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AEROSPACE INFORMATION REPORT

AIR 1939

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AIRCRAFT ENGINE LIFE CYCLE COST GUIDE

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1. **PURPOSE:** Aerospace Information Report (AIR) 1939 provides guidelines in lieu of directives to achieve consistent Life Cycle Cost (LCC) analysis for military aircraft engines.

AIR 1939 deals specifically with the direct Life Cycle Cost elements of Aerospace Propulsion Systems. It is recognized that propulsion is normally one part of a larger system, and that through its performance interaction with this overall system, propulsion can often exert a greater influence on system costs than are possible through changes in the direct propulsion system cost elements. AIR 1939 is not directed at this performance interaction issue. Instead, it provides a Life Cycle Cost approach which is a stand-alone measure of propulsion system cost - but which can also serve as a cost building block for broader system-oriented cost-benefit evaluations.

2. **SCOPE:** AIR 1939 addresses communication of LCC data between equipment suppliers, aircraft engine producers, aircraft manufacturers, and users, as illustrated in Figure 1. The LCC data categories addressed include: research, development, test and evaluation (RDT&E); acquisition (initial procurement and investment); and operating and support (O&S) costs. While input and output formats are suggested, calculation procedures and cost methodology are specifically excluded since many LCC models preferred by the industry are company sensitive or proprietary (Figure 1). The relationship of LCC input data to program phase is described. Ground rules and assumptions are addressed. A glossary of LCC terms is provided. The LCC impact of propulsion systems on other aircraft systems is considered.

This document was specifically developed for military propulsion system cost analysis. However, it is believed that a functional relationship exists between military and commercial Life Cycle Cost analysis and that with some interpretation, sections of AIR 1939 might be applicable to commercial propulsion systems as well.

In summary, AIR 1939 provides a basis for LCC calculations, for monitoring of LCC status resulting from trade studies, and for tracking status against LCC goals in a consistent manner, thus permitting quantitative, comparable assessment. AIR 1939 guidelines recommend that a Life Cycle Cost presentation include consideration of overall cost rather than a sub-optimization of just one or a few cost elements.

3. **BACKGROUND:** Early program LCC analysis recognizes that as the engine design evolves, its LCC becomes more fixed, as illustrated in Figure 2. Typical trends of annual costs as a function of time and throughout the different life cycle phases are shown in Figure 3.

The evolution of LCC estimation has resulted in many different approaches, definitions, directives, and procedures. Consequently, a need has arisen to achieve consistency in the exchange of LCC data without specifying methods to calculate these costs. This AIR responds to this need for consistent format and definitions for LCC inputs and outputs.

3. (Continued):

In addition, the level of LCC detail has sometimes been inappropriately applied. For example, a parametric model at an early phase of LCC might be more appropriate than an accounting model. This AIR recognizes LCC data detail consistent with the phase of project development.

The preparation of this document, AIR 1939, used several SAE documents as role models:

<u>Number</u>	<u>Title</u>
AIR 1812	Aerospace Information Report "Environmental Control Systems Life Cycle Cost"
ARP 1587	Aerospace Recommended Practice "Aircraft Gas Turbine Engine Monitoring System Guide"
AS 681	Aerospace Standard "Gas Turbine Engine Steady State Performance Presentation for Digital Computer Programs"
SP 478	Special Publication "Aircraft Gas Turbine Engine Monitoring Systems"

4. DESCRIPTION: This AIR presents the following guidelines:

- o Defines LCC terms including:
 - Nomenclature
 - Input/Output parameters.
- o Provides input/output compatibility as a function of:
 - Project phase
 - Depth of analysis
- o Describes responsibilities for:
 - Equipment suppliers
 - Engine producers
 - Aircraft manufacturers
 - System users

Life Cycle Costs and related life cycle phases (development, acquisition, operations and support) are shown in Figure 3. Life Cycle Cost practices vary and therefore require coordination for consistent LCC data exchanges (Section 5).

5. PRACTICES: This AIR's dominant emphasis is to present an LCC guide for the consistent exchange of data for use in the achievement of affordable and cost effective total systems and related RDT&E, acquisition and O&S cost elements. This guide serves as a basis for aircraft engine system LCC data exchanges.

