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ESTIMATING KC-137 AIRCRAFT OWNERSHIP COSTS IN THE BRAZILIAN AIR FORCE

THESIS

Ulisses O. Bonasser, B.S.
Captain, Brazilian Air Force

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Ulisses O. Bonasser, B.S.

Captain, Brazilian Air Force

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Preface

My motivation for this research started in 1994, when I worked as the Project Coordinator for the KC-137 aircraft and was asked to estimate future expenses of those aircraft with engines, modification kits, and sustaining engineering. My team soon realized that we lacked the necessary knowledge to accomplish the task with confidence. More than cost numbers, I feel that the methodology for ownership cost estimation is the greater benefit I draw from this work.

This research would not have been possible without the continued help of my thesis advisors, Dr. Roland D. Kankey and Major William L. Scott, whose many hours of advice and orientation guided me throughout this project. I am also in great debt with the people at PAMAGL, who provided the data essential to the completion of the thesis. Special thanks to 1st Lt. Hans-Peter Salz and Major Josias T. Silva, who spent many hours from their tight schedule collecting the huge amount of data that I needed.

I am also grateful to my very patient family, my mother Luiza and my niece Cláudia, who for countless times had to abdicate from their rights of enjoying their stay in such a pleasant country.

Ulisses O. Bonasser

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Abstract

This research addresses the estimation of operation and support (O&S) costs of the Brazilian Air Force KC-137 aircraft. BAF lacks an established set of procedures for computing ownership costs of such aircraft, which prejudices the elaboration of cost-benefit analysis and allocation of budget resources. The purpose of the study is to develop an O&S cost breakdown structure and a set of cost estimating equations that will be used to estimate the ownership costs of the KC-137 aircraft during their expected service life.

The research is divided into five major parts: 1) review of the literature, with a focus on the most commonly used life cycle cost accounting methods; 2) analysis of the KC-137 aircraft maintenance and operating systems, with a focus on the characteristics of existing cost databases; 3) development of an O&S cost breakdown structure, based on the CORE model; 4) selection of cost estimating procedures; and 5) development of cost equations and calculation of costs.

The total annual cost of operating and supporting the KC-137 aircraft was estimated to be US$16,199,041, which corresponds to an average cost of US$9,529 per flight hour, at a usage rate of 1700 hours per year. The results yielded evidence that the current KC-137 O&S systems work with a high percentage of fixed costs (57.5%), as well as allocated costs (43.2%). Therefore, the BAF may benefit from the use of LCC and more accurate cost accounting methods, such as activity-based costing (ABC). Other implications for the Brazilian Air Force and recommendations for further study are also discussed.

ESTIMATING KC-137 AIRCRAFT OWNERSHIP COSTS IN THE BRAZILIAN AIR FORCE

I. Introduction

Chapter Overview

The Brazilian Air Force (BAF) currently owns several models of aircraft that have been in operation for more than 20 years. With time the operation and support (O&S) of such models have become more difficult and expensive, and the question of whether or not their operation is still feasible arose. This type of feasibility study requires the use of life-cycle costing (LCC) techniques, applied to the ownership phase of the life of the aircraft. This research addresses the estimation of ownership costs (operation and support costs) for a specific aircraft model from the BAF inventory, the KC-137. It focuses on the analysis of the existing sources of data related to the operation and support of the KC-137 and the identification of the most appropriate life-cycle costing methods to be used with those data. This chapter provides a background on the BAF KC-137 and describes the specific problem, research objectives, methodology, assumptions, scope and limitations, significance of research, and expected results.

Background

Aircraft operating and support costs (also called ownership costs) represent a large part in the budget of any air force, yet their importance is not always recognized by managers. In some instances this oversight exists because these managers do not have available a proper method to account for such costs. The lack of a method also limits managers' capacity to make good choices when facing different possible alternatives for the future use of an aircraft and its systems.

The Brazilian Air Force currently does not have an established method for computing ownership costs of its KC-137 aircraft. This fact may be the result of a combination of peculiar circumstances such as small fleet size, lack of an integrated computer system to manage operation and maintenance data, and few in-country developed military projects. But the most important single reason probably is that all but one major BAF program relate to old aircraft models, built when the importance of controlling ownership costs was not yet recognized.

The KC-137 aircraft is one such old model. The BAF KC-137 is a Boeing 707 airplane modified to a tanker configuration, and the average age of the fleet is 28 years. The Brazilian Air Force currently intends to operate this fleet through the year 2006. The airplanes were bought from VARIG, a major Brazilian airline that provided maintenance and supply support during the first two years of operation by BAF. After this transition period, BAF took control over all the necessary support.

The Brazilian Air Force decided to continue using the commercial technical manuals provided by Boeing and the maintenance schedule established by VARIG as a starting point for its own maintenance program. Changes were made, however, to reflect lower utilization rates, new safety requirements, and peculiar priorities. Only recently were the tasks of this new maintenance schedule incorporated into a computerized system.

The Boeing 707 is an aging aircraft model, and most of the units still flying have long passed the initial factory-projected life of twenty years of operation. As a result, aviation authorities all over the world have been issuing mandatory supplemental structural inspections, which is making the maintenance more expensive. The maintenance is also becoming more difficult to perform. Spares and repair services are increasingly harder to find, which also contributes to higher ownership costs. Most of the major airline companies in the world have discarded the Boeing 707 model from their fleets.

In 1995 the Brazilian Air Force started to question the feasibility of keeping the KC-137 aircraft in operation. However, the methods, procedures, and database necessary for computing maintenance and operation costs are not yet developed. Without these means, BAF cannot establish values for ownership costs, and a proper cost-benefit analysis cannot be done. The lack of this information is also preventing BAF from adequately allocating budget resources among the existing programs.

Since 1995, a computerized logistics system is being experimentally installed in the depot facility responsible for the heavy maintenance of the KC-137 aircraft. This system is expected to be fully operational by 1997, and it has been designed to integrate maintenance and operational data.

Research Objectives

The objectives of this research are: (1) to determine the most suitable life cycle costing method to be applied to the existing BAF KC-137 aircraft maintenance and operational database and procedures, and (2) by using the chosen method, to estimate the ownership costs of the KC-137 aircraft during their expected service life.

Methodology

This research is divided into five major parts, to be performed in sequence. The first part consists of an analysis of the most commonly used LCC accounting methods. The objective is to understand the principles, cost element structure, and application of each method. Books, papers, Rand reports, and Department of Defense (DoD) manuals will be the principal references for this task.

The second part is an analysis of the current KC-137 aircraft maintenance and operating systems. The objective is to become familiar with the characteristics of databases and cost elements related to the operation and support of the KC-137 model. Maintenance plans, service bulletins, and records from maintenance, supply, and operational sections will provide the most information for this work.

The main task in the third part is to develop a cost breakdown structure for the operating and support activities of the KC-137 aircraft. The data collected during the previous part of the research will be the base for the definition of cost categories and identification of cost drivers.

The fourth part consists of the selection of the most suitable LCC estimating procedure for each one of the cost categories previously defined. Again, the quality and quantity of available data will dictate the appropriate analytical techniques.

The final part is the estimation of the KC-137 aircraft ownership costs for the remainder of their expected service life. The chosen methods will be applied to the collected databases and historical utilization rates.

Assumptions

The literature about life cycle cost methods is readily available. The data about the KC-137 maintenance tasks, however, are not. The results of the second part of this research, estimation of ownership costs, will heavily depend upon the quantity and quality of data received from Brazil.

Scope and Limitations

LCC Method -- the research will not try to identify a LCC method either applicable to all aircraft in the BAF inventory or suitable for general use throughout the BAF logistics system. It will be limited to the specific KC-137 aircraft logistics environment. This limitation is imposed by the fact that different aircraft models in the BAF inventory have somewhat different logistics support schemes.

Ownership Costs Estimate -- the estimation of ownership costs will be performed with data collected from various databases, which differ among themselves in accuracy and comprehensiveness. The estimation approach will have to adapt to each case, and the estimated values will be subjected to different degrees of uncertainty.

Currency -- the values will be shown in American dollars. A significant portion of the spares and materials consumed by the KC-137 O&S activities is quoted in this currency, which possesses a greater stability on the international market.

Utilization Rate -- since the mission profiles of the KC-137 aircraft are expected to remain the same for the near future, this research will estimate ownership costs employing historical utilization rates.

Expected Results

The major product of this research is expected to be a set of cost values related to the operation and support of the KC-137 aircraft through the remainder of their useful life. Each cost category identified during the development of the cost breakdown structure for the O&S activities of the KC-137 shall have an estimated value assigned to it, allowing the computation of an estimated ownership total cost. As a secondary product, the research shall establish the most adequate life-cycle costing methods for each of those cost categories.

Significance of Research

For the KC-137 in particular, the set of cost values is meant to allow the BAF to estimate the resources this aircraft will need and, as a consequence, to aid in cost-benefit analysis and in the proper allocation of budget resources among the existing projects. These numbers are also meant to aid in decisions on the incorporation of major modifications in operational procedures or aircraft configuration, such as the analysis of service bulletins. The analysis of O&S databases is meant to provide BAF Directory of Materiel with a picture of the present structure of its management information systems, which can be used during the development or refinement of the currently experimental computerized maintenance system.

Summary and Research Organization

This thesis consists of five chapters. Chapter I presented the background surrounding the research and the process of designing an O&S cost estimation model for the

KC-137 aircraft. The chapter described the five parts of the methodology and the assumptions made regarding the availability of data from Brazil, and then included a list with research scope and limitations. Finally, the expected results of the research were defined as a set of O&S cost values, which would be valuable for cost-benefit analyses of the KC-137 aircraft operation and the design and refinement of cost databases.

Chapter II is a literature review that describes the concepts of life cycle cost, life cycle cost analysis, and the characteristics of the most commonly used cost estimating methods. This review includes a definition of relevant categories of cost, an example of a cost breakdown structure, a more detailed list of ownership cost elements, and a review of the Cost-Oriented Resource Estimating (CORE) Model.

Chapter III describes the research methodology of this thesis. The five major parts of the research design consist of a review of cost accounting methods, an analysis of the KC-137 O&S systems, the elaboration of a cost breakdown structure, the selection of cost estimating procedures, and the estimation of ownership costs.

Chapter IV presents the results and description of the data collected. Galeão Air Force Base (GAFB) performs unit and intermediate maintenance levels, and Galeão Aeronautical Materiel Depot (GAMD) performs the depot level of maintenance. The research shows that in both organizations some cost databases discriminate among different models of aircraft, while others make necessary the use of allocation factors. The cost breakdown structure for the KC-137 aircraft ownership costs is developed. The total annual cost of operating and supporting the KC-137 aircraft was estimated to be US$16,199,041, or US$9,529 per flight hour, at a usage rate of 1700 hours per year.

Lastly, Chapter V provides conclusions and recommendations derived from the research. The current KC-137 O&S systems work with a high percentage of fixed costs (57.5%) as well as allocated costs (43.2%). Therefore, the BAF may benefit from the use of LCC and more accurate cost accounting methods, such as activity-based costing (ABC). Other implications for the Brazilian Air Force and recommendations for further study are also discussed in Chapter V.

II. Literature Review

Chapter Overview

The purpose of this chapter is to review literature pertinent to the process of selecting life cycle cost (LCC) methods and cost factors for estimating the ownership costs of the BAF KC-137 aircraft. The review starts with a definition of categories of cost pertinent to this research, and follows with a description of the most commonly used cost estimating methods. This information will serve as a base for both the understanding of the concept of LCC and the selection of a proper evaluating model.

The next two parts explain the concept of life cycle cost, describes the four major categories of costs within the LCC concept, and provides an example of a cost breakdown structure. A more detailed picture of ownership costs is included.

The last part introduces the concepts of life cycle analysis and design to cost, which are the integrated, practical applications of the previous concepts. It also includes a summary of quantitative considerations and an overview of cost allocation and activity-based costing (ABC).

Cost Classification

There are several different categories of cost, some of them more apparent to the analysts than others. Depending on the problem at hand, some costs may be irrelevant for the decision process. It is important, however, that the analysts make sure they include all categories of cost in their lists; all costs must be taken into account in a LCC analysis (7:24).

First or Investment Cost. Cost elements that do not recur after the system is acquired. They may include design and development costs, test and evaluation costs, unit purchase price plus shipping costs, and installation and training costs. In some instances, these first costs may be very high, beyond the capabilities of the purchasing agent.

Operation and Support (O&S) Cost. Cost elements that are experienced continually over the useful life of the system. They are also called ownership costs. These typically include costs of labor (for maintenance and operations personnel), fuel and power, spare and repair parts, insurance and taxes, carrying inventory, and other logistics aspects. These costs can be substantial, and have frequently exceeded procurement costs (22:1).

Fixed Cost. Cost elements that are independent from variations in the level of operational activity, that is, are not related to the amount of usage of the system. Depreciation, lease rentals, maintenance, insurance, interest on invested capital, research, and part of administrative expenses are good examples of such costs. Fixed costs are normally difficult to change in a short run.

Variable Cost. Group of costs that relate in some way to the level of operational activity. These costs, normally expenses with direct labor and material, fuel, energy, and so on, may include direct and indirect costs.

Direct Cost. The cost elements most easily perceived, for they are a direct result from the utilization of the system. Taking an airplane as example, the costs of fuel, pilot's salary, and engine oil would be direct costs of the flying activity.

Indirect Cost. Most of the times these costs are difficult to evaluate, because they are not directly related to the utilization of the system. They are associated with the concept of manufacturing overhead. Looking at the previous example, expenses with maintenance personnel and hangar illumination would be indirect costs.

Sunk or Past Cost. Group of costs that were already incurred in the past and cannot be altered by any future action. Although they may be significant in some circumstances, they should influence the decision making process only to the extent that they may serve as a basis for predictions (15:21).

Cost Estimating Methods

A cost estimate represents the expected value of the cost of a product, system, structure, or activity. The analyst makes the estimation following a specific set of rules, or method. Cost estimating methods may have a broad range of formats. According to their purpose and availability of data, they may present simple formulas with basic parameters or a series of complex computer programs (15:134; 12:Ch 2; 14). The three basic methods found in the literature are analogy, parametric, and engineering (22:23).

Analogy Method. This method relates the costs of a current system to the costs of previous similar systems, with adjustments to compensate for differences among them. It is normally used during the preliminary stages of development of the project, when little detail is available. Depending on the ability of the analyst, this method provides managers with a fairly quick, easy, and cheap estimation of costs (22). Its results, however, are strongly based on the degree of judgment, experience, and expertise of the analyst (15:146).

Parametric Method. This method uses a combination of parameters of the system to estimate costs. The analyst gathers data from previous programs and, with the use of statistical analysis, develops mathematical formulas that relate costs to accessible variables. Such formulas, or relationships, are commonly called "Cost Estimating Relationships (CERs)" (13:3-3). They may have various formats, from simple to complex, as illustrated by the following examples taken from Seldon (22:25) and LCC-3 (13:3-4):

- Development cost = (number of men) x (years worked) x (cost constant per man-year)

- Development cost = $Ae^{B(\log V)-D}$ WRST,

  where: A, B, and D are coefficients;

  V = maximum aircraft velocity (knots) at maximum power and 55,000 feet altitude;

  W = airframe weight in tons;

  R = hourly pay rate of engineering manpower;

  S = factor for fixed or variable sweep wing; and

  T = fraction of the airframe which is titanium.

The statistical techniques also vary in complexity, "ranging from simple graphical curve fitting to multiple correlation analysis" (15:147).

These procedures can be used even in early stages of the project, for long-range planning. This is the preferred method in most situations because it provides confidence intervals, can be inexpensively employed once developed, and is based on broad specified parameters rather than detailed data. However, it also presents some disadvantages. New-design systems, economic trends, and evolution of technology can invalidate existing data as a statistical base. Analyst experience is still relevant, and the costs to develop the model increase sharply when many variables are selected. Additionally, most published references on this method do not include O&S costs (13; 15:147).

Engineering Method. This is the method that requires the most amount of data and the greatest level of detail:

> The engineering estimator begins with a complete design and specifies each production or construction task, equipment and tool need, and material requirement. Costs are assigned to each element at the lowest level of detail. These are then combined into a total for the product and system. (15:145)

The assignment of costs for each individual task may be done by the use of any suitable method, and the sum of these costs represents the total cost (22:32). The analysts start to use this method as more information about the system becomes available; there is a gradual transition from the use of analogies and CERs to the use of engineered equations (13).

