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Operations & Support Cost Modeling of Conceptual Space Vehicles

Dr. Charles Ebeling
University of Dayton
Engineering Management and Systems Department
300 College Park
Dayton, Ohio 45469-0236

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OPERATIONS & SUPPORT COST MODELING
of CONCEPTUAL SPACE VEHICLES
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1.0 Introduction

The University of Dayton is pleased to submit this annual report to the National Aeronautics and Space Administration (NASA) Langley Research Center which documents the development of an Operations and Support (O&S) Cost model as part of a larger Life Cycle Cost (LCC) structure. It is intended for use during the conceptual design of new launch vehicles and spacecraft. This research is being conducted under NASA Research Grant NAG-1-1327. This research effort changes the focus from that of the first two years in which a reliability and maintainability model was developed to the initial development of an operations and support life cycle cost model. Cost categories were initially patterned after NASA's three axis work breakdown structure consisting of a configuration axis (vehicle), a function axis, and a cost axis. A revised Cost Element Structure (CES), which is currently under study by NASA, was used to established the basic cost elements used in the model. While the focus of the effort was on operations and maintenance costs and other recurring costs, the computerized model allowed for other cost categories such as RDT&E and production costs to be addressed. Secondary tasks performed concurrent with the development of the costing model included support and upgrades to the Reliability and Maintainability (R&M) model. The primary result of the current research has been a methodology and a computer implementation of the methodology to provide for timely operations and support cost analysis during the conceptual design activities.

1.1 Research Objectives

The major objectives of this research are:

a. to obtain and to develop improved methods for estimating manpower, spares, software and hardware costs, facilities costs, and other cost categories as identified by NASA personnel;

b. to construct an operations and support cost model of a space transportation system for budget exercises and performance- cost trade-off analysis during the conceptual and development stages,

c. to continue to support modifications and enhancements to the R&M model;

d. to continue to assist in the development of other models and to support analysis activities in the study of proposed space systems.

1.2 Status of research tasks

The following tasks, as defined in the proposal, have been completed:

Task 1. (Problem Definition) Cost categories for inclusion in the cost model have been identified. These costs are based upon the three axis work breakdown structure and will include recurring hardware, software, facilities, and manpower costs. Hardware includes vehicle spares and expendables as well as ground support equipment. A proposed Cost Element Structure (CES) pertaining to the operations and support costs has formed the basis for the cost model described below. This cost structure is discussed in Section 2.0 and is recommended to NASA for use in all LCC processes.

Task 2. (Literature Search) An extensive literature review to determine existing methodologies for estimating costs in each of the major categories identified in Task 1 has been completed. Many of the cost estimating relationships identified during this task has been utilized in the operations and support cost model. Primarily Defense Department and contractor life cycle costing models have provided cost data and parametric cost relationships relevant to this study. Section 3.0 summarizes these references and compares and contrasts various LCC models. A completed bibliography is also provided.

Task 3. (Data Collection) From Task 1 and Task 2, it was determined that existing cost models did not adequately address facilities costs. In addition, the uniqueness of the space operations at both Cape Canaveral and the Johnson Space Center necessitated the use of Shuttle and contractor supplied cost data to support the development of new cost estimating relationships. In particular, data to support the life cycle costing of facilities has been obtained from the Air Force. This data and the resulting methodology is described in Section 5.0.

Task 4. (Data Analysis) Parametric cost estimating equations based upon the facilities data obtained in Task 3 have been developed. These equations are documented in Section 5.0. Section 4.0 describes the general methodology utilized in the cost model. This methodology is a result of the insight obtained from the three previous tasks.

Task 5. (Model Development) Based upon the CES and the available and derived parametric cost equations, an initial operations and support cost model has been developed. The model has been structured to include RDT&E costs, investment or acquisition costs and operations costs as inputs in order to provide for a complete cost analysis. However, the model will compute most of the support (maintenance and logistics) costs from various input parameters. This model includes inflation factors and will compute costs inflated to a given base year or compute costs in then year (inflated) dollars. The cost model utilizes output from the R&M model.

Task 6. (Model Implementation) A PC model has been completed for NASA's to use on a trial basis. Updates and revisions to the model are expected. This program is written in compiled BASIC and is compatible with the previously developed R&M model.

Task 7. (R&M Upgrade) Several changes have been accomplished to the R&M model. These include (1) using a weighted average to compute the vehicle manhour per maintenance action factor, (2) redefining ground processing and ground power-on times, (3) converting pad and integration time from hours to days, (4) changing the input parameter from flights per month to flights per year, (5) computing an air abort rate (not integrated into model), (6) computing the number of maintenance crews to be assigned, (7) providing a hard copy reports generator module, (8) revising the method used to account for main engine redundancy, and (9) establishing procedures for the user to specify a subsystem reliability rather than have the model compute one. This last upgrade was significant in that it required reverse engineering the computation of a mean time between maintenance actions in order to provide consistent maintenance manhours, manpower, spares, and vehicle turntime calculations.

Task 8. (Simulation Support) This task has been deferred and will be addressed as part of the follow-on integration effort.

2.0 Cost Element Structure (CES)

A cost element structure (CES) is a methodical representation of the economic activities which make-up an economic entity. The purpose of the structure is to provide visibility to the costs of interest. The cost element structure provides a hierarchial ordering of the costs where the greatest detail is rolled-up into ever higher and larger aggregation of costs. The degree of cost roll-up necessary is dependant upon the initial cost detail and structure. A cost element structure can be used to track the ongoing operations of an economic entity or to predict the future financial condition of an economic entity.

2.1 Program Categories

To track the economic activity of a program the most commonly used cost element structure, in government projects, matches the CES used in how the money is received from the funding organization or congress. This matching of cost categories extends to the level of detail required by the management structure of the organization working the project and the funding organization's requirements. The costs at the lowest level (greatest detail) of the cost element structure is determined by one of two methods, actual cost figures (if they are available) or estimates of the cost figures (typically used in estimating a conceptual program or early in the life cycle of the program). The method used is determined by the availability and quality of actual cost data to be used in the predictive model. A schematic representation of the program phase and estimation technique is shown below.

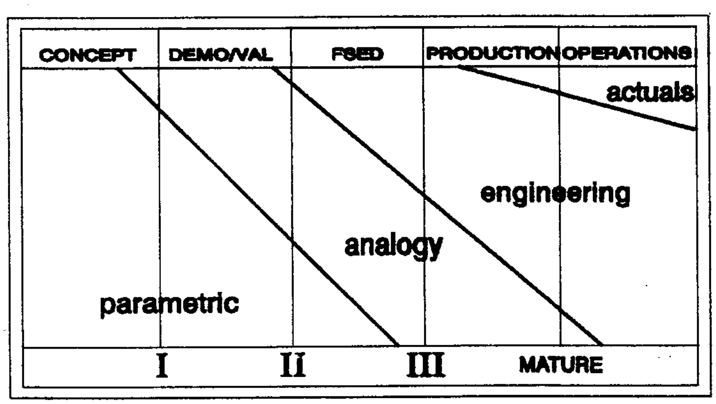


Figure 1 Cost Estimation Technique

A production program goes though a well defined sequence of stages. Briefly, the stages are :

Concept Development - Initial definition of the program elements and the structure of the systems composing the program at a gross level. Technologies are identified and the general subsystem operational parameters and requirements are identified.

Demonstration/Validation (DEM/VAL) - Refinement of the system parameters with the production of test article(s) for further verification of the ability to meet the requirements with the current design. System parameters are relatively well defined and the costs of the systems are becoming more complete.

Full Scale Early Deployment (FSED) - Initial production runs of the system where system parameters are well defined and the costs well understood.

Production - Full production of the system. The system costs are known and the systems parameters are fixed. Operational costs can be estimated accurately at this point.

Operations - The system has entered service and all the costs associated with the system are known and the operational cost are being developed.

An alternative method to define the system stages and the comparison to the system method shown are Research and Development (concept development and dem/val), Production (FSED and production), Operating and Support (operations), and Disposal. The alternative system stage definitions are given in the discussion below.

> Research and Development are those costs associated with research, development, test, and evaluation of system hardware and software. More specifically, it includes the cost of feasibility studies; simulation or modeling; engineering design, development, fabrication, assembly, and test of prototype hardware; initial system evaluation; associated documentation; and test of software.
>
> Production are those costs associated with producing the system, initial support equipment, training, technical and management data, initial spares and repair parts, plus any other items required to introduce a new system.
>
> Operating and Support is the cost of personnel, material, and facilities of both a direct and indirect nature required to operate, maintain, and support the hardware and software of the system.
>
> Disposal is the cost associated with disposing of a system at the end of its useful life, minus any salvage value. This category is seldom estimated in most analyses. Often this value is very small in comparison to the other three cost categories.

The descriptions of the two different representations of the life cycle of a project parallel each other very closely. The primary difference is emphasis placed in the first representation on the early phases of a program while the second includes the cost of disposal of the system. In order to follow the guidance of DoD's cost analysis improvement group (CAIG) we will

2.2 Cost Estimating Techniques

The cost estimating techniques (shown in figure 1, of section 2) are based upon the actual program cost information available to the analyst at that particular stage of the program. The use of parametric cost techniques occurs early in the program when the system is poorly defined and the actual cost can only be estimated, based upon previous systems. This estimation must be done carefully to avoid problems which will be discussed later. As the program progresses the degree of uncertainty in the design decreases and the reliance on cost estimating relationships (CER's) diminishes.

Analogy cost analysis (or historical rates and percentages) requires a well defined program and system that is compared with similar projects to arrive at an estimate of the program cost. The analyst must use caution in applying the analogy and determining the correct allowances for differences between the two programs and systems.

Engineering cost estimates may be the most difficult and time consuming to determine. Almost complete cost data must be available for the smallest component to the largest system. This is a "bottom-up" analysis of costs. The cost at the lowest level of the system (component or individual) is accounted for and then rolled-up into courser divisions of cost. The process requires handling a large volume of data in minute detail. This is the beginning of an "accounting" type of cost estimating.

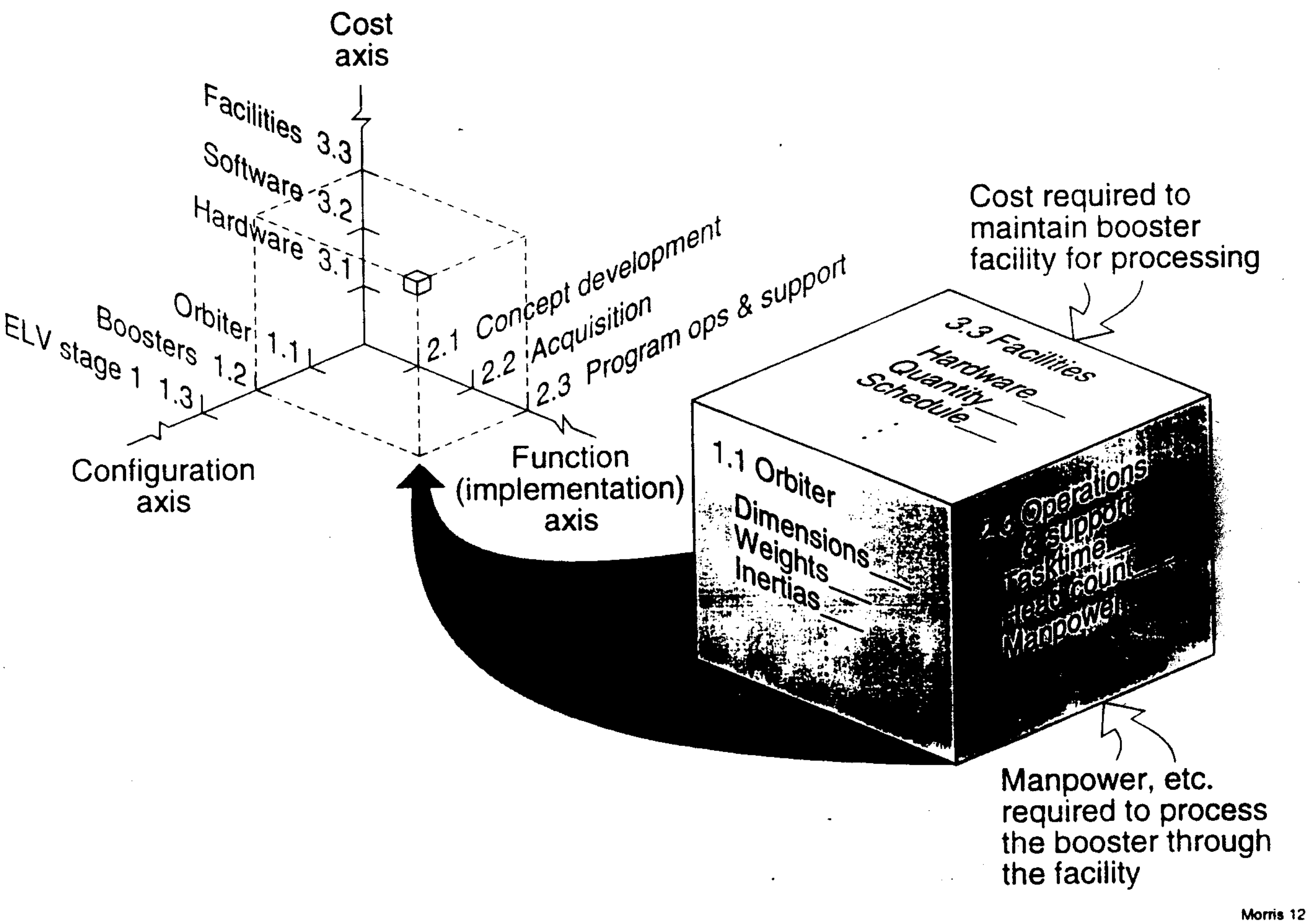
Actual cost analysis relies on a rapidly maturing program where the requirements are fixed and the system is in initial production. Until the system is disposed of a system's cost will never be calculated entirely by the actual method. The disposal cost are unknown exactly until the disposal is performed. So even entering the disposal phase of a systems life cycle there will be some engineering estimates required to develop the costs of the system at this stage.

The accounting method relies upon a relative static financial entity with known historical costs. The use of cost estimating relationships (CER's) to predict costs requires historical cost data for similar financial entities and the best guess as to how the costs of the current financial entity differ from those which comprise the historic cost database from which the CER's were developed. The user of the CER must understand the limitation imposed upon the CER by the data from which the CER was estimated. Estimating costs with parameters outside of the original database must be approached with caution. Extrapolation of cost data is highly dependent upon the mathematical structure of the CER rather than the underlying historical data.

2.3 Three-Axis Model

NASA (LRC) has developed a useful conceptual cost model which will be referred to as the three-axis LCC model. The three axis are: (1) phase (e.g. development, production), (2) system (e.g. vehicle structure, engines), and (3) cost category (e.g. hardware, personnel). A general view of this model is shown on the next page. The three dimensional format of the model allows rapid investigation of different relationships depending upon which face of the "cube" is investigated and at what level. The implementation of the "cube" requires more thought and planning than a more traditional "flat" presentation. The additional planning is a result of resolving the interrelationships (where the three axis cross) and to ensure proper the cell contains the appropriate cost formula. The information required to fill a cubic presentation with appropriate formulas at each intersection of the cell faces may not always be available or appropriate. This results in many empty cells. The result is that in some cases the effort required to develop a cubic presentation is not justified in terms of the additional information to be gained by studying the interrelationships between the different cube faces and what cell intersections are used. The degree to which each cell in the cube is filled is dependent upon the degree of refinement in the data used in creating the formulas in each cell. The cubic format lends itself to the representation of the interrelationships of data if information to fill the cells is abundant and of a high quality. The three-axis model has proven to be a useful conceptual model with which to identify the relevant cost elements. However, in implementing the described model, the more traditional linear approach has been adopted.

WBS ATTRIBUTE REPORTING EXAMPLE



2.4 Cost Element Structure

Table 2-1 represents the linear Cost Element Structure (CES) currently being considered by NASA for the purpose of conducting Life Cycle Costing. This structure has been adopted for use in this study recognizing that changes will probably occur. However, the structure has presented here provides the appropriate level of detail for implementing the costing methodology discussed in Section 4.0.

TABLE 2-1
COST ELEMENT STRUCTURE

- **2.1 Concept Development**
  - 2.1.1 Technology Programs
  - 2.1.2 Phase A/B Contract Work
- **2.2 Acquisition**
  - 2.2.1 Design and Development
    - 2.2.1.1 Configuration Item
    - 2.2.1.2 Operations Capability Development
  - 2.2.2 Production
  - 2.2.3 Integration
    - 2.2.3.1 Hardware Integration
    - 2.2.3.2 HW/SW Integration
  - 2.2.4 Test and Evaluation Phase
    - 2.2.4.1 Ground Test
    - 2.2.4.2 Flight Test
  - 2.2.5 Program Management & Support
  - 2.2.6 Program System Engineering
- **2.3 Program Operations and Support**
  - 2.3.1 Operations
    - 2.3.1.1 Processing Operations
    - 2.3.1.2 Integration Operations
    - 2.3.1.3 Payload Operations
    - 2.3.1.4 Transfer
    - 2.3.1.5 Launch Operations
    - 2.3.1.6 Mission
    - 2.3.1.7 Landing/Recovery/Receiving
    - 2.3.1.8 Non-Nominal Operations
  - 2.3.2 Maintenance
    - 2.3.2.1 Refurbishment
    - 2.3.2.2 Organizational Maintenance
    - 2.3.2.3 Depot Maintenance
    - 2.3.2.4 Modifications
    - 2.3.2.5 Verification & Checkout
  - 2.3.3 Logistics
    - 2.3.3.1 Spares
    - 2.3.3.2 Expendables
    - 2.3.3.3 Consumables
    - 2.3.3.4 Inventory Management & Warehousing
    - 2.3.3.5 Training
    - 2.3.3.6 Documentation
    - 2.3.3.7 Transportation
    - 2.3.3.8 Support Equipment
    - 2.3.3.9 ILS Management
  - 2.3.4 System Support
    - 2.3.4.1 Support Staff
    - 2.3.4.2 Facility O&M
    - 2.3.4.3 Communications
    - 2.3.4.4 Base Operations
    - 2.3.4.5 Launch/Post Launch Cleanup
  - 2.3.5 Program Support
  - 2.3.6 R & D
- **2.4 Program Phaseout**

3.0 Life Cycle Cost (LCC) Models

3.1 Relevant Life Cycle Models

A review of the existing life cycle cost models literature was conducted by searching computerized databases of periodic and published manuscripts. These included library, Defense Technical Information Center (DTIC) and NASA holdings. The library holdings and the periodic literature were mostly generic methodologies on developing LCC models or predicting the production cost of a large number of consumer articles. There was very little utility in these references except as general background material. The DTIC and NASA documents were more illuminating.

The NASA and DTIC documents discussed high-tech systems in a low-production environment and their life cycle costs. The library references did not address the unique aspects of this type of system. The economic environment of a space vehicle is that the prototype or engineering built article will be a significant fraction of the number of vehicles constructed. The NASA and DTIC documents did include references to systems built in such an environment.

From the many references in the bibliography there are a few which are especially noteworthy for their direct application to the development of cost estimating relationships for conceptual design space vehicles. These references include:

1) AFI 655-03 (former AFR 173-13)
2) Conceptual Design & Analysis of Hypervelocity Aerospace Vehicles: Volume 5 - Cost (HVL)
3) Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles: Vol 3. Cost
4) Life Cycle Cost User's Manual (HVLCCM)
5) Modular Life Cycle Cost Model (MLCCM) for Advanced Aircraft Systems
6) NATO: Software Life Cycle Costing
7) Naval Fixed Wing Aircraft Operating and Support Cost Estimating Model
8) PREVAIL: Algorithms for Conceptual Design of Space Transportation Systems (PREV)
9) Strategic Missile (Minuteman) Operating and Support Cost Factors (STRAMICE)
10) Unmanned Space Vehicle Cost Model, Sixth Edition (SD TR-88-97)
11) A New Approach to Modeling the Cost of Ownership for Aircraft Systems (MACO)
12) Logistics Cost Analysis Model (LOG)
13) Reliability and Maintainability Model (RAM)

All but the last two references are addressed in detail in Appendix A and all are discussed briefly below. The last two reference were developed specifically for NASA'a use and are adequately documented separately.

3.1.1 AFI 655-03 (former AFR 173-13), reference 1, is a compilation of cost data appropriate for anyone doing O&S life cycle cost analysis for current (and former) aircraft used in the US Air Force. The data includes military and civilian salaries, support costs by aircraft, and inflation indices. The use of these costs factors is mandated by the regulation to comply with the CAIG requirements. The most important aspect of AFI 655-03 is that it contains a generic O&S cost model. The CORE cost model has seven major cost categories with up to four levels of indenture (ie. 7.1.2.2.1 Officer), for a total of 93 entries. The main levels are: Unit Mission Personnel, Unit Level Consumption, Intermediate Maintenance (external to unit), Depot Maintenance, Contractor Support, Sustaining Support, and Indirect Support. The regulation is updated (at least) quarterly.

3.1.2 References 2 and 3 are the same document separated by three years, number 3 being the later of the two. This is an application of the standard modular life cycle cost model (MLCCM) to a hypervelocity vehicle. The vehicle can be manned or unmanned. The model was verified with shuttle data obtained from outside the contractor for the shuttle (congressional testimony, NASA documentation, etc.) and was found to predict the LCC of the shuttle relatively closely. This reference contains cost and manpower estimating relationships for R&D, production, and O&S life cycle cost for a hypervelocity vehicle. the model was designed to be run as a spreadsheet where the costs associated with each stage of the system is developed separately and then consolidated into a system summary of the life cycle costs over the life of the system. There are only minor revisions to the first document in the second.

3.1.3 Reference 4 documents the operation of the life cycle cost model developed in references 2 and 3 and is derived from reference 5. It explains how multiple stages (segments) of the vehicle can be costed separately using the appropriate CER or using actual cost data, if it is available, and then how the costs are to be accumulated in the appropriate subsystem. This accounting of costs complies with the guidelines of the CAIG. The program itself is implemented as a spreadsheet under LOTUS.

3.1.4 The modular life cycle cost model (MLCCM), reference 5, is the standard LCC model used by the US Air Force to comply with the CAIG directives. Most of the LCC models used in the Air Force are derived from this model. The model has more than 100 different data inputs and encompasses all phases of the life cycle (except disposal) of an avionic system life cycle. The model uses the type of material used in the different aircraft structures to determine the costs of materials, production, and repair based upon a comparison to standard aluminum practices. The shortcoming is the inability to predict disposal costs, but neither does any other appropriate LCC model.

3.1.5 Reference 6 is an attempt by NATO to develop a uniform method to estimate the life cycle cost of computer systems (software and hardware) used in C^3I systems. This reference surveys the different types of models used in developing the cost estimates, which include PRICE-S, COCOMO, etc. The driver used in estimating the other output parameters (facilities, personnel, etc.) is lines of code (LOC). The different models use different methods in developing this simple parameter, depending upon which computer language is used and the complexity of the application. The more sophisticated models also use the size of computer, the application to be hosted, if hardware is to be developed and if it is to be developed in tandem with the software, and what level of experience the team creating the software/hardware has in similar projects. The costs are in international accounting units (IAUs) to reduce the bias involved with selecting a particular monetary unit.

3.1.6 Reference 7 updates a Naval parametric Operating and Support estimating model using the CAIG guidelines for O&S cost analysis. The model updates 14 direct cost elements using 15 different aircraft types which represents the bulk of the Navy and Marine fixed-wing aircraft. Both linear and semi-log (log-linear) cost estimating relationships were developed for each of the direct cost elements. The presentation of the regression equations is the most complete of any of the models. The data points used, the residuals, outliers, and the fitting parameters are shown for each CER, this enables rapid verification of the CER or the development of different (exponential, etc.) relationships. The operational requirements and the maintenance philosophy used by the Navy prevents the direct application of many of the developed CER's for use in this study. The completeness of the data analysis in developing the CER's provides a basis of comparison between those developed for a space system and the CER's developed from the NAVY data. This allows a validity check of the space developed CER's by analogy with the NAVY CER's. The NAVY CER's can be used as a bound on CER's developed for conceptual space systems.

3.1.7 Reference 8 is geared toward a transportation system to place man and/or material in space. The costs are for three different configurations of vehicle (winged, aerodynamic and ballistic) with different launch scenarios. The model can be implemented on a PC using a spreadsheet.

3.1.8 Reference 9 is a summary of the cost model used by the former Strategic Air Command (SAC) to do a high level estimation of the costs associated with the strategic nuclear missile fleet. This high level fast response model relies heavily on readily available information contained in AFI 655-03 (former AFR 173-13) as input to the model. This model will run on a simple PC-based spreadsheet.

3.1.9 Reference 10 is the USAF Space Division's detailed analytic cost estimating relationships derived from eighteen unmanned space vehicles. The CER's are derived from regressions equations encompassing recurring and nonrecurring costs across system phases. The system phases include research and development, and production of space hardware from the component level (when available) through final assembly including normal program costs (like overhead and G&A). Some systems have over 3000 account names which were then incorporated into larger systems. This costing system is organized to be implemented as a PC based spreadsheet.

3.1.10 The study identified in reference 11 is a detailed and comprehensive set of algorithms for estimating operations and support costs of Air Force aircraft systems. Referred to as the Model for estimating Aircraft Costs of Ownership (MACO), the study was completed in 1981 and used as a basis for developing cost relationships. The study used as primary sources of input: AFR 173-13, the Logistics Support Cost Model (LSC), the Logistics Composite Model (LCOM), and AFM 26-3 (Manpower Standards) as well as other models. Much of the organization level manpower was based on LCOM generated manpower obtained from tactical fighter aircraft. There is also considerable detail on the costing of repairable spares which follows the Air Force's methodology for requirements determination. The study is a combination of new cost estimating relationships (CERs), accounting formulas, and some historical rates and percentages. The cost element structure used is consistent with the CAIG guidelines.

3.1.11 The Logistics Cost Analysis Model (which will be referred to as the Logistics Model) was developed in 1993 by Rockwell International at the request of NASA to review, modify and validate costing methodologies that apply to certain categories of logistics costs based upon the Shuttle program and other relevant military and commercial logistics operations. A key feature of this study is the identification of typical input parameter values needed to perform an accounting method of cost estimation. The completed model is available on an EXCEL spreadsheet.

3.1.12 The Reliability and Maintainability (RAM) model was developed by the University of Dayton in order to provide a parametric method for estimating the mean time between maintenance actions and removals as well as the mean time to repair failed components. This model was developed for use during the conceptual design of new space transportation systems. It was originally intended to provide input into a computer simulation model of the proposed space transportation systems. However, the model, using the estimated reliability and maintainability parameters, will provide estimates of organizational level manpower, initial spares, removal rates, and vehicle turn times which can be used in determining support costs. Use of the output of this model for costing provides a direct relationship between design and performance trade-off which impact on reliability and maintainability and the subsequent operations and support costs.

3.2 Application to the NASA Cost Element Structure

Although the cost element structure utilized in this study is the linear one presented in Table 2-1, there is a second dimension to the costing which must be considered. The second dimension is that of time. A typical project will go through a predictable life cycle, as shown in Figure 2-1. Initially the project will be in Research and Development (including testing and evaluation), Production, Operation and Support (including spares), and Disposal. A life cycle cost is the total dollar value of the resources (material, labor, etc.) that the project will consume from its inception to its ultimate disposal. The two dimensional view of the life cycle costs is shown in Table 3-1. In computing operational and support costs, the economic life of the system is assumed to begin at its initial beddown year. Prior years in which conceptual development and acquisition costs were incurred does not include the operations and support costs.

Table 3-1 Life Cycle Costs

Categories	Years of Life Cycle					
	1	2	3	...	n	TOTAL
Concept Development	$ aaa	$ bbb	$ ee	...	$ 0	$ MMM
Acquisition	0	cc	fff	...	0	$ NNN
Operating and Support	0	d	gg	...	hhh	$ PPP
Program Phaseout	0	0	0	...	i	$ QQQ
TOTAL	$ VVV	$ WWW	$ XXX	...	$ YYY	$ ZZZ

Table 3-2 relates the NASA CES to the LCC models and studies identified in Section 3.1. Details concerning the integration of these models into a comprehensive support costing methodology is discussed in Section 6.0.

TABLE 3-2
CES - LCC MODELS

Cost Element	LCC Model used
2.3 Program Operations & Support	
2.3.1 Operations	n/a
2.3.2 Maintenance	
2.3.2.1 Refurbishment	PREV
2.3.2.2 Org Maintenance	RAM, MACO, HVL
2.3.2.3 Depot Maintenance	HVL
2.3.2.4 Modifications	MACO
2.3.2.5 Verify & Checkout	n/a
2.3.3 Logistics	
2.3.3.1 Spares	RAM, HVL, LOG
2.3.3.2 Expendables (EOQ)	MACO
2.3.3.3 Consumables	LOG
2.3.3.4 Inv Mgmt & Warehouse	LOG
2.3.3.5 Training	LOG
2.3.3.6 Documentation	HVL, LOG
2.3.3.7 Transportation	LOG
2.3.3.8 Support Equip	HVL, LOG
2.3.3.9 ILS management	LOG
2.3.4 System Support	
2.3.4.1 Support Staff	HVL, PREV
2.3.4.2 Facility O&M	Section 5.0
2.3.4.3 Communications	MACO
2.3.4.4 Base operations	MACO, HVL
2.3.4.5 Pre/post launch cleanup	not addressed
2.3.5 Program Support	n/a
2.3.6 R&D	n/a

LEGEND
RAM - Reliability & Maintainability Model
LOG - Logistics Cost Analysis Model
HVL - Hypervelocity LCC
PREV - Prevail Model
MACO - Model for estimating Aircraft Cost of Ownership

4.0 Methodology

4.1 General approach

The ultimate objective is the development of an automated life cycle costing model (LCCM) to be used during the conceptual design of a space transportation system. To meet this objective, the following steps were pursued:

4.1.1 The establishment of a Cost Element Structure (CES) useful in the development, implementation, and execution of the LCCM. The structure must be compatible with existing LCC methodologies, be acceptable to NASA, and provide the necessary level of detail to establish a reliable cost estimate. Section 2.0 documented the initial effort in the development of such a CES by identifying NASA's current CES (which is still under review) which was based, in part, on a comparative analysis of the cost element structures used by other LCC models. The CES documented in Section 2.0 formed the basis for the costing model presented in this section.

