### EVALUATION OF LOGAN(LCC)

#### DEFICIENCIES OF LOGAN(LCC)

192. The LOGAN(LCC) module has some important deficiencies. First of all, it has no on-line help function. The program gives some indications about the order of the menu selections, but they are very limited, and in fact, provide nothing of importance.

193. Another shortcoming of LOGAN is its printing capability. It sends the material to be printed to DOS text files while the user may be waiting for the hardcopy of the output. That is, its print function actually is a save function. In order to get a printout, the user must leave LOGAN first, and then use another program with a real printing capability, or use one of the DOS commands enabling printing.

194. It seems that LOGAN has some logical programming errors. In a LCC project with verified echelon and item data having 1 LRU, 10 SRUs and 9 modules, it reported 1 LRU, 10 SRUs and 6 modules. This brings into question the data integrity. Further, sometimes unsuitable data crashes the computer when it is met instead of warning the user.

195. Another disturbing feature of LOGAN is related to the Complete LCC run. The Complete LCC option of LOGAN(LCC) uses the initial spares file, one of the outputs of LOGAN's Sparing module, and forces the user to operate the Sparing module in order to generate this file, by giving a message explaining the situation. The program waits for a selection by the user after finishing all phases

of the sparing analysis and generating the spares file, while the user expects it to return back to the LCC module and to resume and complete the analysis.

196. Similarly, it sometimes requires an "OK" from the user for the verification of echelon data. Actually, the user has no other choice to run the LCC program. It seems that this validation process is unnecessary.

### **STRENGTHS OF LOGAN(LCC)**

197. LOGAN is a user-friendly program. It provides the user with colour displays and mouse-accessible horizontal menus. It has a draft user's manual(\*) that is being updated.

198. The LOGAN(LCC) model has easily understandable input data screens. The user can input data into fields templated. The model adjusts the inclusion of data screens according to the indenture level of the item or the line of maintenance. It also facilitates the input of data by keeping the inclusion of previous item or echelon records, by providing default values, or by providing menus representing possible choices. The model has the ability of controlling the consistency and validity of the entered data, and permits its on-line amendment or correction.

199. The LOGAN(LCC) model covers all phases of the life cycle of a system. It estimates all the potential costs associated with an asset's life cycle, starting with its birth as an idea, and ending with its disposal.

200. The LOGAN(LCC) model is a very flexible life cycle costing model in terms of the amount of data required, and the cost structure utilized. This model

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\* Since the draft user's manual was being updated during the conduct of this study, the author had no chance to evaluate it.

can even make LCC estimations using little data. It also loosens the requirement for detailed data by allowing the values of its data elements to be associated with ranges of uncertainty, and produces meaningful LCC estimations. This feature allows some LSA tasks to be addressed much earlier before all the data is known. Thus, it offers wider scope for the investigation of design and support activities before any commitment of funds.

201. LOGAN(LCC) has a very flexible cost definition ability. It does not utilize a fixed or a pre-determined cost breakdown structure. Except to identify fixed and recurring costs within summary level cost classes, no other pre-defined project cost structure is imposed. This permits the representation of unique project features of significance to its life cycle cost. Each cost element may be associated with an expenditure profile, an escalation rate and a year in which costs start. These data permit a limited assessment of the effect of activity delays on project expenditures.

202. The LOGAN(LCC) model has the ability to create new projects from existing ones. The user is allowed to import the echelon and the parts data from different projects. This feature provides a considerable amount of time savings for projects with the same echelons and/or items data.

## V. CONCLUDING REMARKS AND RECOMMENDATIONS

203. This study attempted to develop recommendations to the improvement of LOGAN(LCC) by trying to make an evaluation of the CASA, ACE, and LOGAN(LCC) models for a user perspective. There are fundamental differences between these models. Each has some individual strengths and weaknesses. These points were expressed here for the purpose of developing new ideas for LOGAN(LCC). Other studies with different purposes may give different evaluation results.