The main advantages of engineering procedures are related to the greater levels of detail that are involved. Engineering estimates tend to be more accurate. They permit a good visualization of detail requirements and "can be applied independently to the various parts of the system" (13). But this method also has disadvantages. It is more costly and time consuming than the previous methods, and can not be used at the beginning of the project, for it requires more data than usually is available. Its level of detail makes for difficult revisions and evaluations. Because the system total cost is the sum of numerous detailed task costs, which are all subject to errors, some authors say that these small errors can result in large estimate errors (15:145). Other authors, however, believe that the summation will tend to cancel these small errors, if they are random (22:34).

All these characteristics make this a good, robust cost estimating method for long and stable production runs or maintenance lines (13; 15).

Selection of a Cost Estimating Method

The analyst has to choose not only among the three basic estimating methods described in the previous section, but also among the several models currently used in the Air

Force to perform logistics-oriented analysis. No single model incorporates all the features that an analyst would desire, and some of these features can be mutually exclusive; as a consequence, the selection process is a compromise exercise (2:7). Nevertheless, proper models should present the following characteristics (15:134):

1)Comprehensiveness. Include all relevant factors;

2)Sensitiveness. React to the dynamics of the system;

3)Flexibility. Enable the evaluation of specific elements of the system independent from other elements. Allow easy modifications and/or expansions to reflect changing environment;

4)Simplicity. Allow timely implementation and ease of use;

5)Integration. Use and generate data in a format interchangeable with other models and data bases.

The choice of an appropriate method is driven by the intended uses and existing constraints; "the models used and the criteria for estimating parameters and testing the model are influenced by the questions that the analysis is used to answer" (28:32). There are, however, some basic steps the analysts can follow to ensure a proper choice (2:10).

STEP 1. Review the analysis requirements and highlight inputs, outputs, constraints, special conditions, official directions, and models previously used for similar work.

STEP 2. Prepare a list of model selection criteria. This list would include the characteristics cited above plus all other deemed relevant by the analyst.

STEP 3. Prepare an evaluation matrix, models vs. Criteria.

STEP 4. Review the models with respect to each criterion, assigning rates.

STEP 5. Choose the best alternatives.

STEP 6. Select the model in cooperation with those who will be the major users of the analysis results.

Seldon (22:165) and Blanchard (7:80) provide comprehensive dissertations about model features, and the Aeronautical Systems Center (2) published an updated guide describing the computer models most frequently used at the Aeronautical Systems Center (ASC) for logistics analyses.

Life Cycle Cost Concept

The life cycle cost (LCC) includes all costs associated with the acquisition and ownership of a system over its full life. It includes four major categories: research and development (R&D) costs, production and construction costs, operation and support (O&S) costs, and retirement and phaseout costs. The LCC concept was adopted by the Department of Defense to encourage long-ranging planning and to ensure that the Government would spend the least overall amount of funds when acquiring new systems (22:2; 5:1). Historically one can verify that many systems are planned, designed, produced, and operated with very little concern for their life cycle costs (15:12). The costs for the different phases of the life cycle have been addressed as they occur, and in a non-integrated basis. However, some authors suggest that "ownership costs- those of operation and support or maintenance- have frequently far exceeded procurement costs" (22:1), and that all costs are interrelated. Furthermore, those authors explain how an integrated approach that considers the ownership cost implications of all alternatives since the initial phases of the analysis process can reduce the overall costs of the system. As a consequence, the Air Force incorporated the LCC concept to ensure that ownership cost objectives are established and that life cycle costs are adequately considered during the initial phases and decision points of the acquisition programs (4).

LCC Categories

Figure 2.1 shows a typical distribution of costs over a system's life cycle.

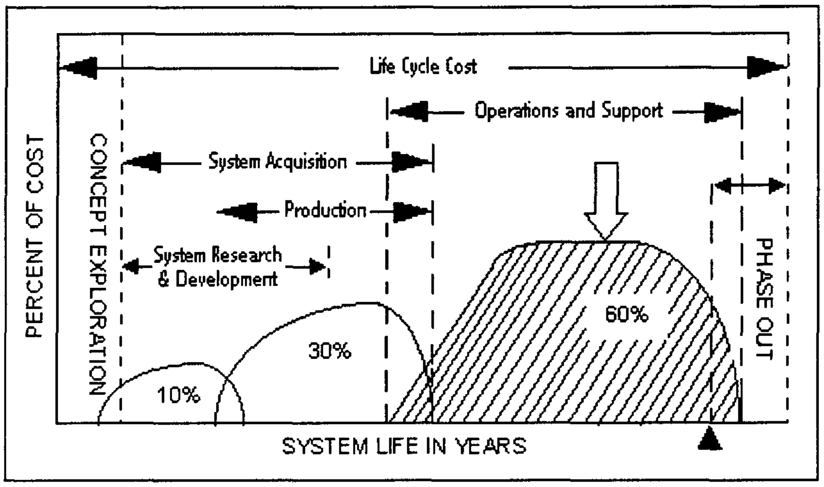

FIGURE 2.1. System Life Cycle Percentage of Cost Distribution (6:5.2-7; 16:3)

Research and Development Costs. Cover the conceptual, validation, and full-scale development phases (22:27). They include feasibility and engineering studies, design, development, testing, prototype fabrication and testing, pilot line fabrication, operations and support planning, manufacturing planning, and documentation (8:23).

Production and Construction Costs. Incurred during the production phase. They include industrial engineering and operations analysis, process development, facility construction, manufacturing (fabrication, assembly, and test of operational systems), quality control, operation and maintenance of the production capability, and initial logistic support requirements (initial consumer support, spare/repair parts, test and support equipment, technical data, and training).

Operation and Support Costs. Incurred during the O&S phase. They include sustaining operation, personnel, maintenance, provisioning, transportation and handling, test and support equipment maintenance, training, technical manuals, some system modifications, facilities, and nonoperating support functions.

Retirement and Phaseout Costs. Cover the disposal of nonrepairable items, recycling, and applicable logistics requirements.

Cost Breakdown Structure

A cost breakdown structure (CBS), or cost tree, is a diagrammatic representation of the segments of costs that combine to provide the total system cost (see Figure 2.2). The CBS is another way of classifying costs, with a life-cycle orientation to facilitate overall visibility, allocation, measurement, and control of costs

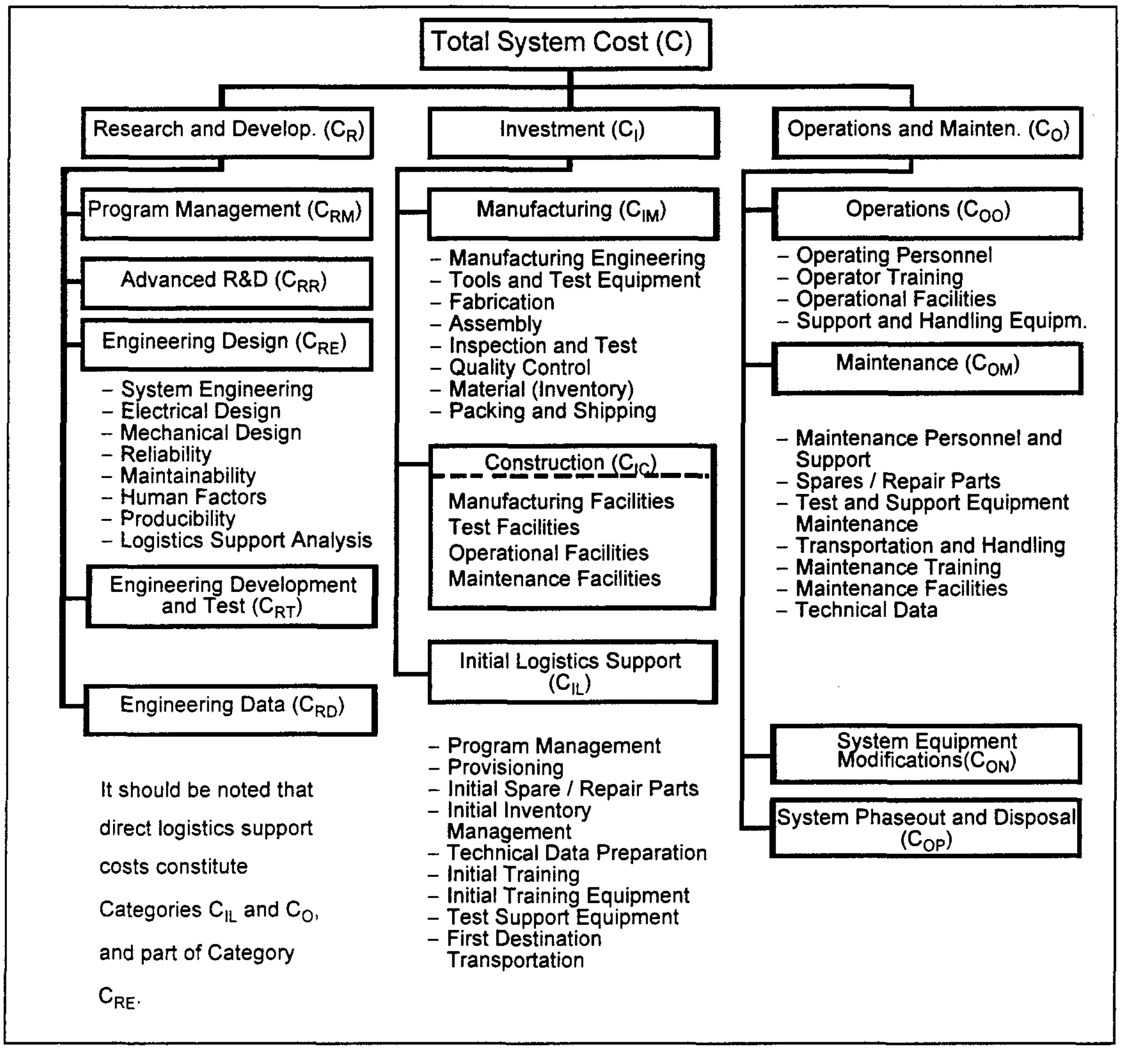

FIGURE 2.2. Cost Breakdown Structure (8:413)

(15:28; 7:191). There is no set method for breaking down costs; each system requires its own particular approach, and the cost categories will vary in terms of coverage depending on the type of system (15:332; 8:411). A proper cost breakdown structure should exhibit the following characteristics (15:28):

1) Inclusion of all cost elements;

2) Precise definition of all cost categories (no cost doubling or omissions);

3) Breakout of costs to the level necessary to provide management with the visibility required in the evaluation of the system;

4) Codification of CBS and categories in a way to facilitate an isolated analysis of specific areas;

5) Direct compatibility with planning documentation, the work breakdown structure, Gantt charts, accounting procedures, and so on.

Operating and Support Costs

"Operating and support (O&S) costs are usually the largest part of LCC" (22:67). These costs depend basically on the system design, on how the system is used, and on the concepts and policies that drive its operation and support. The parameters that compound these costs, however, are the same regardless of such policies. As explained in *An Appraisal of Models Used in LCC Estimation for USAF Aircraft Systems* (19:v), the policies of the Air Force establish crew size and composition, force size and activity rate, basing and deployment, and mission type. All these factors drive operating costs. Such costs, therefore, are functions of number of crew members, flight hours, number of bases, frequency of missions, and so forth.

Support costs, on the other hand, are comprised of

> the costs of maintaining each of the separate components of an aircraft system, including (1)whole aircraft maintenance..., (2)engine overhaul (EOH), (3)repair of exchangeable components, and (4)repair of support equipment. (19:46)

The basic maintenance activities are supported by the parallel policies of supply, training, and ground support equipment (GSE). Table 2.1, which is based on the Cost-Oriented Resource Estimating (CORE) Model, provides a basic description of the typical O&S life-cycle cost categories for an aircraft (3, Table 4.1).

Cost-Oriented Resource Estimating (CORE) Model

The Cost-Oriented Resource Estimating (CORE) Model was designed to provide aircraft squadron annual O&S cost estimates (2:31). It has a hierarchical cost element structure, which permits the basic elements and their subelements to be divided into levels of greater detail. This feature promotes a great flexibility:

- it allows the element estimating techniques to vary as the program progresses through the phases of acquisition.

The user may select the most adequate level and method by which an element is estimated at each phase;

TABLE 2.1

AIRCRAFT O&S COST STRUCTURE (3:Table 4.1)

Operating and Support Costs			
1.0	MISSION PERSONNEL	5.0	CONTRACTOR SUPPORT
1.1	Operations	5.1	Interim Contractor Support
1.1.1	Aircrew	5.2	Contractor Logistics Support
1.2	Maintenance	5.3	Other Contractor Support
1.2.1	Organizational Maintenance		
1.2.2	Intermediate Maintenance	6.0	SUSTAINING SUPPORT
1.2.3	Ordnance Maintenance	6.1	Support Equipment Replacement
1.2.4	Other Maintenance Personnel	6.2	Modification Kit Procurement/Instal.
1.3	Other Mission Personnel	6.3	Other Recurring Investment
1.3.1	Unit Staff	6.4	Sustaining Engineering Support
1.3.2	Security	6.5	Software Maintenance Support
1.3.3	Other	6.6	Simulator Operations
		6.7	Other Sustaining Support
2.0	UNIT LEVEL CONSUMPTION		
2.1	POL/Energy Consumption	7.0	INDIRECT SUPPORT
2.2	Consumable Material/Repair Parts	7.1	Personnel Support
2.3	Depot Level Reparable	7.1.1	Medical Support
2.4	Training Munitions	7.1.2	Special Training
2.5	Other Unit Level Consumption	7.1.3	Permanent Change of Station
		7.2	Installation Support
3.0	INTERMEDIATE MAINTENANCE	7.2.1	Base Operating Support Personnel
	(External to Unit)	7.2.2	Real Property Maint. Personnel
3.1	Maintenance	7.2.3	Installation Support Non-Pay
3.2	Consumable Material/Repair Parts		
3.3	Other Intermediate Maintenance		
4.0	DEPOT MAINTENANCE		
4.1	Overhaul/Rework		
4.2	Other Depot Maintenance		
4.2.1	General Depot Support		
4.2.2	Second Destination Transportation		
4.2.3	Contracted Unit Level Support		
4.2.4	Miscellaneous Depot		

- the model is not complex. It can easily be modified and integrated into a computerized spreadsheet.

A comparison among the operating and support cost models used within the Aeronautical Systems Center (ASC) logistics community at Wright-Patterson AFB revealed the CORE Model to be the most comprehensive (2:8-9). However, it does not account for all the fixed costs associated with O&S activities. It does not include, for example, expenses with replenishment spares or technical data visions and management. Therefore, the CORE Model cost element structure has to be expanded should it be used to estimate all O&S costs.

Life Cycle Cost Analysis

LCC analysis constitutes the systematic analytical process of evaluating alternative configurations in terms of life cycle cost (8:410). LCC analysis has the objectives of choosing the best way to employ available resources (7:11) and providing visibility with respect to the LCC implications of various designs and performance alternatives (4:3.5). These alternatives may relate to different system design configurations, production schemes, logistics support policies, and so on. The LCC analysis constitutes an iterative, step-by-step process, whose methods will vary according to program phase, type of system/equipment, availability of data, nature of decision, etc. The most typical decisions that require analysis are (22:11):

1) Long-range planning and budgeting (an LCC estimate reveals possible alternatives and provides means for evaluating them);

2) Comparison of competing programs;

3) Comparison of logistics concepts (the cost of various approaches to logistics support);

4) Replacement of aging equipment;

5) Control over an ongoing program;

6) Selection among competing contractors;

7) Comparison of alternative production approaches.

Design to Cost. Experience has shown that a major portion of the total life cycle cost for many systems is the result of activities associated with their operation and support. However, the decisions about this phase are normally taken during the early phases of system conceptual design and product planning. As a consequence, if LCC is to be optimized, a high degree of cost emphasis must be stressed at those early phases of system development (7:14; 15:12).

The above considerations naturally lead to the DoD's established design-to-cost (DTC) and Cost as Independent Variable (CAIV) policies. These policies turn cost into a key design parameter, and they are implemented by establishing rigorous cost goals for the system early in the acquisition process (4:3.2). The DTC and CAIV concepts recognize that a proper design has a strong impact on development, production, and ownership costs. However, it also recognizes that all the desired aspects of performance, supportability, producibility, flexibility, maintainability, and many other objectives represent potential sources of conflict; many trade-offs must be evaluated, and achieving a balanced design is often difficult. Figures 2.3, 2.4, and 2.5 highlight some aspects of these relationships.