- 5.1 Analysis: LCC analysis including Design-To-Cost (DTC) is conducted at various levels of detail and data as shown in Figure 4. Analysis during early program phases usually yields the least accurate LCC estimates. As the program continues toward full scale production and deployment, LCC estimates tend to become more accurate as a function of detail data certainty. Figure 5 shows how military funding phases are time related to LCC phases. Combining information shown by Figures 4 and 5 allows recognition of the importance for not overspecifying LCC parameters beyond the probable capability of the supplier community at any particular point in a program.
- 5.1.1 Conceptual LCC Analysis: Aircraft engine parametric LCC analysis can begin during research or exploratory development program tasks. The goal in these very early LCC phases is to determine the gross probable LCC to establish a baseline around which initial engineering design trade studies can be exercised. While a potential large uncertainty in this type of LCC estimate can be expected, such early LCC analysis helps configure an engine design and identify areas having high cost drivers or program elements very sensitive to LCC. This knowledge can be used to structure specific investigations or studies during the Validation Phase. LCC analysis is considered successful at this program phase if it contributes to a preferred and proper selection of an engine type and probable optimum thermodynamic cycle for a baseline aircraft/mission set.
- 5.1.2 Sensitivity Analysis: While perhaps of most value during early LCC Phases when more or larger uncertainties exist in parameters associated with major cost drivers, sensitivity analysis can provide valuable results throughout all LCC Phases. An understanding of the potential impact on incremental LCC, whether from perturbations in challenging design goals or even possible shifts in utilization scenario, or variations in uncontrollable parameters such as fuel price, can be of value in both decision making and contingency planning.
- 5.1.3 Validation LCC Analysis: Continuing LCC analysis during this phase leads to narrowing the estimate uncertainty, thereby allowing more detailed trade studies. More work on the engine cycle is possible. Attention may begin to focus on planned support for the propulsion system. Life limits might now be calculated and traded against material selections made in the Conceptual Phase. Depending on the scope of the Validation Phase, LCC estimates might transition from parametric to a summary bottom-up analysis. This level of program progression allows setting more realistic LCC goals.
- 5.1.4 Full Scale Development LCC Analysis: Sufficient detail now exists, and detailed plans are in place, so that a more refined RDT&E cost estimate can be made. The effect of production rate variations on unit cost is a key variable in the assessment of production cost due to the nature of the competitive split buy. (Reference 29 and 30 in Section 10.4) Moreover, a detailed bottom-up estimate can be generated for the engine portion of production or acquisition at the engine component level. A better understanding of the aircraft interface and intended operating scenario allows the range of uncertainty for O&S to be narrowed. Warranty calculations can be initiated. In other words, the LCC estimate becomes

5.1.4 (Continued):

useful to initiate detailed LCC cost reduction analyses from goals that may already have been set. It should be indicated if past MQT, PV, or CERT development costs (in-service development) are to be included or excluded.

5.1.5 Production LCC Analysis: A major effect of the application of LCC analysis during the production phase is unit engine cost reduction. Trade studies center on reducing unit costs at no sacrifice to performance or supportability. Another goal should be to hold LCC to a minimum even if some unit cost savings cannot be realized. For example, a small savings in production cost generally should not be made if a related maintenance cost increase overwhelms the savings to the production change. It should also be noted that detailed production lot size and timing allows learning curve effects to be optimized so that the lowest average cumulative engine costs can be realized.

5.1.6 Operating and Support LCC Analysis: O&S LCC analysis provides an opportunity to use detail, bottom-up data to determine LCC cost drivers that escaped previous trade studies. In particular, attention might be focused on service revealed deficiencies which might result from actual operations causing behavior different from that predicted or demonstrated during development testing. For example, such a behavior variable might be performance deterioration or another variable not anticipated during FSD. In addition, repair or rework procedures might be reduced thereby achieving further O&S savings. Note that the overall LCC estimate becomes more credible since RDT&E and some portion of production are now sunk costs.