204. The general characteristics of the models reviewed in this study are summarized in Table X. The chart indicates that all the models are engineering-based, but ACE is, at the same time, analogous. CASA and ACE, the US-originated models, disregard the disposal phase of the life cycle. All the models can perform sensitivity analysis, risk analysis, inflation adjustment, and discounting. All of them are user-friendly, but require a large amount of data. LOGAN(LCC) suffers from the lack of an on-line help system, the lack of an effective printing capability, the lack of warranty consideration, and the lack of a summation feature that allows the user to handle very large projects by combining the outputs of several LCC runs. However, it is the sole model that considers all phases of a life cycle, presents graphical outputs, and clearly considers the maintenance organizations in the LCC calculations.

205. The point that should be recommended first for LOGAN(LCC) is that the above-mentioned drawbacks be eliminated. These changes should specifically cover the following matters:

- a. LOGAN(LCC) should be improved with the addition of an on-line help system;

**TABLE X****General Characteristics of Reviewed LCC Models**

Model Characteristics	CASA	ACE	LOGAN(LCC)
Type of Model	E	A/E*	E
P H A S E	RDT&E	X	X*
	Acquisition	X	X*
	Operation & Maintenance	X	X*
	Disposal		X
Sensitivity Analysis	X	X	X
Risk Analysis	X	X	X
Considering Maintenance Organization			X
Inflation Adjustment	X	X	X
Discounting	X	X	X
Warranty	X		
Summation	X	X	
On-Line Help	X	X	
Mouse Support	X		X
Graphical Reports			X
Report Coverage	G	G	G
Printing Capability	G	G	F
Data Intensity	H	H	H
User Friendliness	G	G	G
User Manual	G	G	N/A

(\*) Depends upon the user's definition.

Legend: X - Characteristic exists  
 A - Analogy  
 E - Engineering  
 G - Good  
 N/A - Not Applicable  
 H - High

- b. LOGAN(LCC) should provide a full printing capability. The user should be allowed the option to send output to a printer. It also ought to permit the user to get the hardcopies of graphical outputs.
- c. The logical programming errors in LOGAN must be eliminated. It should report item totals correctly. An error handling system that prevents the computer from crashing due to incorrect data or the lack of data should be designed and embedded into LOGAN(LCC).
- d. In the Complete LCC runs, LOGAN(LCC) should operate the sparing function automatically instead of notifying the user when it needs the initial spares file. It should resume LOGAN(LCC) at the end of the LOGAN(SPARING) run, and complete the LCC calculations.
- e. The validation process that requires a user approval for data verification should be eliminated, and performed automatically.

206. Other recommendations are related to the strengths of the other softwares included in this study. The suggestions in this area are as follows:

- a. LOGAN(LCC) reports only inflated values. It is believed that it would be better in terms of decision making to add reporting options for constant and discounted values into its reporting capabilities.
- b. LOGAN(LCC) should handle warranties specifically in order to provide more accurate estimates.

- c. A feature that sums the outputs of various LCC runs of subsystems, and thus gives the life cycle cost of the whole system should be added to LOGAN(LCC) in order to make it possible to accomplish analysis runs on large projects.

207. Another group of recommendations concerns the general software features. Almost all of today's software is WINDOWS oriented. It is expected that the adaptation of LOGAN(LCC) to the WINDOWS environment will increase its level of user-friendliness. Furthermore, this may provide better memory utilization, and thus raise the LOGAN(LCC)'s input boundaries.

208. Another feature of today's software is the mouse support they provide. They can function with or without a mouse. In terms of LOGAN(LCC), a mouse is a necessity. It is recommended that LOGAN(LCC) be also accessible without mouse support. The additions of a temporary operating system exit function and some DOS utilities may enrich the software.