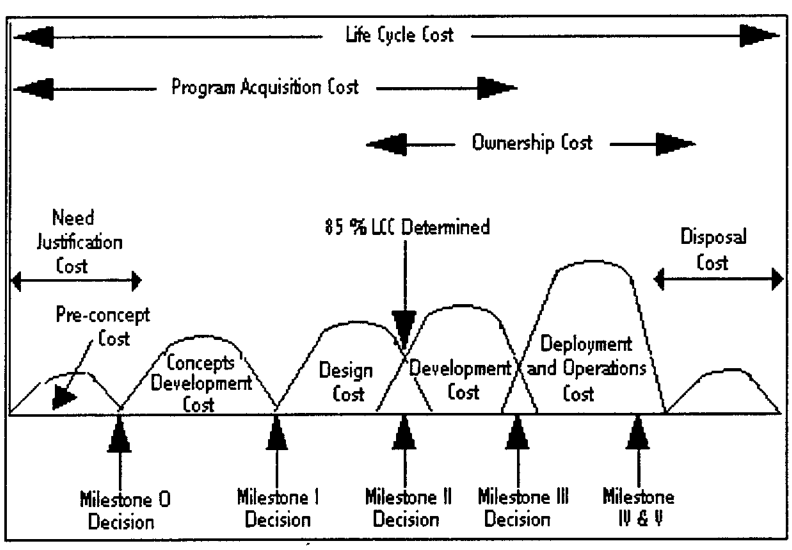

FIGURE 2.3. System Life Cycle Milestones Decision Points (6:5.2-8)

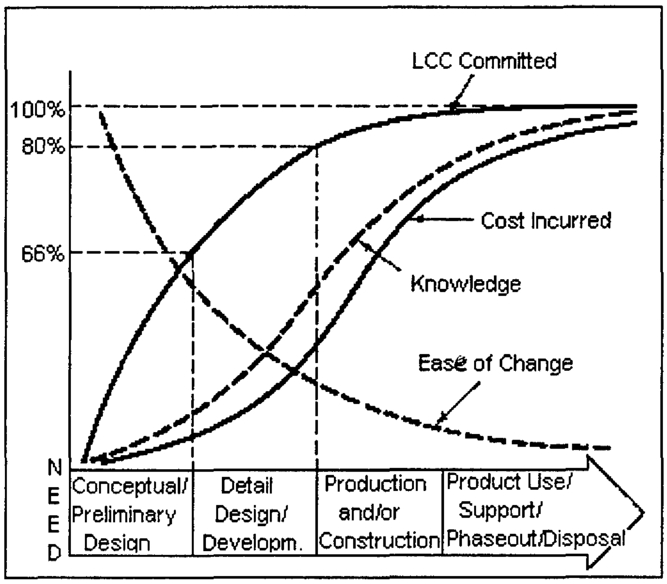

FIGURE 2.4. LCC Committed, Cost Incurred, Knowledge, and Ease of Change (15:13)

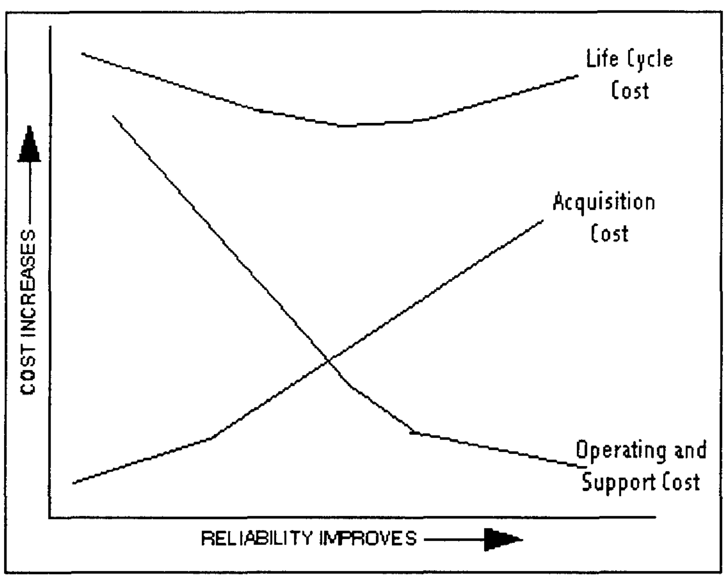

FIGURE 2.5. LCC and Reliability Tradeoff (6:5.2-11)

Quantitative Considerations. The LCC analysis results in an estimated distribution, or profile, of costs throughout the life cycle of the system. However, the analyst cannot use these numbers without first making sure that all data are consistent and comparable (15:152) and that all factors that may influence the distribution were taken into account.

Discounting. The application of a selected rate of interest to adjust the values of the cost distribution to a common reference point in time (8:436). This point is generally the present time, when the decisions are to be made. This procedure assures that the alternatives are evaluated on an equivalent basis.

Inflation. During the past several decades, inflation has significantly increased costs of products and services, and therefore should be incorporated into the cost profiles. Inflation factors should be estimated and reviewed on a year-to-year basis (15:137).

Learning Curves. The effects of experience, job familiarization, better procurement methods, and improved technologies in reducing the cost per unit of a product or a service. These effects are particularly noticeable in the production of large quantities, and normally take place early in the program; there is a leveling off as the program continues on, as shown on Figure 2.6. The concept of learning curves was first noted in the aircraft industry (15:157), and it can be applied to material, labor, or production costs.

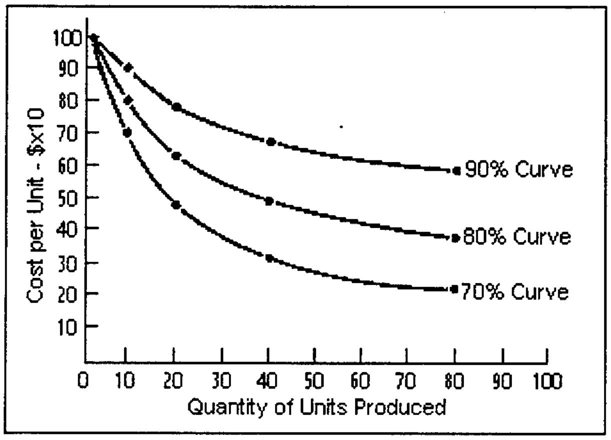

FIGURE 2.6. Unit Learning Curves (8:437)

Cost Profiles. Cost profiles are among the final results of a LCC analysis. The analyst takes the cost breakdown structure and establishes the appropriate cost elements and initial cost distributions. Then, he or she adjusts the numbers for inflation, learning curves' factors, and discounting. The resultant cost streams reflect realistic costs and may be used by the analyst to make the proper decisions. Figure 2.7 exemplifies cost profile curves.

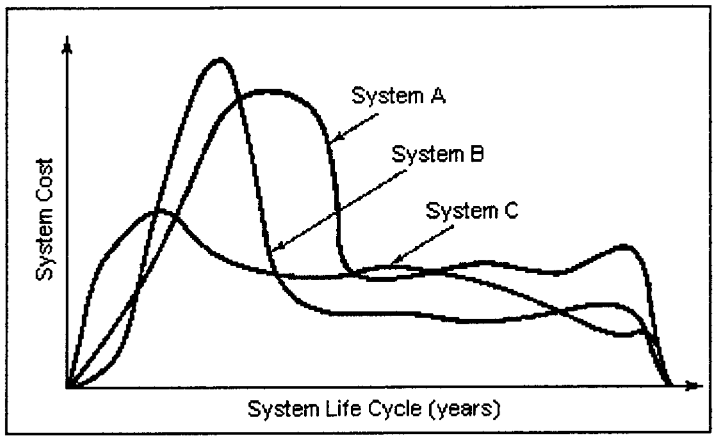

FIGURE 2.7. Life-cycle Cost Profiles of Alternatives (15:139)

Cost Allocation

While direct costs can be obviously traced to the activities that consume them, indirect costs pose more of a difficulty. Indirect costs are incurred for the benefits of several segments and may become very difficult to trace, specially in organizations with different lines of products or services (23:691). Consequently, these costs have to be allocated. Allocation techniques may vary considerably with the characteristics of the processes. With the changes in technology, the proportion of total costs that fall into the manufacturing overhead category is increasing, and so is the necessity for more accurate allocation techniques (23:710). The next paragraphs discuss two approaches for indirect cost allocation: traditional and activity-based costing (ABC).

Traditional Approach. "Conventional cost systems focus on the product in the costing process" (10:45). This traditional method uses only volume attributes of the individual products, such as direct labor or direct machine-hours, to allocate indirect costs. It does not take into consideration, for example, differences in setup times, lot sizes, or complexity of the products or services. As a consequence, where overhead costs are incurred by activities not related to volume, the traditional approach does little to help managers visualize overall cost distribution (23:762).

Activity-Based Costing (ABC). "ABC assumes that *activities*, not *products*, consume resources" (23:762). ABC identifies what activities are required by the products or services and calculates the cost incurred to perform each activity. It uses multiple cost drivers to account for the diversity in resources consumption (21:36). The system works in two stages:

1. costs are traced to activities by dividing overhead costs into homogeneous cost pools;
2. activities are traced to products by selecting a specific cost driver to allocate the costs of each cost pool.

The accuracy of the cost estimation is a function of the number and appropriateness of cost pools and cost drivers.

Benefits of ABC. The literature shows that ABC supports improvement initiatives because it gives management new insights into activity performance, thus allowing them to increase efficiency. Among ABC's many contributions, the major benefits are (23:763, 9:38):

- ABC identifies the activities or processes that consume the majority of an organization's resources;
- ABC helps with performance measurement;
- ABC encourages behavior changes;
- ABC helps direct the manufacturing strategy;
- ABC helps make purchasing decisions; and
- ABC allows for continuous improvement.

Because of these and other benefits, several authors regard ABC as the system of choice for innovative companies (23:710, 11, 27, 18). They stress that ABC is a necessary tool for total quality management (TQM) programs (27), and propose that its efficacy increases when overhead costs are significant, product diversity is high, and measurement costs are low (11:44,47). Some authors suggest the use of ABC by DoD organizations (17:28, 21, 9:38), because "ABC also appears well suited for expansion into government organizations" (9:41).

Activity-based costing systems are able to bring enormous benefits, but their implementation does require an initial investment of resources. Both personnel training and advanced management information systems are necessary conditions for ABC to work.

Summary

This chapter provided background on operation and support costs and the methods used to estimate them. The literature review evidenced the existence of three basic cost estimating methods, which may have a broad range of formats according to the purpose and availability of data. These methods are the tools necessary to implement the concept of life cycle costs, of which some authors suggest ownership costs would represent the largest part. An example of O&S cost breakdown structure, based on the CORE Model, was included. The literature has also shown that the selection of a model should be driven by the intended use, existing constraints, and level of detail of the cost databases. This research attempts to select life cycle costing methods to be applied to the existing BAF KC-137 aircraft maintenance and operational database and procedures, so that the ownership costs of those aircraft can be estimated. The methodology for this research is detailed in the next chapter.

III. Methodology

Chapter Overview

The review of the literature has shown that cost estimating methods may have a broad range of formats, according to their purpose and availability of data. Such methods utilize different underlying techniques, and also vary, for example, in the way they allocate indirect costs. Therefore, an understanding of the KC-137 operational and maintenance philosophies, procedures, and databases is necessary for a proper selection of the cost estimating techniques to be employed in this research. This chapter describes the methodology used for the research, including research objectives, research design and implementation, expected results, and scope and limitations.

Research Objectives

The Boeing 707 is an aging aircraft whose maintenance and operation are becoming more and more expensive. As a consequence, the Brazilian Air Force started to question the feasibility of keeping its KC-137s in operation. However, the BAF currently does not have an established set of procedures for computing ownership costs of such aircraft, which makes it difficult to elaborate cost-benefit analysis and to allocate budget resources. Therefore, the objectives of this research are:

1) to determine the most suitable cost estimation techniques to be applied to the existing BAF KC-137 aircraft maintenance and operational database and procedures, and

2) by using the chosen techniques, to estimate the ownership costs of the KC-137 aircraft during their expected service life (up to year 2006).

Research Design and Implementation

This research is divided into five major parts, to be performed in sequence.

Review of Cost Accounting Methods. The first part consisted of an analysis of the most commonly used LCC accounting methods. The objective was to understand the principles, cost element structure, and application of each method. The textbook used during the Acquisition Logistics Overview course (LOGM 614), by Fabrycky and Blanchard (15), served as a start point. It provided an introduction to LCC analysis and a list of potential references. The next step was a library search using two different search engines, the Online Public Access Catalog (OPAC) and the CD-ROM based

ProQuest. The options used with the first engine were AFIT Library Catalog and FirstSearch.

This effort resulted in the main references listed in this study: books, papers, Rand reports, and DoD manuals. Such sources provided the description of cost accounting techniques and a framework (the CORE Model) necessary for proper execution of the subsequent parts of the research.

Analysis of the KC-137 O&S Systems. The second part is an analysis of the current KC-137 aircraft maintenance and operating systems. The objective is to become familiar with the characteristics of databases and cost elements related to the operation and support of the KC-137 model.

The author of this thesis worked for many years as the project coordinator in the KC-137 program, a function that required his interaction with most of the sectors involved with maintenance and operation of that aircraft, in both the depot and base levels. Therefore, he is already familiar with the *modus operandi* and database structure of these sectors. However, he lacks familiarity with the sectors not directly related to the maintenance and operation functions, such as those involved with facility maintenance and personnel support. In order to acquire all the necessary data, Excel spreadsheets will be sent to the KC-137 Program Office, in Galeão Aeronautical Materiel Depot (GAMD), asking for information regarding cost database structures and values. The KC-137 Program Office will collect such information from the appropriate sectors in GAMD and in the sole operational base, Galeão Air Force Base (GAFB).

This part of the research will collect raw cost numbers and general information about the internal files and working procedures of the various sectors within the base and the depot. Financial statements, maintenance plans, service bulletins, and records from maintenance, supply, operations, and personnel sections will provide the most information for this work.

Cost Breakdown. The main task in the third part is to develop a cost breakdown structure for the maintenance and operating activities of the KC-137 aircraft. The basis for this structure will be the CORE Model, which is described in the Aeronautical Systems Center (ASC) Logistics Analysis Model Guide as being designed to provide annual operating and support cost estimates (2:31). The CORE Model was chosen mainly for the following reasons:

1) it is able to handle different estimating techniques;

2) it is oriented towards aircraft-level estimates;

3) its complexity is within the scope of this research;

4) its equations easily fit into spreadsheet applications.

However, the CORE Model is a variable-cost model, that does not address all the fixed costs associated with the ownership of the aircraft (2:32). Therefore, some of its cost elements will be expanded to account for such expenses.

All the original equations in the CORE Model will also be modified, when necessary, to reflect characteristics peculiar to the KC-137 maintenance and operational systems. The data collected during the previous part of the research will be the base for the definition of cost categories and identification of cost drivers.

Selection of Cost Estimating Techniques. The fourth part consists of the selection of the most suitable cost estimating procedure for each one of the cost categories defined in the previous part. For this study, most suitable will mean able to provide the most precise cost estimate according to the quality and quantity of available data. It is expected that the estimation of certain cost categories will be made with data specific for the KC-137, collected in a straight-forward manner. The estimates for some other costs, however, will require the use of allocation techniques over general pools of cost data. In the latter case, most suitable will also reflect the capacity of the techniques to precisely allocate the costs pertaining to the KC-137 aircraft.

The output of the work, at this point, will be a collection of cost estimating equations that encompass all the expenses BAF has with the maintenance and the operation of its KC-137 aircraft during the period of one year. Some of the equations will make a direct allocation of costs to the KC-137 project, while some others will display allocation factors. Again, the allocation factors will vary with the availability and quality of data.

It is expected that the activities described in this and in the previous parts will not be independent or truly sequential; rather, the work will most probably involve a constant interplay between these phases of the research process. Second and third parts, for example, will be executed concurrently. Figure 3.1 shows how the five parts of the research are interrelated.

Estimation of Ownership Costs. The final part is the estimation of the KC-137 aircraft ownership costs for the remainder of their expected service life, that is, up to year 2006. The spreadsheets with the cost breakdown structure and cost figures developed in the previous parts will be expanded to include the collection of cost estimating equations and calculate annual expenses for each cost category. Corrections to reflect eventual inflation effects will be done whenever necessary. These expenses will then be added up to show an annual total value. Finally, this annual total will be multiplied by the number of remaining years of utilization (from 1997 to 2006) to result in the grand ownership total costs for the KC-137 aircraft in 1996 constant dollars.