5.1.7 Disposal LCC Analysis: Historically, LCC analysis has paid little attention to disposal savings opportunities from a broad analytical viewpoint. Aircraft systems, particularly military systems, pass from active service to support roles to the boneyard. However, cost effective phase outs can be planned using LCC analysis techniques. Inventory levels should be monitored against timed usage so that scrap costs are minimum when the system goes out of service. If a derivative propulsion system is in service, a modification analysis could show LCC savings for the second system. If the system being retired is to be in service for another government, an LCC analysis might show a cost effective way to transfer assets. In any event, LCC analysis techniques might lead to more cost effective plan(s).

5.1.8 Risk Analysis: LCC estimates are subject to many kinds of uncertainty, including those in the estimating procedure and those in the program being estimated. It is desirable that single-point LCC estimates be accompanied by descriptions of these two kinds of uncertainty, quantified where possible.

Risk, a manifestation of uncertainty, is defined in different ways. Risk can be defined as the interaction (arithmetic union) of the probability of an event occurring and the consequence of that event (ultimately, that consequence becomes a change in LCC). Note that risk can be favorable as

5.1.8 (Continued):

well as unfavorable. A common measure of risk is the standard deviation of the probability distribution of a performance measure. A risk profile is the array of known possible events and the product of their consequences and probabilities of occurrence. If this array could be constructed such that the events are mutually exclusive, then binominal probability analysis would provide the overall expected value and standard deviation of total program risk. Otherwise, a more complex Monte Carlo simulation might be required to evaluate overall risk.

5.2 Time Value of Money: Since moneys can be invested and thereby grow with time, economic studies customarily discount future dollar flows to reflect this time-value-of-money concept. Within the Government, a wide range of options is allowed for addressing this issue in Army, Navy and Air Force programs. Where specific Government direction is given in this regard, Propulsion System Life Cycle Cost Analysis should be done accordingly. In the absence of such direction, consideration should be given to employing a suitable discount rate in evaluating Propulsion System Life Cycle Cost tradeoffs.

Selection of a discount rate is very important and requires considerable judgment. Two important issues in this selection involve:

- o Using a baseline interest rate versus using one which includes an allowance for inflation.
- o Using a discount rate which reflects the Government's direct cost of borrowing money versus selecting an interest rate-of-return which reflects average return in the private sector of the national economy (e.g., Government borrowings considered as a lost opportunity for investment in the private sector).

Of utmost importance is clearly identifying the ground rules selected and insuring that they are consistently applied throughout a study. The rate of discounting directly influences the weighting of cost elements within each phase of LCC. Its inclusion in the LCC process might, therefore, affect the outcome of a decision involving the selection of a preferred design option based on a comparison of total discounted Life Cycle Cost.

5.3 Study Types: Subsequent subsections briefly define and describe four fundamental study types as illustrated in the matrix chart of Figure 6 where the Engine System and Airframe System can be either fixed or variable. Typical relationships of these study types to LCC Phases and relative impact on items of LCC emphasis are presented in Figure 7.

- 5.3.1 Engine Studies: LCC analyses focused on Engine Studies are based on a variable engine and fixed airframe scenario. The engine size and/or cycle are key variables. Since the airframe is fixed, no significant airframe cost changes are involved. Such studies may be conducted at any depth. Although any model can be used, it must be consistent with the LCC phase of the specific program (paragraphs 5.1.1-5.1.8). The latter can be and often are different for the airframe and engine.
- 5.3.2 Engine/System Studies: This type of LCC analysis involves a variable airframe as well as a variable engine. In contrast to Section 5.3.1, the airframe is a key variable; and consequently, the engine manufacturer needs airframe data and vice versa. All the ingredients of Section 5.3.1 apply; but in addition, airframe costs are included.
- 5.3.3 System Studies: This type of LCC analysis applies to variable airframe and fixed engine situations. Since the engine is fixed, there is no effect on engine cycle or engine size. Because airframe variations can impact engine usage, severity effects can be important considerations. The ingredients of paragraph 5.3.1 again apply; in addition, however, the engine and airframe costs (often from probably different phases) are added together.
- 5.3.4 Ground Rule Studies: In this situation, both the airframe and engine are fixed, but the scenario is variable. Typically, the impact of changes in the maintenance concept, mission details, delivery schedule, economics, etc. are evaluated. Choice of such specific variables and their allowed variability impact should be consistent with the LCC phase. As in paragraph 5.3.3, engine and airframe costs are added as appropriate.
- 5.4 Projecting/Tracking: LCC tracking projections are used for cost control by design engineers, program managers, financial analysts and many others.