4.1.2 An analysis and summary of current costing models which may be adaptable in the space environment. These models were developed for use in costing aircraft, launch vehicle, and other space systems. The intent was to evaluate the costing methodology and resulting relationships in order to adapt these relationships, where appropriate, to the current study. The existing costing techniques were used to the extent possible. Section 3.0 summarizes those costing studies which were relevant and identifies those costing relations which were utilized.

4.1.3 The identification of those cost elements from the CES which were not appropriately addressed in existing studies. For the facilities cost elements, new cost data has been obtained and new cost relationships established. Since the hypervelocity cost model discussed in Section 3.0 required the use of vehicle design and performance variables not previous used in the RAM model, additional parametric equations were developed to estimate these values from a relatively small set of "driver" variables such as "dry weight", "length plus wing span", "crew size", and "number of main engines." These equations were identical in form to the "secondary variable" equations developed for use in the RAM model. Section 5.0 addresses both these additional secondary equations and the facilities cost relationships developed for direct use in the model.

4.1.4 The integration of new and existing cost element relationships (CER's) into the model in a logical and cohesive manner. This required selective adaptation and, in some cases, modification of existing CER's. In particular, input parameter data had to consist of those performance and design specifications which can be determined during the early conceptual design of the vehicles. Some parameters were estimated from knowledge of others using the parametric equations discussed above and output from the Reliability and Maintainability model using primarily dry weight (a measure of the size of the vehicle) as the independent variable. Different LCCM's also have utilized different costing base years, therefore, using inflation indices, these cost estimates had to be transformed to a common base year.

4.1.5 The development of a user-friendly computer model to implement the costing methodology. This model is compatible with the Reliability and Maintainability Model using both its input and output where appropriate to provide input to the O&S cost model. The computerized model has user friendly input of additional parameter values and provides several levels of output reports in support of the vehicle design studies. In particular, it should be suitable for performing trade and "what-if" studies.

4. 2 Costing Relationships

The final costing model utilizes four different approaches in developing the cost estimates:

a. Cost Estimating Relationships (CERs)
b. Accounting techniques
c. Historical factors (analogy)
d. Direct cost input

Primary use is made of cost estimation relationships (CER) obtained by using multiple regression techniques to fit historical cost data to one or more vehicle design or performance variables. Parametric estimating methods provide a statistical basis for establishing a relationship between costs and one or more "cost-drivers." With the dependent variable being cost, independent variables such as weight, length, thrust, volume, quantities, etc. may be excellent "cost-drivers." Many of these CER's have been derived from aircraft data. To the extent the range of values of the independent variables encompass the space vehicle values, these relationships can be adopted for use in this study. Again, however, the independent variables must consist of those parameters which can be determined or estimated (perhaps themselves parametrically) in the early conceptual phase of the study. Some cost estimates are also based upon analogy using cost data obtained from the shuttle program. Adjustments may be made for difference in size, number of engines, performance, etc. For some subsystems and some functions (particularly in the area of operations) this approach may provide the only means for obtaining a cost estimate since the shuttle is the only vehicle of its type and purpose (a sample size of one).

Accounting techniques make use of direct input of rates and cost factors. Annual and life cycle costs based upon these factors are then computed by multiplying cost rates and quantities and then summing the resulting costs. For example, annual fuel cost (consumables) is obtained by multiplying the fuel requirements (in lbs) per mission by the number of missions per year by the unit cost of the fuel. These costs are summed across each propulsion system (e.g. main engines, OMS, RCS).

Historical factors are generally percentages or rates computed from past data. Examples include ILS management which is a percent of logistics cost elements and modification costs which are computed as a percent of the vehicle unit production cost (flyaway cost). In some cases these factors are based upon Shuttle data and in other cases they reflect an average aircraft environment value.

Finally, in some cases direct costs may be used. This is true for those operational categories in which the shuttle program may provide the only source of data. The primary costing method utilized is CERs with analogy from the space shuttle as a secondary costing method.

Table 4-1 summarizes the methodology used in deriving costs estimates for each of the support cost elements addressed in this study.

TABLE 4-1
COST ESTIMATION METHODOLOGY

Cost Element	Estimation Method
2.3 Program Operations & Support	
2.3.1 Operations	direct cost input
2.3.2 Maintenance	
2.3.2.1 Refurbishment	historical factor
2.3.2.2 Org Maintenance	CER's & RAM model
2.3.2.3 Depot Maintenance	CERs or accounting
2.3.2.4 Modifications	historical factor
2.3.2.5 Verify & Checkout	not addressed
2.3.3 Logistics	
2.3.3.1 Spares	CERs or accounting (RAM input)
2.3.3.2 Expendables (EOQ)	CER
2.3.3.3 Consumables	accounting
2.3.3.4 Inv Mgmt & Warehouse	accounting
2.3.3.5 Training	accounting
2.3.3.6 Documentation	CERs or accounting
2.3.3.7 Transportation	accounting
2.3.3.8 Support Equip	CERs or historical factor
2.3.3.9 ILS management	historical factor
2.3.4 System Support	
2.3.4.1 Support Staff	CERs
2.3.4.2 Facility O&M	CERs
2.3.4.3 Communications	historical factor
2.3.4.4 Base operations	historical factor
2.3.4.5 Pre/post launch cleanup	not addressed
2.3.5 Program Support	direct cost input
2.3.6 R&D	direct cost input

4.3 Inflation Adjustments

Since various cost models have differing historical base years, an inflation adjustment had to be made to bring the costs to an initial 1993 base year. This adjustment was based upon NASA's Code B inflation rate indices providing actual (historical) inflation factors. The basic calculation is:

$$COST_{93} = (inflationfactor)\ COST_{yr\ t}$$

A further calculation is then made to adjust the cost to the base year identified by the user (assuming it is different from 1993) where f' is the geometric average annual inflation factor for the period from 1993 to the base year. This factor is calculated from the NASA inflation rate index (future). The final cost is then given by:

$$COST_{baseyr} = COST_{93}\ (1+f')^{baseyr-93}$$

This cost is then applied to both nonrecurring and recurring costs over the life of the system in order to obtain constant dollars at the base year.

In order to obtain actual (i.e. then year) dollars for year t, the following additional calculation is performed:

$$COST_{yr\ t} = COST_{base\ yr}\ (1+f')^{t-base\ yr}$$

Total life cycle costs may also be computed in two ways: (1) constant base year dollars or (2) then year (inflated) dollars. For constant base year dollars the recurring costs inflated to the base year are multiplied by the system life. For then year calculations, the following formula is used:

$$LCC = \left[\frac{(1+f')^{n}-1}{i} \right] (annual\ recurring\ cost) + nonrecurring\ costs$$

where f' is the geometric mean inflation rate over the beddown life of the system and n is the number of years of system life. Both the recurring and nonrecurring costs are inflated to the beddown year. The only exception to this calculation is Program Phaseout which is reflected as a single annual cost inflated to the last year of the system life.

5.0 Parametric Equation Development

5.1 Facility Operating and Maintenance Costs

Identification of facility requirements necessary to support systems that are in the conceptual design phase is, at best, difficult. Specific requirements of the system concerning the design, operational concepts and maintenance concepts have not been finalized. Additionally, areas such as support equipment development, spares requirements, or maintenance procedures in many cases have not been thought of yet or at best they are in their design infancy. In all likelihood, the design or procedures will change as the system develops and ultimately have a significant impact of the facility requirements needed to support the system. This section provides a methodology that can be used by space systems planners to estimate the gross facility requirements so that an initial life cycle cost can be derived for the proposed conceptual space system. This methodology will not consider facilities that are unique to an operational or maintenance feature of a specific system. These facilities (e.g., composite repair, heat absorbent material repair, etc.) will have to be identified and costed separately based on the information available concerning the facility. However, the methodology developed as a result of this research effort will provide a means to estimate the general facility requirements of a system. Parametric equations for facility square footage will be developed from data applicable to a wide range of aircraft currently in the United States Air Force inventory. Table 5.1, Study Aircraft (USAF), lists the US Air Force aircraft that were used in this study. The assumption here, is that future space systems will be aircraft like and use operational and maintenance procedures similar to those used in the United States Air Force and

TACTICAL	BOMBER	CARGO
A-7	B-52	C-130
A-10	FB-111	C-141
F-4		C-5
F-5		
F-15		
F-16		
F-106		

Table 5.1 Study Aircraft (USAF)

commercial aircraft industry. The effort included a review of the procedures established by the Aeronautical System Center, Directorate of Systems Facility Engineering, Wright-Patterson AFB, Ohio, for identification of facilities required to support bed down of new aircraft weapon systems. The Advanced Manned Launch System study provided the following information of the facilities required to support a space transportation system. The study summarized five major facility areas--landing site, horizontal processing facility, payload containment system processing facility, launch pad and launch/mission control center.

Landing Site. The landing site will be used for arrival of orbiter and booster elements at the launch site. The vehicles will arrive either from the manufacturer on a carrier aircraft such as the Boeing 747, or as part of recovery of the orbiter and boosters upon completion of a mission[1].

Horizontal Processing Facility. The Horizontal Processing Facility will consist of three areas--processing bays, mating bays, and storage bays. Vehicles will be processed in a horizontal position similar to commercial aircraft to decrease the facility height, decrease operational complexity, and permit ease of access to the vehicle elements. The overall impact of these decisions will be a reduction in the initial cost of the facility--using more standard construction techniques--reduce facility operating costs, as well as, the overall operating cost of the system[1].

Payload Containment System Processing Facility. The Payload Containment System Processing Facility consists of a single facility capable of performing minimal checkout and verification of the orbiter and its payload[1].

Launch Pad. The pad will have a minimal tower structure with few umbilical connections to the vehicle. The tower structure will provided access to the crew module and payload containment system[1].

Launch/Mission Control Center. The control center will allow for the integration of data from all aspects of the vehicle operations. Training resources, flight operations and launch control would reside within this one common complex.

The support concepts represent a major change in the maintenance philosophy away from the concept currently used to support space vehicles toward one more similar to that of an aircraft where one-time certification with constant maintenance to ensure air worthiness of the vehicle is the normal certification and mainteneance proceedure for aircraft. The maintenance would be performed by airframe and propulsion technicians as is currently the practice in the commercial airline industry. The various airframe and propulsion skills that would be necessary to perform maintenance include: Structural, Thermal Protection Systems, Helium Purge, Landing Gear and Auxiliary Systems, Main Propulsion, Prime Power, Electrical Conversion and Distribution, Surface Control Actuators, Avionics, Environmental Control, Personnel Provisions. Each of these skill in turn would require facility space to perform the maintenance required on the system.

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[1] "Advanced Manned Launch System Study (AMLS), Interim Review, Rockwell International, June 1991

A review of current United States Air Force standard facility requirements, as well as, procedures used by the Aeronautical Systems Center to identify facilities to support bed down of aeronautical systems resulted the list of general operational and maintenance facilities shown in Table 5.2, General Operational and Maintenance Facilities.

FACILITY TYPE
Covered Maintenance Space
General Purpose Maintenance
Avionics Shop
Corrosion Control
Engine Maintenance
Maintenance Training
Base Operations/Control Tower
Squadron Operations
Flight Simulator Training Facility
Training Classroom
NDI Shop
PMEL Shop
Runway/Overruns
Taxiways
Aprons
Runway/Overruns
Runway/Taxiway Lighting

Table 5.2 General Operational and Maintenance Facilities

Additionally, the support facilities shown in Table 5.3, General Support Facilities, have also been identified as necessary for effective operations of United States Air Force aircraft systems.

FACILITY TYPE
Warehouses
Fire Station
Security
Telecommunications
Medical Clinic

Table 5.3, General Support Facilities

5.1.2 Facility Requirement Comparisons

A comparison of the facilities and technical skill identified by each avenue was then completed and the results are shown in Table 5.4, Facility/Skill Comparison.

AMLS STUDY	AIR FORCE FACILITY
Horizontal Processing Payload Containment System	Covered Maintenance Space
Landing Site	Runway, Taxiways, Aprons, Lighting, etc.
Launch/Mission Control, Training Facility	Base Ops, Control Tower, Simulator Trng/Classroom Fac, Squadron Ops
A&P TECHNICAL SKILLS	**AIR FORCE FACILITY**
Structural	Covered Maint Space General Purpose Shops
Thermal Protection System	Covered Maint Space
Main Propulsion	Engine Maint Shop
Prime Power, Electrical Conversion and Distribution	General Purpose Shops
Surface Control Actuators	General Purpose Shops
Avionics	Avionics Maint Shop
Environmental Control	General Purpose Shops

Table 5.4 Facility/Skill Comparison

A comparison reveals that facilities similar to those supporting United States Air Force aircraft will be required to support conceptual space vehicles using comparable maintenance concepts.

5.2 Estimation of O&S Costs

In this analysis, multiple regression techniques were used to determine parametric relationships for operations and support cost per aircraft as a function of various design, performance, and weight data. Historical operations and support cost were analyzed in an effort to develop general cost estimating relationships that could be used in estimating the facility operations and support costs. The following dependent facility variables were determined using regression analysis: Material Costs, contract costs, personnel costs, and other costs measured in dollars per aircraft.

Table 5.5 identifies the independent variables and the range of the variable used in this analysis.

INDEPENDENT VARIABLE	DEFINITION	RANGE
NO_ENG	Total number of engines on each aircraft	1 -8
DRY_WGT	Weight of vehicle (without fuel) in pounds	9,500 - 320,000
LEN_WNG	Aircraft length plus wing span in feet	75 - 470
WET_AREA	Total external surface area of vehicle in sq ft	950 - 33,710
FUS_VOL	Total volume of the fuselage in cubic ft excluding any engine inlet duct volume	590 - 86,610
FUS_AREA	External area of fuselage in sq ft including canopy	550 - 16,650
AV_SSYS	Total number of avionics subsystems	10 - 37
HY_SSYS	Total number of hydraulic subsystems	16 - 76
TOT_VEH	Total number of vehicle per unit	15 - 72

Table 5-5, Independent Variables

Facility operation and support cost ($ per aircraft) parametric estimating relationships were developed to estimate the yearly cost to operate, repair and maintain the facilities necessary to support the anticipated operational and support concepts of a conceptual space vehicles or systems. The objective for providing these equations is to provide space system planners with a means to identify an initial "ball park" estimate of the facility operation and support cost requirements that will form the basis for performing initial facility life cycle costing on the proposed space system.

The operations and support cost data was obtained from the Visibility and Management of Operating and Support Cost (VAMOSC) System. The costs included those allocated to the personnel assigned to the maintenance and operation of real property facilities and related management and engineering support work and services. The costs also include those associated with materials, contract and other expenses associated with maintenance of real property facility assets. The cost data used to develop the parametric cost estimating relationships was the total yearly aggregated cost for a specific weapon system and mission design series ($ per year and aircraft type). No relationship exists between operation and support cost parametric estimating equations and the size and type of facility. The cost of a specific type of facility type ($ per square foot) could not be obtained for use in the development of the operation and support cost parametric estimating equations.

The operating and support cost parametric estimating equations (Table 5.6) are derived from fiscal year 1989 operation and support cost for the twelve specific aircraft identified in Table 5.1, Study Aircraft (USAF). Four specific cost areas were identified in the Visibility and Management Operating and Support Cost database and they included material, contract, other and personnel costs needed to maintain and repair the facilities necessary to support the mission of the aircraft selected.

Material Costs: This data includes all costs expensed for materials associated with the repair and maintenance of real property facilities identified by specific command and geographical location codes (OAC/OBAN codes). The costs must also carry a PEC code of XXX94 for real property maintenance cost expenses with Element of Expense Investment Code of 60XXX through 63XXX.

Contract Costs: This data includes all costs associated with real property facility maintenance that was completed by contract and are identified by specific command and geographical location codes (OAC/OBAN codes). These costs must also carry a PEC code of XXX94 for real property maintenance cost expenses with Element of Expense Investment Code of 51XXX through 59XXX.

Other Costs: This data includes all remaining Element of Expense Investment Codes associated with real property facility maintenance within PEC code XXX94.

Personnel Costs: This data includes all costs allocated to personnel assigned to the maintenance, repair, and operation of real property facilities and related management and engineering support work and services.

Table 5.6 Facility Operation and Support Cost Requirement Parametric Estimating Relationships

COST CATEGORY	EQUATION	R^2
Material	$MATERIAL = 94{,}327.79 + 0.6206(DRY\ WGT) - 301.5694(LEN\ WNG) - \frac{4{,}787{,}331}{LEN\ WNG} - 6.5950(FUS\ AREA)$	0.5723
Contract	$CONTRACT = 94{,}577.05 - \frac{4{,}938{,}749}{LEN\ WNG} + \frac{935{,}698.6}{WET\ AREA} + \frac{5{,}741{,}874}{FUS\ VOL} - 379.7252(HY\ SSYS)$	0.5179
Other	$OTHER = 16{,}578.32 - 0.8060(WET\ AREA) + 18{,}456.13\ln(NO\ ENG)$	0.9940
Personnel	$PERSONNEL = 174{,}076.9 - \frac{1010e04}{LEN\ WNG}$	0.8392

5.3 Secondary Variable Equations

In order to provide a means of assigning values to many of the independent variables required by the various LCC models, regression equations were developed using the same aircraft data set which was used in the RAM study. The following equations were derived and are consistent with the development and use of the "secondary variable" equations used in the RAM model.

Dependent Variable	Regression Equation	R^2
Max Payload	12105.87 - 310.27 (length+wing span) + 11.752 (wetted area)	.93
Sink Speed	set at 9 feet/second for all Air Force aircraft	
Nbr Seats	-.3227 + .02192 (length + wing span) - .0000616 (fus vol)	.70
Landing Weight (lbs)	-33683.43 + 2.257766 (dry weight)	.98
Nbr brakes	-.4952 + .00007714 (dry weight)	.95
Cargo Volume (cu ft)	-2953.89 + .095946 (dry weight)	.85
Cargo Floor Area (sq ft)	6.939 + .007231 (dry weight)	.96
Cargo Weight (lbs)	-26844.99 + .926718 (dry weight)	.96
Nbr Antennas	49.18029 - 6.9881 (fus density)	.63
Nbr Hydraulic Supply Sys	2.5387 + .000005 (dry weight)	.72
Nbr Fluid Power Subsys	-.1927 + .001748 (wetted area) + 2.5933 (fus density)	.50
Nbr Hydraulic Pumps	2.787 + .00025 (wetted area)	.85
Total Thrust/Aircrft	1499.6 + 205.06 (length + wing span) + .9516 (fus vol)	.82
Avionic installation wt (lbs) (tot avionics wt - wt of black boxes)	-743.64 + 75.871 SQR (length + wing span) + 5.2 Avionics Wt/Nbr avionics subsys	.90

The detailed regression reports may be found in Appendix B. These equations are evaluated based upon values assigned to the independent variables from the RAM model. Therefore, any changes in those variables from the reliability analysis will have an impact on the cost model.

6.0 Support Cost Model

Following the cost element structure described in Section 2.0 and using the LCC models described in Section 3.0, the following cost equations were selected, updated, and implemented into the overall support cost model. The variable definitions may be found in Appendix C and the costing equations are summarized in Appendix D. The following discussion pertains to cost elements 2.3.2 Maintenance, 2.3.3 Logistics, and 2.3.4 System Support. Equations based upon the Logistics Cost Analysis Model are not discussed in detail here since they are adequately presented in the Rockwell study (reference 48) and are being independently evaluated by NASA.

6.1 Refurbishment (CES 2.3.2.1)

The only source of a cost estimating equation was the Prevail model. Since the Prevail model consists of algorithms for the conceptual design of space transportation systems, the cost relationships developed were based in part on Shuttle cost data. Prevail defines refurbishment as a function of those subsystems which must be repaired (refurbished) or replaced and the cost of sustaining engineering for refurbishment items. The assumption is that this task is consistent with NASA's definition of refurbishment which is the restoration of the system from conditions exceeding normal wear and tear. Cost is a function of two elements:

Total Refurb Cost = refurb of vehicle + refurb of engines

where

refurb of vehicle = .02 x avg cost of production stage (AVST) ($M) + .05 x sustaining engineering costs (SE) ($M) for refurbished subsystems

and

refurb of engines = .1 x nbr of engines (NOENG) x avg cost of production engine (AVCE)($M)

+ .1 x sustaining engineering cost for refurbished engines (SENG)($M)

Production costs should be obtained from the acquisition costs (CES 2.2.2) while sustaining engineering costs must currently be estimated. Both costs currently require direct input into the model. Prevail provides a methodology for estimating sustaining engineering costs, however, to implement this methodology, the Prevail CER's for production costs must also be implemented.

6.2 Organizational Maintenance (CES 2.3.2.2)

Organizational maintenance costs consists of three cost elements: (1) direct labor maintenance personnel, (2) maintenance overhead, and (3) maintenance material. Direct labor maintenance personnel costs are determined directly from the total personnel required as computed by the RAM model. This includes both unscheduled and scheduled manpower based upon the maximum of the total manhours of work generated by workcenter or the minimum crew size by workcenter. This number is then converted into a direct labor cost as follows:

direct labor cost = avg technician salary (\$/hr) x 40 x 52 x manpower (from RAM)

Maintenance overhead costs are based upon the MACO model using the following CERs which provide manhours per month:

Function	Equation
Chief of Maintenance	2125.6 + .5032 x msn hrs per month
Quality Control	3477.2 + .7469 x msn per month
Maintenance Control	475.397
Job Control	1082.7 + 1.143 x msn hrs per month
Plan & Scheduling	532.8 + 1.0813 x msn per month
Documentation	264.2 + 6.393 x nbr of vehicles
Material Control	19.18 x $(\text{msn per month})^{0.4269}$
Supply Liaison	505.8 + 1.013 x msn per month
Production Control	713.7 + .9658 x msn per month

Total monthly hours are computed and then divided (and rounded up) by the monthly manhours available per person from the RAM model (default = 144 hours). These numbers are then converted to costs using the same calculation as direct labor.

The material costs (hardware) are based upon the HVL model which provides separate CERs for organizational level maintenance material and depot level maintenance material (both of which are separate from initial and replenishment spares). The regression equations shown provide dollars per flight and are then multiplied by the number of flights per year to obtain a total annual recurring cost.

WBS	EQUATION
Structures	$6.155 \times \text{util rate}^{1.1025} \times \text{total wetted area}^{.79374}$
Landing gear	$3924 \times \text{nbr wheels}^{.43025} \times \text{landing mass} \times \text{speed-sqd}^{.36569}$
Payload deploy & return	$15.2477 \times \text{cargo weight}^{.79221} \times \text{nbr powered exits}^{.024399}$
Avionics	$14476 \times \text{Max KVA}^{.66556} \times \text{nbr avionics subsys}^{.30348}$
Electrical	$98.7584 \times \text{length+wing span}^{1.1251} \times \text{Max KVA}^{.36008}$
Hydraulics	$8389.99 \times \text{nbr hydraulic supply sys}^{.29838} \times \text{nbr hydr subsys}^{.56681}$

ECLS	252.16 x hours per msn$^{.5813}$ x Fuselage vol$^{.46728}$
Flight Provisions	11.5099 x cargo vol$^{.40262}$ x hours per msn$^{.77562}$
Docking	.0749785 x cargo weight$^{.43375}$ x takeoff weight$^{.46765}$

The variable util rate is the number of mission hours per year per vehicle and is computed from the number of vehicles, the hours per mission, and the number of missions per year.

6.3 Depot Maintenance (CES 2.3.2.3)

Depot maintenance consists of two cost elements: (1) personnel and (2) material. Both of these are computed using the HVL CER's which may be found in Appendix D. The primary driver variables are the vehicle design and performance variables obtained from the RAM model, computed from values obtained from the RAM model, or, in a few instances, input directly by the user. These equations provide dollars per flight and are then multiplied by the number of flights per year. All dollars are FY 1980 and are adjusted to an FY 1993 value.

6.4 Modifications (CES 2.3.2.4)

This cost element is based upon a historical factor found in the MACO model. The modification costs are obtained by taking .004494 x unit production costs (flyaway cost) x number of vehicles in the fleet in year t. The number of vehicles in a given year is assumed to be constant in the initial implementation of this model. Therefore, the factor is currently multiplied by the production costs (CES 2.2.2) to arrive at an annual modification cost. It is then treated as a recurring cost.

6.5 Spares (CES 2.3.3.1)

There are two alternative methods for estimating spares cost. One is based upon the HVL model CER's for both initial and replenishment spares. The other is based upon the Logistics Cost Analysis Model (LOG). The HVL cost equations use the design and performance variables as input and computes dollars per flight for each of the nine WBS categories shown above under the organizational maintenance costs. The 18 equations (shown in Appendix D) are then multiplied by the number of flights per year and summed.

The LOG model is based upon the Rockwell study and output from the RAM model. Initial spares costs are computed from the number of spare LRU's generated from the RAM model (rather than the sufficiency formula shown in the Rockwell study) multiplied by an adjusted average dollar cost per LRU. Replenishment spares are computed from:

removals per flt (from the RAM model) x flight/yr x condemnation rate x avg LRU cost

This cost may be further adjusted by a commonality factor.

6.6 Expendables (CES 2.3.3.2)

Expendables are items which are expended on a per flight basis. While NASA treats the external tank as an expendable item, the military has traditional considered expendables to be the non-repairable items used in maintaining components. Items such as transistors, nuts and bolts, circuit boards, cable, etc. are computed using economic order quantity models (EOQ) and are therefore sometimes referred to as EOQ items. This is the category of items which are currently being costed. The MACO model provides the only source for costing this type of expendables. A modified equation from the MACO model resulted in:

EOQ $ = -29.9 +.039 x removals/flight x flights/yr x (1-condemn rate) x avg LRU cost.

6.7 Consumables (CES 2.3.3.3)

The LOG model provides an accounting formula for computing consumables consisting of fuel, oxidizer, and ECLSS costs. Fuel and oxidizer costs are based upon

consumption in lbs per flight x the number of flights per year x $ cost per lb

while life support system costs are computed from:

crew size x ECLSS $ cost/2 person days x mission hrs/48 x flight/yr

Consumption rates and cost factors must be input directly. Both a recurring and nonrecurring cost is computed.

6.8 Inventory Management and Warehouse (CES 2.3.3.4)

Again the LOG model is the basis for computing this cost element. This cost is primary the cost of obtaining and maintaining supplies to support the missions. The LOG model computes both a recurring and nonrecurring cost. The nonrecurring cost is based upon the number of spares LRUs and the number of components per LRU giving a total inventory level which is then multiplied by an initial warehouse manhour value and a logistics salary in dollars per hour. The recurring cost is a multiplicative factor (recurring inventory factor) of the total number of recurring and nonrecurring spares. The implementation of this methodology resulted in computing recurring costs in the same manner as nonrecurring costs. That is,

recur costs = removals/flt x condemnation rate x flights/yr x avg nbr of components/LRU x init warehouse mhrs x logistics salary

6.9 Training (CES 2.3.3.5)

Training includes both organizational and depot level and both nonrecurring and recurring cost categories. The LOG model provides the cost equations which requires course times, course costs, number of technicians, technician turnover rate (for nonrecurring costs) and technician salaries as input. The equations are listed in Appendix D.

6.10 Documentation (CES 2.3.3.6)

Both the LOG model and the HVL model provide a costing methodology for documentation (data in HVL). HVL is broken into the nine WBS categories and provides only recurring costs in dollars per flight based upon vehicle design and performance variables. The LOG model computes both recurring and nonrecurring costs using an estimate for maintenance significant items, tech manual page counts, tech manual page costs, and other factors. The equations are listed in Appendix D.

6.11 Transportation (CES 2.3.3.7)

Addressed only in the LOG model, transportation costs are computed by:

nonrec: **# vehicles x dry weight x packaging weight tax x distance x transporter $/lb-mi**

rec: **nonrec cost + removals/flt x dry weight/# LRUs x packaging wgt tax x depot distance x depot transporter $/lb-mi**

All factors must be input directly.

6.12 Support Equipment (CES 2.3.3.8)

Both the HVL and LOG models provide equations for both recurring and nonrecurring support equipment costs. The LOG model equations are in Appendix D and are functions of the vehicle size (dry weight) launch rate, number of vehicles, and vehicle turnaround times. It is a proration of a shuttle based vehicle GSE cost and DSE (Depot support equipment).

The HVL equations for nonrecurring costs in dollars are given below:

WBS	**EQUATION**
Structure	$644.063 \times \text{fus vol}^{.70503}$
Landing Gear	$.306413 \times \text{takeoff weight}^{.70378} \times \text{maxmach nbr}^{.11614}$

Payload Deply/ret	.02 x unit production cost
Avionics	376.149 x avionics install $wgt^{1.1071}$
Electrical	20536 x Max $KVA^{.18723}$ x Maxmach $nbr^{.87839}$
Hydraulics	2400.88 x nbr hydr $subsys^{.76158}$
ECLS	7812.31 x nbr $seats^{.78697}$ x maxmach $nbr^{.9731}$
Flight Provisions	3.059 x 10^{-9} x tot $thrust^{1.8319}$
Docking	.795139 x fus $volume^{.70503}$

For recurring costs, the cost (dollars) per flight is .2 x nonrecurring cost.