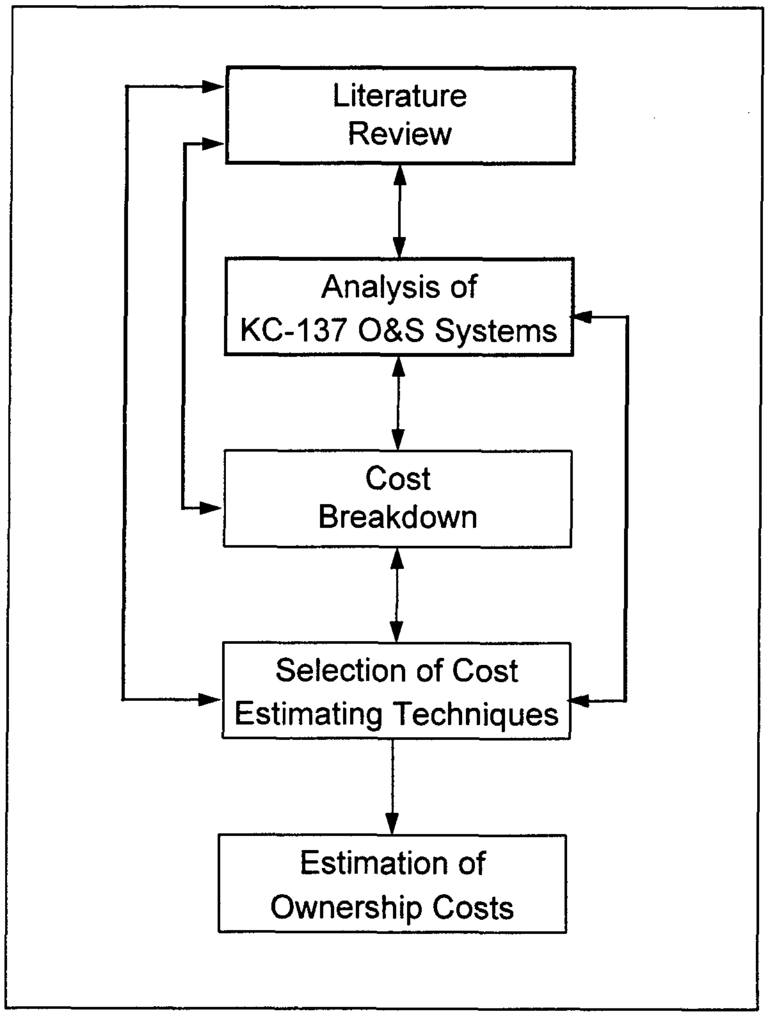

FIGURE 3.1. Methodology

Expected Results

The major product of this research is expected to be a set of cost values related to the operation and support of the KC-137 aircraft up to the remainder of their useful life. This set of cost values may also be used to determine which factors drive KC-137 O&S costs the most, which is relevant information for the establishment of maintenance and operations policies.

As a secondary product, the research shall establish the most adequate cost estimating method for each O&S cost category identified during the development of the cost breakdown structure.

Scope and Limitations

LCC Method -- the research will not try to identify a LCC method either applicable to all aircraft in the BAF inventory or suitable for general use throughout the BAF logistics system. It will not develop a cost estimating model applicable to all BAF aircraft programs; rather, it will result in a single set of cost equations and cost values limited to the specific KC-137 aircraft logistics environment. This limitation is imposed by the fact that different aircraft models in the BAF inventory have somewhat different logistics support schemes, which vary in controls, procedures, and databases.

Ownership Costs Estimate -- the estimation of ownership costs will be performed with data collected from various databases, which differ among themselves in accuracy and comprehensiveness. The estimation approach will have to adapt to each case, and the estimated values will be subjected to different degrees of uncertainty. The year of 1996 will be the basis for the collection of cost data; the KC-137 fleet flew all the annual scheduled effort without any accident or other unusual occurrence during that year.

Currency - the values will be shown in American dollars. A significant portion of the spares and materials consumed by the KC-137 O&S activities is quoted in this currency, which possesses a great stability on the international market.

Utilization Rate -- since the mission profiles of the KC-137 aircraft are expected to remain the same for the near future, this research will estimate ownership costs employing historical utilization rates.

Disclaimer - since this research has not been officially sponsored by any BAF organization, the data here disclosed will not be endorsed by the Brazilian Air Force and may not precisely correspond to the actual expenses resultant from the ownership of the KC-137 aircraft.

Summary

The results of the analysis of the KC-137 aircraft maintenance and operating systems will dictate the development of the O&S cost breakdown structure and the selection of the cost estimating procedures. These procedures will generate cost estimating equations, which will be applied to the data collected from the depot and the operational base in order to achieve the objectives of this research. Chapter IV will present the results of the methodology described in this chapter.

IV. Data Description and Results

Chapter Overview

This chapter presents the results and analysis of procedures outlined in the previous chapter. It includes an analysis of how the operational base and the depot are structured, which is followed by the description of the KC-137 maintenance system. Definition and results for each cost element identified in the cost breakdown structure close the chapter.

Galeão Air Force Base (GAFB)

Galeão Air Force Base (GAFB) is the sole operational base of the KC-137 aircraft. This base houses the squadron that operates the KC-137, the 2nd Squadron of the 2nd Group of Transport (2nd/2nd GT). GAFB is also an operational base for three other flight squadrons, which operate Lockheed C-130 Hercules, British Aerospace (BA) HS-748 Avro, and Embraer EMB-110 Bandeirante aircraft.

The Brazilian Air Force employs a three-level maintenance system. The flight squadrons are responsible for the unit level of maintenance, while the intermediate level is performed by supply and maintenance squadrons

(SMS's) located on each base. The SMS in Galeão Air Force Base, therefore, performs intermediate-level maintenance for all four flight squadrons located on that base.

Galeão Aeronautical Materiel Depot (GAMD)

The depots are responsible for the third level of maintenance in the BAF. Besides the KC-137 aircraft, Galeão Aeronautical Materiel Depot (GAMD) performs heavy-maintenance services in three other models: Lockheed C-130 Hercules, BA HS-748 Avro, and BA HS-135 (the latter model is stationed at Brasília AFB). Each one of these aircraft has its own maintenance line, but they share all other depot resources.

The maintenance lines have fixed staff; the personnel who work directly with the airframe of one aircraft do not do any service for the other maintenance lines. The staff of support sections such as painting, supply, or component repair shops, however, works with all aircraft.

KC-137 Maintenance Program

The KC-137 aircraft maintenance program is based on a calendar inspection system with a six-year cycle (20:3). This cycle interval means that the inspections are allocated to the several types of check in such a way that all inspections are performed at least once between major checks. This maintenance program was adapted from the inspection plan developed by VARIG, the former owner of the aircraft, which was based on the Boeing maintenance planning document (1).

Table 4.1 summarizes the programmed inspections and their intervals and maintenance levels (20:4-5,18). The compliance with manufacturers' service bulletins and special safety programs is scheduled concurrently with the routine inspections.

TABLE 4.1

KC-137 MAINTENANCE PROGRAM INSPECTIONS (20:4-5,18)

Check	Interval	Maintenance
Pre-flight	each flight	unit
Taxi	each flight	unit
A	30 days	unit
B	6 months	intermediate
2B	12 months	intermediate
C1	18 months	intermediate
C2	2 years	intermediate
2C	4 years	depot
D	6 years	depot
Special	as assigned	as assigned

Non-Routine Maintenance Services

The Boeing 707 is an aging model, and most of the units still flying have long passed the initial factory-projected life of twenty years, twenty thousand cycles, or sixty thousand hours of operation (24; 26). As a result, aviation authorities all over the world have mandated compliance with selected safety programs. Therefore, besides the routine tasks included on the regular maintenance inspections, there are three groups of non-routine services programmed to be incorporated on the KC-137 aircraft: regular service bulletins, supplemental structural inspections and mandatory structural modifications.

Service Bulletins - General. These service bulletins (SB) are not included in any safety program. They may be related to operational procedures or to any area of the aircraft, including engines and components (see Appendix G).

Structural Mandatory Program (SMP). The US Federal Aviation Administration (FAA), the Air Transport Association (ATA), and the Aerospace Industries Association of America (AIA) held an Aging Fleet Conference, in June of 1988, to assess the structural airworthiness of aging fleets. As one result, an Airworthiness Assurance Task Force (AATF) was created with participation of aircraft operators, manufactures, regulatory and other aviation authorities from all over the world (24:9). For the Boeing 707, the AATF created the 707/720 Structures Working Group (SWG).

After monitoring a large part of the high-time 707 world fleet, the SWG selected a total of 141 service bulletins to recommend for structural modification (see Appendix F). The criteria for selection were: possible safety problem, frequent problem, or area difficult to inspect. These 141 service bulletins were later included in the special Master Service Bulletin 3480 (24). Following the same criteria cited before, the SWG also selected 28 service bulletins to recommend for structural inspection, and included them in the special Master Service Bulletin 3486 (25).

Supplemental Structural Inspection Document (SSID). Even before the work of the AATF, the FAA had issued the Airworthiness Directive (AD) 85-12-01 requiring the implementation of a supplemental program with the objective of inspecting areas where damage or fatigue characteristics warranted special attention. Complying with the AD, and with the assistance of several 707 operators, Boeing developed this document (see Appendix H). The SSID details structurally significant inspection items determined by test, analysis, or service experience to be significantly impacted by the effects of fatigue and corrosion (26).

Cost Breakdown

Consistent with Chapter III, there was an exchange of information between the author of this thesis and the KC-137 Program Office in GAMD. Through the use of air mail, e-mail, and telephone services, it was possible to assess the characteristics of the existing cost databases related to the KC-137 maintenance and operational systems, in both GAFB and GAMD, and modify the CORE model to reflect such characteristics. Table 4.2 presents the resultant cost breakdown structure.

Cost Elements

This part of the chapter defines the cost elements listed in the cost breakdown structure (Table 4.2), and describes the methods and rationale used to estimate the cost values for each element.

1.0 **GAFB - Personnel:** the cost of pay and allowances for everyone inside GAFB directly or indirectly related to the operation and support of the KC-137 aircraft.

1.1 **2nd/2nd GT - Operations:** the pay and allowances for the crews required to operate the aircraft.

1.1.1 Aircrew: the cost of pay and allowances for all crewmembers in the Squadron. It includes all direct and indirect monetary expenses that the BAF incurs by keeping

TABLE 4.2

KC-137 AIRCRAFT O&S COST STRUCTURE

KC-137 Operating and Support Costs			
1.0	GAFB - PERSONNEL	4.0	GAMD - DEPOT MAINTENANCE
1.1	2nd/2nd GT - Operations	4.1	Overhaul
1.1.1	Aircrew	4.1.1	Airframe
1.2	Maint. - Base / Intermediate Levels	4.1.2	Engines
1.2.1	2nd/2nd GT - Base Maintenance	4.1.3	Reparable
1.2.2	SMS - Intermediate Maintenance	4.1.4	Ground Support Equipment (GSE)
1.3	GAFB - Personnel - Total	4.1.5	Replenishment Spares
		4.2	Other Depot
2.0	GAFB - MATERIAL	4.2.1	General Support
2.1	Fuel, Lubricants, and Energy	4.2.2	Transportation
2.1.1	Fuel and Lubricants		
2.1.2	Electricity	5.0	CONTRACTOR SUPPORT
2.2	Consumable Material		
2.2.1	Aircraft Material	6.0	SUSTAINING SUPPORT
2.2.2	Mission Support Supplies	6.1	GSE Replacement
2.3	Depot Level Supplies	6.2	Modification Kits
2.4	Contractor Support	6.3	Sustaining Engineering Support
2.5	Other Unit Level Consumption		
		7.0	INDIRECT SUPPORT
3.0	INTERMEDIATE MAINTENANCE (External to Unit)	7.1	Personnel Support
		7.1.1	Medical Support
		7.1.2	Specialty Training
		7.1.3	Permanent Change of Station (PCS)
		7.2	Installation Support
		7.3	Administrative Support

the personnel: salary, meals, retirement funds, bonuses, and so forth. Since the crewmembers allocated to the 2nd/2nd GT do not fly for other squadrons, their cost was obtained by multiplying the number of crewmembers by the annual BAF expenses for each of them.

1.2 Maintenance - Base and Intermediate Levels: the cost of pay and allowances for all KC-137 maintenance personnel in GAFB.

1.2.1 2nd/2nd GT - Base Maintenance: the pay and allowances for all 2nd/2nd GT personnel who are not crewmembers. As on the previous item, this cost results from the calculation of the annual salary expenses for each squadron member.

1.2.2 SMS - Intermediate Maintenance: the pay and allowances for military and civilian personnel working in the SMS of Galeão Air Force Base. Since this SMS also performs intermediate maintenance for three other squadrons, but does not keep a record of staff hours spent with each type of aircraft, an allocation factor was used to estimate the part of the cost correspondent to the KC-137 aircraft. The proportion of service orders related to the KC-137 to the total number of service orders processed by the SMS served as the allocation factor.

1.3 Galeão Air Force Base: the pay and allowances for all GAFB personnel not assigned to the flight squadrons or the SMS. It includes, for example, administrative, security, and flight safety personnel. The ratio of 2nd/2nd GT personnel to all flight squadrons' personnel was the allocation factor used in this item.

2.0. GAFB - Material Consumption: the cost of all material purchased by GAFB directly or indirectly spent in the operation and support of the KC-137 aircraft.

2.1. Fuel and Lubricants (POL), and Energy: the cost of aviation POL and energy required for unit flying operations.

2.1.1 Fuel and Lubricants: the cost of fuel and lubricants required for unit flying operations. The average historical KC-137 aircraft consumption of such materials per flight hour, multiplied by the projected annual utilization of the aircraft and the current fuel and lubricant prices in Rio de Janeiro, Brazil, provided the cost estimate for this item.

2.1.2 Electricity: the financial statements of GAFB revealed the total base expenses with electricity. The allocation factor was the ratio of the KC-137 hangar area to the total hangar area for all squadrons.

2.2 **Consumable Material:** the cost of material consumed in the operation, maintenance, and support of the KC-137 at the base level.

2.2.1 **Aircraft Material:** the costs of consumable and repair parts used in maintenance but not individually controlled. This includes parts such as gaskets, drills, lamps, and batteries. The GAFB Supply Sector manages such expenses through a computerized system, but does not discriminate among flight squadrons. Therefore, the service order ratio used on item 1.2.2 was also used for cost allocation on this item.

2.2.2 **Mission Support Supplies:** the cost of support material for mission personnel, such as safety gear, computer consumables, charts and maps, and cleaning and office supplies. The supervisor of the sector in charge of this material developed his own computer program to control these expenses, with discrimination among squadrons. Although no allocation was necessary for the $2^{nd}/2^{nd}$ GT direct costs, it was necessary to account for that part of GAFB expenses not directly related to the flight squadrons. The ratio of the $2^{nd}/2^{nd}$ GT expenses to the total for all flight squadrons was used as allocation factor.

2.3 Depot Level Supplies: the cost of repair or replenishment of items sent to the depot. The present record system for these transactions, however, includes only the total value of the transferred items. GAMD provides for repair and replenishment of this material. Therefore, these expenses are included among the depot expenses with reparables, engines, and replenishment, on item 4.1.

2.4 Contractor Support: the costs of supporting contractor material and technical services, delivered to unit and intermediate levels. GAFB financial statements provided the cost numbers.

2.5 Other Unit Level Consumption: unit level consumption costs not included on previous items, such as water, telephone, and sewage. The ratios of hangar area and flight squadron personnel were used as allocation factors.

3.0 Intermediate Maintenance (External to Unit): GAFB performs both unit and intermediate levels of maintenance, and therefore intermediate maintenance costs are already accounted for on the previous items.

4.0 GAMD - Depot Maintenance: the cost of personnel, material, and contractual services required to perform maintenance of aircraft, components, and GSE at the depot.

4.1 Overhaul: the labor and material cost of direct maintenance services: overhaul or rework services on the aircraft, components, and ground support equipment (GSE).

4.1.1 Airframe: the cost of personnel, material, and contractual support related to airframe services. The KC-137 Maintenance Line keeps a list of the material, while the Supply Division records unit prices. Since the maintenance lines do not exchange personnel, this cost was calculated by using annual salary expenses.

4.1.2 Engines: the cost of personnel and contractual services dealing with engines and engine modules. The cost of engine components, transportation, and depot level material is included on items 4.1.3, 4.1.5, and 4.2, due to the way GAMD manages their business. The Contractor Sector, at the Planning and Control Division, furnished contractor cost numbers. Since the technicians who work with the KC-137 engines are fully allocated to them, their cost was based on annual salary expenses.

4.1.3 Reparable: the cost of personnel and material dedicated to reparable items returned to the depot. Neither the Supply Division nor the depot shops have a discriminated record of the material that is used for the repair of such components. The Supply Division includes expenses with reparable and replenishment material in the same file, and therefore both are accounted for on item 4.1.5. The allocation factor for personnel was the proportion of service orders related to the KC-137 to the total number of service orders processed by the shops.

4.1.4 Ground Support Equipment (GSE): the cost of personnel and material related to common and peculiar ground support equipment. Material numbers are a crude estimate made by the GSE shop, and the allocation factor was direct maintenance personnel (same as on item 4.2.1).