Design engineers use LCC as a technical parameter for improving the engine system. That is, LCC is established as a technical parameter in the same sense and for the same purpose as performance parameters.

Program managers use LCC tracking projections for program cost control. Similarly, financial analysts use LCC tracking projections for contract cost control.

Five elements of LCC tracking projections are (Figure 8):

- initial baseline
- previous projections
- current status
- future projections
- goal or target

The initial baseline LCC is the Initial Projection, sometimes called a calibration, of the total cost of an engine program from start to finish. The current status LCC is the Current Projection or most recent calibration of the total cost of an engine program from start to finish. The goal or target LCC is the projected cost of the engine program that has been established as an achievement objective for engine program participants.

5.4 (Continued):

As the engine program proceeds, improvement changes usually are incorporated into the engine design and its program elements to reduce cost. The results are additional LCC projections generally (but not always) lower than the initial projection.

LCC tracking projections that have been estimated for time periods prior to the current status LCC are Previous Projections. Similarly, LCC tracking projections that are being estimated for time periods beyond the current status LCC are Future Projections, as shown by Figure 8.

LCC tracking projections are either or both of the following cost and cost related data approaches:

- absolute
- relative

Absolute data has not had a quantity multiplied, divided, subtracted, or added to it. Absolute data presents numerical values independent of a baseline.

Relative data has had a quantity multiplied, divided, subtracted, or added to it. Relative data presents numerical values dependent upon another value or values (e.g., net change from an established baseline).

For clarity and improved tracking projections, Life Cycle Costs can be separated as illustrated in Figure 9 (for a scenario different from that depicted in Figure 8). Using this approach to LCC tracking projections, both cost and cost-related actual and updated projections can be better presented and controlled.

Some variants to the above recommended guidelines for LCC tracking projections are practiced by industry and government. Specifically, the claimed baseline LCC might not be the Initial Projection. For example, sometimes the claimed baseline is the Current Status Projection. At other times the claimed baseline is the Goal or Target LCC. For this and other areas of LCC data presentation, both users and suppliers of LCC data should coordinate and mutually agree upon consistent LCC data presentation guidelines.

Breakouts of Life Cycle Cost tracking projections to several higher and lower indenture levels can be helpful to both LCC data presentation users and suppliers. When tracking projections of engine LCC, the engine's ongoing credit and debit impacts on total system LCC (e.g., aircraft/fleet) should be reported. This should be coordinated and mutually agreed upon in advance by LCC data presentation users and suppliers.

5.4 (Continued):

Improvement experience curves, also called learning curves, are frequently applied for tracking projections of cost and cost related LCC parameters. Many different learning curves of the form $y=AX-B$ are in use by industry and government. Plotted data can be a straight line on log-log paper depending on whether the data are cumulative average or per unit data (Figure 10). Users and suppliers of LCC data should clearly indicate which data tracking projections are being presented, e.g., cumulative average or per unit. Historical data actuals should be used as a basis to substantiate and/or verify LCC tracking projections.

- 5.5 Caution: Program managers, financial analysts, design engineers and other technical specialists should be aware of erroneous conclusions resulting from inappropriate input and/or inappropriate comparisons with historical results, in spite of adequate LCC effort and valid LCC output.

For example, a new engine program managed "business not as usual" with novel engine design features might not follow historical trends. LCC analyses intended for engineering design activity might be inappropriate (without additional coordination and costing) for financial budget activity (see Figures 11 and 12).