## REFERENCES

1. Kernzer, Leonard F., DND LCC 2.0 An Improved Concept for Life Cycle Costing (Second Edition), ORAE Project Report No. PR 575, July, 1992.
2. "Cost Analysis Strategy Assessment (CASA) Version 3.0", EG&G, Inc., Manassas, Virginia, February 1994.
3. "A Parametric Method to Estimate the Cost and Duration of a Cost Research Study", Management, February 22, 1994.
4. Automated Cost Estimator (ACE) Basic User's Guide PC Version 2.0, Santa Barbara, CA, July 1993.
5. Automated Cost Estimator (ACE) Advanced User's Guide PC Version 2.0, Santa Barbara, CA, January 1993.
6. COSTAT User's Guide, Santa Barbara, CA, January 1993.
7. RISK User's Guide Version 2.3, Santa Barbara, CA, March 1995.
8. Kerzner, Leonard F. and Bayne Robert H., A User's Guide to DND LCC 2.0, ORAE Project Report No. PR 556, October, 1991.
9. Ormrod, M. K., Draft Logan Shell V1.0: User's Guide (Release 1.0), ORA Project Report No. PR 715, December, 1994.
10. Provencher, M. and Vigneault, M., LOGAN (LCC) V 1.0: Mathematical Theory (Release 1.0), ORA Project Report No. PR 703, November, 1994.

11. A Quick Guide to Life Cycle Costing
12. Reding, Dale F., A Guide to ROSAM 2.1, ORAE Project Report No. PR 518, May, 1990.
13. Provencher, M., LOGAN (LCC) V 1.1: Mathematical Theory Manual (Release 1.0), ORA Project Report No. PR 9522, October, 1995.