4.1.5 Replenishment Spares: the cost of replacement for consumable and condemned components. GAMD financial statements and Supply Division records are the source of these cost numbers.

4.2 Other Depot: the labor and material cost of indirect maintenance services: supply activities, maintenance line administrative services, and transportation.

4.2.1 General Support: the pay and allowances for direct personnel in the Supply Division and indirect personnel in both Maintenance and Supply divisions. The allocation factor was the ratio of direct KC-137 maintenance line staff to the staff in all maintenance lines, and it was applied over annual salary expenses.

4.2.2 Transportation: the cost of transportation of engines, material, and personnel, not accounted for on previous items. The GAMD financial balance lists these cost numbers. Shop service orders and direct maintenance personnel served as allocation factors.

5.0 Contractor Support: the cost of contract labor, material, and assets used in providing depot level logistics, engineering, aircraft support, component repair, and GSE support. It does not include engine support. The Contractor Sector, at the Planning and Control Division, furnished contractor cost numbers.

6.0 Sustaining Support: the cost of labor and material incurred to maintain operational reliability, to approve design changes, to assure conformance with established specifications and standards, and to study improvements in the aircraft, components, and GSE.

6.1 GSE Replacement: the cost for replacement of ground support equipment. The Supply Division has a control that does not discriminate among projects, and therefore the proportion of direct maintenance personnel was used as the allocation factor.

6.2 **Modification Kits:** the cost of procuring and installing modification kits needed to achieve acceptable levels of safety, overcome mission capability deficiencies, improve reliability, or reduce maintenance costs. This item includes material and personnel expenses with the service bulletins listed in Appendix G (Service Bulletins - General) and Appendix F (SMP - Structural Mandatory Program). The total costs on those appendixes were divided by 10, since they cover all scheduled services for the remaining service life of the KC-137 aircraft (ten years). One should expect new service bulletins being released during the next ten years, but since the BAF KC-137 aircraft do not rank among the most flown, these new SB's should not present any major expense.

6.3 **Sustaining Engineering Support:** the costs incurred to provide system engineering and program management oversight. They include the work force to perform the inspections listed in Appendix H (SSID) and direct and indirect personnel at the Planning and Control Division. The allocation factor was the ratio of direct KC-137 personnel to direct personnel in all projects, and it was applied over annual salary expenses.

7.0 Indirect Support: labor and material not assigned to the direct maintenance and operation of the aircraft, but indirectly required for the support of such activities.

7.1 Personnel Support: the cost of labor and material supporting the personnel related to the KC-137 O&S activities.

7.1.1 Medical Support: the cost of medical personnel and material needed to support the unit. The GAMD financial statements listed the cost numbers. Direct maintenance personnel were used to calculate the allocation factor. A Medical Program funded by part of each employee's salary provides most of the medicines and medical equipment, and therefore these costs are not included.

7.1.2 Specialty Training: the cost of training the personnel related to the KC-137 O&S activities.

7.1.2.1 Aircrew: the cost of aircrew training in the KC-137 aircraft. It includes simulators and manuals for pilots but only manuals for non-pilots, since the $2^{nd}/2^{nd}$ GT existing personnel provide all the in-flight training. The cost for each crewmember was multiplied by the average yearly turnover.

7.1.2.2 Non-Aircrew: the cost of material and personnel involved in other than flight-related training. Examples include training in quality control techniques, foreign language, and specialty improvement. The GAMD financial statements listed the cost numbers for material. The allocation factor was direct maintenance personnel, and it was applied over annual salary expenses.

7.1.3 Permanent Change of Station (PCS): the cost of PCS moves for KC-137 personnel. The GAMD Personnel Distribution Chart (PDC) provided the data for this item.

7.2 Installation Support: the cost of material and personnel assigned to the construction, maintenance, and engineering support of real property facilities. The GAMD financial statements listed the cost of material. The allocation factor was the ratio of KC-137 aircraft hangar area to total hangar area, and it was applied over annual salary expenses for base-wide installation support.

7.3 Administrative Support: the cost of basic utility services and personnel supporting the operation of the installation. The latter includes command, administrative, and security personnel, among other services. The GAMD financial statements listed the cost numbers for utility services, and the allocation factor was direct maintenance personnel.

Cost Estimates

The cost breakdown structure and cost estimating methods outlined in previous parts of this chapter were implemented through an Excel spreadsheet in Appendix B. The final cost values in that appendix are expressed in U.S. dollars, base 31 December 1996, although the original cost factors, received from the KC-137 Program Office in Rio de Janeiro and expressed in the Brazilian currency, Real, were also provided. Appendix C and Appendix D present the formulas used for cell and cost calculations, respectively. Appendix E includes a summary of the cost values, which is reproduced in Table 4.3. Appendixes B, E, F, G, and H are linked in the same Excel workbook; the modification of any factor will alter all related values. This linkage will facilitate any future use and refinement of the model or cost factors.

The values in Table 4.3 represent an estimate of the annual BAF expenditures with each cost element allocated to the KC-137 aircraft, considering operations throughout year 2006. All numbers are U.S. dollars, base 31 December 1996, when the U.S. dollar to real rate was 1 US$ = 1.0305 R$.

TABLE 4.3

SUMMARY OF COST VALUES

SUMMARY OF COSTS

The values in this table represent an estimate of the annual BAF expenditures with each cost element allocated to the KC-137 aircraft, and considering operations throughout year 2006. All numbers are U.S. dollars, base 31 December 1996.

1.0	**Galeao Air Force Base (GAFB) - Personnel**		
1.1	Flight Squadron (2nd/2nd GT) - Operations		
1.1.1	Aircrew	**Cost D1**	1,648,426
1.2	Maintenance - Base and Intermediate Levels		
1.2.1	Flight Squadron (2nd/2nd GT) - Maintenance	**Cost D2**	964,985
1.2.2	Supply and Maintenance Squadron (SMS) Intermediate Maintenance	**Cost D3**	486,806
1.3	Galeao Air Force Base (GAFB)	**Cost D4**	1,644,466
2.0	**GAFB - Material Consumption**		
2.1	Fuel, Lubricants, and Energy		
2.1.1	Fuel	**Cost D5**	3,796,568
	Lubricants	**Cost D6**	57,841
2.1.2	Electricity	**Cost D7**	59,939
2.2	Consumable Material		
2.2.1	Aircraft Material	**Cost D8**	21,025
2.2.2	Mission Support Supplies	**Cost D9**	7,653
2.3	Depot Level Supplies	included on item 4.1	
2.4	Contractor Support	**Cost D10**	17,923
2.5	Other Unit Level Consumption	**Cost D11**	82,685

TABLE 4.3 (Cont.)

SUMMARY OF COST VALUES

3.0	**Intermediate Maintenance (External to Unit)**	not applicable	
4.0	**Galeao Aeronautical Materiel Depot (GAMD) - Depot Maintenance**		
4.1	Overhaul		
4.1.1	Airframe		
	KC-137 Maintenance Line - material	**Cost D12**	502,540
	KC-137 Maintenance Line - personnel	**Cost D13**	755,313
4.1.2	Engines	**Cost D14**	665,775
4.1.3	Reparable - material	included on item 4.1.5	
	Reparable - personnel	**Cost D15**	1,098,268
4.1.4	Ground Support Equipment (GSE)	**Cost D16**	33,892
4.1.5	Replenishment Spares	**Cost D17**	199,098
4.2	Other Depot		
4.2.1	General Support	**Cost D18**	428,306
4.2.2	Transportation	**Cost D19**	18,363
5.0	**Contractor Support**		
	Contractor support (all except engines)	**Cost D20**	459,064
6.0	**Sustaining Support**		
6.1	GSE Replacement	**Cost D21**	25,386
6.2	Modification Kits	**Cost D22**	61,522
6.3	Sustaining Engineering Support	**Cost D23**	600,635

TABLE 4.3 (Cont.)

SUMMARY OF COST VALUES

7.0	**Indirect Support**		
7.1	Personnel Support		
7.1.1	Medical Support	**Cost D24**	234,442
7.1.2	Specialty Training		
7.1.2.1	Aircrew	**Cost D25**	24,998
7.1.2.2	Non-Aircrew	**Cost D26**	125,135
7.1.3	Permanent Change of Station (PCS)	**Cost D27**	36,390
7.2	Installation Support	**Cost D28**	351,930
7.3	Administrative Support	**Cost D29**	1,789,668
		Annual Total - US$	16,199,041
		Annual Flight Hours	1,700
		Cost per Flight Hour - US$	9,529
		Total Costs for the Remaining Service Life - US$	161,990,407

The previous table shows that the single most significant cost element is fuel, which has a value of US$ 3,796,568, or 23.4% of the total costs. Other items with significant numbers include personnel and administrative support. However, it may provide more visibility to add the individual cost elements into selected groups: personnel, material, POL, and support. Table 4.4 displays the results of such aggregation.

TABLE 4.4

SUMMARY OF COSTS - AGGREGATE VALUES

SUMMARY OF COSTS - Aggregate Values (US$)			SUB-TOTALS	
Personnel	Operation	1,648,426 10.2%	4,884,471	30.2%
	Unit-Level Maintenance	964,985 6.0%		
	Intermediate-Level Maintenance	486,806 3.0%		
	Depot-Level Maintenance	1,784,254 11.0%		
Material	Airframe	603,011 3.7%	3,084,493	19.0%
	Reparable	1,756,430 10.8%		
	Engines	665,775 4.1%		
	GSE	59,278 0.4%		
POL	Fuel, Oil, Lubricants	3,854,409 23.8%	3,854,409	23.8%
Support	GAFB	1,794,743 11.1%	4,375,667	27.0%
	GAMD	2,580,924 15.9%		
			TOTAL	16,199,041

Table 4.4 reveals that the major expenses BAF has with the KC-137 aircraft relate to personnel, which represents 30.2% of the total. Material, which normally demands a great deal of management work, accounted for only 19.0% of total costs, the least amount. POL and support showed equivalent numbers, 23.8% and 27.0% respectively. Table 4.5 reveals the cost factors that were included in each of the previous aggregate groups.

TABLE 4.5

SUMMARY OF COSTS - AGGREGATE FORMULAS

SUMMARY OF COSTS - Aggregate Values - Formulas		
Personnel	Operation	1.1.1
	Unit-Level Maintenance	1.2.1
	Intermediate-Level Maintenance	1.2.2
	Depot-Level Maintenance	4.1.1, 4.2.1, 6.3
Material	Airframe	2.2.1, 2.4, 4.1.1, 6.2
	Reparable	4.1.3, 4.1.5, 5.0
	Engines	4.1.2
	GSE	4.1.4, 6.1
POL	Fuel, Oil, Lubricants	2.1.1
Support	GAFB	1.3, 2.1.2, 2.2.2, 2.5
	GAMD	4.2.2, 7.1.1, 7.1.2.1, 7.1.2.2, 7.1.3, 7.2, 7.3

Databases and Allocation

The accuracy of the cost estimates developed during this research was somewhat prejudiced by the characteristics of some databases, which made necessary the use of allocation factors. Table 4.6 shows the sources of information for each cost element, and whether or not they discriminate among the different projects.

TABLE 4.6

COST DATABASES AND ALLOCATION

COST ELEMENTS & COST DATABASES		ALLOCATION REQUIRED	
		Yes	No
1.0	**Galeao Air Force Base (GAFB) - Personnel**		
1.1	Flight Squadron (2nd/2nd GT) - Operations		
1.1.1	Aircrew *GAFB Personnel Distribution Chart (PDC)*		X
1.2	Maintenance - Base and Intermediate Levels		
1.2.1	Flight Squadron (2nd/2nd GT) - Maintenance *GAFB PDC*		X
1.2.2	Supply and Maintenance Squadron (SMS) *GAFB PDC*	X	
1.3	Galeao Air Force Base (GAFB) *GAFB PDC*	X	
2.0	**GAFB - Material Consumption**		
2.1	Fuel, Lubricants, and Energy		
2.1.1	Fuel / Lubricants *2nd/2nd GT flight records*		X
2.1.2	Electricity *GAFB financial statements*	X	
2.2	Consumable Material		
2.2.1	Aircraft Material *GAFB Supply Sector records*	X	
2.2.2	Mission Support Supplies *GAFB financial statements*		X

TABLE 4.6 (Cont.)

COST DATABASES AND ALLOCATION

COST ELEMENTS & COST DATABASES		ALLOCATION REQUIRED	
		Yes	No
2.3	Depot Level Supplies	included on item 4.1	
2.4	Contractor Support *GAFB financial statements*		X
2.5	Other Unit Level Consumption *GAFB financial statements*	X	
3.0	**Intermediate Maintenance (External to Unit)**	not applicable	
4.0	**GAMD - Depot Maintenance**		
4.1	Overhaul		
4.1.1	Airframe *GAMD PDC, GAMD Supply Division records, KC-137 maintenance line records*		X
4.1.2	Engines *GAMD PDC, Contractor Sector records*		X
4.1.3	Reparable *GAMD PDC, shop service orders*	X	
4.1.4	Ground Support Equipment (GSE) *GSE shop records*	X	
4.1.5	Replenishment Spares *GAMD financial statements, Supply Division files*		X
4.2	Other Depot		
4.2.1	General Support *GAMD PDC*	X	
4.2.2	Transportation *GAMD financial statements*	X	
5.0	**Contractor Support (all except engines)** *Contractor Sector records*		X
6.0	**Sustaining Support**		
6.1	GSE Replacement *Supply Division records*	X	
6.2	Modification Kits *Supply Division records*		X
6.3	Sustaining Engineering Support *GAMD PDC*	X	
7.0	**Indirect Support**		
7.1	Personnel Support		
7.1.1	Medical Support *GAMD financial statements*	X	

TABLE 4.6 (Cont.)

COST DATABASES AND ALLOCATION

COST ELEMENTS & COST DATABASES		ALLOCATION REQUIRED	
		Yes	No
7.1.2	Specialty Training		
7.1.2.1	Aircrew *GAFB financial statements*		X
7.1.2.2	Non-Aircrew *GAMD financial statements*	X	
7.1.3	Permanent Change of Station (PCS) *GAMD PDC*		X
7.2	Installation Support *GAMD financial statements*	X	
7.3	Administrative Support *GAMD financial statements*	X	

Summary

The results of the analysis of the current KC-137 aircraft maintenance and operation systems and databases were presented in this chapter. GAFB houses four flight squadrons and performs unit and intermediate maintenance, while GAMD performs the depot level of maintenance in four different models of airplane. In both organizations, some of the cost databases are well controlled and discriminate among different models of aircraft, while some others made necessary the use of allocation factors. The KC-137 aircraft employs a calendar maintenance program, which includes both routine and special inspections.

A cost breakdown structure for the KC-137 aircraft ownership costs was developed. This structure included definitions and estimating methods for each cost element. Some cost values could be estimated directly from the existing databases, while some others required the use of allocation factors. A summary of these cost values was also included.

The total annual cost of operating and supporting the KC-137 aircraft was estimated to be US$16,199,041, which corresponds to an average cost of US$9,529 per flight hour, at a usage rate of 1700 hours per year. The single most significant cost element is fuel (23.4% of the total costs), but the major aggregated expenses are with the personnel category (30.2% of the total).

Conclusions from the research, implications for the Brazilian Air Force, and recommendations for future research, based on the results and analysis accomplished in this chapter, will be discussed in Chapter V, which follows.

V. Conclusions and Recommendations

Chapter Overview

This chapter utilizes the analysis of data from the previous chapter to draw conclusions about the current KC-137 aircraft maintenance and operation systems, databases and cost breakdown structure. The focus is on the aspects of the research results that may prove useful for studies on the feasibility of continued aircraft operation and for improvements on both the system and cost databases. As such, the conclusions are interpreted as to their implications for the Brazilian Air Force, and also drive the suggestions for further research.

Interpretations and Conclusions

The developed model estimated the total annual cost of operating and supporting the KC-137 aircraft to be US$16,199,041, which corresponds to an average cost of US$9,529 per flight hour, at a usage rate of 1700 hours per year. The model also showed that the single most significant cost element is fuel (23.4% of the total costs), but the major aggregated expenses are within the personnel category (30.2% of the total). However, as shown on Table

4.6, several cost elements had allocated values assigned. Moreover, another possible aggregation of the cost values is into fixed and variable categories. Table 5.1 classifies the cost elements according to these two aspects, which are discussed in the following items.

Fixed versus Variable Costs. Variable costs relate in some way to the amount of usage of the system, while fixed costs are independent from this operational activity. Although there are certain types of business where the percentage of fixed costs is typically rather large, organizations always try to minimize such costs: smaller percentages indicate more efficient use of fixed assets and management overhead.