6.13 ILS Management (CES 2.3.3.9)

The LOG model determines an ILS management cost as a fixed percent of the sum of all other logistics cost elements. This is done for both recurring and nonrecurring costs. These factors are currently .08 for nonrecurring costs, and .13 for recurring costs.

6.14 Support Staff (CES 2.3.4.1)

Staff consists of administrative and engineering. The HVL model provides the following costing methodology for the administrative costs by first computing aircrew and command staff costs.

aircrew \$ cost = .21458 x crew size$^{1.6422}$ x nbr of vehicles$^{.89681}$

comd staff \$ cost = .21458 x util rate$^{.50621}$ x nbr of vehicles$^{.89225}$

admin staff \$ cost = .2 x (aircrew \$ + comd staff \$)

The Prevail model provides a historical factor for computing an engineering support cost which is 5 percent of the launch, flight, and recovery operations (i.e. CES 2.3.1). Recurring costs for support staff is then computed from:

support staff \$ = admin staff \$ + .05 x annual operations costs \$

6.15 Facilities operations and maintenance costs (CES 2.3.4.2)

These recurring annual costs are computed from the CERs identified and discussed in Section 5.0.

6.16 Communication (CES 2.3.4.3)

Communications costs are estimated from an installation support cost equation found in the MACO model. Installation support costs include communications, civil engineering, supply services, personnel services, security, transportation, financial services, and other base support activities. The communications cost is a one-sixth proration of the total installation support cost as computed in Section 6.17.

comm \$ = installation spt \$ / 6

6.17 Base Operations (CES 2.3.4.4)

This cost category includes various base support functions such as security, fire protection, weather, legal services, personnel services, base transportation, accounting and finance, and etc. The MACO computes a personnel cost and then a material cost based upon a historical factor:

personnel cost \$ = .156 x 40 x 52 x \$/hr technician salary x nbr of mission personnel

Primary mission personnel is defined to be the total number of aircrews + command staff + maintenance personnel assigned at the base level directly supporting the mission activity.

hardware cost \$ = 1920.77 x nbr of mission personnel.

Then **Installation spt \$ = personnel cost \$ + hardware cost \$**

Since this cost includes facility costs (civil engineering) and communications which are addressed under separate cost elements, then

base operations \$ = 4 installation spt \$ / 6

The prorations are arbitrary, and a further analysis of historical cost data is necessary to obtain more valid percentages.

6.18 Pre and Post launch cleanup (CES 2.3.4.5)

This function is normally performed by the civil engineering squadron on an airbase with some support from the aircraft maintenance manpower (as indirect work). Therefore, its cost is assumed to be included in the facilities O&M costs (CES 2.3.4.2).

7.0 Computer Implementation

The equations presented in Section 6.0 and in Appendix D are implemented in PC based model written in compiled BASIC for execution on any DOS computer. This model is compatible with the RAM model and will read directly a data file created by the RAM model. The model is menu driven allowing for easy file maintenance and update of input values.

The program is executed by typing LCC at the DOS prompt (or alternately the model could be loaded via Microsoft windows). The program will request a vehicle/file name. The name assigned should be the same name used in RAM model since the RAM model will produce an output file called "name".CST for use in the LCC model. Input values will be saved and subsequently read in by the LCC model from a file called "name".INP. Therefore the "name" assigned will be part of the file name for three different files each having a different extension (RAM saves its data in a file called "name".DAT).

After assigning a name, the main menu appears as follows:

```
                LIFE CYCLE COST MODEL

                  VEHICLE IS TEST

                     MAIN MENU

      OPTION                              NBR

    INPUT FROM RAM MODEL............1
    GO TO INPUT MENU................2
    DISPLAY RESULTS.................3
    REPORT GENERATOR................4
    SAVE INPUT VALUES...............5
    READ INPUT DATA FROM FILE.......6
    CHANGE VEHICLE/FILE NAME........7
    TERMINATE SESSION...............8
```

Normal use of the model would require the user to read in the "name".CST file from the RAM model. This in turn will update several system parameters variables and many of the design and performance variables including the calculation of the additional secondary variable values computed by the regression equations in Section 5.0. The user should then go to the input menu

```
                 DATA INPUT MENU

    CATEGORY                              NBR

    SYSTEM PARAMETER TABLE............1
    UPDATE WBS COSTING TABLE..........2
    COST FACTORS & RATES .............3
    DESIGN/PERFORMANCE VARIABLES......4
    MISC FACTORS......................5
```

and systematically update the various input factors, costs, and parameters. The system parameter table contains general information for life cycle costing including the number of vehicles, mission lengths, flights per year, inflation factors, economic life of the system, and the base year for costing. The WBS costing table lists the Cost Element Structure from Section 2.0. The user can then identify by cost element whether to compute a value or to default to a user supplied value. Since the equations only address the support costs, the other cost elements should be defaulted to or ignored (if the user is only interested in the support costs). The next table lists all the cost factor and rates. These values should reflect 1993 costs since the model will then inflate these costs from 1993 to the base year (or then year) identified by user. The design and performance variable table (used primarily by the HVL model) lists vehicle characteristics such as design weight, number of control surfaces, total wetted area, etc. Many of these values are obtained from the RAM model and should not be changed unless changed within the RAM model. This will insure compatibility between the two models. The last input table contains almost 40 miscellaneous variables used primarily by the LOG model. The default values are for the most part, those contained within the Rockwell study.

After updating the input tables, the user will return to the main menu and select "Display Result." The following options are available:

```
SCREEN DISPLAY SELECTION MENU

1..........SUMMARY BY WBS
2..........HYPERVEL MODEL COSTS
3..........FACILITY COSTS
4..........LOGISTICS MODEL COSTS
5..........ORG MANPOWER COSTS
6..........SYSTEM SUPPORT COSTS

RETURN.....MAIN MENU
```

The primary output screen is the "SUMMARY BY WBS." This shows the results of the costing model by CES combining both the computed and default values and summing these to the higher level costs. In those cases where both the HLV and the LOG model provide costs estimates, this display will reflect the choice the user made on the System Parameter Table (the default is the LOG model). This display shows an annual cost (which includes any nonrecurring support costs) and a life cycle cost. The remaining menu selections will provide a more detailed breakout of the costing performed by the HVL model, facility O&M equations, LOG model, organization manpower costs, and system support costs.

The user may select to have a hard copy listing of any of these reports by selecting "REPORT GENERATOR" from the main menu.

```
REPORT GENERATOR MENU

NBR                 SELECTION

1........PRINT INPUT DATA
2........PRINT WBS SUMMARY REPORT
3........PRINT HYPERVELOCITY MODEL COSTS
4........PRINT LOGISTICS MODEL COSTS
5........PRINT ORG MANPOWER COSTS
6........PRINT FACILITIES COST
7........PRINT SYSTEM SUPPORT COST
8........PRINT TOTAL OUTPUT
9........PRINT TOTAL INPUT/OUTPUT
RETURN....main menu
```

8.0 Conclusion

The costing methodology identified in this study attempts to integrate the previous developed reliability and maintainability model with existing costing equations and algorithms. It also attempts to integrate the support costs with the other life cycle costs in order to provide the cost analyst with a complete analysis tool. Obviously, the cost elements for those categories not addressed in this study must be obtained from other cost relations and methodologies. This model was developed in a highly modularized fashion with the expectation that additional cost relations will be added later so that eventually this model will become a complete LCC. There has been very little opportunity to validate this implementation and to calibrate the input data. This needs to be done before the model can be used with any confidence.

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MODEL: Avionics Laboratory Predictive Operations and Support (ALPOS) Cost Model

REFERENCE: "A Comparison of Various Life Cycle Cost Models," Welch, 1985

COMPUTER IMPLEMENTATION: CDC-6600 mainframe, Fortran IV

APPLICATION: parametric O&M cost estimate of avionics equipment

SOURCE OF DATA: regression of avionic equipment data

INCLUDES: 15 estimating equations derived from logistics, support, and cost parameters derived from 10 dependent and 20 independent variables

EXCLUDES:

STAGES: operation and maintenance

INPUTS: MMH/OH, MTBF, unit price, unit volume, weight, component type, BIT/FIT factor, number of SRUs per LRU, aircraft type, operating hours per month

WBS: not explicitly stated

SUBSYSTEMS: user input

MODEL: CORE (and ZCORE)

REFERENCE: "Review of Selected USAF Life Cycle Costing Models," Twomey, 1991

COMPUTER IMPLEMENTATION: PC based in BASIC

APPLICATION: constant year LCC estimation of O&S costs

SOURCE OF DATA: AFI 655-03 (former AFR 173-13)

INCLUDES: eight primary cost categories (Unit Mission Personnel, Unit-Level Consumption, Depot-level Maintenance, Sustaining Investment, Installation Support Personnel, Indirect Support Personnel, Depot Nonmaintenance, and Acquisition and Training), class IV modifications, contractor logistics support

EXCLUDES: factors below the system (aircraft) or subsystem (radar, APU, etc.) level are not covered, vary resource inputs (manpower, etc.), aircraft availability

STAGES: O&S

INPUTS: system operating parameters and characteristics

WBS: WUC structure

SUBSYSTEMS: WUC structure

MODEL: Frieman Analysis of Systems Technique (FAST-E)

REFERENCE: "A Comparison of Various Life Cycle Cost Models," Welch, 1985

COMPUTER IMPLEMENTATION: PRIME mainframe

APPLICATION: computerized parametric cost estimating model used primarily by the energy industry to estimate equipment and system costs

SOURCE OF DATA: regression of equipment and system parameters as they relate to cost

INCLUDES: technology maturity (electronic, electrical, heat, motion, mechanical control, containment and supportive components), design masses (energy conversion, design overhead, application, dimensional, and conditional), weight, size, economics of production, engineering,

EXCLUDES:

STAGES: engineering, production, and installation

INPUTS: characteristics (see INCLUDES) of the system or equipment under study

WBS: not applicable

SUBSYSTEMS:

MODEL: Hypervelocity Life Cycle Cost Model (HVLCCM)

REFERENCE: "Users Guide Program HVLCCM," 1989, "Life Cycle Cost User's Manual," Albin, Boeing Aircraft Company, 1989

COMPUTER IMPLEMENTATION: mainframe (Fortran 77) and PC (spreadsheet)

APPLICATION: conceptual military hypervelocity aircraft LCC model

SOURCE OF DATA: modification of MLLCM (cargo plane) based on shuttle data

INCLUDES: PHASES 3 and 14 systems and subsystems, direct and indirect costs, RDT&E (5 CERs), System and Support Investment (Production) (12 CERs), O&S (85 CERs)

EXCLUDES: final disposal

STAGES: 3 and summary

INPUTS: vehicle operational characteristics (fuselage volume, weight, etc.), materials used by subsystem structure, tooling, payload characteristics (volume, weight, etc), system parameters, life cycle, G&A percentage, profit, number of prototypes, production numbers

WBS: RDT&E, production, O&S

SUBSYSTEMS: structure, landing gear, docking, payload Deployment & Retrieval, main propulsion, orbiting maneuvering, RCS, avionics, electrical/mechanical power generation and distribution, hydraulics, ECLS, flight provision, engine installation

MODEL: Logistics Support Cost (LSC) Model

REFERENCE: "User Documentation for the AFLC Logistics Support Cost Model version 2.2a," AFLC, 1991. "Review of Selected USAF Life Cycle Costing Models," Twomey, 1991

COMPUTER IMPLEMENTATION: PC based in Basic

APPLICATION: Operating and Support Cost model at the LRU/SRU level

SOURCE OF DATA: AFLCP 173-3 and AFR 173-13

INCLUDES: initial and replenishment spares, depot maintenance, second destination charges, condemnation spares and spares used to fill the logistics pipeline

EXCLUDES: connection of spare cost to aircraft availability and logistic system, preventive maintenance

STAGES: not typically used prior to Milestone III of a program, O&S costs

INPUTS: ASCII file input of SRU and LRU costs and characteristics, and avionic system characteristics (size, weight, flight hours, etc.).

WBS: three to four (some five) digit WUC structure

SUBSYSTEMS: most subsystems are included in this "accounting-type" model.

MODEL: Modular Life Cycle Cost Model (MLCCM) for Advanced Aircraft

REFERENCE: "MLCCM for Advanced Aircraft Systems-Phase III, Volume VI, rev. 2," 1985. "MLCCM for Advanced Aircraft Systems-Phase III, Volume IV, rev. 3," 1986. "Review of Selected USAF Life Cycle Costing Models." Twomey, 1991

COMPUTER IMPLEMENTATION: Mainframe (CYBER 750 and NOS2 O/S in FORTRAN), PC spreadsheet (LOTUS)

APPLICATION: military aircraft life cycle costing

SOURCE OF DATA: regression of USAF aircraft systems and subsystems

INCLUDES: 4 PHASES, 12 systems/subsystems, MIL and CIV personnel, materials, contract costs (G&A, overhead, profit)

EXCLUDES: final disposal

INPUTS: system operational parameters, and characteristics (ie. weight, length, fuel consumption, construction material, etc.) and costs if known

WBS: Phases: rdt&e, production, initial support, and O&S

SUBSYSTEMS: structures, crew system, landing gear, flight control, engines, ECS, electrical system, hyd/pneumatic system, fuel system, avionics, cargo handling(or armament)

MODEL: Naval Fixed-Wing Aircraft Operating and Support Cost-Estimating Model

REFERENCE: "Naval Fixed-Wing Aircraft Operating and Support Cost-Estimating Model." DRC. 1986. "Naval Fixed-Wing Aircraft Operating and Support Cost-Estimating Model." DRC. 1990

COMPUTER IMPLEMENTATION: PC based spreadsheet (LOTUS)

APPLICATION: Naval Fixed-Wing Aircraft Operating and Support Parametric Cost Estimates

SOURCE OF DATA: regression (linear and log-linear) of current Navy aircraft cost data

INCLUDES: Direct and Indirect costs of 15 current Navy aircraft types (A-4F, A-4M, A-6E, A-7E, AV-8B. KA-6D. EA-6B. F-4S/J. F-14A. F/A-18A, E-2C, S-3A, P-3C, T-39D, and T-44A), in CAIG structure (total of 27 cost elements). FY1990 base year dollars.

EXCLUDES: emergency repair and support costs - regression equation did not provide significant results (low adjusted coefficient of determination ("goodness-of-fit")), modification procurement - unable to segregate costs for emergency versus non-emergency modification of aircraft

STAGES: O&S

INPUTS: personnel by job function (air or ground crew, maintenance, etc.), pay rates. flying hours, empty loaded, empty, airframe, and engine weight of aircraft, maximum aircraft speed at sea level. number of engines, maximum thrust per engine, cost of procurement of safety related items, POL costs, cost of first 100 aircraft, aircraft rework cost/yr, and unscheduled maintenance manhours per aircraft.

WBS: CAIG structure

SUBSYSTEMS: none

MODEL: PREVAIL

REFERENCE: PREVAIL Algorithms for Conceptual Design of Space Transportation Systems

COMPUTER IMPLEMENTATION: FORTRAN 77 on a MAINFRAME (CDC Cyber. VAX. IBM 3090) and IBM PC.

APPLICATION: Sizing and cost of launch and orbital transfer vehicles

SOURCE OF DATA: Centaur. IUS. Titan III, STS (Shuttle)

INCLUDES: Subsystem (15) CER's for three primary cost categories: Design Engineering, Test and Evaluation. and Production for LO_2-LH_2 motors, solid rocket motor, winged stages and whether the stages are manned or reusable.

EXCLUDES: Cost for ground equipment, facilities, military pay, sharing of common subsystems, horizontal launch.

STAGES: reusable or expendable liquid oxygen, liquid hydrogen, solid rocket motor, liquid fuels, winged or manned stages.

INPUTS: vehicle/subsystem parameters, launch parameters, payload parameters, orbital parameters

WBS: 15 primary systems/subsystems in three cost categories

SUBSYSTEMS: structures. thermal, reentry protection, landing system. electrical-power. electrical-wiring, guidance&control, data handling, instrumentation, communications, propulsion systems, engine(s), RCS, interstage adapter, payload faring.

MODEL: Programmed Review of Information for Costing and Evaluation (PRICE)

REFERENCE: "A Comparison of Various Life Cycle Cost Models," Welch, 1985

COMPUTER IMPLEMENTATION: mainframe

APPLICATION: life cycle costing of electro-mechanical hardware assemblies and systems

SOURCE OF DATA: RCA - purchase of network time

INCLUDES: design, drafting, project management, documentation, sustaining engineering, special tooling and test equipment, government furnished or modified equipment, material, labor, testing, and overhead

EXCLUDES: non-hardware costs of field test, site construction, and software

STAGES: development, production, purchase

INPUTS: quantity of equipment, schedule, hardware geometry (size, weight,etc.), complexity, operational environment, fabrication process, fixed and variable costs of material, facilities, and labor, and technology improvement

WBS: none implicit in the model

SUBSYSTEMS: none implicit in the model

MODEL: Reliability, Maintainability and Cost Model (RMCM)

REFERENCE: "Adapting Logistics Models to a Microcomputer for Interface With Computer-aided Design Systems," Davidson and Fraser, 1984, "A Comparison of Various Life Cycle Cost Models," Welch, 1985

COMPUTER IMPLEMENTATION: CDC-6600 Cyber 74 mainframe, using Fortran IV

APPLICATION: weapons system and support equipment's life cycle costs used to conduct requirements, costs, and trade-off analyses

SOURCE OF DATA:

INCLUDES: recurring, nonrecurring, and disposal costs

EXCLUDES:

STAGES: conceptual, development, production, and operation and support

INPUTS: reliability and maintainability of subsystems, unit costs, number of units procured, depot repair cycle time, etc.

WBS: three to four digit level of the WUC structure

SUBSYSTEMS: at the LRU level (see WBS)

MODEL: TI-59 Handheld Calculator Aircraft Top Level Life Cycle Cost Model (TI-59 ATL^2C^2)

REFERENCE: "A Comparison of Various Life Cycle Cost Models," Welch, 1985

COMPUTER IMPLEMENTATION: TI-59 Handheld Calculator

APPLICATION: flyaway cost of quantity 750 aircraft

SOURCE OF DATA: LSC model

INCLUDES: 42 inputs (30 default)

EXCLUDES:

STAGES: RDT&E, Production, initial and recurring O&S

INPUTS: required: empty weight, material of airframe % (3), rated thrust of engine (military-uninstalled, 30 minutes), number of engines, avionics weight per aircraft

WBS: none specified by model

SUBSYSTEMS: none specified by model

MODEL: Unmanned Space Cost Model 6 (USCM6)

REFERENCE: "Unmanned Space Vehicle Cost Model," US Air Force Space Division, 1988

COMPUTER IMPLEMENTATION: PC - LOTUS spreadsheet

APPLICATION: CERs for estimating hardware costs of earth-orbiting space vehicles

SOURCE OF DATA: regression of historic earth-orbiting space vehicles (18 programs)

INCLUDES: recurring and nonrecurring costs for: Payload (mission equipment), Spacecraft, Aerospace Ground Equipment, Launch & Orbital Operation Support, Integration and Assembly, Program Level, Dispenser (including structure), Structures & Interstages, ACS, Thermal Control, EPS, Telemetry, Tracking and Command (TT&C), Apogee Kick Motor (AKM) (propulsion), and Communications

EXCLUDES: Ground C^3, Launch Vehicle, Sensors, Cameras, and Other Payloads

STAGES: Purchase of the hardware

INPUTS: Structure, Apogee Kick Motor (AKM), and Altitude Control System weight, Space vehicle weight, electrical power weight, power required, AKM impulse and stabilization, mission equipment weight, number of solar cells, communications subsystem weight, number of altitude sensors and weight, RF power output, receiver/exciter design life, weight of subsystems, G&A costs, profit, and number of vehicles

WBS: I. Space Vehicle, A) Integration and Assembly, B) Spacecraft, 1. structure, interstage/adapter, dispenser, 2. altitude control system, 3. thermal control, 4. electrical power supply, 5. telemetry, tracking & command, 6. apogee kick motor, C) Communications Payload, D) Program Level - program management, systems engineering, systems test and evaluation, data, II. Aerospace Ground Equipment, III. Launch & Orbital Operations Support

SUBSYSTEMS: see INCLUDES

MODEL: Model for estimating Aircraft Cost of Ownership (MACO)

REFERENCE: "A New Approach to Modeling the Cost of Ownership for Aircraft Systems", Marks, Kenneth E. & H. Garrison Massey, The Rand Corporation, R-2601-AF. Santa Monica, CA, August 1981.

COMPUTER IMPLEMENTATION: none identified

APPLICATION: Parametric O&M cost estimates of base and depot level maintenance manpower (including overhead). Accounting type equations for estimating scheduled maintenance manpower requirements and spares requirements. CER estimate for expendable (EOQ) items. Accounting approach used for support equipment, aircrews, wing/base support manpower, and training. Some historical factors developed for computing modifications and installation support hardware (material).

SOURCE OF DATA: Tactical Air Command LCOM studies, AFR 173-13. For the accounting type calculations, the user must supply the cost factors and rates. Air Force data systems are identified.

INCLUDES: Numerous CER's developed for base level maintenance manpower by workcenter. Also considerable detail on the calculation of reparable spares including jet engines.

EXCLUDES: Six cost elements in the CAIG structure: including facility costs, war readiness spares, some support equipment acquisition costs, documentation costs, and training equipment and services.

STAGES: operation and maintenance

INPUTS: Flying hours, sortie rates, number of aircraft, salary rates, component daily demand rates, base repair rates, repair cycle times, average flyaway cost, manpower productivity (manhours per month), condemnation rates, consumable unit costs, various manpower work standards, activity rates, and cost factors.

WBS: A mapping into the (1980) CAIG structure is provided.

SUBSYSTEMS: organization level manpower maps to the Air Force 2-digit WUCs

Regression Analysis Results

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:17:53
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: MAX_PAY

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	12105.87	0.0000	9897.09	1.22	0.2311		
LEN_WING	-310.2692	-0.5393	113.5482	-2.73	0.0106	0.8020	0.8020
WETAREA	11.75155	1.4796	1.567428	7.50	0.0000	0.9326	0.9153

Analysis of Variance Report

Dependent Variable: MAX_PAY

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	2.945465E+10	2.945465E+10		
Model	2	9.435693E+10	4.717847E+10	200.67	0.000
Error	29	6.818056E+09	2.351054E+08		
Total	31	1.01175E+11	3.263709E+09		

Root Mean Square Error	15333.15
Mean of Dependent Variable	30339.05
Coefficient of Variation	.5053932
R Squared	0.9326
Adjusted R Squared	0.9280

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 09:59:21
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: NO SEAT

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-.3227205	0.0000	.4058052	-0.80	0.4323		
LEN_WING	.2192E-01	1.2675	.3081E-02	7.11	0.0000	0.5981	0.5981
FUS VOL	-.616E-04	-0.5885	.1865E-04	-3.30	0.0024	0.7003	0.2263

Analysis of Variance Report

Dependent Variable: NO SEAT

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	241.8286	241.8286		
Model	2	65.94476	32.97238	37.38	0.000
Error	32	28.22667	.8820834		
Total	34	94.17143	2.769748		

Root Mean Square Error	.939193
Mean of Dependent Variable	2.628572
Coefficient of Variation	.3573017
R Squared	0.7003
Adjusted R Squared	0.6815

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:01:42
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: LDNGWT

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-33683.43	0.0000	17779.83	-1.89	0.0948		
DRY_WGT	2.257766	0.9884	0	0.00	1.0000	0.9769	0.9769

Analysis of Variance Report

Dependent Variable: LDNGWT

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	4.866511E+11	4.866511E+11		
Model	1	4.240084E+11	4.240084E+11	338.67	0.000
Error	8	1.001579E+10	1.251974E+09		
Total	9	4.340242E+11	4.822491E+10		

Root Mean Square Error	35383.25
Mean of Dependent Variable	220601.7
Coefficient of Variation	.1603943
R Squared	0.9769
Adjusted R Squared	0.9740

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:02:38
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: LDGBRK

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-.4951968	0.0000	.9725487	-0.51	0.6263		
DRY_WGT	.7714E-04	0.9769	0	0.00	1.0000	0.9543	0.9543

Analysis of Variance Report

Dependent Variable: LDGBRK

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	711.1111	711.1111		
Model	1	451.2696	451.2696	146.11	0.000
Error	7	21.61932	3.088475		
Total	8	472.8889	59.11111		

Root Mean Square Error	1.757406
Mean of Dependent Variable	8.888889
Coefficient of Variation	.1977081
R Squared	0.9543
Adjusted R Squared	0.9478

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:03:23
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: CARVOL

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-2953.888	0.0000	2066.492	-1.43	0.1907		
DRY_WGT	.0959459	0.9219	0	0.00	1.0000	0.8498	0.8498

Analysis of Variance Report

Dependent Variable: CARVOL

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	6.165704E+08	6.165704E+08		
Model	1	7.657192E+08	7.657192E+08	45.28	0.000
Error	8	1.353E+08	1.691249E+07		
Total	9	9.010191E+08	1.001132E+08		

Root Mean Square Error	4112.481
Mean of Dependent Variable	7852.2
Coefficient of Variation	.5237361
R Squared	0.8498
Adjusted R Squared	0.8311

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:03:48
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: CARFLA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	6.939	0.0000	59.03185	0.12	0.9093		
DRY_WGT	.7231E-02	0.9875	0	0.00	1.0000	0.9752	0.9752

Analysis of Variance Report

Dependent Variable: CARFLA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	6746980	6746980		
Model	1	4349838	4349838	315.18	0.000
Error	8	110408.5	13801.07		
Total	9	4460247	495582.9		

Root Mean Square Error	117.478
Mean of Dependent Variable	821.4
Coefficient of Variation	.1430216
R Squared	0.9752
Adjusted R Squared	0.9722

-------------------------------Multiple Regression-------------------------------

Date/Time 05-08-1994 10:04:06
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: CARGWT

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-26844.99	0.0000	11081.49	-2.42	0.0459		
DRY_WGT	.9267182	0.9792	0	0.00	1.0000	0.9588	0.9588

Analysis of Variance Report

Dependent Variable: CARGWT

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	6.799074E+10	6.799074E+10		
Model	1	6.350245E+10	6.350245E+10	162.85	0.000
Error	7	2.729656E+09	3.899508E+08		
Total	8	6.623211E+10	8.279013E+09		

Root Mean Square Error	19747.17
Mean of Dependent Variable	86916.78
Coefficient of Variation	.2271963
R Squared	0.9588
Adjusted R Squared	0.9529

-------------------------------Multiple Regression-------------------------------

Date/Time 05-08-1994 10:06:02
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: NANTNA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	49.18029	0.0000	7.71748	6.37	0.0004		
FUS DENS	-6.988057	-0.7910	2.043184	-3.42	0.0111	0.6256	0.6256

Analysis of Variance Report

Dependent Variable: NANTNA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	4900	4900		
Model	1	257.7558	257.7558	11.70	0.011
Error	7	154.2442	22.03488		
Total	8	412	51.5		

Root Mean Square Error	4.694132
Mean of Dependent Variable	23.33333
Coefficient of Variation	.2011771
R Squared	0.6256
Adjusted R Squared	0.5721

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:08:19
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: NHYDSP

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	2.538731	0.0000	.1765923	14.38	0.0000		
DRY_WGT	.5005E-05	0.8479	0	0.00	1.0000	0.7189	0.7189

Analysis of Variance Report

Dependent Variable: NHYDSP

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	87.11112	87.11112		
Model	1	2.076941	2.076941	17.91	0.004
Error	7	.8119479	.1159926		
Total	8	2.888889	.3611111		

Root Mean Square Error	.3405768
Mean of Dependent Variable	3.111111
Coefficient of Variation	.1094711
R Squared	0.7189
Adjusted R Squared	0.6788

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:12:52
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: NHYDSS

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-.1926917	0.0000	6.670964	-0.03	0.9771		
WETAREA	.1748E-02	0.8235	.3158E-03	5.53	0.0000	0.2925	0.2925
FUS DENS	2.593352	0.5386	.716413	3.62	0.0010	0.5027	0.0113

Analysis of Variance Report

Dependent Variable: NHYDSS

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	28016.94	28016.94		
Model	2	3690.4	1845.2	15.67	0.000
Error	31	3650.658	117.7632		
Total	33	7341.059	222.4563		

Root Mean Square Error	10.85187
Mean of Dependent Variable	28.70588
Coefficient of Variation	.3780366
R Squared	0.5027
Adjusted R Squared	0.4706

```
----------------------------Descriptive Statistics----------------------------
Date/Time        05-08-1994  10:20:18
Data Base Name  C:\NASA\SECOND
Description      Merge of WUC72 and WUC11 created 05-08-1994

                              Detail Report

Variable: NHYDSS
Mean - Average           28.70588        No. observations          35
Lower 95% c.i.limit      23.50198        No. missing values        1
Upper 95% c.i.limit      33.90978        Sum of frequencies        34
Adj sum of squares       7341.059        Sum of observations       976
Standard deviation       14.91497        Std.error of mean         2.557896
Variance                 222.4563        T-value for mean=0        11.22246
Coef. of variation       .5195789        T prob level              0.0000
Skewness                 1.573437        Kurtosis                  3.439063
Normality Test Value     1.59556         Reject if >  1.133(10%)   1.202(5%)
K.S. Normality Test       0.15680        Reject if >  0.137(10%)   0.151(5%)
√b1     1.50 Skew-Z      3.37 Pr 0.0008  b2     5.78 Kurt-Z     2.65 Pr 0.0081
D'Agostino-Pearson Omnibus K² Normality Test        18.4        Pr 0.0001
100-%tile (Maximum)      76              90-%tile                  39
 75-%tile                35              10-%tile                  14
 50-%tile (Median)       27.5            Range                     68
 25-%tile                20              75th-25th %tile           15
  0-%tile (Minimum)      8               C.L. Median(95%)     20, 34
8----------------------------Line Plot / Box Plot----------------------------76
1    2 2 12   6 1  1  11 21  221  4 1     1                               1    1
       -------[XXXXXXXmXaXXXXXX]-----
```