ANNEX  
D Log A RESEARCH NOTE 9601  
JANUARY 1996

**ACE ESTIMATING METHODOLOGY LIBRARY**

WBS	METHODOLOGY(*)
1 Development Hardware CERs	
2 Radar Hdwe Cost-1	[RDev1] 4.27*UC150^1.162*RT^1.19*(Q2^59-Q1^59)/.59
3 Radar Hdwe Cost-2	[RDev2] 8.04*UC150*(Q2^753-Q1^753)/.753
4 Comm Hdwe Dev Cost	[FATES] 4.74*UC150C*(Q2^699-Q1^699)/.699
5	
6 Software CERs/Factors	
7 Simple S/W (\$/LOC)	[ESC Factors] 50*(FRSUB*1.35+(1-FRSUB))*LOC
8 Average S/W (\$/LOC)	[ESC Factors] 103*(FRSUB*1.35+(1-FRSUB))*LOC
9 Difficult S/W (\$/LOC)	[ESC Factors] 192*(FRSUB*1.35+(1-FRSUB))*LOC
10	
11 Dev Acq Spt CERs	
12 Sys T&E (excl lge pgms)	[ESC CERs] 0.336 * (PMP_F^0.916)
13 Sys T&E (S/W Intensive Pgms Only)	[ESC CERs] 1.908 * (PMP_F^0.699) * (2.807^COM)
14 S/P Mgt (incl lge pgms)	[ESC CERs] 2.026*(PMP_F^0.824)*(1.694^SUBKR)*(1.309^SWINT)
15 S/P Mgt (excl lge pgms)	[ESC CERs] 1.950 * (PMP_F^0.833) * (1.827^SUBKR)
16 S/P Mgt (Abn Pgms Only)	[ESC CERs] 2.087 * (PMP_F^0.807)
17 S/P Mgt (S/W Intensive Pgms Only)	[ESC CERs] 1.9*(PMP_F^0.849)*(1.889^SUBKR)*(3.25^SSYS)
18 Data (incl lge pgms)	[ESC CERs] 3.567 * (PMP_F^0.626) * (0.420^SUBKR)
19 Data (excl lge pgms)	[ESC CERs] 3.130 * (PMP_F^0.640) * (0.418^SUBKR)
20 ST&E+S/PM+Data (incl lge pgms)	[ESC CERs] 4.688 * (PMP_F^0.804) * (1.283^SUBKR)
21 ST&E+S/PM+Data (excl lge pgms)	[ESC CERs] 4.963 * (PMP_F^0.798) * (1.287^SUBKR)
22 ST&E+S/PM+Data (CMU-type pgms)	[CMU CER] 249.327 * (PMP_F^0.444)
23 ST&E+S/PM+Data (Box/LRU type Pgms Only)	[ESC CERs] 1.614 * (PMP_F^0.936) * (0.823^FIXD)
24 ST&E+S/PM+Data (System or Box ty Pgms Only)	[ESC CERs] 2.705 * (PMP_F^0.848) * (1.385^COM)
25 ST&E+S/PM+Data (Abn Pgms Only)	[ESC CERs] 5.35 * (PMP_F^0.779) * (1.243^BOX)
26 ST&E+S/PM+Data (Abn Pgms Only)	[ESC CERs] 3.631 * (PMP_F^0.81) * (1.315^COM)
27 ST&E+S/PM+Data (S/W Intensive Pgms Only)	[ESC CERs] 1.509 * (PMP_F^0.909) * (1.756^SUBKR)
28 ST&E+S/PM+Data (S/W Intensive Pgms Only)	[ESC CERs] 3.797 * (PMP_F^0.832) * (0.417^SSYS)
29 ST&E+S/PM+Data (S/W Intensive Pgms Only)	[ESC CERs] 2.152 * (PMP_F^0.877) * (1.443^COM)
30 ST&E+S/PM+Data (System type Pgms Only)	[ESC CERs] 3.583 * (PMP_F^0.822) * (1.512^COM)
31 ST&E+S/PM+Data (C3 Pgms Only)	[ESC CERs] 2.78 * (PMP_F^0.849) * (1.54^SUBKR)
32 ST&E+S/PM+Data	[ESC CERs] 3.076*(PMP_F^0.832)*(1.21^SUBKR)*(1.497^COM)
33 ST&E+S/PM+Data	[ESC CERs] 3.269 * (PMP_F^0.828) * (1.519^COM)
34 ST&E+S/PM+Data	[ESC CERs] 5.202 * (PMP_F^0.805) * (0.732^RDR)
35 Non-PMP (incl lge pgms)	[ESC CERs] 5.766 * (PMP_F^0.803) * (1.239^SUBKR)
36 Non-PMP (incl lge pgms)	[ESC CERs] 5.548*(PMP_F^0.799)*(1.252^SUBKR)*(1.182^PSE)
37 Non-PMP (excl lge pgms)	[ESC CERs] 6.008 * (PMP_F^0.798) * (1.242^SUBKR)
38 Non-PMP (excl lge pgms)	[ESC CERs] 5.525*(PMP_F^0.798)*(1.256^SUBKR)*(1.230^PSE)
39 Non-PMP	[ESC CERs] 3.608 * (PMP_F^0.835) * (1.544^COM)
40 Non-PMP	[ESC CERs] 4.415 * (PMP_F^0.827) * (1.329^SSYS)
41 Non-PMP	[ESC CERs] 2.886*(PMP_F^0.854)*(1.509^COM)*(1.247^SSYS)
42 Non-PMP (S/W Intensive Pgms Only)	[ESC CERs] 1.905 * (PMP_F^0.9) * (1.528^COM)
43 Non-PMP (S/W Intensive Pgms Only)	[ESC CERs] 3.147 * (PMP_F^0.861) * (0.49^SSYS)
44	
45 Dev Acq Spt Factors	
46 Integr & Assembly	[ESC Factors] 0.173*(PMP_F - 1&A_F)
47 Training	[ESC Factors] 0.012*PMP_F
48 Peculiar Spt Equip	[ESC Factors] 0.163*PMP_F
49 System Test & Eval	[ESC Factors] 0.192*PMP_F
50 System/Project Mgt	[ESC Factors] 0.519*PMP_F
51 Data	[ESC Factors] 0.133*PMP_F
52 Opnl Site Activation	[ESC Factors] 0.163*PMP_F
53 Common Spt Equip	[ESC Factors] 0.009*PMP_F
54 Spares	[ESC Factors] 0.085*PMP_F
55 Non-PMP	[ESC Factors] 1.017 * PMP_F
56 Prime Contractor Loading	[ESC/FMCT Load] 1.226
57	
58 Production CERs	

\* The bracketed label indicates which library study the CER came from, or the name of the cost model.