Table 5.1 shows that the model developed in Chapter IV classifies 57.5% of the total costs as fixed costs. This classification considers a short run perspective; all costs are variable in the long run (23:691). Variable costs were related to flight hours and included fuel, lubricants, unit-level aircraft consumable material, unit-level contractor support, SMS intermediate maintenance, engines, reparables, replenishment spares, transportation, and contractor support. Since the KC-137 aircraft employs a calendar maintenance system, maintenance expenses with airframe overhaul were considered fixed costs.

TABLE 5.1

COST ELEMENT CLASSIFICATION:

FIXED VERSUS VARIABLE, ALLOCATED

COST ELEMENTS		US$	%	Fixed Costs	Variable Costs	Allocated Costs
1.1.1	Cost D1	1,648,426	10.2%	X		
1.2.1	Cost D2	964,985	6.0%	X		
1.2.2	Cost D3	486,806	3.0%		X	X
1.3	Cost D4	1,644,466	10.2%	X		X
2.1.1	Cost D5	3,796,568	23.4%		X	
	Cost D6	57,841	0.4%		X	
2.1.2	Cost D7	59,939	0.4%	X		X
2.2.1	Cost D8	21,025	0.1%		X	X
2.2.2	Cost D9	7,653	0.0%	X		
2.4	Cost D10	17,923	0.1%		X	
2.5	Cost D11	82,685	0.5%	X		X
4.1.1	Cost D12	502,540	3.1%	X		
	Cost D13	755,313	4.7%	X		
4.1.2	Cost D14	665,775	4.1%		X	
4.1.3	Cost D15	1,098,268	6.8%		X	X
4.1.4	Cost D16	33,892	0.2%	X		X
4.1.5	Cost D17	199,098	1.2%		X	
4.2.1	Cost D18	428,306	2.6%	X		X
4.2.2	Cost D19	18,363	0.1%		X	X
5.0	Cost D20	459,064	2.8%		X	
6.1	Cost D21	25,386	0.2%	X		X
6.2	Cost D22	61,522	0.4%		X	
6.3	Cost D23	600,635	3.7%	X		X
7.1.1	Cost D24	234,442	1.4%	X		X
7.1.2.1	Cost D25	24,998	0.2%	X		
7.1.2.2	Cost D26	125,135	0.8%	X		X
7.1.3	Cost D27	36,390	0.2%	X		
7.2	Cost D28	351,930	2.2%	X		X
7.3	Cost D29	1,789,668	11.0%	X		X
	Totals	16,199,041		9,316,787	6,882,253	7,000,944
		100.0%		57.5%	42.5%	43.2%

The numbers in Table 5.1 imply that even if the KC-137 fleet stops flying completely, almost 60% of the current annual costs would still be incurred. This significant value is mostly due to the contribution of fixed-cost direct O&S personnel: 27.2% (items 1.1.1, 1.2.1, 4.1.1-cost D13, 4.2.1, and 6.3).

Direct versus Indirect Costs. Direct costs are most easily perceived, for they are specifically traceable to the cost element being analyzed. Indirect costs, on the other hand, are incurred for the benefit of more than one project. As some authors suggest, when indirect costs are significant and cannot be traced to specific cost elements, the resultant cost figures can be so inaccurate that will not provide managers the information necessary for sound decisions (23:755, 21:36).

Table 5.1 shows that a high percentage of total costs, 43.2%, could not be directly traced to KC-137 O&S activities and had to be allocated. The major costs in this category corresponded to GAFB support personnel (10.2%), GAMD administrative support (11.0%), and reparable-shop personnel (6.8%).

Implications for the Brazilian Air Force

The conclusions discussed in this chapter have some implications for the operation and support of the KC-137 aircraft. First, the aging process of the KC-137 fleet and the consequent increase in operation and maintenance costs justify the BAF concerns with the feasibility of the continued operation of those aircraft. The literature review showed that the BAF may benefit from LCC studies: they are commonly used for comparison of competing alternatives, control over ongoing programs, and decisions about the replacement of aging equipment. The ownership cost estimating model developed in Chapter IV may provide future cost-benefit and budget-allocation analyses with a useful insight into the current cost structure of the KC-137 aircraft. The model was designed to permit the cost estimating techniques to vary as improvements are made in the databases. It also permits each cost element to be divided into levels of greater detail (model refinement). All tables with numeric results in Chapter IV and in this chapter correspond to worksheets in an Excel workbook. These worksheets are all linked together: the modification of any factor will alter all related values. This linkage will facilitate any future use and refinement of the model or cost factors, including *what-if* analyses. A floppy disk containing a copy of the Excel workbook is included in the department copy of this thesis.

Second, this research shows evidence that a high percentage of total O&S costs corresponds to fixed costs. Most of these fixed costs include either the salary of direct maintenance personnel or indirect costs that were allocated with the use of direct maintenance personnel as the allocation factor. As a consequence, it is recommended that future analyses of the substitution of the KC-137 aircraft pay close attention to the maintainability characteristics of each alternative. Maintainability factors have a major impact in total ownership costs, as demonstrated by the cost model developed in this research. Aircraft models whose direct maintenance system and procedures tie up fewer personnel would incur lower O&S costs. Moreover, since fuel was demonstrated to be the single most significant cost element, fuel consumption becomes a natural candidate for the group of prime decision factors.

A third implication is that some major costs may have not been properly accounted for. As Table 5.1 shows, 43.2% of the total costs had to be allocated. These results evidence that the BAF may benefit from more accurate cost accounting techniques, those that allow the tracing of costs from budget categories to sectors, and from sectors to activities and processes. Such techniques would bring the potential to promote the measurement, management, and improvement of existing activities and processes.

Suggestions for Further Research

The results in Chapter IV and the implications cited in this chapter drive the following suggestions for further research:

1. A more comprehensive study could be done on the existing cost accounting systems and databases, with the objective of identifying improvement opportunities. A possible approach would be to study the application of activity-based costing (ABC) methods. ABC is a method of costing that allocates overhead to products and services on the basis of activities consumed in making these products and services. As Skousen and others state in their book,

> Advocates of this approach maintain that activity-based costing (ABC) can provide management with a more accurate overhead assignment to products and therefore a better understanding of profitability. (23:711)

Some authors have already highlighted the potential usefulness of ABC methods for Government organizations, including the Defense area (9:37), and how the effective management of overhead becomes increasingly important as overhead becomes a larger share of total costs (11:4).

2. As stated in Chapter I, GAMD is experimentally utilizing a computerized logistics system, that has been designed to integrate maintenance and operational data. The objectives of this system are to integrate all logistics functions, to promote short, medium, and long run control of these functions, and to permit a systemic visualization of logistics activities. The system is composed of several modules, including planning, control, maintenance, and supply. Another interesting topic for future research would be the development of a LCC module inside this logistics system, a module that would integrate with the existing modules in order to compute selected parts of life cycle costs.

3. This research focused only on cost considerations of the KC-137 aircraft maintenance and operation. However, there are some other aspects that are also relevant for an analysis of alternative tanker models. Therefore, the BAF might also benefit from studies addressing the KC-137 aircraft according to the following factors:

Maintainability -- due to the old age of the Boeing 707 fleet, the maintenance of the KC-137 aircraft is becoming more difficult and expensive to perform. Spares and repair parts are increasingly harder to find. The impact of such difficulties over maintenance lead times (and consequently over aircraft availability) would provide important management information;

Flight Restrictions -- the current model of engines is the target of environment-driven flight restrictions in many countries. Some of the navigational instruments are also bound to become obsolete according to emerging standards in the major airports. The impact of these and other potential flight restrictions over future aircraft airworthiness would also be a consideration during feasibility analyses.

Closing Remarks

This research addressed the estimation of ownership costs of the BAF KC-137 aircraft during their expected service life. As a means to this end, the research also investigated the characteristics of the KC-137 operation and maintenance systems and databases. This study provided insight on the current way O&S costs are accounted for, and may serve as an aid for future studies concerning the utilization of more accurate cost allocating methods. The model developed during this study may also be used to verify the factors that drive ownership costs the most, information that supports decisions about operation and maintenance policies. The results of this research should be seen as a point estimate. As the estimating model is refined and more years of data are collected, better and more accurate estimates can be developed.

Appendix A. List of Acronyms and Abbreviations

$2^{nd}/2^{nd}$ GT	2^{nd} Squadron of the 2^{nd} Group of Transport
AATF	Airworthiness Assurance Task Force
ABC	Activity-Based Costing
acft	aircraft
AD	Airworthiness Directive
AFB	Air Force Base
AFIT	Air Force Institute of Technology
AIA	Aerospace Industries Association of America
ASC	Aeronautical Systems Center
ATA	Air Transport Association
BA	British Aerospace
BAF	Brazilian Air Force
CAIV	Cost as Independent Variable
CBS	Cost Breakdown Structure
CD-ROM	Compact Disc - Read-Only Memory
CER	Cost Estimating Relationship
Cont.	Continued
CORE	Cost-Oriented Resource Estimating
Develop.	Development
DoD	Department of Defense
DTC	Design-to-Cost
EOH	Engine Overhaul
FAA	Federal Aviation Administration
GAFB	Galeão Air Force Base
GAMD	Galeão Aeronautical Materiel Depot
GSE	Ground Support Equipment
hr	hour
Instal.	Installation
kg	kilogram
l	liter
LCC	Life Cycle Cost, Life Cycle Costing

M	manpower
m	meter
Maint.	Maintenance
Mainten.	Maintenance
O&S	Operation and Support
OPAC	Online Public Access Catalog
PAMAGL	Parque de Material Aeronáutico do Galeão
PCS	Permanent Change of Station
PDS	Personnel Distribution Chart
POL	Petroleum, Oil, and Lubricants
R&D	Research and Development
SB	Service Bulletin
SMP	Structural Mandatory Program
SMS	Supply and Maintenance Squadron
SSID	Supplemental Structural Inspection Document
SWG	Structures Working Group
TQM	Total Quality Management
VARIG	Viação Aérea Rio-Grandense
yr	year

Appendix B: Cost Elements

COST ELEMENTS

All final cost values are expressed in U.S. dollars, base 31 Dec 1996.

Dollar to Real rate: 1 US$ 1.0305 R$

Officer Pay:

		US$	R$
Lieutenant	C1	38147	39311
Captain	C2	41987	43268
Major	C3	56768	58500
Lt Colonel	C4	58742	60534
Colonel	C5	65716	67721
Average	C6	44772	46138

Enlisted Pay:

		US$	R$
3rd Sgt	C7	17787	18330
2nd Sgt	C8	20505	21130
1st Sgt	C9	24309	25050
Average	C10	20200	20816
Airman	C11	11502	11853

Civilian Pay:

		US$	R$
Superior level	C12	23548	24266
Intermediate level	C13	14491	14933
Auxiliar level	C14	7246	7467
Average	C15	12010	12376

1.0 Galeao Air Force Base (GAFB) - Personnel

1.1 Flight Squadron (2nd/2nd GT) - Operations

1.1.1 Aircrew

Lieutenant	C16	3
Captain	C17	8
Major	C18	3
Lt Colonel	C19	1
Sergeant	C20	40
Airman	C21	14
Civilian	C22	0

	US$
Cost D1	1,648,426

1.2 Maintenance - Base and Intermediate Levels

1.2.1 Flight Squadron (2nd/2nd GT) - Base Maintenance

Lieutenant	C23	1
Captain	C24	2
Major	C25	1
Lt Colonel	C26	0
Sergeant	C27	15
Airman	C28	42
Civilian	C29	0

US$

Cost D2 964,985

1.2.2 Supply and Maintenance Squadron (SMS) - Intermediate Maintenance

Lieutenant	C30	4
Captain	C31	3
Major	C32	2
Lt. Colonel	C33	0
Sergeant	C34	40
Airman	C35	91
Civilian	C36	0
SMS service orders - total	C37	1440
SMS service orders - KC-137	C38	312
Allocation factor	C39	0.217

US$

Cost D3 486,806

1.3 Galeao Air Force Base (GAFB) - Personnel - Total

Lieutenant	C41	58
Captain	C42	37
Major	C43	15
Lt Colonel	C44	5
Colonel	C45	1
Sergeant	C46	329
Airman	C47	734
Civilian		
Superior level	C48	0
Intermediate level	C49	25
Auxiliar level	C50	4

GAFB - Total Flight Squadrons Minus 2nd/2nd GT

Lieutenant	C51	34
Captain	C52	17
Major	C53	7
Lt Colonel	C54	3
Sergeant	C55	222
Airman	C56	160
Civilian	C57	0

Allocation Factors for GAFB Manpower

Lieutenant	C60	0.105
Captain	C61	0.370
Major	C62	0.364
Lt Colonel	C63	0.250
Colonel	C64	0.227
Sergeant	C65	0.199
Airman	C66	0.259
Civilian	C67	0.227
General	C68	0.227

	US$
Cost D4	1,644,466

2.0 GAFB - Material Consumption

2.1 Fuel, Lubricants, and Energy

2.1.1 Fuel and Lubricants

		US$	R$
Squadron flight hours per year	C75	1700	
Fuel consumption (l/hr.acft)	C76	9100	
Fuel price (per liter)	C77	0.2454	0.2529

Cost D5 US$ 3,796,568

Oil consumption (l/hr.acft)	C78	2	
Other lubricants (kg/yr)	C79	295	

		US$	R$
Oil price (per liter)	C80	16.29	16.79
Other lubricants (per kilogram)	C81	8.29	8.54

Cost D6 US$ 57,841

2.1.2 Electricity

		US$	R$
Electricity - base total	C85	190332	196137

Total built area - m^2	C86	49558
Hangar - KC-137 - m^2	C87	5854
Hangar - all flight squadrons - m^2	C88	18589
Allocation factor	C89	0.315

Cost D7 US$ 59,939

2.2 Consumable Material

2.2.1 Aircraft Material

		US$	R$
Consumable - total	C91	97040	100000

Cost D8 US$ 21,025

NOTE - use allocation factor on item 1.2.2.

2.2.2 Mission Support Supplies

		US$	R$
Total	C96	29953	30867
2nd/2nd GT	C97	2237	2305
All flight squadrons	C98	8755	9022

Allocation factor	C99	0.255

	US$
Cost D9	7,653

2.3 Depot Level Supplies

	US$	R$
Reparable	7453531	7680864
Consumable	319895	329652
GSE/Miscellaneous	118847	122472

NOTE - these numbers do not represent cost of services, but the total value of the material transferred from depot to base. Due to the way the depot controls such transferences, these costs are accounted for on item 4.1.

2.4 Contractor Support

		US$	R$
Contractor Support	C100	17923	18470

	US$
Cost D10	17,923

2.5 Other Unit Level Consumption

		US$	R$
Water / sewage	C101	179677	185158

NOTE - use allocation factor on item 2.1.2.

		US$	R$
Telephone	C102	77161	79514
Miscellaneous	C103	37888	39044

NOTE - use allocation factor on item 1.3.

	US$
Cost D11	82,685

3.0 Intermediate Maintenance (External to Unit)

Not applicable, GAFB performs both base and intermediate level maintenance.

4.0 Galeao Aeronautical Materiel Depot (GAMD) - Depot Maintenance

4.1 Overhaul

4.1.1 Airframe

KC-137 Maintenance Line

		US$	R$
Consumable	C110	501375	516667
Contractor support - airframe	C111	1164	1200

Cost D12 US$ 502,540

Officer	C112	1
Sergeant	C113	30
Airman	C114	7
Civilian	C115	2

Cost D13 US$ 755,313

4.1.2 Engines

		US$	R$
Contractor support - engines	C117	564774	582000

Shop personnel	C118	5

Cost D14 US$ 665,775

NOTE - the cost of depot material is included on items 4.1.3, 4.1.5, and 4.2.

4.1.3 Reparable

	US$	R$
Reparable - material	8026467	8271275

NOTE - this number does not represent cost of materials used for repairs, but the total value of the components that arrived at the depot shops. Due to the way the depot controls service orders, this cost is accounted for on item 4.1.5.

Shop personnel

Officer	C120	7
Sergeant	C121	183
Airman	C122	115
Civilian	C123	74
Shop service orders - total	C124	12372
Shop service orders - KC-137	C125	2184
Allocation factor	C126	0.177

Cost D15 US$ 1,098,268

4.1.4 Ground Support Equipment (GSE)

		US$	R$
Material	C128	116448	120000

NOTES - manpower is included on item 4.2.1;
- use allocation factor on item 4.2.1.