- 5.5.1 Engine Fleet Size LCC Impact: The smaller the engine fleet size the more dominant is the engine development cost. Conversely, the larger the engine fleet size the more dominant is the engine acquisition, maintenance and fuel cost. With only engine fleet size as a variable, a typical trend of impact on LCC percentage allocations is shown for a 50-50,000 unit range of engine fleet size (Figure 11).
- 5.5.2 Engine Program Life LCC Impact: The shorter the engine program life the more dominant is the engine development and acquisition cost. Conversely, the longer the engine program life the more dominant is the engine maintenance and fuel cost. With only engine program life as a variable, a typical trend of impact on LCC percentage allocations is shown for a 1-45 year range of engine program life (Figure 12).
- 5.6 Coordination and Responsibility Requirements: As was indicated in Figure 1, LCC involves several different participants. Consequently, a well-coordinated LCC effort is important. Furthermore, many of the LCC functions addressed in this AIR can be accomplished by more than one of these participants. To reduce duplication and improve productivity, a thorough delineation of these responsibilities should be made and understood by the LCC participants. For example, the amount of input/output detail can vary with program phase and funding.

6. INPUT: There are no rigid guidelines which can be applied to classify input information used to calculate aircraft engine Life Cycle Cost. As noted elsewhere, parameters regarded as an input to one analysis, i.e., shop visit rate goal, can in different circumstances be correctly identified as an output. Sometimes the same parameter is utilized as both an input and an output. This apparent anomaly is illustrated in Figure 13. In a top-down "scoping" study, Life Cycle Cost and possibly even RDT&E, Acquisition and O&S might be input. In such cases, the objective would be to determine the corresponding output values of the corresponding sub-elements consistent with the input objectives. On the other hand, a bottom-up study would utilize sub-element values as input to build up the resulting output Life Cycle Cost.

In the latter case when LCC is an output, the principal sources of input information required by the Engine Producer to calculate aircraft engine Life Cycle Cost are:

- System User
- Engine Producer
- Airframe Manufacturer
- Equipment Suppliers

The responsibilities for providing specific data items is likely to vary between types of analyses and also at different phases of the program (see paragraph 5.6). Prior to expecting responsive LCC calculated results to be furnished by the Engine Producer, it is important that the Customer specify which values of the functional parameters (input and/or output) will be furnished to the Engine Producer consistent with the appropriate program phase. For example, relatively few input parameters should be assumed, scaled or adjusted by the Engine Producer from similar, previously completed LCC studies or related experience to provide Engine LCC estimates after completion of the Conceptual Phase (Figure 4).

While the unit of currency used throughout this document is the U.S. dollar, the unit of currency actually used for the Input and Output parameters of this document should be that appropriate for the particular Life Cycle Cost application.

The following should be regarded as a typical, but not exhaustive list of input requirements to support the calculation of Engine LCC. (Note: These input parameters include such items as engine goal values. Some Engine Producers may require such goals as an input for their methodology. For other Engine Producers, the engine goals may be an output of their methodology.)

It should be noted that engine modules or accessories which can be line replaceable units (LRU/WRA) have several descriptive functions also requiring identification to permit proper establishment of their maintenance cost contributions. For example, such functions include ERR, NRTS(M), and MMH/ERR(M) as listed in paragraph 6.3.

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6.1 General Description of the Project: Under this heading, a general narrative description of the project might be provided.

6.2 System Parameters including:

EPA	Number of engines per aircraft
DMM	Design Missions + Mix + Payloads + Expendables
PMM	Peacetime Missions + Mix + Payloads + Expendables
ADR	Additional Design Requirements (g's, Accel Time, etc.)

6.3 Engine Design and Development Requirements including:

FOD	Engine Foreign Object Damage Rate: (Events/1,000 EFH)
FODOW	Requiring On-Wing Repair
FODSV	Causing a Shop Visit
ERR	Engine Repair Rate (events/1000 EFH)
MMH/ER(M)	Maintenance Man Hours Per Engine Removal (At Appropriate Maintenance Level, M)
NRTS(M)	Not Repairable This Station (For Appropriate Maintenance Level, M)
LRR	Line Replaceable Unit Removal Rate (Events/1000 EFH)
TMC	Total Maintenance Cost [Parts, Consumables + Labor] (Dollars)
TDC	Total Development Cost, Engine Only (Dollars)
UFC	Average Unit Flyaway Cost, Engine Only (Dollars)
MP	Measuring Point for Goals (Cumulative Engine Flight Hours)
SFC	Specific Fuel Consumption Based on Average Mission Usage Fuel Consumption
LCC	Sum of RDT&E, Acquisition and O&S Costs (can also be Output - see Section 7)