## ACE ESTIMATING METHODOLOGY LIBRARY (Cont.)

## WBS

## METHODOLOGY

59	RADARPROD Model	[ABM] [The sum will equal total Radar cost]
60	Antenna Group	[ABM] $22.6 * APER^{.364} * EXP(.7 * AXES) * (1-.4 * AIR)$
61	Pedestal	[ABM] $37.5 * PAP^{.39} * EXP(.0002 * NPS) * (1-.3 * AIR)$
62	Surface/Feed	[ABM] $6.22 * (BITS/4) * PE^{.0278} * NPS^{.564}$
63	Phase Shifters	[ABM] $216.1 * PAVG^{.508} * TDC^{-.11} * (1+.79 * SS)$
64	Transmitter Group	[ABM] $89 * PAP^{.08} * NCH^{.5} * (1+.5 * ST) * (1+.8 * AIR) * (1+.8 * BA)$
65	Receiver Group	
66	Processor Group	
67	Signal Processor	[ABM] $204 * EXP(.08 * (FYP-79)) * PAP^{.07} * (1+.9 * AIR) * (1+.8 * BA)$
68	Pulse Compression	[ABM] $3.36 * MPCR^{.593} * (1+.169 * AIR)$
69	Data Processor	[ABM] $.2 * (ANT + XMTR + RCVR + SPROC + PCU) * EXP(-.04 * (FYP-79))$
70	Other and I&A	[ABM] $0.1 * (ANT + XMTR + RCVR + PROC) * (1-.39 * AIR)$
71		
72	A-Kit Install Hours	[MILSTAR LCT] $(318.032 + (0.3941 * AVOL)) * PCF$
73	Data Processor - NMP w/o Wt	[GBR] $28.264 * RM^{.0228} * MFLOP\_D^{.178} * DS\_D^{.230}$
74	Data Processor - NMP w/ Wt	[GBR] $7.701 * RM^{.0162} * MFLOP\_D^{.225} * DS\_D^{.173} * WPDP^{.207}$
75	Encrypt/Decrypt Units	[SDICC Handbook] $.01 * N\_CRYPT$
76	Host Computer - Fixed	[SDICC Handbook] $0.54 * (MM)^{.13} * (CT)^{-.029} * (PP)^{.059} * N\_COMP$
77	Large Switch	[RSA ICE] $1.863 * QQ^{.0943} * USE^{.538}$
78	Lg Screen Display - Fixed	[SDICC Handbook] $42.394 * (RES)^{.043} * (D\_SZE)^{1.17} * N\_LSDSP$
79	Radar Analog Blk Box	[JS ICS] $2.35 * WABX^{.293} * PABX^{.483}$
80	Radar Digital Blk Box	[JS ICS] $1.48 * WDBX^{.098} * PDBX^{.656}$
81	Radar Transmitter	[JS ICS] $151 * PAVG^{.493}$
82	Signal Processor - MP w/o Wt	[GBR] $49.616 * RM^{.0336} * MFLOP\_S^{.0111} * DS\_S^{.074}$
83	Signal Processor - MP w/ Wt	[GBR] $0.076 * RM^{.0243} * MFLOP\_S^{.0385} * DS\_S^{.192} * WPS^{.667}$
84	Solid State Transmitter	[RSA ICE] $11.229 * POWOUT^{.528}$
85		
86	Communications CERs	[FATES]
87	Transmitter Group	[FATES] $115.2 * N\_TWT^{.9} * MKW^{.608}$
88	Receiver Group	[FATES] $39.6 + 25.3 * NDNC + 126.3 * TT \& C$
89	Signal Processor Gp	[FATES] $82.4 * EXP(.17 * NCU + .18 * NCD + 1.135 * DUM)$