	US$
Cost D16	33,892

4.1.5 Replenishment Spares

		US$	R$
Replenishment spares	C130	199098	205171

	US$
Cost D17	199,098

4.2 Other Depot

4.2.1 General Support

Supply division - KC-137

Officer	C132	1
Sergeant	C133	3
Airman	C134	0
Civilian	C135	1

Maintenance line and supply division - support personnel

Officer	C136	5
Sergeant	C137	28
Airman	C138	27
Civilian	C139	0

Direct maintenance personnel - KC-137

Officer	C141	1
Sergeant	C142	30
Airman	C143	7
Civilian	C144	1

Direct maintenance personnel - total

Officer	C146	4
Sergeant	C147	101
Airman	C148	25
Civilian	C149	4

Allocation factors			
Officer	C151	0.250	
Sergeant	C152	0.297	
Airman	C153	0.280	
Civilian	C154	0.250	
Average	C155	0.291	US$
		Cost D18	428,306

4.2.2 Transportation

		US$	R$
Material	C156	78545	80941

Allocation factor	C157	0.234	US$
(items 4.1.3 and 4.2.1)		**Cost D19**	18,363

NOTE - the cost of personnel is included on item 7.3.

5.0 Contractor Support

		US$	R$
Contractor support	C159	459064	473065
(all except engines and airframe)			US$
		Cost D20	459,064

6.0 Sustaining Support

6.1 GSE Replacement

		US$	R$
GSE replacement - all projects	C161	87223	89883

		US$
Cost	D21	25,386

NOTE - use allocation factor on item 4.2.1.

6.2 Modification Kits

		US$
Structural Mandatory Program	C162	38,253
Service Bulletins - General	C163	23,270

		US$
Cost	D22	61,522

NOTE - remaining service life of the KC-137 aircraft: 10 years.

6.3 Sustaining Engineering Support

		US$
SSID	C165	15185

Planning and control sector - personnel - KC-137

Officer	C166	2
Sergeant	C167	3
Airman	C168	1
Civilian	C169	0

Planning and control sector - personnel - all projects

Officer	C171	7
Sergeant	C172	11
Airman	C173	3
Civilian	C174	3

Planning and control sector - personnel - total

Officer	C176	15
Sergeant	C177	61
Airman	C178	15
Civilian	C179	6

Allocation factors

Officer	C181	0.286
Sergeant	C182	0.273
Airman	C183	0.333
Civilian	C184	0.000

		US$
Cost	D23	600,635

7.0 Indirect Support

7.1 Personnel Support

7.1.1 Medical Support

		US$	R$
Material	C189	52111	53700
Officers	C191	13	
Sergeant	C192	8	
Airman	C193	8	
Civilian	C194	0	

Cost D24 US$ 234,442

NOTE - use allocation factors on item 4.2.1.

7.1.2 Specialty Training

7.1.2.1 Aircrew

		US$	R$
Pilot training	C196	6211	6400
Pilot turnover	C197	4	
Non-pilot aircrew training	C198	78	80
Non-pilot aircrew turnover	C199	2	

Cost D25 US$ 24,998

7.1.2.2 Non-Aircrew

		US$	R$
Material	C201	143814	148200
Officers	C202	2	
Sergeant	C203	6	
Airman	C204	4	
Civilian	C205	4	

Cost D26 US$ 125,135

NOTE - use allocation factors on item 4.2.1.

7.1.3 Permanent Change of Station (PCS)

		US$	R$
PCS - cost per move	C208	6065	6250
PCS - moves	C209	6	

Cost D27 US$ 36,390

7.2 Installation Support

		US$	R$
Material	C211	162131	167076

Officers	C212	3
Sergeant	C213	16
Airman	C214	24
Civilian	C215	17

GAMD - Total built area - m^2	C217	42044
Hangar - KC-137 - m^2	C218	6100
Hangar - all projects - m^2	C219	19064

Allocation factor	C220	0.320

	US$
Cost D28	351,930

7.3 Administrative Support

		US$	R$
Eletricity	C221	235039	242208
Water / sewage	C222	216035	222624
Telephone	C223	66282	68304
Miscellaneous	C224	119616	123264

Officers	C226	23
Sergeant	C227	118
Airman	C228	162
Civilian	C229	39

	US$
Cost D29	1,789,668

NOTE - use allocation factors on item 4.2.1.

Appendix C: Cell Formulas

C39 = C38/C37

C60 = (C16+C23)/(C16+C23+C51)

C61 = (C17+C24)/(C17+C24+C52)

C62 = (C18+C25)/(C18+C25+C53)

C63 = (C19+C26)/(C19+C26+C54)

C64 = (C16+C17+C18+C19+C20+C21+C22+C23+C24+C25+C26+C27+C28+
+C29)/(C16+C17+C18+C19+C20+C21+C23+C24+C25+C26+C27+
+C28+C29+C51+C52+C53+C54+C55+C56+C57)

C65 = (C20+C27)/(C20+C27+C55)

C66 = (C21+C28/(C21+C28+C56)

C67 = C64

C68 = C64

C89 = C87/C88

C99 = C97/C98

C126 = C125/C124

C151 = C141/C146

C152 = C142/C147

C153 = C143/C148

C154 = C144/C149

C155 = (C141+C142+C143+C144)/(C146+C147+C148+C149)

C157 = (C126+C152)/2

C162 = Cost SMP/10

C163 = Cost SB-General/10

C165 = Cost SSID/10

C181 = C166/C171

C182 = C167/C172

C183 = C168/C173

C184 = C169/C174

C220 = C218/C219

Appendix D: Cost Formulas

D1 = C16*C1+C17*C2+C18*C3+C19*C4+C20*C10+C21*C11+C22*C15

D2 = C23*C1+C24*C2+C25*C3+C26*C4+C27*C10+C28*C11+C29*C15

D3 = (C30*C1+C31*C2+C32*C3+C33*C4+C34*C10+C35*C11+C36*C15)*
*C39

D4 = C1*C60*(C41-C16-C23-C30-C51)+
+C2*C61*(C42-C17-C24-C31-C52)+
+C3*C62*(C43-C18-C25-C32-C53)+
+C4*C63*(C44-C19-C26-C33-C54)+C5*C64*C45+
+C10*C65*(C46-C20-C27-C34-C55)+
+C11*C66*(C47-C21-C28-C35-C56)+
+C15*C67*(C48+C49+C50-C22-C29-C36-C57)

D5 = C75*C76*C77

D6 = C75*C78*C80+C79*C81

D7 = C85*C89

D8 = C91*C39

D9 = C96*C99

D10 = C100

D11 = C101*C89+(C102+C103)*C68

D12 = C110+C111

D13 = C6*C112+C10*C113+C11*C114+C15*C115

D14 = C117+C118*C10

D15 = C126*(C120*C6+C121*C10+C122*C11+C123*C15)

D16 = C128*C155

D17 = C130

D18 = (C132*C6+C133*C10+C134*C11+C135*C15)+(C6*C151*C136+
+C10*C152*C137+C11*C153*C138+C15*C154*C139)

D19 = C156*C157

D20 = C159

D21 = C161*C155

D22 = C162+C163

D23 = C165+C166*C6+C167*C10+C168*C11+C169*C15+
+(C176-C171)*C6*C181+(C177-C172)*C10*C182+
+(C178-C173)*C11*C183+(C179-C174)*C15*C184

D24 = C189*C155+C191*C6*C151+C192*C10*C152+C193*C11*C153+
+C194*C15*C154

D25 = C196*C197+C198*C199

D26 = C201*C155+C202*C6*C151+C203*C10*C152+C204*C11*C153+
+C205*C15*C154

D27 = C208*C209

D28 = C220*(C211+C212*C6+C213*C10+C214*C11+C215*C15)

D29 = (C221+C222+C223+C224)*C155+C226*C6*C151+
+C227*C10*C152+C228*C11*C153+C229*C15*C154

SUMMARY OF COSTS

The values in this table represent estimates of the annual BAF expenditures with each cost element allocated to the KC-137 aircraft, and considering operations throughout year 2006. All numbers are U.S. dollars, base 31 December 1996.

1.0	**Galeao Air Force Base (GAFB) - Personnel**		
1.1	Flight Squadron (2nd/2nd GT) - Operations		
1.1.1	Aircrew	**Cost D1**	1,648,426
1.2	Maintenance - Base and Intermediate Levels		
1.2.1	Flight Squadron (2nd/2nd GT) - Maintenance	**Cost D2**	964,985
1.2.2	Supply and Maintenance Squadron (SMS) Intermediate Maintenance	**Cost D3**	486,806
1.3	Galeao Air Force Base (GAFB)	**Cost D4**	1,644,466
2.0	**GAFB - Material Consumption**		
2.1	Fuel, Lubricants, and Energy		
2.1.1	Fuel	**Cost D5**	3,796,568
	Lubricants	**Cost D6**	57,841
2.1.2	Electricity	**Cost D7**	59,939
2.2	Consumable Material		
2.2.1	Aircraft Material	**Cost D8**	21,025
2.2.2	Mission Support Supplies	**Cost D9**	7,653
2.3	Depot Level Supplies	included on item 4.1	
2.4	Contractor Support	**Cost D10**	17,923
2.5	Other Unit Level Consumption	**Cost D11**	82,685
3.0	**Intermediate Maintenance (External to Unit)**	not applicable	

4.0	**Galeao Aeronautical Materiel Depot (GAMD) - Depot Maintenance**		
4.1	Overhaul		
4.1.1	Airframe		
	KC-137 Maintenance Line - material	**Cost D12**	502,540
	KC-137 Maintenance Line - personnel	**Cost D13**	755,313
4.1.2	Engines	**Cost D14**	665,775
4.1.3	Reparable - material	included on item 4.1.5	
	Reparable - personnel	**Cost D15**	1,098,268
4.1.4	Ground Support Equipment (GSE)	**Cost D16**	33,892
4.1.5	Replenishment Spares	**Cost D17**	199,098
4.2	Other Depot		
4.2.1	General Support	**Cost D18**	428,306
4.2.2	Transportation	**Cost D19**	18,363
5.0	**Contractor Support**		
	Contractor support (all except engines)	**Cost D20**	459,064
6.0	**Sustaining Support**		
6.1	GSE Replacement	**Cost D21**	25,386
6.2	Modification Kits	**Cost D22**	61,522
6.3	Sustaining Engineering Support	**Cost D23**	600,635
7.0	**Indirect Support**		
7.1	Personnel Support		
7.1.1	Medical Support	**Cost D24**	234,442

7.1.2	Specialty Training		
7.1.2.1	Aircrew	**Cost D25**	24,998
7.1.2.2	Non-Aircrew	**Cost D26**	125,135
7.1.3	Permanent Change of Station (PCS)	**Cost D27**	36,390
7.2	Installation Support	**Cost D28**	351,930
7.3	Administrative Support	**Cost D29**	1,789,668

Annual Total - US$	16,199,041
Annual Flight Hours	1,700
Cost per Flight Hour - US$	9,529
Total Costs for the Remaining Service Life - US$	161,990,407

Appendix F. Structural Mandatory Program

SMP - STRUCTURAL MANDATORY PROGRAM

Modification

SB	M.hr	Material US$	Executions
2489	190	9675	4
2952	110	2025	4
2999	150	1550	3
3144	650	5400	1
3305	190	100	2
3313	400	25	4
3365	30	25	4
3387	240	7550	4
3398	120	50	4
3427	120	375	4

SB	M.hr	Material US$	Executions
2837	460	6250	4
2983	110	3700	4
3098	350	1675	4
3253	180	8150	4
3310	120	4900	4
3335	180	125	4
3381	130	5800	4
3388	240	100	1
3419	40	100	4
3429	25	50	4

Inspection Only

SB	M.hr	Executions
1964	2	8
3056	2	4
2862	95	8
2962	3	20
3216	6	0
3381	24	20

SB	M.hr	Executions
2489	33	8
2511	4	4
2912	12	8
3098	4	20
3356	8	24
3399	9	24

Total Material (US$)	212,250
Total manpower (M.hr)	15128
Cost of manpower (US$/M.hr)	11.26

	US$
Cost	382,526

OBS - The final cost value in this page represents the total costs over the remaining life of the aircraft, and is expressed in American dollars, base 31 Dec 1996.

Appendix G. Service Bulletins - General

SERVICE BULLETINS - GENERAL

Modification

SB	M.hr	Material US$	Executions
3253	146	957	4
2976	42	6000	4
3445	8	1200	3
3373	6	6	4
3236	24	54	3
3322	6	4	4
3487	2	514	4
2956	32	200	4
3044	2	315	4

SB	M.hr	Material US$	Executions
3059	229	2200	4
3393	96	2200	4
3361	32	80	4
3423	160	500	4
3307	2	10	4
3379	1	20	4
2789	2	15	4
2991	8	84	4
3323	48	2460	4

Inspection Only

SB	M.hr	Executions
3145	23	24
3410	4	20
3309	8	40
3007	1	8
3240	130	40
3298	8	40
3386	38	8
3413	16	0
3218	24	40
2970	1	8
3326	3	80

SB	M.hr	Executions
A3308	8	12
3411	16	40
3436	48	8
3222	6	20
3251	31	40
3373	3	40
3400	4	40
3409	8	40
3488	8	8
3154	10	8
3424	12	20

Total Material (US$)	66,022
Total manpower (M.hr)	14808
Cost of manpower (US$/M.hr)	11.26

Cost US$ 232,696

OBS - The final cost value in this page represents the total costs over the remaining life of the aircraft, and is expressed in American dollars, base 31 Dec 1996.

Appendix H. Supplemental Structural Inspection Document

SSID- Supplemental Structural Inspection Document

Scheduled flight hours - hr/airplane.year	425	
Flight hours to cycles ratio - hr/cycle	2.4856	
Total flight hours per aircraft (end of 1996)	61711.5	2401
	62956.0	2402
	58096.5	2403
	59430.0	2404
Total flight cycles per aircraft (end of 1996)	17579	2401
	17643	2402
	15730	2403
	18347	2404

Significant Structural Details (SSD)

Part 52

	M.hr	Executions
52-A40-01	12	2
52-A45-02	6	1

	M.hr	Executions
52-A40-02A	8	3
52-A45-03	1	0

Part 53

	M.hr	Executions
53-A40-01	3	0
53-A40-03	5	0
53-A40-05	57	0
53-A40-08	1	3
53-A40-10	16	3
53-A40-12	29	3
53-A40-14	15	0
53-A40-16	25	3
53-A40-18	87	4
53-A40-21	20	0
53-A40-23	60	3
53-A40-26	22	3
53-A40-07	1	7
53-A45-03	1	0
53-A45-06A	1	0
53-A45-10	25	4
53-A45-12	80	8
53-A45-14	1	0

	M.hr	Executions
53-A40-02	30	0
53-A40-04	53	0
53-A40-06	16	0
53-A40-09	12	0
53-A40-11	29	3
53-A40-13	2	0
53-A40-15	16	3
53-A40-17	87	5
53-A40-20	156	10
53-A40-22	3	3
53-A40-25	12	3
53-A40-19	12	0
53-A40-24	1	1
53-A45-05	2	1
53-A45-08	18	3
53-A45-11B	16	0
53-A45-13	34	0
53-A45-15	1	3

Part 54

	M.hr	Executions
54-A40-01	14	3
54-A40-03	10	4
54-A45-02	2	10
54-A45-04	6	14

	M.hr	Executions
54-A40-02	2	20
54-A45-01	14	3
54-A45-03A	1	11

Part 55

	M.hr	Executions
55-A40-01	1	4
55-A40-06	11	3
55-A45-01	3	13
55-A45-03	4	8

	M.hr	Executions
55-A40-02	42	0
55-A40-07	60	3
55-A45-02	1	6
55-A45-04	1	3

Part 57

	M.hr	Executions
57-A40-01	170	3
57-A40-03	196	3
57-A40-07	114	3
57-A40-11	10	4
57-A40-13	108	3
57-A45-05	126	3
57-A45-07	156	3
57-A45-12	132	3
57-A40-05	180	3
57-A45-08C	160	3
57-A45-11D	125	1
57-A45-15	96	3
57-A45-17	4	4
57-A45-20	4	6
57-A45-22C	6	0
57-A45-24C	110	0

	M.hr	Executions
57-A40-02	177	3
57-A40-04	255	3
57-A40-08	5	3
57-A40-12	10	4
57-A40-14	148	3
57-A45-06	120	3
57-A45-09	130	3
57-A45-13	128	3
57-A40-16	123	4
57-A45-10C	120	2
57-A45-1A4	96	3
57-A45-16	6	0
57-A45-19	4	4
57-A45-21E	142	4
57-A45-23	5	4

Total manpower (M.hr) 13491

Cost of manpower (US$/M.hr) 11.26

Cost US$ 151,851

OBS - The final cost value in this page represents the total costs over the remaining life of the aircraft, and is expressed in American dollars, base 31 Dec 1996.

Appendix I. Original Questionnaire in Portuguese

INFORMAÇÕES SOBRE CUSTOS

»Por favor preencha os campos com moldura.
»Especificar unidades (ex: US$/mês, R$/ano, etc.)