Distribution & Histogram

Variable: NHYDSS

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	8	13.66667	3	8.8	3	8.8	:***
2	13.66667	19.33333	5	14.7	8	23.5	:*****
3	19.33333	25	7	20.6	15	44.1	:*******
4	25	30.66667	5	14.7	20	58.8	:*****
5	30.66667	36.33333	6	17.6	26	76.5	:******
6	36.33333	42	5	14.7	31	91.2	:*****
7	42	47.66666	1	2.9	32	94.1	:*
8	47.66666	53.33333	0	0.0	32	94.1	:
9	53.33333	59	0	0.0	32	94.1	:
10	59	64.66666	0	0.0	32	94.1	:
11	64.66666	70.33333	0	0.0	32	94.1	:
12	70.33333	76	2	5.9	34	100.0	:**

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:14:00
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: NHYPMP

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	2.787008	0.0000	.5567673	5.01	0.0010		
WETAREA	.2500E-03	0.9215	.3724E-04	6.71	0.0002	0.8492	0.8492

Analysis of Variance Report

Dependent Variable: NHYPMP

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	336.4	336.4		
Model	1	48.91634	48.91634	45.07	0.000
Error	8	8.683657	1.085457		
Total	9	57.6	6.4		

Root Mean Square Error	1.041853
Mean of Dependent Variable	5.8
Coefficient of Variation	.1796298
R Squared	0.8492
Adjusted R Squared	0.8304

------------------------------Multiple Regression------------------------------

Date/Time 05-08-1994 10:16:28
Data Base Name C:\NASA\SECOND
Description Merge of WUC72 and WUC11 created 05-08-1994

Multiple Regression Report

Dependent Variable: TOTHST

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	1499.603	0.0000	7144.23	0.21	0.8351		
LEN_WING	205.0589	0.5335	53.74213	3.82	0.0006	0.7711	0.7711
FUS VOL	.9516296	0.4106	.3240532	2.94	0.0062	0.8209	0.7368

Analysis of Variance Report

Dependent Variable: TOTHST

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	5.469159E+10	5.469159E+10		
Model	2	3.774873E+10	1.887436E+10	71.06	0.000
Error	31	8.233927E+09	2.656105E+08		
Total	33	4.598265E+10	1.393414E+09		

Root Mean Square Error	16297.56
Mean of Dependent Variable	40107.06
Coefficient of Variation	.4063515
R Squared	0.8209
Adjusted R Squared	0.8094

------------------------------Multiple Regression------------------------------

Date/Time 07-01-1994 01:50:52
Data Base Name C:\NASA\AVIONICS
Description Backup of AVIONICS created 11-14-1992

Multiple Regression Report

Dependent Variable: AV INSTA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-743.6426	0.0000	111.1399	-6.69	0.0000		
SQR LEN	75.87092	0.4944	9.717987	7.81	0.0000	0.5619	0.5619
AVG WT/S	5.19961	0.6343	.5190874	10.02	0.0000	0.8992	0.6943

Analysis of Variance Report

Dependent Variable: AV INSTA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	1.577623E+07	1.577623E+07		
Model	2	8330920	4165460	133.76	0.000
Error	30	934262.1	31142.07		
Total	32	9265182	289536.9		

Root Mean Square Error	176.4712
Mean of Dependent Variable	691.4243
Coefficient of Variation	.2552285
R Squared	0.8992
Adjusted R Squared	0.8924

GLOSSARY

NR =Nonrecurring, R = Recurring

AFLRU	Avionics fraction of LRUs.
ALRUCOST	Average LRU cost, $. **Index to FY93.**
ATE	Automatic test equipment, $. **Index to FY93.**
AV	Avionics costs for a given component, NR-$, R-$/yr.
AVCE	Average cost of production engines, in $M
AVINWT	Avionics installation weight - less black boxes, lbs.
AVNCWT	Weight of avionics black box equipment uninstalled. Does not include wiring, shelves, cooling ducts, and fasteners.
AVST	Average cost of production stages less engines, $M.
BCBT$	Basic CBT cost, $/hr. **Index to FY93.**
BTUPHR	BTUs per hour per person, BTU.
CARFLA	Cargo floor area, ft^2.
CARGWT	Maximum internal cargo weight, lbs.
CARVOL	Total volume of all components in which cargo is carried, ft^3.
CF	Commonality Factor
CONSUM	Consumables costs, $.
CON	Facility contracts costs, $/yr.
COTS%	Percentage commercial-off-the-shelf.
CR	Condemnation rate.
CRE	Total refurbishment cost, including fee, of engines, $/yr.
CREW$	Cost of crew, $/yr.
CWS	Total refurbishment cost, including fee, of winged stage less engines, $/yr.
DCF	Depot coverage factor.
DDIST	Depot distance, mi.
DEPTNG	Depot training costs, $.
DEPTRP$	Depot transporter cost per lb-mi, $/lb-mi. **Index to FY93.**
DF	Depot factor.
DIST	Manufacturer distance, mi.
DITCT	Depot initial training course time, hrs.
DM	Depot maintenance costs, $/yr.
DMANUAL	Depot manual costs, $.
DMH	Depot maintenance hardware costs, $/yr.
DMP	Depot maintenance personnel costs, $/yr.
DMPC	Depot manual page count.
DOCK	Docking system costs for a given component, NR-$, R-$/yr.
DODEN$	Department of Defense engineering support costs, $/yr.
DPTR	Depot personnel turnover rate.
DSE	Depot support equipment costs, $.
DSE$	DSE costs, $. **Index to FY93.**
DTECH	Number of depot technician.
DTECHSAL	Depot technician salary, $/hr. **Index to FY93.**
ECLS	Environmental control/life support system costs for a given component, NR-$, R-$/yr.
ECLSS$	Cost of environmental control/life support system, STS LIOH based, $. **Index to FY93.**
ELEC	Electrical system costs for a given component, NR-$, R-$/yr.

ENGSUP	Engineering and technical support for operations, $/yr.
FLGDEN	Fuselage density, lb/ft^3.
FLIGHT	Per flight basis.
FOM	Facility operations and maintenance costs, $/yr.
FP	Flight provision costs for a given component, NR-$, R-$/yr.
FUSAREA	External area of fuselage including canopy, ft^2.
FUSVOL	Fuselage volume, ft^3.
F/Y	Flights per year
GSE	Ground support equipment costs, $.
HRPMIS	Hours per mission.
HYDR	Hydraulics system costs for a given component, NR-$, R-$/yr.
ICALSF	Initial CALS factor.
ICBTF	Initial CBT factor.
ILSM	ILS management costs, $.
IILSM	Initial ILS management.
IMWC	Inventory management and warehousing costs, $.
ITCT	Initial training course time, hrs.
IWMH	Initial warehouse manhours.
LDOC	Cost for initial documentation, $.
LDGBRK	Number of landing gear brakes.
LDNGWT	Maximum basic mission weight, lbs.
LENSPN	Vehicle length plus wing span, ft.
LFROPS	Annual cost of launch, flight and recovery, $/yr.
LG	Landing gear system costs for a given component, NR-$, R-$/yr.
LR	Launch rate per vehicle.
LRU	Number of line replaceable units.
LSAL	Logistics salary, $/hr. **Index to FY93.**
LSI	Initial spares cost, $.
LSR	Recurring spares cost, $/yr.
MANUAL	Manual costs, $.
MAT	Facility material costs, $/yr.
MAXMCH	Vehicle speed in terms of maximum mack number, ratio. Does not include re-entry speeds. Typically up to mach 7.
MD	Mission duration, hr.
MPSFW	Main propulsion system fuel weight, lbs.
MPSFW$	Main propulsion system fuel cost, $/lb. **Index to FY93.**
MPSOW	Main propulsion system oxidizer weight, lbs.
MPSOW$	Main propulsion system oxidizer cost, $/lb. **Index to FY93.**
MR/F	Maintenance removals per flight.
MSILRU	Maintenance Significant Items (MSI) LRUs.
MVSQ	Mass times velocity squared, lb x knots
NANTNA	Number of antennas.
NASAEN$	NASA engineering support costs, $/yr.
NCONSUM	Nonrecurring consumables costs, $.
NDEPTNG	Nonrecurring depot training costs, $.
NDMANUAL	Nonrecurring depot manual costs, $.
NDSE	Nonrecurring depot support equipment costs, $.
NGSE	Nonrecurring ground support equipment costs, $.
NHS	Nonrecurring hardware spares costs, $.
NHYDSP	Number of hydraulic supply systems.
NHYDSS	Total number of hydraulic subsystems.
NHYPMP	Number of hydraulic pumps.

NILSMC	Nonrecurring ILS management costs, $.
NIMWC	Nonrecurring inventory management and warehousing costs, $.
NOACTS	Number of flight control actuators.
NOCREW	Number of crew members.
NOCTSU	Number of control surfaces.
NOENG	Number of engines per stage/element.
NOGEN	Number of generators.
NOMANUAL	Nonrecurring organization manual costs, $.
NORGTNG	Nonrecurring organizational training costs, $.
NOSEAT	Number of seats per aircraft, including bunks.
NOWHEL	Number of primary landing gear wheels used in taxi, takeoff, and landing.
NTRANS	Nonrecurring transportation costs, $.
OMANUAL	Organization manual costs, $.
OMPC	Org manual page count.
OMSFW	Orbital maneuvering system fuel weight, lbs.
OMSFW$	Orbital maneuvering system fuel cost, $/lb. **Index to FY93.**
OMSOW	Orbital maneuvering system oxidizer weight, lbs.
OMSOW$	Orbital maneuvering system oxidizer cost, $/lb. **Index to FY93.**
OPTR	Organization personnel turnover rate.
OPYR	Number of operating years.
ORGTNG	Organizational training costs, $.
OTHER	Other facility costs, $/yr.
PCR	Page change rate.
PC$	Page change costs, $. **Index to FY93.**
PDR	Payload deployment and retrieval system costs for a given component, NR-$, R-$/yr.
PERS	Facility personnel costs, $/yr.
PP/SRU	Piece parts per SRU.
PRICMP	Number of primary compartments.
PWT	Packaging weight tax.
QF	Quantity of stages flown (clustering, if applicable, must be included)
RCALSF	Recurring CALS factor.
RCONSUM	Recurring consumables costs, $.
RCSFW	Reaction control system fuel weight, lbs.
RCSFW$	Reaction control system fuel cost, $/lb. **Index to FY93.**
RCSOW	Reaction control system oxidizer weight, lbs.
RCSOW$	Reaction control system oxidizer cost, $/lb. **Index to FY93.**
RDEPTNG	Recurring depot training costs, $.
RDMANUAL	Recurring depot manual costs, $.
RDSE	Recurring depot support equipment costs, $.
RECDIST	Recovery distance, mi.
RECTRP$	Recovery transporter cost per lb-mi, $/lb-mi. **Index to FY93.**
RGSECF	Recurring GSE cost factor.
RHS	Recurring hardware spares costs, $.
RIF	Recurring inventory factor.
RILSM	Recurring ILS management.
RILSMC	Recurring ILS management costs, $.
RIMWC	Recurring inventory management and warehousing costs, $.
ROMANUAL	Recurring organization manual costs, $.
RORGTNG	Recurring organizational training costs, $.

RTAT	Depot repair turnaround time.
RTF	Recurring training factor.
SE	Sustaining engineering cost for total refurb subsystems, less engines, in $M
SECURITY	Annual security costs, $/yr.
SENG	Sustaining engineering cost of refurb engines, in $M
SLRU	Number of spare LRUs.
SNKSPD	Sink speed, maximum vertical landing velocity the vehicle can withstand, .
SRU/LRU	Number of SRUs per LRU.
SSPODWT	SSP Orbiter dry weight.
STAFF$	Annual cost of staff personnel, $/yr.
STRUC	Structural costs for a given component, .
SUBSYS	Number of subsystems.
TECH	Number of technicians.
TECHSAL	Technician salary, $/hr. **Index to FY93.**
TFF	Date of first flight of vehicle design expressed as months since 1 January 1950, months.
TGWMAX	Maximum takeoff gross weight, lbs.
TMP$	Technical manual page costs, $. **Index to FY93.**
TNG	Training costs, $.
TOPERS	Total number of crew members plus passengers.
TOTAVS	Total number of avionic AN nomenclature subsystems per vehicle. If two identical subsystems are used, count as two.
TOTELSUP	Annual cost of DoD stage/element support, $/yr.
TOTKVA	Total kVa maximum design. Total normal electrical power output capability of engine, auxiliary power unit driven generators/alternators, kVa.
TPSF	Thermal Protection System factor.
TRANS	Transportation costs, $.
TRANSP$	Transporter cost per lb-mi, $/lb-mi. **Index to FY93.**
TWTAREA	Total external surface area of vehicle, ft^2.
UPC	Unit production cost, $. **Index to FY93.**
UTLRAT	Hours of flight time, including time in orbit, per year.
VDWT	Vehicle dry weight, lbs.
VEH	Number of vehicles.
VGSE	Vehicle GSE, with or without ECLSS, $. **Index to FY93.**
VTT	Vehicle turnaround time.

FORMULAE

MAINTENANCE

Refurbishment

PREVAIL ($FY77)

REFURB=CWS+CRE+CRSRM Hardware

$CWS=\underline{QF}(0.02)\underline{AVST}+(0.05)\underline{SE}$

$CRE=\underline{NOENG}(\underline{QF})(0.1)\underline{AVCE}+(0.1)\underline{SENG}$

Depot Maintenance

Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles ($FY85)

DM=DMP+DMM ($/F) Depot maintenance

DMP=STRUCP+LGP+PDRP+AVP+ELECP+HYDRP+ECLSP+FPP+DOCKP Personnel

$STRUCP=5466.0*\underline{UTLRAT}^{0.17293}*\underline{TWTAREA}^{0.5389}$

$LGP=1436.4*\underline{NOWHEL}^{0.30068}*\underline{LDNGWT}^{0.42521}$

$PDRP=350.272*\underline{CARVOL}^{0.55731}*\underline{TOPERS}^{0.022272}$

$AVP=4053.0*\underline{TOTKVA}^{0.64027}*\underline{TOTAVS}^{0.30348}$

$ELECP=256.191*\underline{NOCTSU}^{1.2603}*(\underline{UTLRAT}/\underline{F/Y})^{0.30284}$

$HYDRP=32661.8*\underline{NOCTSU}^{0.3451}*\underline{NHYPMP}^{0.70715}$

$ECLSP=3938.44*\underline{HRPMIS}^{0.36061}*\underline{FUSVOL}^{0.36541}$

$FPP=5.65649*\underline{LENSPN}^{0.97927}*\underline{TFF}^{0.19409}$

$DOCKP=0.0612697*\underline{CARFLA}^{0.040297}*\underline{TGWMAX}^{0.6539}$

DMM=STRUCM+LGM+PDRM+AVM+ELECM+HYDRM+ECLSM+FPM+DOCKM Hardware

$STRUCM=33844.1*\underline{TWTAREA}^{0.40781}$

$$LGM=939.794*\underline{LENSPN}^{0.66587}*\underline{LDGBRK}^{0.60526}$$

$$PDRM=9.65239*\underline{CARVOL}^{0.44168}*\underline{CARGWT}^{0.39999}$$

$$AVM=4.1221*\underline{AVINWT}^{0.38875}*\underline{NANTNA}^{2.8235}$$

$$ELECM=148.709*\underline{CARFLA}^{0.93869}*\underline{TOTKVA}^{0.13678}$$

$$HYDRM=0.738358*\underline{LENSPN}^{2.1815}*\underline{NHYDSP}^{0.15009}$$

$$ECLSM=196.918*\underline{TOPERS}^{0.0031839}*\underline{FUSVOL}^{0.69177}$$

$$FPM=0.00321882*\underline{LENSPN}^{2.1661}*\underline{PRICMP}^{0.34181}$$

$$DOCKM=0.0560647*\underline{CARFLA}^{0.67061}*\underline{LENSPN}^{0.93312}$$

LOGISTICS

Spares (initial)

Advanced Manned Launch System ($FY93)

MHS=(1-COTS%)*CF*SLRU*ALRUCOST ($) Hardware

Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles ($FY85)

LSI=STRUCSI+LGSI+PDRSI+AVSI+ELECSI+HYDRSI+ECLSSI+FPSI+DOCKSI ($) Hardware

$STRUCSI=4.08905*\underline{TWTAREA}^{1.4795}*\underline{MAXMCH}^{0.8881}$

$LGSI=1.14042*\underline{TGWMAX}^{1.0393}$

$PDRSI=0.025*UPC$

$AVSI=9675.31*\underline{AVINWT}^{0.78372}*\underline{FLGDEN}^{0.37412}$

$ELECSI=932.337*\underline{MAXMCH}^{0.62003}*\underline{TOTKVA}^{0.7465}$

$HYDRSI=3.1879*\underline{LENSPN}^{1.8749}*\underline{MAXMCH}^{0.8138}$

$ECLSSI=2.86158*(\underline{BTUPHR}*\underline{TOPERS})^{0.6701}*\underline{TOTKVA}^{1.0107}$

$FPSI=14.4453*\underline{MAXMCH}^{0.72729}*\underline{FUSVOL}^{0.6217}$

$DOCKSI=0.00514174*\underline{TWTAREA}^{1.4795}*\underline{MAXMCH}^{0.8881}$

Spares (Recurring)

Advanced Manned Launch System ($FY93)

RHS=(F/Y)*OPYR*(MR/F)*CR*ALRUCOST*CF ($) Hardware

Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles ($FY85)

LSR=STRUCSR+LGSR+PDRSR+AVSR+ELECSR+HYDRSR+ECLSSR+FPSR+DOCKSR ($/F) Hardware

$STRUCSR=1310.2*\underline{UTLRAT}^{0.44611}*\underline{TWTAREA}^{0.42599}$

$LGSR=2877.49*\underline{NOWHEL}^{0.9313}*\underline{MVSQ}^{0.2789}$

$PDRSR=10.6276*\underline{CARVOL}^{0.20537}*\underline{CARGWT}^{0.70128}$

$AVSR=10.799*\underline{TOTKVA}^{.89189}*\underline{AVNCWT}^{.68652}$

$ELECSR=115.132*\underline{CARFLA}^{0.9355}*\underline{NOGEN}^{0.95695}$

$HYDRSR=0.290026*\underline{LENSPN}^{2.3754}*\underline{NHYPMP}^{0.21649}$

$ECLSSR=57.1462*\underline{HRPMIS}^{0.29514}*\underline{FUSVOL}^{0.66886}$

$FPSR=0.0344495*\underline{PRICMP}^{0.56086}*\underline{LENSPN}^{2.1661}$

$DOCKSR=0.0938672*\underline{CARGWT}^{0.57147}*\underline{CARVOL}^{0.36911}$

Consumables

Advanced Manned Launch System

CONSUM=NCONSUM+RCONSUM

$$NCONSUM=3*\sum_{MPS}^{RCS}\{(FW*F\$/LB)+(OW*O\$/LB)\} \qquad (\$)$$

RCONSUM=

$$\left[\sum_{MPS}^{RCS}\{[(FW*(F\$/LB))+(OW*(O\$/LB))]\div FLIGHT\}+\{(CREW*(MD/48)*ECLSS\$)\div FLIGHT\}\right]*(F/Y)*OPYR$$

($/Yr)

Inventory Management & Warehousing

Advanced Manned Launch System

IMWC=NIMWC+RIMWC+GSE

$NIMWC=NHS*\{1+((\underline{SRU/LRU})*(1+(\underline{PP/SRU})))\}*\underline{IWMH}*\underline{LSAL}$ ($)

$RIMWC=(NHS+RHS)*\underline{RIF}*\underline{OPYR}$ ($/Yr)

Training

Advanced Manned Launch System

TNG=ORGTNG+DEPTNG

ORGTNG=NORGTNG+RORGTNG

NORGTNG=(SUBSYS*CF*(1-COTS%)*BCBT$*ICBTF*ITCT)
+(ICBTF*ITCT*TECH*TECHSAL) ($)

RORGTNG={(BCBT$*ICBTF*RTF*ITCT*SUBSYS)
+(ITCT*ICBTF*TECH*TECHSAL*OPTR)}*OPYR ($/Yr)

DEPTNG=NDEPTNG+RDEPTNG

NDEPTNG=(MSILRU*DF*CF*(1-COTS%)*BCBT$*ICBTF*DITCT)
+(ICBTF*DITCT*DTECH*DTECHSAL) ($)

RDEPTNG={(BCBT$*ICBTF*RTF*DITCT*MSILRU*DCF)
-(DITCT*ICBTF*DTECH*DTECHSAL*DPTR)}*OPYR ($/Yr)

Documentation

Advanced Manned Launch System

MANUAL=OMANUAL+DMANUAL

OMANUAL=NOMANUAL+ROMANUAL

NOMANUAL=MSILRU*CF*(1-COTS%)*OMPC*TMP$*ICALSF ($)

ROMANUAL=MSILRU*OMPC*PC$*PCR*OPYR*RCALS$ ($/Yr)

DMANUAL=NDMANUAL+RDMANUAL

NDMANUAL=MSILRU*DF*CF*(1-COTS%)*DMPC*TMP$*ICALSF ($)

RDMANUAL=MSILRU*DCF*CF*DMPC*PC$*PCR*OPYR*RCALS$ ($/Yr)

Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles

LDOC=STRUCLD+LGLD+PDRLD+AVLD+ELECLD+HYDRLD+ECLSLD+FPLD+DOCKLD
($) or ($/Yr)

STRUCLD=401.439*TGWMAX$^{0.6394}$

$LGLD=214.6*\underline{TFF}^{0.6664}*\underline{SNKSPD}^{0.30877}$

PDRLD=0.01*UPC.

$AVLD=142345*\underline{AVNCWT}^{0.091207}$

$ELECLD=38.7703*\underline{TOTKVA}^{1.0292}$

$HYDRLD=741.81*\underline{NOACTS}^{0.95341}$

$ECLSLD=29077.9*\underline{AVNCWT}^{0.18719}$

$FPLD=15.5429*\underline{NOSEAT}^{0.70674}*\underline{TFF}^{0.9167}$

$DOCKLD=0.517318*\underline{TGWMAX}^{0.6394}$

Transportation

Advanced Manned Launch System

TRANS=NTRANS+RTRANS

NTRANS=VEH*(VDWT*PWT)*DIST*TRANSP$ ($)

RTRANS={(F/Y)*OPYR*(VDWT*PWT)*RECDIST*RECTRP$}
+{(F/Y)*OPYR*(MR/F)*((VDWT/LRU)*PWT)*DDIST*DEPTRP$} ($/Yr)

Support Equipment

Advanced Manned Launch System

GSE=NGSE+RGSE Hardware

NGSE=(VDWT/SSPODWT)*CF*(1-COTS%)*{(LR*VEH*VTT)/(12*4*60)}*VGSE
($)

RGSE=NGSE*RGSECF*OPYR ($/Yr)

DSE=NDSE+RDSE Hardware

NDSE={DCF*(1-COTS%)*((LR*VEH*VTT)/(18*4*60))*DSE$}
If ATE is available for avionics testing
+{ATE+(TPSF*DCF*MSILRU*AFLRU)} ($)

RDSE=NDSE*RGSECF*OPYR ($/Yr)

ILS Management

Advanced Manned Launch System

ILSM=NILSM+RILSM

$$NILSM = \sum ANLCE * IILSM \qquad (\$)$$

$$RILSM = \sum ARLCE * RILSM \qquad (\$/Yr)$$

System Support Activities

Support

Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles

Unit level personnel other (administrative, planning) (FY85)

SS-AP=0.2*(AIRCREW$+COMSTAF$) ($/YR) Personnel

$AIRCREW\$=0.21458*\underline{NOCREW}^{1.6422}*\underline{VEH}^{0.89681}$

$COMSTAF\$=0.21458*\underline{UTLRAT}^{0.50621}*\underline{VEH}^{0.89225}$

PREVAIL

Unit level personnel other (engineering) Personnel

ENGSUP=NASAEN$+DODEN$

NASAEN$=0.05*<u>LFROPS</u>

DODEN$=0.03*<u>TOTELSUP</u>

Facility O&M

Exploration of Facility Life Cycle Cost Modeling for Conceptual Space Systems

FOM=MAT+CONT+OTHER+PERS ($/Yr-Vehicle)

MAT=94327.79+0.6206(<u>VDWT</u>)-301.5694(<u>LENSPN</u>) Hardware
-4787331(1/<u>LENSPN</u>)-6.5950(<u>FUSAREA</u>)

CONT=94577.05-4938749(1/<u>LENSPN</u>)+935698.6(1/<u>TWTAREA</u>)
+5741874(1/<u>FUSVOL</u>)-379.7252(<u>NHYDSS</u>)

OTHER=16578.32-0.8060(<u>TWTAREA</u>)+18456.13(ln(<u>NOENG</u>))

PERS=174076.9-10100000(1/<u>LENSPN</u>) Personnel

Base Operations

Conceptual Design and Analysis of Hypervelocity Aerospace Vehicles

Security (FY85)

SEC=0.07*(AIRCREW$+COMSTAF$) ($/YR) Personnel

$$\text{AIRCREW\$} = 0.21458 * \underline{\text{NOCREW}}^{1.6422} * \underline{\text{VEH}}^{0.89681}$$

$$\text{COMSTAF\$} = 0.21458 * \underline{\text{UTLRAT}}^{0.50621} * \underline{\text{VEH}}^{0.89225}$$

Appendix E

COSTING MODEL - SOURCE LISTING

Module Definitions:

LCC.BAS primary input file - contains main menu, initialization and data input

CST - cost parameter input/display
DATAIN - read in input data from a file
DRIVERS - design/performance variable input/display
INFA - inflation factor computations
INPT - contains input menu
MISC - miscellaneous factors input/display (LOG model)
RAMI - read in data from RAM model
SAVE - saves input data
SYS - system parameter table - input/display
WBSS - cost element structure input/display

LCC2.BAS computational file - evaluates all equations
COMP - main computational module for CES calculations
DRIVER - calls other computational modules in the proper order
FACILITY - computes facility O&S costs
ORG - computes organization maintenance personnel & hardware costs
OS - secondary calculations for HYP model
SECOND - evaluates regression equations for design/performance variables
TOT - performs a cost structure roll-up to the higher levels