90	Timing Group	[FATES] $38.2 * (.178)^{FTYP} + 17.3 * NGD$
91	External Comm Interface	[FATES] $43.5 * MBS^{.121} * NMMDM^{.755} * EXP(.331 * NMUX)$
92	Ruggedization	[FATES] $.5 * NRACKS + .2 * NCHAS$
93		
94	Airborne Electronics CERs	[AGMEBA] [Tecolote CR-0146]
95	Receiver-Abn	[AGMEBA] $7.36 * WRCV^{.109}$
96	Transmitter-Abn 1	[AGMEBA] $13.9 * WTX * EXP(.388 * SS - .0404 * DIA)$
97	Transmitter-Abn 2	[AGMEBA] $8.08 * PTX^{.079} * EXP(-.0723 * DIA)$
98	Digital Processor-Abn 1	[AGMEBA] $9.21 * WPC^{.105} * EXP(.453 * AIR - .436 * HRD)$
99	Digital Processor-Abn 2	[AGMEBA] $13.6 * MOPS * WL * EXP(.595 * HRD - .117 * (FYP-75))$
100	Digital Processor-Abn 3	[AGMEBA] $.113 * NEIC * EXP(.116 * AIR + .0214 * (FYP-75))$
101	Antenna Assembly-Abn	[AGMEBA] $167.3 * APER^{.558}$
102	Analog Electronics-Abn 1	[AGMEBA] $7.46 * WAN^{.817}$
103	Analog Electronics-Abn 2	[AGMEBA] $2.54 * PAN * EXP(.889 - .696 * HRD)$
104	Inertial Sensor Assy-Abn	[AGMEBA] $17.5 * WIN^{.932}$
105	Inertial Platform Assy-Abn	[AGMEBA] $4.39 * WIN * EXP(1.41 * BM)$
106	Rate Gyroscope Assy-Abn	[AGMEBA] $2.37 * WGY^{.147}$
107	Power Conditioner-Abn	[AGMEBA] $4.66 * WPS^{.716} * EXP(1.204 * HVPS + .414 * AIR)$
108	Battery (Missile)-Abn	[AGMEBA] $3.97 * WBT^{.495}$
109		
110	Ground Mobile Electronics	[AGMEBA] [Tecolote CR-0146]
111	Receiver/Exciter-Gnd	[AGMEBA] $1.52 * WRP^{.106} * EXP(-1.41 * SEA)$
112	Transmitter-Gnd 1	[AGMEBA] $1.37 * WTX^{.919}$
113	Transmitter-Gnd 2	[AGMEBA] $29.7 * VTX^{.877}$
114	Digital Processor-Gnd 1	[AGMEBA] $4.95 * WTX^{.853} * EXP(-.863 * SEA)$
115	Digital Processor-Gnd 2	[AGMEBA] $66.7 * VTX^{.892} * EXP(-.405 * SEA)$
116	Antenna Assembly-Gnd	[AGMEBA] $.181 * APER^{.209} * EXP(-2.42 * SS)$
117	Analog Electronics-Gnd 1	[AGMEBA] $1.62 * WAN * EXP(-1.023 * SEA)$
118	Analog Electronics-Gnd 2	[AGMEBA] $.206 * PAN * EXP(1.13 * SEA)$
119	Analog Electronics-Gnd 3	[AGMEBA] $43.4 * VAN^{.817}$
120	Power Conditioner-Gnd	[AGMEBA] $.364 * WPS * EXP(-.458 * SEA)$
121	Display & Control-Gnd 1	[AGMEBA] $.562 * PDS^{.1043}$
122	Display & Control-Gnd 2	[AGMEBA] $12.8 * VDS^{.8037}$
123	Shelter-Gnd 1	[AGMEBA] $5.21 * WSH^{.601}$