6.4 Fleet Size and Structure including:

CCA	No. of Combat Coded Aircraft (Integer)
TRA	No. of Training Aircraft (Integer)
PAA	No. of Primary Authorized Aircraft = CCA + TRA (Integer)
ATA	No. of Attrition Aircraft (Integer)
BAI	No. of Backup Authorized Inventory Aircraft (Integer)
FTA	No. of Flight Test Aircraft (Integer)
TA	No. of Total Aircraft = PAA + ATA + BAI + FTA (Integer)
FTEI	No. of Flight Test Engine: Installs (Integer)
FTES	Spares (Integer)
FTET	Total = FTEI + FTES
PEI	No. of Production Engine: Installs (Integer)
PES	Spares (Integer)
PET	Total = PEI + PES
APS	No. of Aircraft Per Squadron (Integer)
SPW	No. of Squadrons Per Wing (Integer)
WPB	No. of Wings Per Base (Integer)
BUS	No. of Bases: CONUS (Integer)
BOS	Non-CONUS (Integer)
BTOT	Total = BUS + BOS (Integer)

6.4 (Continued):

SPCV	No. of Squadrons Per Carrier Vessel (CV) (Integer)
SPNAS	No. of Squadrons Per Naval Air Station, NAS (Integer)
NCV	No. of CV's (Integer)
NBUS	No. of NAS's: CONUS (Integer)
NBOS	Non-CONUS (Integer)
NBTOT	Total = NBUS + NBOS (Integer)

6.5 Overall Timescales and Delivery Schedules including:

IOC	Initial Operational Capability (Date)
EPY(i)	No. of Engines Produced Each Year (Integer)
YEP	No. of Years of Engine Production (Integer)
SI	Study Interval (Indicate Life Cycle Phases)

6.6 Fleet Utilization including:

FTP	Flight Test Period (Number of Months)
FTH	Total Number of Flight Test Hours (Integer)
AFHPAA	No. of Aircraft Flight Hours Per Year Per PAA (Integer)
AFHCV	No. of Aircraft Flight Hours Per Year Per CV Aircraft (Integer)
AFHNAS	No. of Aircraft Flight Hours Per Year Per NAS Aircraft (Integer)
EFHEOH	No. of Engine Flight Hours Per Engine Operating Hour (Ratio)
EOPY	No. of Engines Operating Per Year (Integer)

6.7 Maintenance Organization including:

EML	Number of Engine Maintenance Levels (Integer)
PWF	Packaged Weight Factor, Shipping Weight/Item Weight (Ratio)
MAX(M)	Maximum Engine Units Repair Capability, Maintenance Level M (Integer)
TOCV	CV Annual Turnover Rate (Personnel Per Year)
TONAS	NAS Annual Turnover Rate (Personnel Per Year)
TOB(M)	Base Annual Turnover Rate, Maintenance Level M (Personnel Per Year)
AMHCV	CV Available Personnel Hours (Personnel Hours Per Personnel Month)
AMHNAS	NAS Available Personnel Hours (Personnel Hours Per Personnel Month)
AMMHRT	Total Available Military Personnel Hours for All Maintenance Levels (Personnel Hours Per Month)
ACMHD	Depot Available Civilian Personnel Hours (Personnel Hours per Personnel Month)

6.8 Maintenance Demands including:

SII	Scheduled Inspection Interval (Flight Hours or Cycles)
SIW	Scheduled Inspection Window (Flight Hours or Cycles)
SMI	Scheduled Maintenance Interval (Flight Hours or Cycles)
LEFF	Labor Efficiency (%)
PCUS	Packaging Cost Per Pound: CONUS (\$/Pound)
PCOS	Non-CONUS (\$/Pound)

6.8 (Continued):