LCC3.BAS - output file
DISMENU - displays output menu
DISMAN - displays organizational maintenance manpower results
DISWBS - genertes primary output screen by CES
SPTC - displays systsem support costs
FACCOST - displays facility O&S costs
HYPDIS - displays hypervelocity model output in detail
LOGS - display logistics cost model output in detail
(plus corresponding print modules)

note: Several modules contained in the files and not listed above are currently not in use. They pertain to development and acquisition cost equations which are not being evaluated.

```
DECLARE SUB REPORT ()
DECLARE SUB DATAIN ()
DECLARE SUB DISWBS ()
DECLARE SUB SAVE ()
DECLARE SUB SECOND ()
DECLARE SUB MISC ()
DECLARE SUB totdd ()
DECLARE SUB year2 ()
DECLARE SUB dismenu2 ()
DECLARE SUB WBSS ()
DECLARE SUB FACCOST ()
DECLARE SUB INFBED ()
DECLARE SUB INFBA ()
DECLARE SUB INFLATE ()
DECLARE SUB FCONST ()
DECLARE SUB DISMENU ()
DECLARE SUB SUBSYS ()
DECLARE SUB DRIVERS ()
DECLARE SUB SOFT ()
DECLARE SUB WGT ()
DECLARE SUB DRIVER ()
DECLARE SUB CST ()
DECLARE SUB SYS ()
DECLARE SUB RAMI ()
DECLARE SUB INIT ()
DECLARE SUB FILEI ()
DECLARE SUB INPT ()
DECLARE SUB COMPUTE ()
DECLARE SUB DISPLAY ()
DECLARE SUB FILEO ()
DECLARE SUB INFLBA ()
DECLARE SUB INFLBED ()
DECLARE SUB INFLCC ()
DECLARE SUB WBSS ()
'
'NASA LANGLEY RESEARCH CENTER
'LIFE CYCLE COST MODEL developed by University of Dayton,
'EMS Department, Dayton, Ohio 45469-0236,
'Dr. Charles Ebeling, Kenneth Beasley, (513) 229-2238, (f) (513) 229-2698,
'Under NASA Contract NAG1-1327, June, 1994
'save as LCC.BAS
'
COMMON SHARED VNAM$, SMP, TME, TMF, SDE, STE, SUP, TW, AF, FLCC, INFB, INFBDd, I
COMMON SHARED TFCC, TFSC, MAT, CNT, OTH, PER, FAF, AMMC, TMMC, inx, year
COMMON SHARED MM, TDSC, ADJ, INST, INTEG, RESO, APPL, CPLX, UTIL, FLTFM, WEIGHT
COMMON SHARED vs$, selv, wbs, totd, AVWT, lcf, inxf, TOMO, lctot
COMMON SHARED SI, RS, NC, RC, NIMWC, RIMWC, RGSE, NGSE, N1, N2, N3, N4, M1, M2,
COMMON SHARED AC, CS, HYPS, PRVS1, PRVS2, SEC, RTITLE$, OVH
DIM SHARED wbs$(2, 60), P$(15), XP(25), X(20), V(12), wb$(15), isc(20, 20)
DIM SHARED W(35), S(35), MP(35), CF$(30), XCF(30), AMC(2, 50), MC(2, 50), id(5),
DIM SHARED A(50, 3), B(50, 3), DE(16), TE(16), UP(16), WT(15), HYP$(16), rncs(10
DIM SHARED CF(35), LCS(35), QTY(35), VX$(60), VX(60), mh(20), rd(10), OSCL$(10)
DIM SHARED FSQ(20), FC(20), F$(20), FCC(20), mhc(20), rdc(10), ism(20, 10), INFf
DIM SHARED TOTH(10), TOTV(10), wbsc(4, 50), wbscc(50), MF$(40), MCF(40)
DIM SHARED HP(10), HH(10), HS(10), HR(10), HD(10), infv(50), OPH(35), OMO(10), O
COMMON SHARED HP(), HH(), HS(), HR(), HD()
COMMON SHARED wbs$(), PH$(), P$(), XP(), X(), V(), wb$(), isc()
COMMON SHARED W(), S(), MP(), CF$(), XCF(), AMC(), MC(), id(), DC()
COMMON SHARED A(), B(), DE(), TE(), UP(), WT(), HYP$()
COMMON SHARED CF(), LCS(), QTY(), VX$(), VX(), mh(), rd(), OSCL$()
COMMON SHARED FSQ(), FC(), F$(), FCC(), mhc(), rdc(), ism(), INFf()
COMMON SHARED TOTH(), TOTV(), wbsc(), wbscc(), MF$(), MCF(), infv(), OPH(), OMO(

'BEGIN PROGRAM
'  ON ERROR GOTO ERRSUB
'
' disp' display banner

CLS : COLOR 8
PRINT "Doug Morris, LaRC"
PRINT "NASA Grant NAG1-1327"
PRINT "Dr. Charles Ebeling and"
PRINT "Kenneth Beasley"
PRINT "University of Dayton"
PRINT "300 College Park"
PRINT "Dayton, Ohio 45469-0236"
PRINT "(513) 229-2238"
PRINT " June 1994"
COLOR 10

LOCATE 12, 20: PRINT "NASA - LANGLEY RESEARCH CENTER"
PRINT TAB(20); "OPERATIONS & SUPPORT COSTING MODEL";
COLOR 9: LOCATE 16, 20: PRINT "ENTER VEHICLE NAME   ";
COLOR 14: INPUT "", VNAM$

'
GOSUB INIT  'initialize all arrays, constants to default values
'
'  main menu
TOP: CLS : COLOR 12
PRINT : PRINT TAB(20); "LIFE CYCLE COST MODEL"
PRINT : PRINT TAB(22); "VEHICLE IS ";
COLOR 11: PRINT VNAM$
COLOR 15: PRINT : PRINT TAB(25); "MAIN MENU": COLOR 14
PRINT : PRINT TAB(17); "OPTION                        NBR":
COLOR 3: PRINT
PRINT TAB(15); "INPUT FROM RAM MODEL...........1"
PRINT TAB(15); "GO TO INPUT MENU...............2"
      COLOR 10
PRINT TAB(15); "DISPLAY RESULTS................3"
      COLOR 3
PRINT TAB(15); "REPORT GENERATOR...............4"
PRINT TAB(15); "SAVE INPUT VALUES..............5"
PRINT TAB(15); "READ INPUT DATA FROM FILE......6"
PRINT TAB(15); "CHANGE VEHICLE/FILE NAME.......7"
PRINT TAB(15); "TERMINATE SESSION..............8"
COLOR 2
LOCATE 22, 15: INPUT "ENTER SELECTION ", nbr

IF nbr = 1 THEN CALL RAMI
IF nbr = 2 THEN CALL INPT
IF nbr = 3 THEN
        CALL DRIVER
        CALL DISMENU
END IF
IF nbr = 4 THEN
        CALL DRIVER
        CALL REPORT
END IF
IF nbr = 5 THEN CALL SAVE
```

```
IF nbr = 6 THEN CALL DATAIN
IF nbr = 7 THEN GOSUB NAM
IF nbr = 8 THEN GOTO BT1
GOTO TOP

NAM:  CLS : COLOR 10
LOCATE 10, 20: PRINT "CURRENT VEHICLE/FILE NAME IS ";
COLOR 7: PRINT ""; VNAM$
COLOR 10: LOCATE 12, 20: PRINT "ENTER NEW NAME ";
COLOR 11: INPUT "", VNAM$
RETURN
'
INIT: 'INITIALIZATION SUBROUTINE
'
X(11) = 144      ' manh/mo factor
FOR I = 1 TO 2
        FOR j = 1 TO 60
                wbs$(I, j) = " "
        NEXT j
NEXT I
FOR I = 1 TO 57       '       Vehicle WUC
        READ wbs$(2, I)
NEXT I
FOR I = 1 TO 45       '       NASA WBS (CES)
        READ wbs$(1, I)
        NEXT I
FOR I = 1 TO 12
        READ P$(I), XP(I)   ' SYSTEM PARAMETERS
NEXT I
FOR I = 1 TO 29       'COST FACTORS
        READ CF$(I), XCF(I)
NEXT I

FOR I = 1 TO 39
        READ MF$(I), MCF(I)    ' MISC factors
NEXT I

FOR j = 1 TO 3
        FOR I = 1 TO 42
                READ A(I, j), B(I, j)  ' PWR FUNCTION PARAMETERS
        NEXT I
NEXT j
FOR I = 1 TO 34
        CF(I) = 1: LCS(I) = .9: QTY(I) = 1 'COMPLXTY FAC, LEARNING CURVE SLOPE,
NEXT I
CF(34) = .9: QTY(34) = 4

FOR I = 1 TO 53
        READ VX$(I), VX(I)    ' DESIGN/PERFORMANCE VARIABLES
NEXT I
FOR I = 1 TO 16
        READ F$(I), FC(I)    'FACILITY COSTS
NEXT I

FOR I = 1 TO 16
  READ HYP$(I)    'HYPERVELOCITY WBS
NEXT I

FOR I = 1 TO 15
        READ wb$(I)  'PREVAIL model
NEXT I

FOR I = 1 TO 9
        READ OSCL$(I)   'O&S COST CATEGORIES
NEXT I

lccl = 0
thn = 0
INFBDd = 1.381820452#   'inflation from 1993 to base year of 2000
INFB = 1!              'inflation to base year
INFLC = 2.049426384#   'inflation from 2000 to 2015 - life cycle of vehicle

FOR I = 0 TO 7
        READ INFf(I)
NEXT I
'
' Input the WBS costs.  1=default costs,  2=computed costs.
'
FOR I = 1 TO 45
       READ wbsc(1, I)
       wbsc(3, I) = wbsc(1, I)
NEXT I

FOR I = 1 TO 20
        wbscc(I) = 1
NEXT I
wbscc(11) = 2
FOR I = 21 TO 41
        wbscc(I) = 2
NEXT I
FOR I = 42 TO 45: wbscc(I) = 1: NEXT I

FOR I = 1 TO 9: READ OMO$(I): NEXT I            'org maint overhead

IF year = 0 THEN year = XP(4) + XP(7)

RETURN

BT1: CLS : COLOR 3
LOCATE 10, 20: INPUT "DO YOU WISH TO SAVE INPUT VALUES - (Y/N)"; ANS$
IF ANS$ = "Y" OR ANS$ = "y" THEN CALL SAVE
LOCATE 14, 20: PRINT "SESSION TERMINATED"
END

ERRSUB: 'ERROR HANDLING ROUTINE
       IF ERR = 53 OR ERR = 61 OR ERR = 71 OR ERR = 25 OR ERR = 27 OR ERR = 68 T
          IF ERR = 25 THEN PRINT "DEVICE FAULT"
          IF ERR = 27 THEN PRINT "OUT OF PAPER"
          IF ERR = 68 THEN PRINT "DEVICE UNAVAILABLE"
          IF ERR = 53 THEN PRINT "FILE NOT FOUND"
          IF ERR = 61 THEN PRINT "DISK FULL"
          IF ERR = 71 THEN PRINT "DISK NOT READY"
          INPUT "ENTER RETURN"; RET
          RESUME TOP 'MAIN MENU
       ELSE
          PRINT "UNRECOVERABLE ERROR"
          ON ERROR GOTO 0
       END IF

10000 'INPUT DATA
```

```
10005 DATA 1.00 WING GROUP,2.00 TAIL GROUP,3.00 BODY GROUP
10007 DATA 3.10 TANKS-LOX,3.20 TANKS-LH2,4.10 IEP-TILES,4.20 IEP-TCS
10008 DATA 4.30 IEP-PVD
10010 DATA 5.00 LANDING GEAR,6.00 PROPULSION-MAIN,7.00 PROPULSION-RCS
10020 DATA 8.00 PROPULSION-OMS,9.10 POWER-APU,9.20 POWER-BATTERY
10022 DATA 9.30 POWER-FUEL CELL,10.00 ELECTRICAL
10030 DATA 11.00 HYDRAULICS/PNEUMATICS,12.00 AERO SURF ACTUATORS
10033 DATA 13.10 AVIONICS-GN&C,13.20 AV-HEALTH MONITOR
10034 DATA 13.30 AVIONICS-COMM & TRACK,13.40 AV-DISPLAYS & CONTR
10035 DATA 13.50 AVIONICS-INSTRUMENTS,13.60 AVIONICS-DATA PROC
10040 DATA 14.10 ENVIRONMENTAL CONTROL,14.20 ECS-LIFE SUPPORT
10050 DATA 15.00 PERSONNEL PROVISIONS, 16.10 REC & AUX-PARACHUTES
10055 DATA 16.20 REC & AUX-ESCAPE SYS,16.30 REC&AUX-SEPARATION
10056 DATA 16.40 REC&AUX-CROSS FEED
10060 DATA 16.50 REC & AUX DOCKING SYS,16.60 REC&AUX MANIPULATOR
10070 DATA 17.00 PERSONNEL CREW GEAR,18.00 PAYLOAD PROVISIONS
10080 DATA 19.00 CARGO (RETURN), 20.00 RESIDUAL FLUIDS, 21.00 RESERVES
10090 DATA 22.00 RCS PROP, 23.00 ACS PROP, 24.00 CARGO (DEL), 25.00 (ASCENT RES)
10100 DATA 26.00 INFLIGHT LOSSES, 27.00 ASCENT PROPELLENT, 28.00 PRE-LAUNCH LOSS
10110 DATA EXT TANK, ELECTRICAL, PROP/FLUIDS,RANGE SAFETY, STRUCTURES, TPS
10120 DATA SRB,ELECTRICAL, PROP/FLUIDS, RANGE SAFETY, STRUCTURES, TPR
' BEGIN LIFE CYCLE PHASE INPUT
DATA 2.1  Concept Devl (R&D), 2.1.1  Tech Prog, 2.1.2  Phase A/B Cont
DATA 2.2  Acquisition (Invst), 2.2.1  Design & Devl, 2.2.2  Production
DATA 2.2.3  Integration, 2.2.4  Test & Eval, 2.2.5  Prog Mgmt & Spt
DATA 2.2.6  Prog Sys Eng, 2.3  Program Oper & Spt
DATA 2.3.1  Operations, 2.3.1.1  Processing Ops, 2.3.1.2  Integration Ops, 2.3.1
DATA 2.3.1.4  Transfer, 2.3.1.5  Launch Operations, 2.3.1.6  Mission Ops, 2.3.1.
DATA 2.3.1.8  Non-nom Ops
DATA 2.3.2  Maintenance, 2.3.2.1  Refurbishment, 2.3.2.2  Org Maintenance
DATA 2.3.2.3  Depot Maintenance, 2.3.2.4  Modifications, 2.3.2.5  Verify and Che
DATA 2.3.3  Logistics, 2.3.3.1  Spares, 2.3.3.2  Expendables, 2.3.3.3  Consumabl
DATA 2.3.3.4  Inv Mgmt & Warehse, 2.3.3.5  Training, 2.3.3.6  Documentation
DATA 2.3.3.7  Transportation, 2.3.3.8  Support Equip, 2.3.3.9  ILS Management
DATA 2.3.4  System Support, 2.3.4.1  Support Staff, 2.3.4.2  Facility O&M, 2.3.4
DATA 2.3.4.4  Base Ops, 2.3.4.5  Pre/post lch cleanup, 2.3.5  Program Support
DATA 2.3.6  R&D, 2.4  Prog Phaseout
' BEGIN SYS PARAMETERS
DATA NBR OF VEHICLES,4
DATA FLIGHTS/YR,4
DATA HOURS/MISSION,120
DATA SYS LIFE IN YRS, 11
DATA BASE YEAR $, 1993
DATA CONSTANT $'s 0-NO/1-YES,1
DATA INITIAL BEDDOWN, 2000
DATA reserved,0
DATA FUTURE INFLATION RATE, .049
DATA reserved, 0
DATA TFF (mo since Jan50), 600
DATA LOG COST MODEL-0 HYPERVEL-1,0

' BEGIN COST FACTORS
DATA Avg Cost of Prod Engines $M,4
DATA Base Lvl Support Staff salary-$/hr,15.00
DATA AVG Cost of Prod stages - eng/SRM-$M,100
DATA Average LRU Cost-$, 129930
DATA ORG Technician salary - $/hr,22.37
DATA reserved,0
DATA Depot Technician Salary - $/hr,25.94
DATA Logistics Salary - $/hr,20.44
```

```
DATA Basic CBT cost-$/hr,13396
DATA Depot Transporter Cost-$/lb-mi,.000203
DATA DSE Costs-$K,5825000
DATA ECLSS Cost-$,8313
DATA Page Change Cost,249
DATA Rec Transporter Cost $/lb-mi,.000705
DATA Transporter Cost $/lb-mi,.000705
DATA Vehicle GSE-$K,506862
DATA Annual Cost of DoD stage/element spt,0
DATA MPS Fuel Cost - $/lb,2.8
DATA MPS Oxidizer Cost - $/lb,.028
DATA OMS Fuel Cost - $/lb,.17
DATA OMS Oxidizer Cost - $/lb,.0015
DATA RCS Fuel Cost - $/lb,.17
DATA RCS Oxidizer Cost - $/lb,.0015
DATA SE For Tot Refurb-$M,3
DATA SE For Refurb Eng-$M,2
DATA Reserved,0
DATA Tech Manual Page Costs,1136
DATA reserved,0
DATA ATE Costs,6989458

' BEGIN MISC FACTORS
DATA Avionics fraction of LRUs,.054
DATA Commonality Factor,1
DATA Percent Commercial Off-Shelf,.3
DATA Condemnation Rate (fraction) ,.025
DATA Depot Coverage Factor, .56
DATA Depot Distance - mi,30
DATA Depot Initial Trnging time - hrs,80
DATA Depot manual page count,75
DATA Org manual page count,75
DATA Page change rate,.1
DATA Depot Personnel turnover rate,.0611
DATA Org personnel turnover rate,.0611
DATA Nbr of Depot Technicians,15
DATA Initial CALS factor,.7
DATA Initial CBT Factor,.5
DATA Initial ILS Mgmt,.08
DATA Initial trng Course time - hrs,24
DATA Initial Warehouse manhrs , 2.4
DATA MPS Fuel Weight - lbs,227641
DATA MPS Oxidizer Wt - lbs, 1361936
DATA OMS Fuel Weight - lbs,9010
DATA OMS Oxidizer Wt - lbs, 14866
DATA RCS Fuel Weight - lbs,2954
DATA RCS Oxidizer Wt - lbs, 1853
DATA Piece Parts per SRU,10
DATA Packaging Wgt Tax,1.941
DATA Quantity of stages flown,1
DATA Recovery Distance - mi,2200
DATA Recurring GSE cost factor,.1
DATA Recurring Inventory Factor,.2
DATA Recurring ILS mgmt,.13
DATA Recurring training factor,.1
DATA Recurring CALS Factor,.3
DATA Nbr SRU's per LRU,8
DATA Nbr of ORG Technicians,1230
DATA TPS factor,320000
DATA NBR Spare LRU'S,432
```

```
DATA Depot Factor,.56
DATA Distance-Trans -MI,2100


'
' BEGIN POWER FCN PARAMETERS FOR DESIG, T&E, AND UNIT PROD CER'S
'
' winged
'
DATA .21457,.669,.1065,.675,.1250,.675,1.16056,.483,.22095,.677
DATA 2.39276,.575,.2487,.805,.508,.583,2.16075,.588,.04935,.736
DATA .101,.711,.16187,.736,.0241,.633,.0168,.678,.1236,.677
DATA .065,.7,.05,.7,.114,.745,.09172,.666,.5316,.67,.05356,.873
DATA .1229,.676,.324,.67,.0952,.642,5.595,.537,.357,.642,.0619
DATA .675,.0466,.675,.026926,.761,.03,.76,.0236,.76,.06936,.674
DATA .0202,.762,.105515,.762,.24058,.585,.0531,.762,.12288,.776
DATA .05929,.67,.0213,.74,.087318,.67,.002815,.758,.0044,.761
'
'lifting body
'
DATA .21457,.669,.1065,.675,.1250,.675,1.16056,.483,.22095,.677
DATA 2.39276,.575,.2487,.805,.508,.583,2.16075,.588,.04935,.736
DATA .101,.711,.16187,.736,.0241,.633,.0168,.678,.1236,.677
DATA .065,.7,.05,.7,.114,.745,.09172,.666,.5316,.67,.05356,.873
DATA .1229,.676,.324,.67,.0952,.642,5.595,.537,.357,.642,.0619
DATA .675,.0466,.675,.026926,.761,.03,.76,.0236,.76,.06936,.674
DATA .0202,.762,.105515,.762,.24058,.585,.0531,.762,.12288,.776
DATA .05929,.67,.0213,.74,.087318,.67,.002815,.758,.0044,.761
'
' ballistic
'
DATA .21457,.669,.1065,.675,.1250,.675,1.16056,.483,.22095,.677
DATA 2.39276,.575,.2487,.805,.508,.583,2.16075,.588,.04935,.736
DATA .101,.711,.16187,.736,.0241,.633,.0168,.678,.1236,.677
DATA .065,.7,.05,.7,.114,.745,.09172,.666,.5316,.67,.05356,.873
DATA .1229,.676,.324,.67,.0952,.642,5.595,.537,.357,.642,.0619
DATA .675,.0466,.675,.026926,.761,.03,.76,.0236,.76,.06936,.674
DATA .0202,.762,.105515,.762,.24058,.585,.0531,.762,.12288,.776
DATA .05929,.67,.0213,.74,.087318,.67,.002815,.758,.0044,.761
'
' BEGIN DESIGN/PERFORMANCE VARIABLES
DATA DRY WGT (LBS) , 223289
DATA VEH LENGTH+WING (ft), 200.33
DATA CREW SIZE, 8
DATA NBR PASSENGERS, 0
DATA NBR MAIN ENGINES, 3
DATA FUSELAGE AREA, 7650
DATA FUSELAGE VOLUME, 12013
DATA TOT WETTED AREA, 10873
DATA NBR WHEELS, 10
DATA NBR ACTUATORS, 35
DATA NBR CONTRL SURFACES, 6
DATA MAX KVA, 285
DATA NBR HYDR SUBSYS, 35
DATA NBR FUEL TANKS (internal),4
DATA TOT NBR AVIONICS SUBSYS, 31
DATA NBR DIFF AVIONICS SUBSYS, 16
DATA BTU/HR/person, 119
DATA TAKEOFF GVW-LBS, 232500
DATA SINK SPEED FT/SEC, 9
DATA PAYLOAD ARM LENGTH-METERS, 5.94
DATA TOT THRUST OF 1 MAIN ENGINE-LBS, 390068
DATA THRUST OF OME ENGINE-LBS, 4000
DATA THRUST OF RCS1-LBS, 825
DATA THRUST OF RCS2-LBS, 8
DATA JET-M3 THRUST-LBS, 52500
DATA TURBINE INLET TEMPERATURE-DEG R, 2828
DATA JET-M3 TTW, 6.1
DATA ENGINE MQT (yr-1900),100
DATA NUMBER OF JET-M3 ENGINES, 4
DATA LENGTH-FT, 122.2
DATA MIN LANDING DIST [FT],15000
DATA LANDING MASS*VEL^2-lbxknots,433.2
DATA LANDING WEIGHT, 202000
DATA NUMBER OF BRAKES/VEH, 5
DATA CARGO VOLUME [FT^3], 14152
DATA CARGO WEIGHT (PAYLOAD), 82729
DATA NUMBER OF POWERED EXITS, 2
DATA NUMBER OF ANTENNAS, 22
DATA CARGO FLOOR AREA [FT^2], 721
DATA NUMBER OF GENERATORS, 10
DATA NUMBER OF HYD. PUMPS, 18
DATA NUMBER OF HYD. SUPPLY SYS., 9
DATA NUMBER OF POSSIBLE EMERG. EXITS, 3
DATA NUMBER OF PRIMARY COMPARTMENTS, 4
DATA NBR OF SEATS INC BUNKS,8
DATA AVIONICS BLACK BOX WGT -LBS,4306
DATA AVIONICS INSTALL WGT -LBS,2239
DATA MAXMACH NBR,7
DATA LRU REMOVALS/FLIGHT,300
DATA VEH TURNAROUND TIME-DAYS?,55
DATA TOT NBR SUBSYSTEMS,105
DATA MAINT SIGNF ITEM-LRUs,40
DATA NBR LRU'S,500
'
'unused
'
'DATA NACELLE WETTED AREA,1
'DATA NBR PRIMARY COMPRTMTS,1
'DATA TAIL AREA,1
'DATA MAX TAKE-OFF WGT,1
'DATA CARGO FLOOR AREA (sq ft),1
'DATA CARGO WGT (lbs?),1
'DATA CARGO VOL(cu ft),1
'DATA INT FUEL WGT (lbs),1
'DATA GALS FUEL/HR,1
'DATA MAIN ENG THURST,1
'DATA OMS THURST,1
'DATA RCS THURST,1
'DATA MIN LANDING DIS (ft),1
'DATA MAX MACH NBR,7
'DATA NBR GENERATORS,1
'DATA TOT EVA,1
'
'FACILITY COST DATA
DATA COVERED MAINTENANCE [$/FT²], 132
DATA GENERAL MAINT SHOP [$/FT²],89
DATA AVIONICS SHOPS [$/FT²],117
DATA CORROSION CONTROL [$/FT²],128
```

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DATA ENGINE MAINTENANCE [$/FT²],88
DATA OPERATIONS [$/FT²],100
DATA RUNWAY [$/FT],16
DATA FIRE STATION [$/FT²],95
DATA CONTROL TOWER [$/FT²],297
DATA SECURITY [$/FT²],104
DATA TELECOMMUNICATIONS [$/FT²],148
DATA NDI SHOP [$/FT²],142
DATA PMEL LAB [$/FT²],114
DATA MAINT TRAINING [$/FT²],100
DATA TAXIWAYS [$/FT],16
DATA WAREHOUSES [$/FT²],46
'
'hyperveolcity WBS
'
DATA STRUCTURES,LANDING GEAR,DOCKING SYSTEM,PAYLOAD DEP&RETR
DATA MAIN PROP,OMS,RCS1,RCS2,JET-M3,JET+M3,ENGINE INSTALL,AVIONICS,ELECTRICAL
DATA HYDRAULICS,ECS,FLIGHT PROV
'
' PREVAIL - DT&E COST CATEGORIES
'
DATA Structure, Thermal, Reentry Protection, Landing System, Electrical-Power
DATA Electrical-Wiring, Guidance&Control,Data Handling, Instrumentation
DATA Communications, Propulsion System, Engine, RCS, Interstage Adapter, Payload
'
' O&S COST CATEGORIES
'
DATA STRUCTURE, LANDING GEAR, PAYLOAD DEP & RET, AVIONICS, ELECTRICAL, HYDRAULIC
DATA ECLS, FLIGHT PROVISIONS, DOCKING
'
'STAGE TYPE (from PREVAIL)
'
' LO2-LH2
'
'DATA .0577,.480,.0499,.669,.1065,.675,.0625,.675,.0712,.483
'DATA .0697,.677,1.4590,.575,.2144,.805,.1270,.583,.3225,.588
'DATA .1974,.736,.1010,.711,.0658,.736,.0241,.633,.0168,.678
'DATA .1530,.510,.0412,.677,.0650,.700,.0250,.700,.0500,.745
'DATA .1079,.666,.7088,.670,.0206,.873,.1229,.676,.3240,.670
'DATA .5950,.642,5.5950,.537,.2380,.642,.0619,.675,.0466,.675
'DATA .00697,.575,.00343,.761,.03000,.760,.00590,.760,.00578,.674
'DATA .01010,.762,.04490,.762,.05230,.585,.02950,.762,.01920,.776
'DATA .05390,.670,.02130,.740,.05390,.670,.002815,.758,.00440,.761
'
' Other liquid propellant
'
'DATA .02885,.480,.0499,.669,.1065,.675,.0625,.675,.0712,.483
'DATA .0697,.677,1.4590,.575,.2144,.805,.1270,.583,.3225,.588
'DATA .0658,.736,.03667,.711,.0658,.736,.01607,.633,.0168,.678
'DATA .10205,.510,.0412,.677,.0650,.700,.0250,.700,.0500,.745
'DATA .1079,.666,.7088,.670,.0206,.873,.1229,.676,.3240,.670
'DATA .2380,.642,1.8650,.537,.2380,.642,.0619,.675,.0466,.675
'DATA .004649,.575,.00343,.761,.03000,.760,.00590,.760,.00578,.674
'DATA .01010,.762,.04490,.762,.05230,.585,.02950,.762,.01920,.776
'DATA .05390,.670,.00852,.740,.05390,.670,.002815,.758,.00440,.761
'
' Solid rocket motor
'
'DATA .0241,.633,.0,.0,.1065,.675,.0125,.675,.0712,.483
'DATA .0697,.677,1.4590,.575,.2144,.805,.0,.0,.3225,.588
'DATA .0,.0,.0,.0,.0,.0,.008035,.633,.0168,.678
'DATA .0619,.675,.0,.0,.0650,.700,.0050,.700,.0500,.745 'possibly .0050=.0250
'DATA .1079,.666,.7088,.670,.0206,.873,.0,.0,.3240,.670
'DATA .0,.0,.0,.0,.0,.0,.03095,.675,.0466,.675
'DATA .002815,.758,.0,.0,.03000,.760,.00236,.760,.00578,.674
'DATA .01010,.762,.04490,.762,.05230,.585,.0,.0,.01920,.776
'DATA .0,.0,.0,.0,.0,.0,.000704,.758,.00440,.761
'
' inflation factors from NASA for the years 1993 to 2000
'
DATA 1.046, 1.047, 1.046, 1.044, 1.05, 1.048, 1.047, 1.049
'
' WBS default costs (in wbsc matrix)
'
DATA 0,0,0,0,0,0,0,0,0,0,0,0, 413.40, 0,0,0,0,0,0,0,0,0,0,0,0,0,
DATA 0, 0,0,0,0,0,0,0,0,0,0,0,0 ,0,0,0,1,7.33, 1.28,1.5
'
'ORG LEVEL OVERHEAD
DATA Chief of Maintenance
DATA Quality Control
DATA Maintenance Control
DATA Job Control
DATA Plans & Schedules
DATA Documentation
DATA Materiel Control
DATA Supply Liason
DATA Production Control
```

```
SUB DATAIN
CLS : COLOR 10
LOCATE 8, 15: PRINT "INPUT DATA WILL BE READ IN FROM FILE "; VNAM$; ".INP"
LOCATE 10, 15: INPUT "ENTER RETURN TO PROCEED OR A POSITIVE NBR TO ABORT"; RET
IF RET > 0 THEN EXIT SUB
OPEN VNAM$ + ".INP" FOR INPUT AS #2
FOR I = 1 TO 44
INPUT #2, wbsc(3, I), wbscc(I)
NEXT I
FOR I = 1 TO 12: INPUT #2, XP(I): NEXT I
FOR I = 1 TO 53: INPUT #2, VX(I): NEXT I
FOR I = 1 TO 39: INPUT #2, MCF(I): NEXT I
FOR I = 1 TO 29: INPUT #2, XCF(I): NEXT I
FOR I = 1 TO 33
INPUT #2, W(I), S(I), MP(I), OPH(I)
NEXT I
INPUT #2, SMP
CLOSE #2
END SUB

SUB SAVE
CLS : COLOR 10
LOCATE 8, 15: PRINT "INPUT DATA WILL BE SAVED IN FILE "; VNAM$; ".INP"
LOCATE 10, 15: INPUT "ENTER RETURN TO PROCEED OR A POSITIVE NBR TO ABORT"; RET
IF RET > 0 THEN EXIT SUB
OPEN VNAM$ + ".INP" FOR OUTPUT AS #2
FOR I = 1 TO 44
WRITE #2, wbsc(3, I), wbscc(I)
NEXT I
FOR I = 1 TO 12: WRITE #2, XP(I): NEXT I
FOR I = 1 TO 53: WRITE #2, VX(I): NEXT I
FOR I = 1 TO 39: WRITE #2, MCF(I): NEXT I
FOR I = 1 TO 29: WRITE #2, XCF(I): NEXT I
FOR I = 1 TO 33
WRITE #2, W(I), S(I), MP(I), OPH(I)
NEXT I
WRITE #2, SMP
CLOSE #2
END SUB