## ACE ESTIMATING METHODOLOGY LIBRARY (Cont.)

## WBS

## METHODOLOGY

124 Shelter-Gnd 2	[AGMEBA]	1.12*VSH^1.05
125		
126 Production Support CERs		
127 S/P Mgt (Gnd Pgms Only)	[ESC CERs]	3.279*(PMP_P^0.708)*(1.641^SSYS)*(1.84^LOT1)
128 S/P Mgt (Gnd Pgms Only)	[ESC CERs]	1.699*(PMP_P^0.774)*(1.509^COM)*(1.722^LOT1)
129 S/P Mgt (Gnd Pgms Only)	[ESC CERs]	.997 * (PMP_P^0.804) * (1.495^LOT1)
130 S/P Mgt (Gnd Pgms Only)	[ESC CERs]	1.627 * (PMP_P^0.791) * (1.515^COM)
131 S/P Mgt (Subsystem type Pgms Only)	[ESC CERs]	4.365 * (PMP_P^0.686) * (1.715^FIXD)
132 S/PM+Data (incl lge pgms)	[ESC CERs]	3.404 * (PMP_P^0.728) * (2.371^LOT1)
133 S/PM+Data (excl lge pgms)	[ESC CERs]	5.696 * (PMP_P^0.671) * (2.226^LOT1)
134 S/PM+Data (Gnd Pgms Only)	[ESC CERs]	3.208 * (PMP_P^0.747) * (2.089^LOT1)
135 ST&E+S/PM+Data (incl lge pgms)	[ESC CERs]	3.956 * (PMP_P^0.725) * (2.202^LOT1)
136 ST&E+S/PM+Data (excl lge pgms)	[ESC CERs]	6.318 * (PMP_P^0.673) * (2.074^LOT1)
137 Non-PMP (incl lge pgms)	[ESC CERs]	2.887*(PMP_P^0.786)*(1.813^LOT1)*(1.897^OSA)
138 Non-PMP (incl lge pgms)	[ESC CERs]	2.572*(PMP_P^0.783)*(1.681^LOT1)*(1.972^OSA)*(1.620^SPRS)
139 Non-PMP (Comm Pgms Only)	[ESC CERs]	0.674 * (PMP_P^0.901) * (2.374^FIXD)
140		
141 Production Support Factors		
142 Integr & Assembly	[ESC Factors]	0.083 * (PMP_P - I&A_P)
143 Training	[ESC Factors]	0.015 * PMP_P
144 Peculiar Spt Equip	[ESC Factors]	0.031 * PMP_P
145 System/Project Mgt	[ESC Factors]	0.268 * PMP_P
146 Data	[ESC Factors]	0.087 * PMP_P
147 Opnl Site Activation	[ESC Factors]	0.389 * PMP_P
148 Common Spt Equip	[ESC Factors]	0.081 * PMP_P
149 Initial Spares	[ESC Factors]	0.135 * PMP_P
150 Non-PMP	[ESC Factors]	0.633 * PMP_P
151		
152 Warranty Factors/CERs		
153 Parallel Processor (Low Lvl)	[GBR]	0.09 * PROC_SYS
154 Parallel Processor (Med Lvl)	[GBR]	0.11 * PROC_SYS
155 Parallel Processor (High Lvl)	[GBR]	0.74 * PROC_SYS
156 ASD Avionics Systems	[ASD Avionics Warranty]	
157 Prime Contractor Loading	[ESC/FMCT Load]	1.226
158		
159 ESC O&S Cost Model		
160 O&S Depot Level Repair		
161 LRU Repairables	LDLR(@LRU,NLRU,SRCHG)	
162 SRU Repairables	SDLR(@SRU,NSRU,SRCHG)	
163 O&S Labor Cost Equations		
164 Officers	OPSORATE*OPSONUM	
165 Enlisted	OPSERATE*OPSENUM	
166 Civilian	OPSCRATE*OPSCNUM	
167 Hardware Cost Models		
168 ESC Black Box Estimator Models (2.0)	BBEST Version 2.0, i.e., [BBEST2]	
169 Analog Devices	[BBEST2 - ANALOG]	
170 Antennas (Airborne)	[BBEST2 - ANTENNA_AIR]	
171 Antennas (Ground Based)	[BBEST2 - ANTENNA_GND]	
172 Antennas (Phased Array)	[BBEST2 - ANTENNA_PHSD]	
173 Black Box Development	[BBEST2 - BOX_DEV]	
174 Digital Interfaces	[BBEST2 - DIF]	
175 Digital Processors	[BBEST2 - DIGI]	
176 Displays & Controls	[BBEST2 - DISP_CONT]	
177 High Power RF, Tube Type	[BBEST2 - HPRF_TUBE]	
178 Integration	[BBEST2 - INTEG]	
179 Low Power RF	[BBEST2 - LPRF]	
180 Power Supplies	[BBEST2 - POWSUP]	
181 System Development	[BBEST2 - SYS_DEV]	
182 ESC BBEST Model Functions	[BBEST2 Functions]	
183 Antennas (Airborne)	[BBEST2]	ANT_AIR(AWT,AAPER,ATYPE)
184 Antennas (Ground Based)	[BBEST2]	ANT_GND(GAPER,GTYPE)
185 Antennas (Phased Array)	[BBEST2]	ANT_PHSD(PAPER,PSHFT,PTPOW,PTYPE)
186 Analog Electronics	[BBEST2]	ANALOG(GWT,GVOL,GAIR)
187 Box Level Development	[BBEST2]	BOXDEV(BUC,BNPR,BEXP,BDEF,BPSUP)
188 Digital Interface Devices	[BBEST2]	DIF(DWT,DVOL,DPOW,DCCA)