TC	Transportation Cost from Int Shop to Depot, One-Way: (\$/pound)
TCUS	CONUS
TCOS	Non-CONUS
OSTUS	Order and Ship Time [Parts Only]: CONUS (Days)
OSTOS	Non-CONUS (Days)
RCTMS(M)	Repair Cycle Time at Maintenance Level M for Modules and SRU's (Days)
RCTPL(M)	Repair Cycle Time at Maintenance Level M for Parts and LRU's (Days)
ETT(M)	Engine Turn Time, Exclusive of In-Work, at Maintenance Level M (Days)

6.9 Spares Requirements including:

SPCF(i)	Spares Confidence Factor for Each Engine, Module, SRU, LRU and Part (%)
IPSE	No. of Initial Pipeline Spare Engines
IPSM(i)	No. of Initial Pipeline Spare Modules and/or SRU's
IPSP(i)	No. of Initial Pipeline Spare Parts and/or LRU's
ECON	No. of Engine Condemns (Integer or % of Installs)

6.10 Cost Basis including:

BYD	Base Year Dollars (Government Fiscal Year or Calendar Year)
FC	Fuel Cost (\$/Gallon)
LRB(M)	Government Labor Rates, Burdened at Maintenance Level M (\$/Personnel Hour)
DMC(M)	Direct Material Cost at Maintenance Level M (\$/Personnel Hour)
IMC(i)	Initial Management Cost (Dollars Per Item)
RMC(i)	Recurring Management Cost (Dollars Per Item Per Year)
BMC(i)	Base Supply Management Cost (Dollars Per Item Per Year)
TDC	Technical Data Cost Per Page: (Dollars)
TDCPAC	Acquisition
TDCPUP	Update
TDCPRE	Reproduction
DISC(i)	Annual Net Discount Rate (%)

7. OUTPUT: Section 6, Input, should be considered when reading this section.

7.1 RDT&E: A series of currency values representing total Engine Research, Development, Test and Evaluation costs over the life cycle of the weapon system. These values include the following RDT&E cost categories (dollars):

RDMQT	RDT&E Through PV/MQT, Including AMT Testing
RDIOC	RDT&E from Completion of PV/MQT to IOC
RDFTE	Number of Flight Test Engines:
RDFTEI	Installs (\$ and Number of Engines)
RDFTES	Spares (\$ and Number of Engines)

7.1 (Continued):

RDFTS	Flight Test Support
RDILS	ILS Development:
RDILDSD	Data: Support Data
RDILDTP	Technical Publications
RDILSEBO	Support Equipment: Base - Organizational
RDILSEBI	- Intermediate
RDILSED	Depot
RDILSPIL	Sys/Proj Mgmt: ILS Management
RDILSPSP	Sys Eng'g + Proj Mgmt
RDILTS	Training: Services

7.2 Acquisition: A series of currency values representing total Engine Acquisition costs over the life cycle of the weapon system. Also called Production or Investment. These values include the following cost categories (dollars):

ACIE	Installed Engines (\$ and Number of Engines)
ACSE	Pipeline Spare Engines (\$ and Number of Engines)
ACSP	Pipeline Spare Modules + Parts:
ACSPMS	Modules + SRU's (\$ and Equivalent Number of Engines)
ACSPPL	Parts + LRU's (\$ and Equivalent Number of Engines)
ACPSE	Peculiar Support Equipment:
ACSEDMD	Data: Management Data
ACSESDS	Support Data
ACSEBO	Support Equipment: Base - Organizational
ACSEBI	- Intermediate
ACSED	Depot
ACSESPIL	Sys/Proj Mgmt: ILS Management
ACSESPSP	Sys Eng'g and Proj Mgmt
ACSETE	Training: Engines (\$ and Number of Engines)
ACSETET	Equipment/Tooling
ACPTI	Personnel Training - Type I
ACPT	Production Tooling
ACTO	Technical Orders
ACWRS	War Reserve Spares

7.3 O&S: A series of currency values representing total Engine Operating & Support costs over the life cycle of the weapon system. These output parameters are functionally responsive to the engine related cost categories of the OSD (CAIG) Aircraft O&S Cost Development Guide (Reference 21 of paragraph 10.2). These values include the following O&S cost categories (dollars):

OSL	Labor Expended:
OSLB	Base
OSLBFL	Flight Line Inspections (Organizational)
OSLBON	On-Wing (Organizational)
OSLBOF	Off-Wing (Intermediate)
OSLD	Depot