SUB INPT
tp2: CLS : COLOR 7
LOCATE 6, 28: PRINT "DATA INPUT MENU"
PRINT : PRINT TAB(20); "CATEGORY                              NBR"
PRINT : COLOR 10
PRINT TAB(20); "SYSTEM PARAMETER TABLE............1"
COLOR 14
PRINT TAB(20); "UPDATE WBS COSTING TABLE..........2"
COLOR 10
PRINT TAB(20); "COST FACTORS & RATES .............3"
PRINT TAB(20); "DESIGN/PERFORMANCE VARIABLES......4"
PRINT TAB(20); "MISC FACTORS......................5"
PRINT : COLOR 2: LOCATE 20, 20: INPUT "ENTER NUMBER ", nbr
IF nbr = 0 THEN EXIT SUB
IF nbr = 1 THEN CALL SYS
```

```
SUB SYS
tp3: CLS : COLOR 10
PRINT TAB(1); "VEHICLE IS ";
COLOR 11: PRINT VNAM$;
COLOR 10: PRINT TAB(30); "SYSTEM PARAMETERS - INPUT SCREEN"
PRINT :  COLOR 11
COLOR 12: PRINT TAB(5); "requires update"
COLOR 14: PRINT TAB(5); "computed from RAM input/output": PRINT
COLOR 11: PRINT TAB(10); "NBR"; TAB(20); "PARAMETER"; TAB(50); "VALUE"
PRINT
FOR I = 1 TO 12
        IF I = 8 OR I = 10 THEN COLOR 5 ELSE COLOR 12
        IF I < 4 THEN COLOR 14
        PRINT TAB(10); I; TAB(20); P$(I); TAB(50);
        IF I = 9 THEN
                PRINT USING "###.## %"; XP(I) * 100
        ELSE
                PRINT USING "#####"; XP(I)
        END IF
NEXT I
COLOR 3
LOCATE 22, 10: INPUT "ENTER NUMBER TO CHANGE ", nbr
IF nbr = 6 THEN XP(6) = 1 - XP(6): GOTO tp3
IF nbr = 12 THEN XP(12) = 1 - XP(12): GOTO tp3
IF nbr < 0 THEN GOTO tp3
IF nbr = 0 THEN GOTO BT2
IF nbr = 9 THEN
        LOCATE 22, 10: COLOR 15: PRINT "Enter percentage in decimal form (8%=.08
END IF
tpp: LOCATE 23, 20: INPUT "ENTER NEW VALUE ", XP(nbr)
IF XP(nbr) < 0 THEN GOTO tpp
IF nbr = 4 OR nbr = 5 OR nbr = 6 OR nbr = 7 OR nbr = 9 THEN CALL INFBA

GOTO tp3

BT2: END SUB
```

```
SUB RAMI
'MODULE TO INPUT DATA FROM RAM MODEL
     CLS : COLOR 11
     PRINT : PRINT TAB(10); "DATA WILL BE INPUT FROM FILE ";
     COLOR 10: PRINT VNAM$; ".CST"
     COLOR 11: LOCATE 8, 10: INPUT "ENTER RETURN TO PROCEED ELSE ENTER A POSITIV
     IF NUM > 0 THEN GOTO BT5
     VN$ = VNAM$
     NSP = 0: NTC = 0
     OPEN VN$ + ".CST" FOR INPUT AS #1
     INPUT #1, VN$
     FOR I = 1 TO 33
        INPUT #1, W(I), S(I), MP(I), OPH(I)
        NSP = NSP + S(I)
        NTC = NTC + MP(I)
     NEXT I
     INPUT #1, SMP, VX(50), XP(3), VX(49) ' SCH MNPW,VEH TAT,HRS/MSN,REMOVALS/FL
     FOR I = 1 TO 12: INPUT #1, V(I): NEXT I
     FOR I = 1 TO 20: INPUT #1, X(I): NEXT I
     FOR I = 0 TO 5: INPUT #1, X: NEXT I
     INPUT #1, AREM, TMA
     INPUT #1, TME, TMF 'ET AND LBR MANPOWER
     PRINT : PRINT : PRINT TAB(10); "DATA INPUT FROM ";
     COLOR 10: PRINT VNAM$; ".CST"
     CLOSE #1
     MCF(37) = NSP
     MCF(35) = INT(NTC + SMP + .5)
     XP(2) = X(15)                    'FLIGHTS/YR
     AVWT = 0
     FOR I = 19 TO 24: AVWT = AVWT + W(I): NEXT I
     FOR I = 1 TO 5: VX(I) = X(I): NEXT I
     FOR I = 1 TO 12: VX(I + 5) = V(I): NEXT I
     IF AVWT > VX(46) THEN VX(47) = AVWT - VX(46)
     IF AVWT <= VX(46) THEN VX(46) = AVWT: VX(47) = 0
     VX(52) = .8 * VX(49) * XP(2)
     VX(45) = VX(3) + VX(4)                          'NBR SEATS+BUNKS
     COLOR 11: LOCATE 22, 10: INPUT "ENTER RETURN....", RET

CALL SECOND

BT5: END SUB
```

```
SUB CST
IO = 1: IE = 14
CST: CLS : COLOR 10
PRINT TAB(1); "VEHICLE IS ";
COLOR 11: PRINT VNAM$;
COLOR 10: PRINT TAB(30); "COST FACTORS & RATES TABLE": PRINT
PRINT TAB(5); "Note: all costs should be entered in 1993 year dollars"
COLOR 5: PRINT TAB(5); "currently not used in O&S costing"
PRINT : COLOR 11
PRINT TAB(5); "NBR"; TAB(15); "CATEGORY"; TAB(60); "VALUE"
PRINT
FOR I = IO TO IE
        IF I = 6 OR I = 17 OR I = 26 OR I = 28 THEN COLOR 5 ELSE COLOR 12
        PRINT TAB(5); I; TAB(15); CF$(I); TAB(60);
        PRINT USING "$########.####"; XCF(I)
NEXT I
COLOR 3
LOCATE 23, 20: INPUT "ENTER NUMBER TO CHANGE ", nbr
IF nbr > 0 THEN LOCATE 24, 20: INPUT "ENTER NEW VALUE ", XCF(nbr):  GOTO CST
IF IO = 1 THEN IO = 15: IE = 29:  GOTO CST
BT3: END SUB

SUB DATAIN
CLS : COLOR 10
LOCATE 8, 15: PRINT "INPUT DATA WILL BE READ IN FROM FILE "; VNAM$; ".INP"
LOCATE 10, 15: INPUT "ENTER RETURN TO PROCEED OR A POSITIVE NBR TO ABORT"; RET
IF RET > 0 THEN EXIT SUB
OPEN VNAM$ + ".INP" FOR INPUT AS #2
FOR I = 1 TO 44
INPUT #2, wbsc(3, I), wbscc(I)
NEXT I
FOR I = 1 TO 12: INPUT #2, XP(I): NEXT I
FOR I = 1 TO 53: INPUT #2, VX(I): NEXT I
FOR I = 1 TO 39: INPUT #2, MCF(I): NEXT I
FOR I = 1 TO 29: INPUT #2, XCF(I): NEXT I
FOR I = 1 TO 33
INPUT #2, W(I), S(I), MP(I), OPH(I)
NEXT I
INPUT #2, SMP
CLOSE #2
END SUB
```

```
SUB DRIVERS
ia = 1: ib = 16
BK1: CLS : COLOR 10
PRINT TAB(1); "VEHICLE IS ";
COLOR 11: PRINT VNAM$;
COLOR 10: PRINT TAB(35); "DESIGN/PERFORMANCE VARIABLES ": PRINT
COLOR 14: PRINT TAB(5); "Obtained from or computed from RAM input/output"
COLOR 5: PRINT TAB(5); "currently not used in O&S costing"
IF ia = 31 OR ia = 41 THEN COLOR 12: PRINT TAB(5); "requires update-not obtained
PRINT : COLOR 11
PRINT TAB(1); "NBR"; TAB(5); "VARIABLE"; TAB(47); "VALUE"

FOR I = ia TO ib
IF I = 14 OR I = 20 OR (I > 21 AND I < 32) OR I = 43 THEN COLOR 5 ELSE COLOR 14
IF I = 21 OR I = 32 OR I = 37 OR I = 40 OR I = 44 OR I = 51 OR I > 52 THEN COLOR
        PRINT TAB(1); I; TAB(5); VX$(I); TAB(45);
        PRINT USING "#######"; VX(I)
NEXT I
COLOR 3
PRINT : INPUT "ENTER NBR FOR CHANGE - else enter return ", nbr
IF nbr = 0 THEN GOTO SK1
INPUT "ENTER NEW VALUE ", VX(nbr)
GOTO BK1
SK1: IF ib = 16 THEN ia = 17: ib = 30: GOTO BK1
     IF ib = 30 THEN ia = 31: ib = 40: GOTO BK1
     IF ib = 40 THEN ia = 41: ib = 53: GOTO BK1


END SUB

SUB SAVE
CLS : COLOR 10
LOCATE 8, 15: PRINT "INPUT DATA WILL BE SAVED IN FILE "; VNAM$; ".INP"
LOCATE 10, 15: INPUT "ENTER RETURN TO PROCEED OR A POSITIVE NBR TO ABORT"; RET
IF RET > 0 THEN EXIT SUB
OPEN VNAM$ + ".INP" FOR OUTPUT AS #2
FOR I = 1 TO 44
WRITE #2, wbsc(3, I), wbscc(I)
NEXT I
FOR I = 1 TO 12: WRITE #2, XP(I): NEXT I
FOR I = 1 TO 53: WRITE #2, VX(I): NEXT I
FOR I = 1 TO 39: WRITE #2, MCF(I): NEXT I
FOR I = 1 TO 29: WRITE #2, XCF(I): NEXT I
FOR I = 1 TO 33
WRITE #2, W(I), S(I), MP(I), OPH(I)
NEXT I
WRITE #2, SMP
CLOSE #2
END SUB
```

```
SUB MISC
IO = 1: IE = 15
FC1: CLS : COLOR 10
PRINT TAB(1); "VEHICLE IS ";
COLOR 11: PRINT VNAM$;
COLOR 10: PRINT TAB(30); "MISCELLANEOUS FACTORS"
COLOR 12: PRINT TAB(5); "requires verify/update"
COLOR 14: PRINT TAB(5); "computed from RAM input/output"
IF IO = 16 THEN COLOR 5: PRINT TAB(5); "currently not used"
PRINT : COLOR 11
PRINT TAB(5); "NBR"; TAB(15); "CATEGORY"; TAB(65); "VALUE"
PRINT
FOR I = IO TO IE
        IF I = 35 OR I = 37 OR I = 57 THEN COLOR 14 ELSE COLOR 12
        IF I = 27 THEN COLOR 5
        PRINT TAB(5); I; TAB(15); MF$(I); TAB(60);
        PRINT USING "#########.##"; MCF(I)
NEXT I
COLOR 3
LOCATE 23, 20: INPUT "ENTER NUMBER TO CHANGE ", nbr
IF nbr > 0 THEN LOCATE 24, 20: INPUT "ENTER NEW VALUE ", MCF(nbr):  GOTO FC1
IF IO = 1 THEN IO = 16: IE = 30:  GOTO FC1
IF IO = 16 THEN IO = 31: IE = 39: GOTO FC1

END SUB

SUB SYS
tp3: CLS : COLOR 10
PRINT TAB(1); "VEHICLE IS ";
COLOR 11: PRINT VNAM$;
COLOR 10: PRINT TAB(30); "SYSTEM PARAMETERS - INPUT SCREEN"
PRINT :  COLOR 11
COLOR 12: PRINT TAB(5); "requires update"
COLOR 14: PRINT TAB(5); "computed from RAM input/output": PRINT
COLOR 11: PRINT TAB(10); "NBR"; TAB(20); "PARAMETER"; TAB(50); "VALUE"
PRINT
FOR I = 1 TO 12
        IF I = 8 OR I = 10 THEN COLOR 5 ELSE COLOR 12
        IF I < 4 THEN COLOR 14
        PRINT TAB(10); I; TAB(20); P$(I); TAB(50);
        IF I = 9 THEN
                PRINT USING "###.## %"; XP(I) * 100
        ELSE
                PRINT USING "#####"; XP(I)
        END IF
NEXT I

COLOR 3
LOCATE 22, 10: INPUT "ENTER NUMBER TO CHANGE ", nbr
IF nbr = 6 THEN XP(6) = 1 - XP(6): GOTO tp3
IF nbr = 12 THEN XP(12) = 1 - XP(12): GOTO tp3
IF nbr < 0 THEN GOTO tp3
IF nbr = 0 THEN GOTO BT2
IF nbr = 9 THEN
        LOCATE 22, 10: COLOR 15: PRINT "Enter percentage in decimal form (8%=.08
END IF
tpp: LOCATE 23, 20: INPUT "ENTER NEW VALUE ", XP(nbr)
IF XP(nbr) < 0 THEN GOTO tpp
IF nbr = 4 OR nbr = 5 OR nbr = 6 OR nbr = 7 OR nbr = 9 THEN CALL INFBA
```

```
SUB WBSS
CLS : ia = 1: ib = 10
FOR I = 1 TO 45: wbsc(1, I) = wbsc(3, I): NEXT I
bk9: COLOR 14: PRINT TAB(20); "Cost Element Structure"
LOCATE 3, 55: COLOR 10: PRINT "default";
COLOR 15: PRINT " / ";
COLOR 14: PRINT "compute": COLOR 13
PRINT
COLOR 11: PRINT "nbr"; TAB(11); "WBS"; TAB(55); "Cost [93 M$]": COLOR 10
ib2 = ib
FOR I = ia TO ib
        IF I = 4 OR I = 12 OR I = 21 OR I = 37 OR I = 43 OR I > 42 THEN PRINT
        PRINT TAB(1); I; TAB(8); wbs$(1, I); TAB(55); ,
        IF wbscc(I) = 2 THEN COLOR 14
        IF wbscc(I) = 1 THEN COLOR 10
        PRINT USING "######.###"; wbsc(1, I)
        COLOR 10
NEXT I

COLOR 10
IF ib = 10 THEN
wbb:    COLOR 11: PRINT : INPUT "Enter number to change or RETURN... ", RET: COL
        IF RET < ia AND RET > ib AND RET <> ASC(CHR$(13)) GOTO wbb



        IF RET >= ia THEN
                INPUT "Enter 1 to toggle or 2 to enter new default value. ", tog
                        IF tog = 1 THEN
                                IF wbscc(RET) = 1 THEN
                                        wbscc(RET) = 2
                                ELSE
                                        wbscc(RET) = 1
                                        INPUT "Enter the default value ", wbsc(1
                                END IF
                                CLS
                                GOTO bk9
                        ELSE
                                INPUT "Enter the new default value ", wbsc(1, RE
                                CLS
                        END IF
                GOTO bk9
        ELSE
                CLS
        END IF
 ia = 11: ib = 26: GOTO bk9
 END IF
 IF ib = 26 THEN
 wbb1:  COLOR 11: PRINT : INPUT "Enter number to change or RETURN... ", RET: COL
        IF RET < ia AND RET > ib AND RET <> ASC(CHR$(13)) GOTO wbb1
        IF RET >= ia THEN
                INPUT "Enter 1 to toggle or 2 to enter new default value. ", tog
                IF tog = 1 THEN
                        IF wbscc(RET) = 1 THEN
                                wbscc(RET) = 2
                        ELSE
                                wbscc(RET) = 1
                                INPUT "Enter the default value ", wbsc(1, RET)
                        END IF
                        CLS
                        GOTO bk9
                ELSE
                        COLOR 11: INPUT "Enter the new default value ", wbsc(1,
                        CLS
                        GOTO bk9
                END IF
        ELSE
                CLS
        END IF

 ia = 27: ib = 36: GOTO bk9
 END IF
 IF ib = 36 THEN
 wbb12: COLOR 11: PRINT :  INPUT "Enter number to change or RETURN... ", RET: CO
        IF RET < ia AND RET > ib AND RET <> ASC(CHR$(13)) GOTO wbb12
        IF RET >= ia THEN
                COLOR 11: INPUT "Enter 1 to toggle or 2 to enter new default val
                IF tog = 1 THEN
                        IF wbscc(RET) = 1 THEN
                                wbscc(RET) = 2
                        ELSE
                                wbscc(RET) = 1
                                INPUT "Enter the default value ", wbsc(1, RET)
                        END IF
                        CLS
                        GOTO bk9
                ELSE
                        COLOR 11: INPUT "Enter the new default value ", wbsc(1,
                        CLS
                        GOTO bk9
                END IF
        ELSE
                CLS
        END IF
        ia = 37: ib = 45: GOTO bk9
END IF
'
IF ib = 45 THEN
wbb2:   COLOR 11: PRINT : INPUT "Enter number to change or RETURN... ", RET: COL
        IF RET < ia AND RET > ib AND RET <> ASC(CHR$(13)) GOTO wbb2
        IF RET >= ia THEN
                COLOR 11: INPUT "Enter 1 to toggle or 2 to enter new default val
                IF tog = 1 THEN
                        IF wbscc(RET) = 1 THEN
                                wbscc(RET) = 2
                        ELSE
                                wbscc(RET) = 1
                                INPUT "Enter the default value ", wbsc(1, RET)
                        END IF
                        CLS
                        GOTO bk9
                ELSE
                        COLOR 11: INPUT "Enter the new default value ", wbsc(1,
                        CLS
                        GOTO bk9
                END IF
        ELSE
                CLS
        END IF
END IF
PRINT : COLOR 13
PRINT TAB(1); "TOTALS"; TAB(45); AMMC; TAB(65); TMMC
PRINT : COLOR 3
FOR I = 1 TO 45
wbsc(3, I) = wbsc(1, I)       'save original default values
NEXT I
END SUB
```

```
DECLARE SUB ORG ()
DECLARE SUB TOT ()
DECLARE SUB INFBA ()
DECLARE SUB INFBED ()
DECLARE SUB COMP ()
DECLARE SUB totdd ()
DECLARE SUB MANPOWER ()
DECLARE SUB SOFTWARE ()
DECLARE SUB FACILITY ()
DECLARE SUB PWRCER ()
DECLARE SUB DRIVER ()
DECLARE SUB HYPER ()
DECLARE SUB OS ()
DECLARE SUB totdd ()
DECLARE SUB costc ()
'
'NASA LANGLEY RESEARCH CENTER
'LIFE CYCLE COST MODEL developed by Univ of Dayton
'Dr. Ebeling and Mr. Beasley
'save as LCC2.BAS **** COMPUTATIONAL MODULE ******
'
COMMON SHARED VNAM$, SMP, TME, TMF, SDE, STE, SUP, TW, AF, FLCC, INFB, INFBDd, I
COMMON SHARED TFCC, TFSC, MAT, CNT, OTH, PER, FAF, AMMC, TMMC, inx, year
COMMON SHARED MM, TDSC, ADJ, INST, INTEG, RESO, APPL, CPLX, UTIL, PLTFM, WEIGHT
COMMON SHARED vs$, selv, wbs, totd, AVWT, lcf, inxf, TOMO, lctot
COMMON SHARED SI, RS, NC, RC, NIMWC, RIMWC, RGSE, NGSE, N1, N2, N3, N4, M1, M2,
COMMON SHARED AC, CS, HYPS, PRVS1, PRVS2, SEC, RTITLE$, OVH
DIM SHARED wbs$(2, 60), P$(15), XP(25), X(20), V(12), WB$(15), isc(20, 20)
DIM SHARED W(35), S(35), MP(35), CF$(30), XCF(30), AMC(2, 50), MC(2, 50), ID(5),
DIM SHARED A(50, 3), B(50, 3), DE(16), TE(16), UP(16), WT(15), HYP$(16), rncs(10
DIM SHARED CF(35), lcs(35), QTY(35), VX$(60), VX(60), mh(20), rd(10), OSCL$(10)
DIM SHARED FSQ(20), FC(20), F$(20), FCC(20), mhc(20), rdc(10), ism(20, 10), INFf
DIM SHARED TOTH(10), TOTV(10), wbsc(4, 50), wbscc(50), MF$(40), MCF(40)
DIM SHARED HP(10), HH(10), HS(10), HR(10), HD(10), infv(50), OPH(35), OMO(10), O

COMMON SHARED HP(), HH(), HS(), HR(), HD()
COMMON SHARED wbs$(), PH$(), P$(), XP(), X(), V(), WB$(), isc()
COMMON SHARED W(), S(), MP(), CF$(), XCF(), AMC(), MC(), ID(), DC()
COMMON SHARED A(), B(), DE(), TE(), UP(), WT(), HYP$()
COMMON SHARED CF(), lcs(), QTY(), VX$(), VX(), mh(), rd(), OSCL$()
COMMON SHARED FSQ(), FC(), F$(), FCC(), mhc(), rdc(), ism(), INFf()
COMMON SHARED TOTH(), TOTV(), wbsc(), wbscc(), MF$(), MCF(), infv(), OPH(), OMO(

CALL DRIVER
```

```
SUB INFBA
'
' This subroutine moves the base year from 1993 to any year after 1993.
' It uses the NASA inflation indicies from FY 1991, Code BA NASA New Start
' Inflation Index--(actuals from 1991).
'
INFB = 1
CT = XP(5) - 1993
CT2 = XP(7) - 1993
FOR I = 1 TO CT2 + XP(4)
IF I <= 7 THEN infv(I) = INFf(I) ELSE infv(I) = XP(9)
NEXT I

FOR I = 1 TO CT           'compute base yr inf factor
INFB = INFB * infv(I)
NEXT I

CT3 = XP(7) - XP(5)      'compute beddown yr inf factor
INFBD = INFB
FOR I = CT + 1 TO CT + CT3
INFBD = INFBD * infv(I)
NEXT I

INFLC = INFBD            'compute LCC inf fac
FOR I = CT + CT3 + 1 TO CT2 + XP(4) - 1
INFLC = INFLC * infv(I)
NEXT I
AVINF = INFLC ^ (1 / XP(4))       'geometric avg inf rate over life cycle
FV = ((1 + AVINF) ^ XP(4) - 1) / AVINF      'future value factor for LCC

IF XP(6) = 1 THEN inx = INFB ELSE inx = INFBD
IF XP(6) = 1 THEN lcf = XP(4) ELSE lcf = FV
IF XP(6) = 1 THEN year = XP(5) ELSE year = XP(7)
IF XP(6) = 1 THEN inxf = 1 ELSE inxf = (1 + AVINF) ^ XP(4)
IF XP(5) = 1993 THEN inx = 1
END SUB
```

```
SUB DRIVER
' this module controls execution of the computations

CALL INFBA     'compute inf factors

'CALL PWRCER                'computes facility const & O&S costs
CALL FACILITY               'currently not used
'CALL SOFTWARE              'R&D/PROD costs
'CALL HYPER                 'used for hypervel -partial
CALL OS                     'computes org pers/hardware
CALL ORG                    'main computational module for O&S costs
CALL COMP                   'roll-up the WBS (CES)
CALL TOT

BTD: END SUB

SUB HYPDIS
CLS
PRINT TAB(5); "HYPERVEL COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM LI
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 15: PRINT TAB(10); "DEPOT PERSONNEL COSTS"
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(30); "ANNUAL RECUR COSTS"; TAB(50); "LIFE CYCLE COSTS"
PRINT : COLOR 12
AD1 = 0: AD2 = 0
FOR I = 1 TO 9
AD1 = AD1 + HP(I)
AD2 = AD2 + lcf * HP(I)
PRINT TAB(1); OSCL$(I); TAB(30); HP(I); TAB(50); lcf * HP(I)
NEXT I
PRINT : COLOR 11
PRINT TAB(1); "TOTALS"; TAB(30); AD1; TAB(50); AD2
PRINT
PRINT : COLOR 2: INPUT "ENTER RETURN..."; RET

CLS
PRINT TAB(5); "HYPERVEL COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM LI
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 15: PRINT TAB(10); "DEPOT HARDWARE COSTS"
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(30); "ANNUAL RECUR COSTS"; TAB(50); "LIFE CYCLE COSTS"
PRINT : COLOR 12
AD1 = 0: AD2 = 0
FOR I = 1 TO 9
AD1 = AD1 + HH(I)
AD2 = AD2 + lcf * HH(I)
PRINT TAB(1); OSCL$(I); TAB(30); HH(I); TAB(50); lcf * HH(I)
NEXT I
PRINT : COLOR 11
PRINT TAB(1); "TOTALS"; TAB(30); AD1; TAB(50); AD2
PRINT
PRINT : COLOR 2: INPUT "ENTER RETURN..."; RET

CLS
PRINT TAB(5); "HYPERVEL COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM LI
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 15: PRINT TAB(10); "SPARES COSTS"
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(20); "INITIAL SPARES"; TAB(40); "ANNUAL RECUR SPARES";
PRINT : COLOR 12
AD1 = 0: AD2 = 0: AD3 = 0
FOR I = 1 TO 9
AD1 = AD1 + HR(I)
AD2 = AD2 + lcf * HR(I) + HS(I)
AD3 = AD3 + HS(I)
PRINT TAB(1); OSCL$(I); TAB(20); HS(I); TAB(40); HR(I); TAB(60); lcf * HR(I) + H
NEXT I
PRINT : COLOR 11
PRINT TAB(1); "TOTALS"; TAB(20); AD3; TAB(40); AD1; TAB(60); AD2
PRINT
PRINT : COLOR 2: INPUT "ENTER RETURN..."; RET

CLS
PRINT TAB(5); "HYPERVEL COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM LI
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 15: PRINT TAB(10); "DOCUMENTATION COSTS"
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(30); "ANNUAL RECUR COSTS"; TAB(50); "LIFE CYCLE COSTS"
PRINT : COLOR 12
AD1 = 0: AD2 = 0
FOR I = 1 TO 9
AD1 = AD1 + HD(I)
AD2 = AD2 + lcf * HD(I)
PRINT TAB(1); OSCL$(I); TAB(30); HD(I); TAB(50); lcf * HD(I)
NEXT I
PRINT : COLOR 11
PRINT TAB(1); "TOTALS"; TAB(30); AD1; TAB(50); AD2
PRINT
PRINT : COLOR 2: INPUT "ENTER RETURN..."; RET

CLS
PRINT TAB(5); "HYPERVEL COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM LI
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 15: PRINT TAB(10); "ORGANIZATIONAL MAINTENANCE HARDWARE COSTS"
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(30); "ANNUAL RECUR COSTS"; TAB(50); "LIFE CYCLE COSTS"
PRINT : COLOR 12
AD1 = 0: AD2 = 0
FOR I = 1 TO 9
AD1 = AD1 + DC(I, 2)
AD2 = AD2 + lcf * DC(I, 2)
PRINT TAB(1); OSCL$(I); TAB(30); DC(I, 2); TAB(50); lcf * DC(I, 2)
NEXT I
PRINT : COLOR 11
PRINT TAB(1); "TOTALS"; TAB(30); AD1; TAB(50); AD2
COLOR 2
PRINT : INPUT "ENTER RETURN.."; RET
CLS
PRINT TAB(5); "HYPERVEL COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM LI
COLOR 3
```

```
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 15: PRINT TAB(10); "SUPPORT EQUIPMENT"
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(20); "SUPPORT EQUIP"; TAB(40); "REPLACE SPT EQUIP"; TAB
PRINT : COLOR 12
AD1 = 0: AD2 = 0: AD3 = 0
FOR I = 1 TO 9
AD1 = AD1 + DC(I, 9)
AD2 = AD2 + lcf * DC(I, 9) + DC(I, 7)
AD3 = AD3 + DC(I, 7)
PRINT TAB(1); OSCL$(I); TAB(20); DC(I, 7); TAB(40); DC(I, 9); TAB(60); lcf * DC(
NEXT I
PRINT : COLOR 11
PRINT TAB(1); "TOTALS"; TAB(20); AD3; TAB(40); AD1; TAB(60); AD2
PRINT
PRINT : COLOR 2: INPUT "ENTER RETURN..."; RET

END SUB
```

```
SUB LOGS
CLS
SM1 = SI + NC + NIMWC + NGSE + N1 + N3 + M1 + M3 + T1 + S1 + NILSM
SM2 = RS + RC + RIMWC + RGSE + N2 + N4 + M2 + M4 + T2 + S2 + RILSM
SM3 = SM1 + SM2
SM4 = SM1 + lcf * SM2
PRINT TAB(5); "LOGISTICS COST MODEL FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM L
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 10
PRINT TAB(1); TAB(18); "NON-RECURRING"; TAB(35); "RECURRING"; TAB(50); "TOTAL 1s
PRINT TAB(1); "CATEGORY"; TAB(18); "ANNUAL COST"; TAB(33); "ANNUAL COSTS"; TAB(5
PRINT : COLOR 15
PRINT TAB(1); "SPARES"; TAB(20); SI; TAB(35); RS; TAB(50); SI + RS; TAB(65); SI
PRINT TAB(1); "CONSUMABLES"; TAB(20); NC; TAB(35); RC; TAB(50); NC + RC; TAB(65)
PRINT TAB(1); "INV MGMT & WAREHSE"; TAB(20); NIMWC; TAB(35); RIMWC; TAB(50); NIM
PRINT TAB(1); "ORG TRAINING"; TAB(20); N1; TAB(35); N2; TAB(50); N1 + N2; TAB(65
PRINT TAB(1); "DEPOT TRAINING"; TAB(20); N3; TAB(35); N4; TAB(50); N3 + N4; TAB(
COLOR 14
PRINT TAB(5); "TOT TRAINING"; TAB(23); N1 + N3; TAB(38); N2 + N4; TAB(53); N1 +
COLOR 15
PRINT TAB(1); "ORG DOCUMENT"; TAB(20); M1; TAB(35); M2; TAB(50); M1 + M2; TAB(65
PRINT TAB(1); "DEPOT DOCUMENT"; TAB(20); M3; TAB(35); M4; TAB(50); M3 + M4; TAB(
COLOR 14
PRINT TAB(5); "TOT DOCUMENT"; TAB(23); M1 + M3; TAB(38); M2 + M4; TAB(53); M1 +
COLOR 15
PRINT TAB(1); "TRANSPORTATION"; TAB(20); T1; TAB(35); T2; TAB(50); T1 + T2; TAB(
PRINT TAB(1); "GRND SPT EQUIP"; TAB(20); NGSE; TAB(35); RGSE; TAB(50); NGSE + RG
PRINT TAB(1); "DEPOT SPT EQUIP"; TAB(20); S1; TAB(35); S2; TAB(50); S1 + S2; TAB
COLOR 14
PRINT TAB(5); "TOT SPT EQUIP"; TAB(23); S1 + NGSE; TAB(38); S2 + RGSE; TAB(53);
COLOR 15
PRINT TAB(1); "ILS MGMT"; TAB(20); NILSM; TAB(35); RILSM; TAB(50); NILSM + RILSM
PRINT : COLOR 14
PRINT TAB(5); "TOTALS"; TAB(20); SM1; TAB(35); SM2; TAB(50); SM3; TAB(65); SM4
COLOR 3
INPUT "ENTER RETURN...."; RET