1.0 Esquadrão (2º/2º) - Pessoal

1.1 Operações

1.1.1 Tripulação

nº de tenentes	
nº de capitães	
nº de majores	
nº de ten-cel	
nº de graduados	
nº de praças	
pagamento dos oficiais:	
tenentes	
capitães	
majores	
ten-cel	
coronéis	
pagamento dos graduados:	
1 Sgt	
2 Sgt	
3 Sgt	
pagamento dos praças:	
pagamento de civis:	
grau superior	
grau técnico	

OBS
»informar somente o nº de tripulantes (o resto do pessoal será incluido nos itens 1.2 e 1.3.
»as informações quanto a pagamento darão um pouco de trabalho, mas creio que podem ser conseguidas na tesouraria do Parque. Não basta listar apenas o salário de cada militar, é necessário saber quanto a FAB gasta envolvendo salários diretos e outros benefícios ou impostos (aqueles que os empregadores são obrigados a pagar à União) Inclui, também, despesas com alimentação e outras do gênero.
»Não precisa investigar detalhes ou situações especiais. Médias já são suficientes.
»Se por acaso se lembrar de algum gasto que não esteja incluido nestas listas, por favor me informe.

Se verificar que alguma informação não está arquivada no formato que eu imaginei, por favor me informe o formato real.

1.2 Manutenção

» estes itens de pessoal são um difíceis. Eu preciso estimar o gasto da Base com o Boeing, se possível separando entre Esquadrão (2º/2º), ESM e demais setores. Para conseguir esta divisão, eu precisaria do pessoal da Base dividido nos seguintes conjuntos (todos eles mutuamente exclusivos):
Esquadrão (2º/2º) - tripulantes e não tripulantes
ESM - todo o efetivo
Base - todo o efetivo menos (2º/2º, ESM, 1º/1º, 1º/2º e ETA3)

1.2.1 Manutenção - 2º/2º

nº de tenentes	
nº de capitães	
nº de majores	
nº de ten-cel	
nº de graduados	
nº de praças	
nº de civis	

1.2.2 Efetivo Total do ESM

nº de tenentes	
nº de capitães	
nº de majores	
nº de ten-cel	
nº de graduados	
nº de praças	
nº de civis	

Neste ponto eu pergunto: o ESM tem algum controle sobre a mão-de-obra gasta com cada aeronave?

1.3 Efetivo da Base - Total Geral

nº de tenentes	
nº de capitães	
nº de majores	
nº de ten-cel	
nº de coronéis	

nº de graduados
nº de praças

nº de civis - grau superior
nº de civis - grau técnico

Efetivo da Base - Total menos (2º/2º, 1º/1º, 1º/2º, ESM e ETA3)

nº de tenentes
nº de capitães
nº de majores
nº de ten-cel
nº de coronéis

nº de graduados
nº de praças

nº de civis - grau superior
nº de civis - grau técnico

2.0 Base - Consumo de Materiais

Talvez o primeiro passo para este item seja conseguir o balanço financeiro da Base, do ano passado
Se me mandar uma cópia creio que poderemos identificar alguns dos itens abaixo.

2.1 Combustíveis, Lubrificantes e Energia

2.1.1 Combustíveis e Lubrificantes

Total de horas voadas pelo esquadão, por ano (soma de todas as aeronaves) — 1996

Consumo de combustível por hora
Consumo de óleo por hora
Consumo de outros lubrificantes

Preço do combustível
Preço do óleo
Preço médio dos outros lubrificantes

"Outros lubrificantes" inclui graxas e afins. Neste caso, provavelmente será obtido um consumo por mês ou ano, e não por vôo.

2.1.2 Eletricidade

Gasto médio da base com eletricidade

Esta média pode ser mensal, anual, etc. Eu vou arranjar um jeito de determinar a fatia deste gasto que corresponde às atividades do Boeing

2.2 Consumo de Materiais

2.2.1 Materiais de Manutenção

2.2.1.1 Materiais de Aeronaves

Este parece ser um item difícil. Ele inclui o custo de materiais de consumo e peças usados regularmente pela Base na manutenção das aeronaves (e que não sejam fornecidos pelo Parque), tais como gaxetas, componentes eletrônicos, brocas, produtos químicos, etc). Confesso não ter ainda uma idéia sobre como estimar estes gastos, e estou aceitando sugestões.
A Base possui algum ponto central de distribuição? Caso positivo, como é o controle?

????????

2.2.2 Suprimento de Apoio às Missões

Outro item difícil, que inclui custo de suprimentos e equipamentos gastos no apoio do pessoal envolvido com as missões, tais como mapas, papéis, canetas, materiais de limpeza, xerox, etc. Talvez seja possível obter uma estimativa do total da Base, o que já serviria. Qualquer total que encontre com o título de "despesas gerais" provavelmente servirá. Suprimentos de fundo também podem ser pertinentes. Também neste item aceito sugestões.
A Base possui algum ponto central de distribuição? Caso positivo, como é o controle?

????????

2.3 Suprimentos recebidos do Parque

Custo médio de todo o material que o Parque envia para a Base por ano (ou mês, etc.) Inclui todo tipo de itens, reparáveis, consumo, ferramentas, etc.
Será que o suprimento do Parque tem como fornecer este apanhado geral? Se for necessário (e possível...)fazer uma pesquisa manual, escolha um período razoável.

Reparáveis	
Consumo	
Feramentas	
Outros	

2.4 Munições

Não aplicável

2.5 Outros Gastos da Base

Água	
Esgoto	
Telefone	
Outros	

Especificar se possível. Procure saber se a Base, o ESM ou o 2º/2º contratam os serviços de alguma firma particular, e inclua o custo neste campo.

3.0 Manutenção Intermediária (externa à base)

Não aplicável, a própria Base (ESM) executa a manutenção intermediária.

4.0 Manutenção Nível Parque

Novamente neste caso, uma cópia do balanço financeiro do Parque do ano passado iria ajudar.

4.1 Overhaul

4.1.1 Célula

Inclui gastos com pessoal, material e serviços contratados a terceiros.

Linha do KC-137

nº de oficiais	
nº de graduados	
nº de praças	
nº de civis - grau superior	
nº de civis - grau técnico	

Linha do C-130

nº de oficiais	
nº de graduados	
nº de praças	
nº de civis - grau superior	
nº de civis - grau técnico	

Linha do Avro

nº de oficiais	
nº de graduados	
nº de praças	
nº de civis - grau superior	
nº de civis - grau técnico	

Linha do VU-93

nº de oficiais
nº de graduados
nº de praças
nº de civis - grau superior
nº de civis - grau técnico

material para revisão do KC-137 (custo)

Se eu me lembro bem, o pessoal da linha tem preparada uma lista com os materiais de consumo usados em cada cheque das aeronaves. Creio que com essa lista dá para calcular os custos do item acima. (Reparáveis serão incluidos em outro item)

serviços contratados

Incluir os custos daqueles testes que a VARIG costuma realizar no final de cada inspeção. Escolha um avião que já tenha saído de inspeção e pegue os dados com o pessoal do planejamento.

TPL

Incluir todos os elementos designados exclusivamente para cada projeto (por exemplo, Coordenador do Projeto e auxiliares, inspetores, planej. de manutenção, etc)

nº de oficiais - KC-137
nº de graduados - KC-137
nº de praças - KC-137
nº de civis - grau superior - KC-137
nº de civis - grau técnico - KC-137

nº de oficiais - C-130
nº de graduados - C-130
nº de praças - C-130
nº de civis - grau superior - C-130
nº de civis - grau técnico - C-130

nº de oficiais - Avro
nº de graduados - Avro
nº de praças - Avro
nº de civis - grau superior - Avro
nº de civis - grau técnico - Avro

nº de oficiais - VU-93
nº de graduados - VU-93
nº de praças - VU-93
nº de civis - grau superior - VU-93
nº de civis - grau técnico - VU-93

TSU

Incluir todos os elementos designados exclusivamente para cada projeto

nº de oficiais - KC-137
nº de graduados - KC-137
nº de praças - KC-137
nº de civis - grau superior - KC-137
nº de civis - grau técnico - KC-137

nº de oficiais - C-130
nº de graduados - C-130
nº de praças - C-130
nº de civis - grau superior - C-130
nº de civis - grau técnico - C-130

nº de oficiais - Avro
nº de graduados - Avro
nº de praças - Avro
nº de civis - grau superior - Avro
nº de civis - grau técnico - Avro

nº de oficiais - VU-93
nº de graduados - VU-93
nº de praças - VU-93
nº de civis - grau superior - VU-93
nº de civis - grau técnico - VU-93

Coordenadoria do A-1
nº de oficiais
nº de graduados
nº de praças
nº de civis - grau superior -
nº de civis - grau técnico -

TPL
nº de oficiais - todo o efetivo
nº de graduados - todo o efetivo
nº de praças - todo o efetivo
nº de civis - grau superior - todo o efetivo
nº de civis - grau técnico - todo o efetivo

TAE
nº de oficiais - todo o efetivo
nº de graduados - todo o efetivo
nº de praças - todo o efetivo
nº de civis - grau superior - todo o efetivo
nº de civis - grau técnico - todo o efetivo

TSU
nº de oficiais - todo o efetivo
nº de graduados - todo o efetivo
nº de praças - todo o efetivo
nº de civis - grau superior - todo o efetivo
nº de civis - grau técnico - todo o efetivo

TOF
nº de oficiais - todo o efetivo
nº de graduados - todo o efetivo
nº de praças - todo o efetivo
nº de civis - grau superior - todo o efetivo
nº de civis - grau técnico - todo o efetivo

TEI
nº de oficiais - todo o efetivo
nº de graduados - todo o efetivo
nº de praças - todo o efetivo
nº de civis - grau superior - todo o efetivo
nº de civis - grau técnico - todo o efetivo

PAMAGL
nº de oficiais - todo o efetivo
nº de graduados - todo o efetivo
nº de praças - todo o efetivo
nº de civis - grau superior - todo o efetivo
nº de civis - grau técnico - todo o efetivo

4.1.2 Motores

efetivo total da oficina
pessoal exclusivo do Boeing

4.1.3 Reparáveis

Para esse item eu vou precisar de uma maneira de distribuir a mão-de-obra da TOF e da TEI entre Boeing e não Boeing.
Eu não sei como essas sub-divisões controlam os serviços que realizam. Eu sei que elas trabalham com ordens de serviço, mas quão completo é o controle dessas OS? Elas são separadas por oficinas? Por projeto? Elas incluem quantidade de mão-de-obra? E material?

Caso o controle de ordens de serviço inclua material e mão-de-obra, eu precisaria dos totais relativos ao Boeing do ano passado (incluindo todos os serviços/oficinas):

custo de material - TOF
custo de material - TEI

mão-de-obra - TOF
mão-de-obra - TEI

Caso não seja possível extrair diretamente estes dados do controle de OS, tente conseguir o número total de ordens de serviço abertas:

nº de OS - TOF - total
nº de OS - TOF - Boeing

nº de OS - TEI - total
nº de OS - TEI - Boeing

Porém, somente com o número de ordens de serviço não é possível estimar o custo do material utilizado nos reparos. Esta situação é semelhante àquela do item 2.2.1.1, e novamente estou aceitando sugestões. Talvez o pessoal do suprimento possa dar alguma idéia.

custos de material de reparo - TOF	????????
custos de material de reparo - TEI	????????

4.1.4 Equipamentos de Apoio

Este é um item que só será viável se houver controle de ordens de serviço por projetos. Neste caso, verificar os dados relativos a EAS:

custo de material - EAS
custo de mão-de-obra - EAS

4.1.5 Reposição de Material

Este é o custo de reposição de materiais condenados. Creio que o suprimento tem como fornecer este dado. Aqui entram todas as compras de equipamentos, peças, etc. que foram feitas com o objetivo de repor estoque. Se não houve nenhuma aquisição grande de materiais específicos para reparo, aqui entratarão todas as aquisições para o Boeing. Novamente, escolha um período que achar razoável (um mês, ou um ano, etc).

material de reposição

4.2 Outros Gastos - Parque

4.2.1 Apoio Geral

4.2.2 Transporte de Peças

4.2.3 Miscelânea

Acredito que só com o balanço financeiro do Parque será possível estimar esses três itens acima.

outros gastos ☐

5.0 Serviços de Terceiros

5.1 Contratos Temporários

5.2 Suporte Logístico

5.3 Outros

Consiga o total de gastos com o Boeing em todas as firmas externas (Celma, Varig, etc). No caso da Varig teremos que descontar aqueles serviços do item 4.1.1.

serviços de terceiros ☐

6.0 Apoio

6.1 Reposição de EAS

Lembra do item 4.1.5? Pois bem, nesse caso temos que listar todas as compras que o Suprimento fez para o projeto de EAS. Caso não haja um controle separado, creio que poderei usar o balanço financeiro do Parque para estimar isso.

reposição de EAS ☐

6.2 Kits de Modificação

Aqui vão entrar os custos de incorporação de boletins.

6.3 Outros Investimentos

Não é aplicável.

6.4 Apoio de Engenharia

Aqui vão estar incluidos os gastos com a Coordenadoria de Projetos e com a Inspetoria. Creio já haver pedido os dados necessários no item 4.1.1.

pessoal de apoio ☐

6.5 Manutenção de Software

Não é aplicável.

6.6 Simulador

Não é aplicável.

6.7 Outros

Já incluido em itens anteriores.

7.0 Apoio Indireto

7.1 Pessoal

7.1.1 Apoio Médico

7.1.1.1 oficiais do posto médico
graduados do posto médico
praças do posto médico

7.1.1.2 civis do posto médico - nível superior
civis do posto médico - nível técnico

7.1.1.3 gastos com material no posto médico

Creio que este último será mais um item a ser retirado do balanço financeiro do parque

7.1.2 Treinamento

7.1.2.1 Pilotos - não aplicável ao parque

7.1.2.2 Outros membros da tripulação - não aplicável ao parque

Verificar porém o custo de treinamento de tripulantes que a base gasta com a Varig, e o número médio de tripulantes novos por ano (incluir todos os tripulantes: pilotos, navegadores, etc)

custo do curso de piloto
custo dos demais cursos

renovação de pilotos
renovação de tripulantes

7.1.2.3 Não tripulantes

Verificar o efetivo da seção de treinamento (e também os gastos com material).

oficiais
graduados
praças
civis - nível superior
civis - nível técnico

material

7.1.3 Transferência de pessoal

Tente conseguir uma estimativa sobre a renovação do pessoal envolvido com o Boeing, [redacted]

7.2 Instalações

7.2.1 Pessoal de operação orgânica

7.2.2 Pessoal de manutenção das instalações

7.2.3 Despesas com instalações

Os dados de efetivo da unidade incluidos em itens anteriores, mais o balanço financeiro do parque, resolvem esse item.

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Vita

Captain Ulisses O. Bonasser [redacted] graduated from M. C. Bahiense High School in 1978 and entered undergraduate studies at the Technological Institute of Aeronautics (ITA) in São José dos Campos, SP, in 1979. He received his commission on 14 November 1980, and graduated with a Bachelor of Science degree in Aeronautical Engineering in December 1983. He was then assigned to Galeão Aeronautical Materiel Depot (PAMAGL), where he worked first as an Engineering Officer and later as KC-137 Project Coordinator. In March 1995 he entered the Graduate School of Logistics and Acquisition Management, Air Force Institute of Technology, and will move on to the Brazilian Air Force Institute of Logistics (ILA) at São Paulo AFB, SP, Brazil, upon graduation in June 1997.

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13. ABSTRACT (*Maximum 200 Words)*

This research addresses the estimation of operation and support (O&S) costs of the Brazilian Air Force KC-137 aircraft. BAF lacks an established set of procedures for computing life cycle costs, which prejudices the management of the KC-137 program. The purpose of the study is to develop an O&S cost breakdown structure and a set of cost estimating equations in order to calculate the ownership costs of the KC-137 aircraft.

The research is divided into five parts: 1) review of the most commonly used LCC accounting methods, 2) analysis of the KC-137 O&S systems and database characteristics, 3) development of an O&S cost breakdown structure based on the CORE model, 4) selection of cost estimating procedures, and 5) development of cost equations and calculation of costs.

The annual KC-137 O&S costs resulted in US$9,529 per flight-hour at a yearly usage rate of 1700 hours. The study yielded evidence that the current O&S systems incur a high percentage of fixed costs (57.5%) and allocated costs (43.2%). Therefore, the BAF may benefit from the use of LCC and more accurate cost accounting methods, such as activity-based costing. Other implications for the Brazilian Air Force and recommendations for further research are also discussed.

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1. Did this research contribute to a current research project? a. Yes b. No

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4. Whether or not you were able to establish an equivalent value for this research (in Question 3), what is your estimate of its significance?

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