## ACE ESTIMATING METHODOLOGY LIBRARY (Cont.)

## WBS

## METHODOLOGY

WBS	METHODOLOGY
189 Display and Control	[BBEST2] DISP_CONT(DCWT,DCVOL,DCAIR,DCDISP)
190 System Level Integration	[BBEST2] INTEG(IUC,ISHLTR,IAIR)
191 Avionics Reliability Cost (ARC) Model	[ARC Model]
192 Dig Sig/Dat Processor Cost Model (DSDPM)	[DSDPM]
193 GE Electronic Hardware Model	[GE PRICE-H]
194 GE Printed Circuit Board Model	[GE PRICE-M]
195 Radar Engrg & Cost Tool (REACT)	[REACT]
196 Tecolote Radar RDT&E Cost Model	[Tecolote RADARDEV]
197 Tactical Missile EMD Cost Model	[Tecolote MISLDEV]
198 Software Cost Models	
199 Constructive Cost Model	[COCOMO]
200 GE Software Cost Model	[GE PRICE-S]
201 GE Software Lifecycle Cost Model	[GE PRICE-SL]
202 Reduced COCOMO	[REDUCOMO]
203 SEER Software Est Model	[Gai SEER-SEM]
204 Software Lifecycle Cost Model	[SLIM]
205 General	
206 Direct Labor Cost per Man-Year	[BLS Annual Study]
207 Hardware	
208 A-Kit and Install Costs	[ESC Factors]
209 AN Equip Descriptions/Contr/SPOs	[DMS AN/ Equip]
210 Data Communications	[DATAPRO COMM]
211 DEFENSE Organization Service	[DEFENSE Org Service]
212 Electronics	[IHS: Vendor Cat]
213 Electronics	[IHS: GSA Cat]
214 Electronics	[DATAPRO 70]
215 Elect Equip Descriptions/Contr/SPOs	[DMS Elect Equip]
216 Electronics Warranty Costs	[MCR Warranty Study]
217 ESC Electronics Technical Data	[ESC Elec Database]
218 Intrusion Detection Sensor (IDS) LCC Ests	[External IDS LCC]
219 Intrusion Detection Sys (IDS) Cost Guide	[USACoE Cost Guide for IDS]
220 JETDS Data Base	[JETDS]
221 Minicomputers	[DATAPRO MINI]
222 OTH-B Database	[OTH-B Database]
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This report analyzes three life cycle costing models LOGAN(LCC), CASA and ACEIT in order to validate and make recommendations for improvements to LOGAN(LCC). It develops recommendations in three areas: the elimination of LOGAN(LCC)'s weakness, the powerful features of similar softwares, and general software characteristics.

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