END SUB
```

```
SUB OS
'
' Operations and Support Costs, "Conceptual Design and Analysis of
' Hypervelocity Aerospace Vehicles, Volume III.  Cost," 20 July 1991
' AD-B159 615, 1985 $'s
'
' Indirect Costs ($85), translated to 1993 by NASA table.
aa93 = 1.914      '1.390857677#
'                                                    Unit Level Personnel
ID(1) = 755130 * VX(3) ^ 1.6422 * XP(1) ^ .89681 * aa93 * inx       'Aircrew
ID(2) = 537990 * (XP(2) * XP(3)) ^ .50621 * XP(1) ^ .89225 * aa93 * inx 'Command
ID(3) = .07 * (ID(1) + ID(2))                                       'Securit
ID(4) = .2 * (ID(1) + ID(2))                                        'Other
'
' Direct Costs ($85) converted to 1993.
'        1-Maintenance Personnel [$/FH]
'        2-Maintenance Material [$/FH]
'        3-Depot Personnel [$/FH]
'        4-Depot Material [$/FH]
'        5-Replenishment Spares [$/FH]
'        6-Data [$/FH]
'        7-Support Equipment [$/(4 HVV)]
'        8-Initial Spares [$/HVV]
'        9-Replacement Support Equipment [$]

UR = XP(3) * XP(2) / XP(1)     ' util rate hrs/yr per veh
' structure
'
DC(1, 1) = 1083.9 * UR ^ .55687 * VX(8) ^ .66207 * aa93 * inx
DC(1, 2) = 6.155 * (UR) ^ 1.1025 * VX(8) ^ .79374 * aa93 * inx
DC(1, 3) = 6838.9 * (UR) ^ .17293 * VX(8) ^ .5389 * aa93 * inx
DC(1, 4) = 12773! * UR ^ .40781 * aa93 * inx
DC(1, 5) = 2235.7 * (XP(2)) ^ .44611 * VX(8) ^ .42599 * aa93 * inx
DC(1, 6) = 407.53 * VX(18) ^ .6394 * aa93 * inx
DC(1, 7) = 644.063 * VX(7) ^ .70503 * aa93 * inx
DC(1, 8) = 4.08905 * VX(8) ^ 1.4795 * 5.6303 * aa93 * inx'  5.6.. is the (max ma
DC(1, 9) = .2 * DC(1, 7)
'
' Landing Gear
'
DC(2, 1) = 40.2249 * VX(31) ^ .072882 * VX(8) ^ .53446 * aa93 * inx
DC(2, 2) = 3924 * VX(9) ^ .43025 * VX(32) ^ .36569 * aa93 * inx
DC(2, 3) = 1697.4 * VX(9) ^ .30068 * VX(33) ^ .42521 * aa93 * inx
DC(2, 4) = 1187.3 * VX(2) ^ .66587 * VX(34) ^ .60526 * aa93 * inx
DC(2, 5) = 2877.49 * VX(9) ^ .9313 * VX(32) ^ .2789 * aa93 * inx
DC(2, 6) = 214.6 * XP(11) ^ .6664 * VX(19) ^ .30877 * aa93 * inx
DC(2, 7) = .306413 * VX(18) ^ .70378 * VX(48) ^ .11614 * aa93 * inx' mach^ a : 1
DC(2, 8) = 1.14042 * VX(18) ^ 1.0393 * aa93 * inx
DC(2, 9) = .2 * DC(2, 7)
'
' Payload Deployment and Return
'
DC(3, 1) = 21436.3 * VX(35) ^ .3562 * aa93 * inx
DC(3, 2) = 15.2477 * VX(36) ^ .79221 * VX(37) ^ .024399 * aa93 * inx
DC(3, 3) = 350.272 * VX(35) ^ .55731 * (VX(3) + VX(4)) ^ .022272 * aa93 * inx
DC(3, 4) = 9.65239 * VX(35) ^ .44168 * VX(36) ^ .39999 * aa93 * inx
DC(3, 5) = 10.6276 * VX(35) ^ .20537 * VX(36) ^ .70128 * aa93 * inx
DC(3, 6) = .01 * prodcst
DC(3, 7) = .02 * wbsc(wbscc(6), 6) / XP(1)
DC(3, 8) = .025 * prodcst
DC(3, 9) = .02 * DC(3, 7)
'
' Avionics
'
DC(4, 1) = 379670 * VX(12) ^ .3672 * (avinwt / .52) ^ .050126 * aa93 * inx
DC(4, 2) = 14476 * VX(12) ^ .66556 * aa93 * inx
DC(4, 3) = 4053! * VX(12) ^ .64027 * VX(15) ^ .30348 * aa93 * inx
DC(4, 4) = 4.1221 * avinwt ^ .38875 * VX(38) ^ 2.8235 * aa93 * inx
DC(4, 5) = 10.427 * VX(12) ^ .89189 * (avinwt / .52) ^ .68652 * aa93 * inx
DC(4, 6) = 142345 * (avinwt / .52) ^ .091207 * aa93 * inx
DC(4, 7) = 376.149 * VX(47) ^ 1.1071 * aa93 * inx
DC(4, 8) = 9675.31 * avinwt ^ .78372 * (VX(1) / VX(7)) ^ .37412 * aa93 * inx
DC(4, 9) = .2 * DC(4, 7)
'
' Electrical
'
DC(5, 1) = 2.11812 * VX(39) ^ .8642 * VX(5) ^ 2.0721 * aa93 * inx
DC(5, 2) = 98.7584 * VX(2) ^ 1.1251 * VX(12) ^ .36008 * aa93 * inx
DC(5, 3) = 381.17 * VX(2) ^ 1.2603 * XP(3) ^ .30284 * aa93 * inx
DC(5, 4) = 148.709 * VX(39) ^ .93869 * VX(12) ^ .13678 * aa93 * inx
DC(5, 5) = 115.132 * VX(39) ^ .9355 * VX(40) ^ .95695 * aa93 * inx
DC(5, 6) = 38.7703 * VX(12) ^ 1.0292 * aa93 * inx
DC(5, 7) = 20536 * VX(12) ^ .18723 * VX(48) ^ .87839 * aa93 * inx
DC(5, 8) = 932.337 * 3.3418 * VX(12) ^ .7465 * aa93 * inx'  3.3=7^.62003
DC(5, 9) = .2 * DC(5, 7)
'
' Hydraulics
'
DC(6, 1) = 13315.4 * VX(2) ^ .16752 * VX(41) ^ .81458 * aa93 * inx
DC(6, 2) = 8389.99 * VX(42) ^ .29838 * VX(13) ^ .56681 * aa93 * inx
DC(6, 3) = 32661.8 * VX(11) ^ .3451 * VX(41) ^ .70715 * aa93 * inx
DC(6, 4) = .738358 * VX(2) ^ 2.1815 * VX(42) ^ .15009 * aa93 * inx
DC(6, 5) = .290026 * VX(2) ^ 2.3754 * VX(41) ^ .21649 * aa93 * inx
DC(6, 6) = 741.81 * VX(10) ^ .95341 * aa93 * inx
DC(6, 7) = 2400.88 * VX(13) ^ .76158 * aa93 * inx
DC(6, 8) = 3.1879 * VX(2) ^ 1.8749 * 4.8724 * aa93 * inx'  4.8...=max mach^.8138
DC(6, 9) = .2 * DC(6, 7)
'
' ECLS
'
DC(7, 1) = 5845.5 * VX(43) ^ .31313 * XP(3) ^ 1.2395 * aa93 * inx
DC(7, 2) = 252.16 * XP(3) ^ .5813 * VX(7) ^ .46728 * aa93 * inx
DC(7, 3) = 6428.7 * XP(3) ^ .36061 * VX(7) ^ .36541 * aa93 * inx
DC(7, 4) = 196.918 * (VX(3) + VX(4)) ^ .0031839 * VX(7) ^ .69177 * aa93 * inx
DC(7, 5) = 88.903 * XP(3) ^ .29514 * VX(7) ^ .66886 * aa93 * inx
DC(7, 6) = 29077.9 * (avinwt / .52) ^ .18719 * aa93 * inx
DC(7, 7) = 7812.31 * VX(45) ^ .78697 * VX(48) ^ .9731 * aa93 * inx
DC(7, 8) = 2.86158 * (VX(17) * (VX(3) + VX(4))) ^ .6701 * VX(12) ^ 1.0107 * aa93
DC(7, 9) = .2 * DC(7, 7)
'
' Flight Provisions
'
DC(8, 1) = 354.58 * VX(3) ^ .80328 * XP(3) ^ 1.0034 * aa93 * inx
DC(8, 2) = 11.5099 * VX(35) ^ .40262 * XP(3) ^ .77562 * aa93 * inx
DC(8, 3) = 5.65649 * VX(2) ^ .97927 * XP(11) ^ .19409 * aa93 * inx
DC(8, 4) = .00321882# * VX(2) ^ 2.1661 * VX(44) ^ .34181 * aa93 * inx
DC(8, 5) = .0344495 * VX(2) ^ 2.1661 * VX(44) ^ .56086 * aa93 * inx
DC(8, 6) = 15.5429 * (VX(3) + VX(4)) ^ .70674 * XP(11) ^ .9167 * aa93 * inx
DC(8, 7) = 3.05923E-09 * (VX(5) * VX(21)) ^ 1.8319 * aa93 * inx


DC(8, 8) = 14.4453 * 4.1175 * VX(7) ^ .6217 * aa93 * inx '4.1.. = max mach^.7272
DC(8, 9) = .2 * DC(8, 7)
'
' Docking
'
DC(9, 1) = 41.9232 * VX(36) ^ .4924 * aa93 * inx '[$/flight ????]
DC(9, 2) = .0749785 * VX(36) ^ .43375 * VX(18) ^ .46765 * aa93 * inx
DC(9, 3) = .612697 * VX(39) ^ .040297 * VX(18) ^ .6539 * aa93 * inx
DC(9, 4) = .0560647 * VX(39) ^ .67061 * VX(2) ^ .933312 * aa93 * inx
DC(9, 5) = .0938672 * VX(36) ^ .57147 * VX(35) ^ .36911 * aa93 * inx
DC(9, 6) = .517318 * VX(18) ^ .6394 * aa93 * inx
DC(9, 7) = .795139 * VX(7) ^ .70503 * aa93 * inx
DC(9, 8) = .00514174# * VX(8) ^ 1.4795 * 5.6303 * aa93 * inx' 5.6=max mach^.8881
DC(9, 9) = .2 * DC(9, 7)
END SUB
```

```
SUB COMP
' basic computational module for computing at the NASA CES (WBS) level
aa93 = 1.914  '80 TO 93  inx * 1.390857677#   'inf fac to move from fy85 to fy93
' 1.6 estimated inf fac from fy77 to fy85
prvinx = 2.501
'2. 3.2  MAINTENANCE
'2.3.2.1  REFURBISHMENT  - prevail $FY77
CWS = .02 * XCF(3) + .05 * XCF(24)        ' assume MCF(27)=1
CRE = .1 * VX(5) * XCF(25)                ' asumme MCF(27)=1
'CSRM = 17.377254# * VX(46) / 10 ^ 4     '??check PI in eq
'CRSRM = MCF(27) * (.1 * XCF(2) + .5 * CSRM) + .1 * XCF(26)
wbsc(2, 22) = prvinx * (CWS + CRE)
wbsc(4, 22) = lcf * wbsc(wbscc(22), 22)

UR = XP(3) * XP(2) / XP(1)       'vehicle util rate = hrs/yr per veh for HVL

'2.3.2.3 DEPOT MAINTENANCE  hypervelocity $FY85
' personnel
HP(1) = 5466 * (UR) ^ .17293 * VX(8) ^ .5389
HP(2) = 1436.4 * VX(9) ^ .30068 * VX(33) ^ .42521
HP(3) = 350.272 * VX(35) ^ .55731 * (VX(3) + VX(4)) ^ .022272
HP(4) = 4053 * VX(12) ^ .64027 * VX(15) ^ .30348
HP(5) = 256.191 * VX(11) ^ 1.2603 * (XP(3) * XP(2)) ^ .30284
HP(6) = 32661.8 * VX(11) ^ .3451 * VX(41) ^ .70715
HP(7) = 3938.44 * XP(3) ^ .36061 * VX(7) ^ .36541
HP(8) = 5.65649 * VX(2) ^ .97927 * XP(11) ^ .19409
HP(9) = .0612697 * VX(39) ^ .040297 * VX(18) ^ .6539
' hardware
HH(1) = 33844.1 * VX(8) ^ .40781
HH(2) = 939.794 * VX(2) ^ .66587 * VX(34) ^ .60526
HH(3) = 9.65239 * VX(35) ^ .44168 * VX(36) ^ .39999
HH(4) = 4.1221 * VX(47) ^ .38875 * VX(38) ^ 2.8235
HH(5) = 148.709 * VX(39) ^ .93869 * VX(12) ^ .13678
HH(6) = .738358 * VX(2) ^ 2.1815 * VX(42) ^ .15009
HH(7) = 196.918 * (VX(3) + VX(4)) ^ .0031839 * VX(7) ^ .69177
HH(8) = .00321882# * VX(2) ^ 2.1661 * VX(44) ^ .34181
HH(9) = .0560647 * VX(39) ^ .67061 * VX(2) ^ .93312
THH = 0: THP = 0
FOR I = 1 TO 9
HP(I) = aa93 * XP(2) * HP(I) / 1000000
HH(I) = aa93 * XP(2) * HH(I) / 1000000
THP = THP + HP(I)
THH = THH + HH(I)
NEXT I
wbsc(2, 24) = THP + THH
wbsc(4, 24) = lcf * wbsc(wbscc(24), 24)

'2.3.2.4  MODIFICATIONS   from Cost of Ownership Model
wbsc(2, 25) = inx * .004494 * wbsc(wbscc(6), 6)
wbsc(4, 25) = lcf * wbsc(wbscc(25), 25)

'2.3.2.5  VERIFICATION & CHECKOUT
wbsc(4, 26) = lcf * wbsc(wbscc(26), 26)


' 2.3.3 LOGISTICS
'    2.3.3.1 SPARES - initial
'        AMLS ($FY93) - hardware
    SI = inx * (1 - MCF(3)) * MCF(2) * MCF(37) * XCF(4) / 1000000
'        HYPERVEL - ($FY85)
HS(1) = 4.08905 * VX(8) ^ 1.4795 * VX(48) ^ .8881
HS(2) = 1.14042 * VX(18) ^ 1.0393
HS(3) = .025 * wbsc(1, 6) / XP(1)
    ' W(3) = 55860.45   ' !!!!!!!!!!!
HS(4) = 9675.31 * VX(47) ^ .78372 * (W(3) / VX(7)) ^ .37412
HS(5) = 932.337 * VX(48) ^ .62003 * VX(12) ^ .7465
HS(6) = 3.1879 * VX(2) ^ 1.8749 * VX(48) ^ .8138
HS(7) = 2.86158 * (VX(17) * (VX(3) + VX(4))) ^ .6701 * VX(12) ^ 1.0107
HS(8) = 14.4453 * VX(48) ^ .72729 * VX(7) ^ .6217
HS(9) = .00514174# * VX(8) ^ 1.4795 * VX(48) ^ .8881
THS = 0
FOR I = 1 TO 9
HS(I) = aa93 * HS(I) / 1000000
THS = THS + HS(I)
NEXT I

' recurring spares AMLS - ($FY93)
   RS = inx * XP(2) * VX(49) * MCF(4) * XCF(4) * MCF(2) / 1000000
'  HYPERVEL - ($FY85)
HR(1) = 1310.2 * UR ^ .44611 * VX(8) ^ .42599
HR(2) = 2877.49 * VX(9) ^ .9313 * VX(32) ^ .2789
HR(3) = 10.6276 * VX(35) ^ .20537 * VX(36) ^ .70128
HR(4) = 10.799 * VX(12) ^ .89189 * VX(46) ^ .68652
HR(5) = 115.132 * VX(39) ^ .9355 * VX(40) ^ .95695
HR(6) = .290026 * VX(2) ^ 2.3754 * VX(41) ^ .21649
HR(7) = 57.1462 * XP(3) ^ .29514 * VX(7) ^ .66886
HR(8) = .0344495 * VX(44) ^ .56086 * VX(2) ^ 2.1661
HR(9) = .0938672 * VX(36) ^ .57147 * VX(35) ^ .36911
THR = 0
FOR I = 1 TO 9
HR(I) = aa93 * XP(2) * HR(I) / 1000000
THR = THR + HR(I)
NEXT I

IF XP(12) = 0 THEN wbsc(2, 28) = (SI + RS) ELSE wbsc(2, 28) = (THS + THR)
IF XP(12) = 0 THEN wbsc(4, 28) = lcf * RS + SI ELSE wbsc(4, 28) = lcf * THR + TH
IF wbscc(28) = 1 THEN wbsc(4, 28) = lcf * wbsc(1, 28)

'2.3.3.2  EXPENDABLES  based upon Cost of Ownership model - tot EOQ
TEOQ = -29.9 + .039 * (VX(49) * XP(2) * (1 - MCF(4)) * XCF(4))
IF TEOQ < 0 THEN TEOQ = 10000
wbsc(2, 29) = inx * TEOQ / 1000000
wbsc(4, 29) = lcf * wbsc(wbscc(29), 29)

' 2.3.3.3 CONSUMABLES - AMLS
NC = 0
FOR I = 18 TO 23
NC = NC + XCF(I) * MCF(I + 1)
NEXT I
RC = NC * XP(2) + (VX(3) + VX(4)) * (XP(3) / 48) * XCF(12) * XP(2)
NC = 3 * NC
NC = inx * NC / 1000000: RC = inx * RC / 1000000
wbsc(2, 30) = (NC + RC)
IF wbscc(30) = 2 THEN wbsc(4, 30) = NC + lcf * RC ELSE wbsc(4, 30) = lcf * wbsc(

' 2.3.3.4 INVENTORY MANAGMENT & WAREHOUSE
' AMLS
NIMWC = MCF(37) * (1 + (MCF(34) * (1 + MCF(25)))) * MCF(18) * XCF(8)
RSPARES = XP(2) * VX(49) * MCF(4)
'RIMWC = RSPARES * (1 + (MCF(34) * (1 + MCF(25)))) * MCF(18) * XCF(8)
```

```
RIMWC = 1000000 * (SI + RS) * MCF(30)
NIMWC = inx * NIMWC / 1000000: RIMWC = inx * RIMWC / 1000000
wbsc(2, 31) = (NIMWC + RIMWC)
wbsc(4, 31) = NIMWC + lcf * RIMWC
IF wbscc(31) = 1 THEN wbsc(4, 31) = lcf * wbsc(1, 31)

' 2.3.3.5   TRAINING - AMLS
N1 = VX(51) * MCF(2) * (1 - MCF(3)) * XCF(9) * MCF(15) * MCF(17) + MCF(15) * MCF
N2 = XCF(9) * MCF(15) * MCF(32) * MCF(17) * VX(51) + MCF(17) * MCF(15) * MCF(35)
N3 = VX(52) * MCF(38) * MCF(2) * (1 - MCF(3)) * XCF(9) * MCF(15) * MCF(7) + MCF(
N4 = XCF(9) * MCF(15) * MCF(32) * MCF(7) * VX(52) * MCF(5) + MCF(7) * MCF(15) *
N1 = inx * N1 / 1000000: N2 = inx * N2 / 1000000
N3 = inx * N3 / 1000000: N4 = inx * N4 / 1000000
wbsc(2, 32) = (N1 + N2 + N3 + N4)
wbsc(4, 32) = N1 + lcf * N2 + N3 + lcf * N4
IF wbscc(32) = 1 THEN wbsc(4, 32) = lcf * wbsc(1, 32)

' 2.3.3.6  DOCUMENTATION
'    AMLS
M1 = VX(52) * MCF(2) * (1 - MCF(3)) * MCF(9) * XCF(27) * MCF(14)
M2 = VX(52) * MCF(9) * XCF(13) * MCF(10) * MCF(33)
M3 = VX(52) * MCF(38) * MCF(2) * (1 - MCF(3)) * MCF(8) * XCF(27) * MCF(14)
M4 = VX(52) * MCF(5) * MCF(2) * MCF(8) * XCF(13) * MCF(10) * MCF(33)
M1 = inx * M1 / 1000000: M2 = inx * M2 / 1000000
M3 = inx * M3 / 1000000: M4 = inx * M4 / 1000000
wbsc(2, 33) = (M1 + M2 + M3 + M4)
wbsc(4, 33) = M1 + lcf * M2 + M3 + lcf * M4

'  HYPERVEL
HD(1) = 401.439 * VX(18) ^ .6394
HD(2) = 214.6 * XP(11) ^ .6664 * VX(19) ^ .30877
HD(3) = .01 * wbsc(1, 6) / XP(1)
HD(4) = 142345 * (VX(46)) ^ .091207
HD(5) = 38.7703 * VX(12) ^ 1.0292
HD(6) = 741.81 * VX(10) ^ .95341
HD(7) = 29077.9 * (VX(46)) ^ .18719
HD(8) = 15.5429 * VX(45) ^ .70674 * XP(11) ^ .9167
HD(9) = .517318 * VX(18) ^ .6394
THD = 0
FOR I = 1 TO 9
HD(I) = aa93 * HD(I) / 1000000
THD = THD + HD(I): NEXT I
IF XP(12) = 1 THEN wbsc(2, 33) = THD: wbsc(4, 33) = lcf * wbsc(2, 33)
IF wbscc(33) = 1 THEN wbsc(4, 33) = lcf * wbsc(1, 33)

' 2.3.3.7  TRANSPORTATION
' AMLS
T1 = XP(1) * VX(1) * MCF(26) * MCF(39) * XCF(15)
T2 = XP(2) * VX(1) * MCF(26) * MCF(28) * XCF(14) + XP(2) * VX(49) * (VX(1) / VX(
T1 = inx * T1 / 1000000: T2 = inx * T2 / 1000000
wbsc(2, 34) = (T1 + T2)
wbsc(4, 34) = T1 + lcf * T2
IF wbscc(34) = 1 THEN wbsc(4, 34) = lcf * wbsc(1, 34)

' 2.3.3.8  SUPPORT EQUIPMENT  AMLS
S1 = MCF(5) * (1 - MCF(3)) * ((XP(2) * VX(50)) / (18 * 4 * 60)) * XCF(11)
S1 = S1 + XCF(29) + MCF(36) * MCF(5) * VX(52) * MCF(1)
S2 = S1 * MCF(29)
S1 = inx * S1 / 1000000: S2 = inx * S2 / 1000000

NGSE = (VX(1) / 178289) * MCF(2) * (1 - MCF(3)) * ((XP(2) * VX(50)) / (12 * 4 *
RGSE = NGSE * MCF(29)
NGSE = inx * NGSE / 1000000
RGSE = inx * RGSE / 1000000
GSE = NGSE + RGSE

wbsc(2, 35) = (S1 + S2) + GSE
wbsc(4, 35) = S1 + lcf * S2 + NGSE + lcf * RGSE

' support equip -hypervel
HVLRSE = 0: HVLNSE = 0
FOR I = 1 TO 9
DC(I, 7) = (XP(1) / 4) * DC(I, 7) / 1000000
DC(I, 9) = .2 * DC(I, 7)
HLVNSE = HLVNSE + DC(I, 7)
HLVRSE = HLVRSE + DC(I, 9)
NEXT I
IF XP(12) = 1 THEN wbsc(2, 35) = HLVRSE + HLVNSE: wbsc(4, 35) = HLVNSE + lcf * H
IF wbscc(35) = 1 THEN wbsc(4, 35) = lcf * wbsc(1, 35)

'  NAVAL FIXED WING
'  wbsc(2,35) = .1965*(60*XP(3))^.4517/1000000

' 2.3.3.9  ILS MANAGEMENT
NILSM = MCF(16) * (SI + NC + NIMWC + NGSE + N1 + N3 + M1 + M3 + T1 + S1)
RILSM = MCF(31) * (RS + RC + RIMWC + RGSE + N2 + N4 + M2 + M4 + T2 + S2)
wbsc(2, 36) = NILSM + RILSM
wbsc(4, 36) = NILSM + lcf * RILSM
IF wbscc(36) = 1 THEN wbsc(4, 36) = lcf * wbsc(1, 36)

' 2.3.4  SYSTEM SUPPORT
'    2.3.4.1  SUPPORT STAFF
'  HYPERVEL  FY85
AC = .21458 * VX(3) ^ 1.6422 * XP(1) ^ .89681
CS = .21458 * (UR) ^ .50621 * XP(1) ^ .89225
AC = aa93 * AC: CS = aa93 * CS
HYPS = .2 * (AC + CS)
' PREVAIL
PRVS1 = .05 * wbsc(wbscc(12), 12)
PRVS2 = .03 * XCF(17)
wbsc(2, 38) = HYPS + PRVS1
wbsc(4, 38) = lcf * wbsc(wbscc(38), 38)


'2.3.4.3  COMMUNICATIONS  (i=40)

' 2.3.4.4   BASE OPS  - HYPERVEL  FY85 (i=41)

'installation support from Cost of Ownership Model
OPER = XP(1) * VX(3) + .8 * (XP(1) * VX(3))
ISPT = .156 * XCF(2) * 40 * 52 * (MCF(35) + OVH + OPER)'personnel cost
MSPT = prvinx * 768 * (MCF(35) + OVH + OPER)'hardware costs
TOSPT = inx * (ISPT + MSPT) / 1000000

'SEC = inx * .07 * (AC + CS) / 1000000     ' security
wbsc(2, 41) = 4 * TOSPT / 6
wbsc(2, 40) = TOSPT / 6


wbsc(4, 40) = lcf * wbsc(wbscc(40), 40)
wbsc(4, 41) = lcf * wbsc(wbscc(41), 41)

'2.3.4.5   launch post launch cleanup
wbsc(4, 42) = lcf * wbsc(wbscc(42), 42)

END SUB
```

```
SUB FACILITY
' FACILITY COST EQUATIONS -Triplett 12/93  ENM 590
FSQ(1) = -324775.9 + 2.5907 * VX(1) - 2383.25 * VX(2) + 55728.93 * SQR(X(2)) - 2
IF FSQ(1) < 35000 THEN FSQ(1) = 35000 ' covered maintenance
IF FSQ(1) > 200000 THEN FSQ(1) = 200000
FSQ(2) = 56212 - .5756 * VX(8) - 1.9567 * VX(7) + 21.175 * VX(6) - 1046.75 * SQR
IF FSQ(2) < 30000 THEN FSQ = 30000' general purpose maintenance shops
IF FSQ(2) > 100000 THEN FSQ(2) = 100000
FSQ(3) = 565089 - 4603 * VX(2) + .831 * VX(8) + 2389.9 * XP(1) - 2167771 / XP(1)
IF FSQ(3) < 30000 THEN FSQ(3) = 30000' avionics shops
IF FSQ(3) > 100000 THEN FSQ(3) = 100000
FSQ(4) = 54702.6 + 205.98 * VX(2) + .1019 * VX(7) - 15529.7 * LOG(VX(2))
IF FSQ(4) < 10000 THEN FSQ(4) = 10000 'corrosion contrl
IF FSQ(4) > 100000 THEN FSQ(4) = 100000
FSQ(5) = 187272 + 3 * VX(7) - 22.694 * VX(6) + 773.04 * SQR(VX(6)) - 8104.9 * VX
IF FSQ(5) < 10000 THEN FSQ(5) = 10000    'engine shop
IF FSQ(5) > 80000 THEN FSQ(5) = 80000
FSQ(6) = 263506.8 - 590 * VX(5) - 16788.7 * XP(1) + 409852.7 * SQR(XP(1)) - 5842
IF FSQ(6) < 7000 THEN FSQ(6) = 7000 'operations
IF FSQ(6) > 60000 THEN FSQ(6) = 60000
FSQ(7) = 5444.8 + .08443 * VX(1) - .2322 * VX(7) - 137.13 * SQR(VX(7)) + 2.164 *
IF FSQ(7) < 5000 THEN FSQ(7) = 5000' runway
IF FSQ(7) > 20000 THEN FSQ(7) = 20000
FSQ(8) = 12224.8 + 14.36 * VX(2) + 370.98 * VX(5) + 739.22 / VX(5) - 1385.76 * L
IF FSQ(8) < 8000 THEN FSQ(8) = 8000' fire station
IF FSQ(8) > 13000 THEN FSQ(8) = 13000
FSQ(9) = 9800        'control tower
FSQ(10) = 6900      'security
FSQ(11) = 5000      'telecomm
FSQ(12) = 4000     'NDI
FSQ(13) = 5000     'PMEL
FSQ(14) = 20000    'maintenance training
FSQ(15) = 15000    'taxiways
FSQ(16) = -498939 - 19027.7 / VX(1) + 275.07 * SQR(VX(1)) - 992.84 * SQR(VX(8))
IF FSQ(16) < 11000 THEN FSQ(16) = 11000'warehouse
IF FSQ(16) > 70000 THEN FSQ(16) = 70000
'compute cost  costs are in millions of 1993 dollars
' then inx moves them to base yr or beddown yr
TFCC = 0
ADJ = inx * 1.045 * 1.036 * 1.038 * 1.046' 1993 INFLATION ADJ, 89 to 93, using N
FOR I = 1 TO 16
        TEMPC = ADJ * FSQ(I) * FC(I)
        FCC(I) = TEMPC / 1000000
        TFCC = TFCC + FCC(I)
NEXT I
'compute support costs IN 1989 DOLLARS  ($/vehicle)
MAT = 94327.8 + .6206 * VX(1) - 301.57 * VX(2) - 4787331 / VX(2) - 6.595 * VX(6)
IF MAT < 10000 THEN MAT = 10000
CNT = 94577 - 4938749 / VX(2) + 935699 / VX(8) + 5741874 / VX(7) - 379.73 * VX(1
IF CNT < 11000 THEN CNT = 11000
OTH = 16578.3 - .806 * VX(8) + 18456.1 * LOG(VX(5))
IF OTH < 5500 THEN OTH = 5500


PER = 174077 - 1.01E+07 / VX(2)
IF PER < 30500 THEN PER = 30500
MAT = XP(1) * MAT / 1000000
CNT = XP(1) * CNT / 1000000
OTH = XP(1) * OTH / 1000000
PER = XP(1) * PER / 1000000
MAT = ADJ * MAT: CNT = ADJ * CNT: OTH = ADJ * OTH: PER = ADJ * PER
FLCC = MAT + CNT + OTH + PER
wbsc(2, 39) = FLCC
wbsc(4, 39) = lcf * wbsc(wbscc(39), 39)

END SUB
```

```
SUB ORG
' 2.3.2.2 Oragnizational Maintenance costs - IN $M - read MP(I) from RAM
TMMC = 0: AMMC = 0
FOR I = 1 TO 33
        AMC(2, I) = inx * (MP(I) + SMP * MP(I) / MCF(35)) * (40 * 52 * XCF(5)) /
        MC(2, I) = lcf * AMC(2, I)
        AMMC = AMMC + AMC(2, I)
        TMMC = TMMC + MC(2, I)
NEXT I
'maint overhead costs from Cost of Ownership Model
HM = XP(2) * XP(3) / 12      ' msn hr per mo
SM = XP(2) / 12              ' msn per mo
OMO(1) = 2125.6 + .5032 * HM                     'CHIEF OF MAINT X(11) = avail hr
OMO(2) = 3477.2 + .7469 * SM                     'QC
OMO(3) = 475.397                                 'MAINT CONTR
OMO(4) = 1082.7 + 1.143 * HM                     'JOB CONTROL
OMO(5) = 532.8 + 1.0813 * SM                     'PLANS & SCHED
OMO(6) = 264.2 + 6.393 * XP(1)                   'DOCUMENTATION
OMO(7) = 19.18 * SM ^ .4269                      'MATERIEL CONTROL
OMO(8) = 505.8 + 1.013 * SM                      'SUPPLY LIASON
OMO(9) = 713.7 + .9658 * SM                      'PROD CONTR
TOMO = 0: OVH = 0
FOR I = 1 TO 9
OVH = OVH + INT(OMO(I) / X(11) + .95)
OMO(I) = inx * 40 * 52 * XCF(5) * INT(OMO(I) / X(11) + .95) / 1000000
TOMO = TOMO + OMO(I)
NEXT I
AD = 0
FOR I = 1 TO 9
DC(I, 2) = XP(2) * DC(I, 2) / 1000000
AD = AD + DC(I, 2)
NEXT I

wbsc(2, 23) = AMMC + TOMO + AD
wbsc(4, 23) = lcf * wbsc(wbscc(23), 23)

END SUB
```

```
SUB SECOND
' Calculates the basic variables from regression of aircraft.
' Sink Speed is bimodal.  Air Force is 10, Navy is 20 ft/sec.
'
VX(36) = 12105.87 - 310.2692 * VX(2) + 11.75155 * VX(8)
IF VX(36) < 0 THEN
        VX(36) = 0 'HVLCCM
        'PRINT "Defaulting the payload weight to 65000 pounds.  Is this acceptab
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the payload weight.  ", V
END IF
IF VX(36) > 295000 THEN
        VX(36) = 295000
        'PRINT "CAUTION:  Extrapolating default payload weight volume "; VX(36)
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the payload weight.  ", V
END IF

'seat: seats = CINT(-.3227205 + .02192 * VX(2) - .0000616 * VX(7))'seats, includ
'IF seats <= 0 THEN
'         'COLOR 12: PRINT "Defaulting the number of seats to 2 from"; seats,
'         'COLOR 9: PRINT "Do you want to change the default value (Y/N)? ";
'         'INPUT ans$
'        ' COLOR 11
'         'IF ans$ = "Y" OR ans$ = "y" THEN INPUT "Enter number of seats. ", seat
'         'ELSE
'                 seats = 2
'END IF

VX(45) = VX(3) + VX(4)


land: VX(33) = -33683.43 + 2.257766 * VX(1)
IF VX(33) <= VX(1) THEN
        VX(33) = VX(1)
         'COLOR 12: PRINT "Defaulting the landing weight to 30,000 pounds from";
         'COLOR 9: PRINT "Do you want to change the default value (Y/N)? ";
         'INPUT ans$
         'COLOR 11
         'IF ans$ = "Y" OR ans$ = "y" THEN INPUT "Enter landing weight. ", VX(33)
         'ELSE
         '        VX(33) = 30000!
         'ELSE IF VX(33) < 30000 AND VX(33) > 0 THEN PRINT "CAUTION:  extrapolati
         '        COLOR 12
END IF

IF VX(33) > VX(1) + VX(36) THEN
        VX(33) = VX(1) + VX(36)
        'COLOR 11: PRINT "CAUTION:  extrapolating default landing weight", VX(33
        'INPUT ans$
        'F ans$ = "N" OR ans$ = "n" THEN INPUT "Enter the number of seats. ", se
END IF

brake: VX(34) = CINT(-.4951968 + 7.714E-05 * VX(1))
IF VX(34) < 4 THEN
        VX(34) = 4
        'PRINT "Defaulting the number of brakes to 10.  Is this acceptable (Y/N)
        'VX(34) = 10
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of brakes.  ",
END IF
IF VX(34) > 24 THEN
        VX(34) = 24
        'PRINT "CAUTION:  Extrapolating default brakes to "; VX(34)
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of brakes.  ",
END IF

car: VX(35) = -2953.888 + .0959459 * VX(1)
IF VX(36) = 0 THEN VX(35) = 0
IF VX(35) > 35000 THEN VX(35) = 35000
IF VX(35) < 0 AND VX(36) > 0 THEN VX(35) = 900 ELSE VX(35) = 0
        'PRINT "Defaulting the cargo volume 6500 cubic feet.  Is this acceptable
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of brakes.  ",
'END IF
'IF VX(35) > 35000 THEN
'         PRINT "CAUTION:  Extrapolating default cargo volume "; VX(35)
'         INPUT "Is this acceptable (Y/N)?", ans$
'         IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the cargo volume.  ", VX(
'END IF

carf: VX(39) = 6.939 + .007231 * VX(1)' includes passengers but no baggage floor
IF VX(36) = 0 THEN VX(39) = 0
IF VX(39) < 0 THEN
        VX(39) = 0
        'PRINT "Defaulting the cargo floor area to 721 square feet.  Is this acc
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the floor area [ft^2].  "
END IF
IF VX(39) > 2300 THEN
        VX(39) = 2300
        'PRINT "CAUTION:  Extrapolating default cargo floor area "; VX(39)
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the cargo floor area.  ",
END IF
' ?????? check payload weight ?????
carw: carwgt = -26845 + .9267182 * VX(1)
IF carwgt <= 0 THEN
        carwgt = 65000
        'PRINT "Defaulting the cargo weight 65000 pounds.  Is this acceptable (Y
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the cargo weight.  ", car
END IF
'IF carwgt > 295000 THEN
'         PRINT "CAUTION:  Extrapolating default cargo weight "; carwgt
'         INPUT "Is this acceptable (Y/N)?", ans$
'         IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the cargo weight.  ", car
'END IF


VX(38) = CINT(-49.18029 - 6.988057 * W(3) / VX(7))
IF VX(38) <= 0 THEN
        VX(38) = 2
        'PRINT "Defaulting the number of antennas to 20.  Is this acceptable (Y/
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of antennas.
END IF
IF VX(38) > 33 THEN
        VX(38) = 33
        'PRINT "CAUTION:  Extrapolating default number of antennas "; VX(38)
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of antennas.
END IF
'
'
'
VX(42) = CINT(2.538731 + 5.005E-06 * VX(1))
IF VX(42) <= 0 THEN
        VX(42) = 3
        'PRINT "Defaulting the number of hydraulic supply systems to 9 systems.
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of hydraulic s
END IF
IF VX(42) > 8 THEN
        VX(42) = 8
        'PRINT "CAUTION:  Extrapolating default hydraulic supply systems "; VX(4
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the hydraulic supply syst
END IF

nyhdss = CINT(-.1926917# + .001748 * VX(8) + 2.593352 * W(3) / VX(7))
IF nyhdss <= 0 THEN
        nyhdss = 12
        'PRINT "Defaulting the fluid power subsystems to 36.  Is this acceptable
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of fluid power
END IF
IF nyhdss > 76 THEN
        nyhdss = 76
        'PRINT "CAUTION:  Extrapolating default fluid power subsystems "; nyhdss
```

```
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the fluid power subsystem
END IF

VX(41) = CINT(2.787008 + .00025 * VX(8))
IF VX(41) <= 0 THEN
        VX(41) = 3
        'PRINT "Defaulting the number of hydraulic pumps to 18.  Is this accepta
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of hydraulic p
END IF
IF VX(41) > 11 THEN
        VX(41) = 11
        'PRINT "CAUTION:  Extrapolating the number of hydraulic pumps. "; VX(41)
        'INPUT "Is this acceptable (Y/N)?", ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the number of hydraulic p
END IF

VX(21) = 1499.603 + 205.0589 * VX(2) + .9516296 * VX(7)
IF VX(21) <= 0 THEN
        VX(21) = 52500
        'PRINT "Defaulting the jet engine thrust to 52500 pounds.  Is this accep
        'INPUT ans$
        'IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the jet thrust.  ", VX(21
END IF
'IF VX(21) > 164400 THEN
'        PRINT "CAUTION:  Extrapolating default jet thrust "; VX(21)
'        INPUT "Is this acceptable (Y/N)?", ans$
'        IF ans$ = "n" OR ans$ = "N" THEN INPUT "Enter the jet thrust.  ", VX(21
'END IF
'reconcile vehicle weights
AD1 = 0
FOR I = 19 TO 24: AD1 = AD1 + MCF(I): NEXT I      'tot fuel wgt
VX(18) = VX(1) + VX(36) + AD1
IF VX(33) > VX(18) - AD1 THEN VX(33) = VX(18) - AD1
IF VX(33) < VX(1) THEN VX(33) = VX(1)

'avionics installed weight
VX(47) = -743.6426 + 75.871 * SQR(VX(2)) + 5.2 * AVWT / VX(15)
IF VX(47) < 70 THEN VX(47) = 70
IF VX(47) > AVWT THEN VX(47) = AVWT
VX(46) = AVWT - VX(47)
IF VX(46) < VX(47) THEN VX(46) = VX(47) / 2: VX(47) = VX(47) / 2

END SUB
```

```
SUB TOT
' Computation of the NASA WBS cost elements
jj = 2
wbsc(jj, 1) = wbsc(wbscc(2), 2) + wbsc(wbscc(3), 3)
gg = wbsc(wbscc(jj), 5)
FOR j = 6 TO 10
        gg = gg + wbsc(wbscc(j), j)
NEXT j
wbsc(jj, 4) = gg
'
'
gg2 = wbsc(wbscc(13), 13)
FOR j = 14 TO 20
        gg2 = gg2 + wbsc(wbscc(j), j)
NEXT j
wbsc(jj, 12) = gg2
'
'
gg3 = wbsc(wbscc(22), 22)
gh3 = wbsc(4, 22)
FOR j = 23 TO 26
        gg3 = gg3 + wbsc(wbscc(j), j)
        gh3 = gh3 + wbsc(4, j)
NEXT j
wbsc(jj, 21) = gg3
wbsc(4, 21) = gh3

FOR I = 12 TO 20
wbsc(wbscc(I), I) = inx * wbsc(wbscc(I), I)
wbsc(4, I) = lcf * wbsc(wbscc(I), I)
NEXT I

gg4 = wbsc(wbscc(28), 28)
gh4 = wbsc(4, 28)
FOR j = 29 TO 36
        gg4 = gg4 + wbsc(wbscc(j), j)
        gh4 = gh4 + wbsc(4, j)
NEXT j
wbsc(jj, 27) = gg4
wbsc(4, 27) = gh4
'
gg5 = wbsc(wbscc(38), 38)
gh5 = wbsc(4, 38)
FOR j = 39 TO 42
gg5 = gg5 + wbsc(wbscc(j), j)
gh5 = gh5 + wbsc(4, j)
NEXT j
wbsc(jj, 37) = gg5
wbsc(4, 37) = gh5

wbsc(jj, 11) = wbsc(wbscc(12), 12) + wbsc(wbscc(21), 21) + wbsc(wbscc(27), 27) +
wbsc(4, 11) = wbsc(4, 12) + wbsc(4, 21) + wbsc(4, 27) + wbsc(4, 37) + wbsc(4, 43

FOR I = 1 TO 10
wbsc(wbscc(I), I) = inx * wbsc(wbscc(I), I)
wbsc(4, I) = wbsc(wbscc(I), I)
NEXT I

FOR I = 43 TO 44
wbsc(wbscc(I), I) = inx * wbsc(wbscc(I), I)


wbsc(4, I) = lcf * wbsc(wbscc(I), I)
NEXT I
wbsc(wbscc(45), 45) = inx * wbsc(wbscc(45), 45)
wbsc(4, 45) = inxf * wbsc(wbscc(45), 45)

totd = wbsc(wbscc(1), 1) + wbsc(wbscc(4), 4) + wbsc(wbscc(11), 11) + wbsc(wbscc(
lctot = wbsc(4, 1) + wbsc(4, 4) + wbsc(4, 11) + wbsc(4, 45)

END SUB
```

```
DECLARE SUB PRINTFAC ()
DECLARE SUB PRINTSYS ()
DECLARE SUB ECHO ()
DECLARE SUB PRINTMAN ()
DECLARE SUB PRINTHYP ()
DECLARE SUB PRINTWBS ()
DECLARE SUB PRINTLOG ()
DECLARE SUB SPTC ()
DECLARE SUB LOGS ()
DECLARE SUB HYPDIS ()
DECLARE SUB totdd ()
DECLARE SUB OSC ()
DECLARE SUB DISHYPER ()
DECLARE SUB DISMAN ()
DECLARE SUB DISWBS ()
DECLARE SUB DISSOFT ()
DECLARE SUB SUMMARY ()
DECLARE SUB PHASE ()
DECLARE SUB FACCOST ()
DECLARE SUB ACQ ()
DECLARE SUB OSC ()
'
'NASA LANGLEY RESEARCH CENTER
'LIFE CYCLE COST MODEL developed by Univ of Dayton
'save as LCC3.BAS
'File 3 - display modules
'
COMMON SHARED VNAM$, SMP, TME, TMF, SDE, STE, SUP, TW, AF, flcc, infb, infbdd, i
COMMON SHARED tfcc, TFSC, MAT, CNT, OTH, PER, FAF, AMMC, TMMC, inx, year
COMMON SHARED MM, TDSC, ADJ, INST, INTEG, RESO, APPL, CPLX, UTIL, PLTFM, WEIGHT
COMMON SHARED vs$, selv, wbs, totd, AVWT, lcf, inxf, TOMO, lctot
COMMON SHARED SI, RS, NC, RC, NIMWC, RIMWC, RGSE, NGSE, N1, N2, N3, N4, M1, M2,
COMMON SHARED AC, CS, HYPS, PRVS1, PRVS2, SEC, RTITLE$, OVH
DIM SHARED wbs$(2, 60), P$(15), XP(25), X(20), V(12), WB$(15), ISC(20, 20)
DIM SHARED W(35), S(35), MP(35), CF$(30), XCF(30), AMC(2, 50), MC(2, 50), ID(5),
DIM SHARED A(50, 3), B(50, 3), DE(16), TE(16), UP(16), WT(15), HYP$(16), rncs(10
DIM SHARED CF(35), lcs(35), QTY(35), VX$(60), VX(60), mh(20), rd(10), OSCL$(10)
DIM SHARED FSQ(20), FC(20), F$(20), FCC(20), mhc(20), rdc(10), ism(20, 10), INFf
DIM SHARED TOTH(10), TOTV(10), wbsc(4, 50), wbscc(50), MF$(40), MCF(40)
DIM SHARED HP(10), HH(10), HS(10), HR(10), HD(10), infv(50), OPH(35), OMO(10), O

COMMON SHARED HP(), HH(), HS(), HR(), HD()
COMMON SHARED wbs$(), PH$(), P$(), XP(), X(), V(), WB$(), ISC()
COMMON SHARED W(), S(), MP(), CF$(), XCF(), AMC(), MC(), ID(), DC()
COMMON SHARED A(), B(), DE(), TE(), UP(), WT(), HYP$()
COMMON SHARED CF(), lcs(), QTY(), VX$(), VX(), mh(), rd(), OSCL$()
COMMON SHARED FSQ(), FC(), F$(), FCC(), mhc(), rdc(), ism(), INFf()
COMMON SHARED TOTH(), TOTV(), wbsc(), wbscc(), MF$(), MCF(), infv(), OPH(), OMO(
```

```
SUB DISMAN
wbs = 2
ia = 1: ib = 15
BK4: CLS : COLOR 2
PRINT TAB(5); "ORG MAINT MANPOWER COSTS FOR "; VNAM$; " OVER A"; XP(4); "YR SYST
COLOR 3: PRINT
PRINT TAB(5); "Note:  costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 13
PRINT TAB(1); "WBS"; TAB(35); "ANNUAL MAINT COSTS"; TAB(60); "LIFE CYCLE COSTS"
PRINT : COLOR 12
IF wbs = 2 THEN
FOR I = ia TO ib
        PRINT TAB(1); wbs$(2, I); TAB(45); AMC(wbs, I); TAB(65); MC(wbs, I)
NEXT I
        COLOR 3
        IF ib = 15 THEN PRINT : INPUT "ENTER RETURN... ", RET
        IF ib = 15 THEN ia = 16: ib = 33: CLS : GOTO BK4
        'PRINT : COLOR 13
        'IF ib = 33 THEN PRINT TAB(1); "TOTALS"; TAB(45); AMMC; TAB(65); TMMC
        COLOR 3
        INPUT "ENTER RETURN... ", RET

        ELSE

BK5: FOR I = ia TO ib
                PRINT TAB(1); wbs$(1, I); TAB(40); AMC(wbs, I); TAB(60); MC(wbs,
        NEXT I
        COLOR 3
        IF ib = 15 THEN
                PRINT : INPUT "ENTER RETURN... ", RET
                ia = 16: ib = 33: GOTO BK5
        END IF
        IF ib = 33 THEN
                PRINT : INPUT "ENTER RETURN... ", RET
                ia = 34: ib = 44: GOTO BK5
        END IF
END IF

CLS : COLOR 2
PRINT TAB(5); "ORG MAINT MANPOWER COSTS FOR "; VNAM$; " OVER A"; XP(4); "YR SYST
COLOR 3: PRINT
PRINT TAB(5); "Note:  costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 12
PRINT TAB(1); "MAINTENANCE OVERHEAD"; TAB(25); "ANNUAL COST"; TAB(45); "LCC"
PRINT : COLOR 15
FOR I = 1 TO 9
PRINT TAB(1); OMO$(I); TAB(25); OMO(I); TAB(45); lcf * OMO(I)
NEXT I
PRINT
PRINT TAB(1); "SUBTOTAL"; TAB(25); TOMO; TAB(45); lcf * TOMO
PRINT : COLOR 13
PRINT TAB(1); "DIRECT LABOR"; TAB(25); AMMC; TAB(45); TMMC: PRINT
PRINT TAB(1); "TOTALS"; TAB(25); AMMC + TOMO; TAB(45); TMMC + lcf * TOMO
COLOR 3
INPUT "ENTER RETURN... ", RET

END SUB
```

```
SUB DISMENU
'Menu for screen display of output
'
ST1: CLS : COLOR 9
LOCATE 5, 25: PRINT "SCREEN DISPLAY SELECTION MENU"
PRINT : PRINT : COLOR 15
PRINT TAB(25); "1.........SUMMARY BY WBS"
COLOR 14
PRINT TAB(25); "2.........HYPERVEL MODEL COSTS"
PRINT TAB(25); "3.........FACILITY COSTS"
PRINT TAB(25); "4.........LOGISTICS MODEL COSTS"
PRINT TAB(25); "5.........ORG MANPOWER COSTS"
PRINT TAB(25); "6.........SYSTEM SUPPORT COSTS"
PRINT
PRINT TAB(25); "RETURN.....MAIN MENU"
PRINT : COLOR 11
LOCATE 22, 25: INPUT "ENTER SELECTION ", SEL
IF SEL = 1 THEN CALL DISWBS
IF SEL = 2 THEN CALL HYPDIS
IF SEL = 3 THEN CALL FACCOST
IF SEL = 4 THEN CALL LOGS
IF SEL = 5 THEN CALL DISMAN
IF SEL = 6 THEN CALL SPTC
IF SEL > 0 THEN GOTO ST1
END SUB
```


```
SUB DISMENU
'Menu for screen display of output
'
ST1: CLS : COLOR 9
LOCATE 5, 25: PRINT "SCREEN DISPLAY SELECTION MENU"
PRINT : PRINT : COLOR 15
PRINT TAB(25); "1.........SUMMARY BY WBS"
COLOR 14
PRINT TAB(25); "2.........HYPERVEL MODEL COSTS"
PRINT TAB(25); "3.........FACILITY COSTS"
PRINT TAB(25); "4.........LOGISTICS MODEL COSTS"
PRINT TAB(25); "5.........ORG MANPOWER COSTS"
PRINT TAB(25); "6.........SYSTEM SUPPORT COSTS"
PRINT
PRINT TAB(25); "RETURN.....MAIN MENU"
PRINT : COLOR 11
LOCATE 22, 25: INPUT "ENTER SELECTION ", SEL
IF SEL = 1 THEN CALL DISWBS
IF SEL = 2 THEN CALL HYPDIS
IF SEL = 3 THEN CALL FACCOST
IF SEL = 4 THEN CALL LOGS
IF SEL = 5 THEN CALL DISMAN
IF SEL = 6 THEN CALL SPTC
IF SEL > 0 THEN GOTO ST1
END SUB
```


```
SUB DISWBS
CLS : ia = 1: ib = 10
IF XP(6) = 1 THEN yr = year ELSE yr = XP(7) + XP(4)
bk9d:
COLOR 15: LOCATE 1, 20: PRINT "WBS SYSTEM COST"
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
LOCATE 5, 55: COLOR 10: PRINT "default";
COLOR 15: PRINT " / ";
COLOR 14: PRINT "computed": COLOR 14
PRINT
COLOR 11: PRINT ""; TAB(2); "WBS"; TAB(38); "Cost [M year"; year; "$]"; TAB(62);
PRINT
FOR I = ia TO ib
        IF wbscc(I) = 2 THEN COLOR 14 ELSE COLOR 10
        PRINT TAB(1); wbs$(1, I); TAB(30); ,
        PRINT USING "####.###  ##########.###"; wbsc(wbscc(I), I); wbsc(4, I)

NEXT I
        IF ib = 45 THEN LOCATE 17, 69: PRINT yr; "yr-$"

IF ib = 10 THEN
wbbd: COLOR 11: PRINT : INPUT "Enter RETURN... ", RET
        COLOR 14
        CLS
        ia = 11: ib = 20: GOTO bk9d
END IF

IF ib = 20 THEN
   COLOR 11: PRINT : PRINT : INPUT "Enter RETURN... ", RET
        COLOR 14
        CLS
        ia = 21: ib = 26: GOTO bk9d
END IF
'

IF ib = 26 THEN
wbb1d: COLOR 11: PRINT : INPUT "Enter RETURN... ", RET
        CLS
        ia = 27: ib = 36: GOTO bk9d
END IF
'
IF ib = 36 THEN
wbb1e: COLOR 11: PRINT : INPUT "Enter RETURN... ", RET
        CLS
        ia = 37: ib = 45: GOTO bk9d
END IF
'
IF ib = 45 THEN
PRINT : COLOR 13
PRINT TAB(30); "TOTAL"; TAB(42);
PRINT USING "######.###  ##########.###"; totd; lctot
PRINT : COLOR 3
wbb2d: LOCATE 20, 35: COLOR 11: PRINT : INPUT "Enter RETURN... ", RET: COLOR 14

END IF

END SUB
```

```
SUB FACCOST
GOTO DWN2
CLS : COLOR 2
PRINT TAB(25); "FACILITY COSTS"
COLOR 9: PRINT TAB(5); "Note:  costs are in millions of year"; year; " dollars"
PRINT : COLOR 13
PRINT TAB(5); "FACILITY"; TAB(25); "SQ FT/LENGTH"; TAB(45); "CONSTRUCTION COSTS"
PRINT : COLOR 14
FOR I = 1 TO 16
        COLOR 14: PRINT TAB(1); F$(I); TAB(30); FSQ(I); TAB(50);
        COLOR 6: PRINT USING "####.###"; FCC(I)
NEXT I
PRINT : COLOR 15
PRINT TAB(1); "SUBTOTALS"; TAB(50);
PRINT USING "####.###"; tfcc
COLOR 3
LOCATE 25, 25: INPUT "ENTER RETURN...", RET
DWN2: CLS : COLOR 2
PRINT TAB(25); "FACILITY COSTS"
COLOR 9
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
PRINT : COLOR 13
PRINT TAB(5); "OPERATIONS AND SUPPORT COSTS": PRINT : COLOR 9
PRINT TAB(25); "ANNUAL COST"; TAB(43); "LIFE CYCLE COST": COLOR 14
PRINT : PRINT TAB(5); "MATERIAL COSTS"; TAB(25);
PRINT USING "####.###"; MAT; TAB(45); lcf * MAT
PRINT TAB(5); "CONTRACT COSTS"; TAB(25);
PRINT USING "####.###"; CNT; TAB(45); lcf * CNT
PRINT TAB(5); "PERSONNEL COSTS"; TAB(25);
PRINT USING "####.###"; PER; TAB(45); lcf * PER
PRINT TAB(5); "OTHER O&S COSTS"; TAB(25);
PRINT USING "####.###"; OTH; TAB(45); lcf * OTH
PRINT : COLOR 11
PRINT TAB(5); "TOTAL"; TAB(25);
PRINT USING "####.###"; flcc; TAB(45); lcf * flcc
PRINT : COLOR 10
COLOR 3
LOCATE 25, 25: INPUT "ENTER RETURN...", RET

END SUB
```

```
SUB SPTC
CLS : COLOR 14
PRINT TAB(5); "SYSTEM SUPPORT COSTS FOR "; VNAM$; " OVER A"; XP(4); "YR SYSTEM L
COLOR 3
PRINT TAB(5); "Note:  Annual costs are in millions of year"; year; "dollars."
IF XP(6) = 1 THEN PRINT TAB(5); "Life cycle costs are in constant"; year; "dolla
COLOR 5: PRINT TAB(5); "not included in support staff costs"
PRINT : COLOR 15
PRINT TAB(5); TAB(25); "ANNUAL"; TAB(45); "LCC"
PRINT TAB(3); "CATEGORY"; TAB(25); "COSTS"; TAB(45); "COSTS"
PRINT
PRINT TAB(1); "SUPPORT STAFF"
COLOR 5
PRINT TAB(3); "AIRCREWS"; TAB(25); AC; TAB(45); lcf * AC
PRINT TAB(3); "CMD STAFF"; TAB(25); CS; TAB(45); lcf * CS
COLOR 15
PRINT TAB(3); "ADMIN STAFF"; TAB(25); HYPS; TAB(45); lcf * HYPS
PRINT TAB(3); "ENG STAFF"; TAB(25); PRVS1; TAB(45); lcf * PRVS1
PRINT : COLOR 14
TX = HYPS + PRVS1
PRINT TAB(5); "TOTALS"; TAB(25); TX; TAB(45); lcf * TX
PRINT : COLOR 15
PRINT TAB(1); "FACILITIES"; TAB(25); wbsc(wbscc(39), 39); TAB(45); wbsc(4, 39)
PRINT TAB(1); "COMMUNICATIONS"; TAB(25); wbsc(wbscc(40), 40); TAB(45); wbsc(4, 4
PRINT TAB(1); "BASE OPERATIONS"; TAB(25); wbsc(wbscc(41), 41); TAB(45); wbsc(4,
'PRINT TAB(3); "SECURITY"; TAB(25); SEC; TAB(45); lcf * SEC
'PRINT TAB(3); "SVC,SUPPLY,TRANS"; TAB(25); wbsc(wbscc(41), 41) - SEC; TAB(45);
PRINT : COLOR 14
PRINT TAB(3); "TOTAL"; TAB(25); wbsc(wbscc(37), 37), TAB(45); wbsc(4, 37)

PRINT : COLOR 3
INPUT "ENTER RETURN..."; RET

END SUB
```