7.3 (Continued):

OSRM	Repair Material (Expendables) Used:
OSRMB	Base
OSRMB0	On-Wing (Organizational)
OSRMBI	Off-Wing (Intermediate)
OSRMD	Depot
OSRS	Spare Parts Consumed:
OSRSB	Base
OSRSB0	On-Wing (Organizational)
OSRSBI	Off-Wing (Intermediate)
OSRSD	Depot
USEC	Engineering Change/TCTO Retrofit
OSFSS	Field Service Support
OSF	Fuel:
OSFCM	Composite Mission
OSFEM	Engine Maintenance
OSIL	ILS Management
OSIM	Inventory Management
OSPTI	Personnel Training
OSSE	Recurring Maintenance Support Equipment
OSTUR	Technical Orders (Revisions)
OST	Transportation
OSUF	Unique Facilities

- 7.4 CIP: A yearly projection representing total Engine Component Improvement Program costs (dollars) over the life cycle of the weapon system. It includes all design, fabrication and test costs associated with component improvement, once the engine design is finalized and goes into production.
- 7.5 Miscellaneous: This output format concentrates on elements that are specifically cost oriented. The need to provide additional output categories in the form of other parameters (such as engine removal rate) is recognized, but excluded from this document. Understandably, different customers will have need for other related parameter values; and such parameters will change with both time and specific program details. A separate advance request (possibly in the Request for Proposal, if extensive) should be made of the Engine Producer(s) to provide any such (non-cost oriented) information.
8. COLLABORATION: Guidelines presented in AIR 1939 establish a framework for communications in collaborative ventures. The following describes the principal areas which generally need to be addressed to ensure successful pursuit of LCC objectives.
- 8.1 Language: In a multi-lingual collaboration, English is suggested for a common language. To assist non-English speaking nations, the Simplified English System should be used wherever possible. This system was developed by AECMA and agreed to by AIA. (See paragraph 10.4, Reference 27.)

- 8.2 Accounting: Each LCC participant may have different accounting practices, e.g., overhead structures and methods of overhead recovery. To ensure that effective cost comparisons can be made, close attention should be directed to detailed agreement of definitions of cost structure elements. Accounting practices should be coordinated for effective cost control.
- 8.3 Currency and Inflation: In a multi-currency collaboration, cost should be translated to a common currency or LCC Index. There is a danger that variations in exchange rate and differential inflation rates might distort the contributions of cost elements with time. This increases the difficulty of tracking and controlling project costs. Formulae can be embodied in the cost calculation process to minimize these effects.
- 8.4 Tracking and Monitoring: Important agreements include:
- o Datum designs against which improvements can be measured
 - o Targets for LCC elements
 - o Procedures for adjustment to above
 - o Mechanisms for monitoring progress
 - o Working practices for LCC
- 8.5 Data: Common questionnaires should be adopted for obtaining information from customer, suppliers, etc., at different phases of the project. Common formats and routes for data feedback from operators should be established to ensure a coordinated approach to in-service support and management.

9. TERMINOLOGY AND GLOSSARY:

9.1 Acronyms and Abbreviations:

AECMA	Association Europeenne Des Constructeurs De Materiel Aerospatial
AIA	Aerospace Industries Association
AIR	Aerospace Information Report
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
CERT	FAA Certification Test
CIP	Component Improvement Program
CONUS	Continental United States
DOD	Department Of Defense
DT	Development Test
DTC	Design To Cost
DTUPC	Design To Unit Production Cost
DTLCC	Design to Life Cycle Cost
FMECA	Failure Mode, Effects and Criticality Analysis
FSD	Full Scale Development
FSP	Full Scale Production

9.1 (Continued):

GFE	Government Furnished Equipment
ILS	Integrated Logistics Support
JRMB	Joint Requirements Management Board
LCC	Life Cycle Cost
LRIP	Low Rate Initial Production
LSAR	Logistic Support Analysis Record
MQT	Military or Model Qualification Test
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NAS	Naval Air Station
O&M	Operations and Maintenance
O&S	Operating and Support
OT	Operational Testig
PEP	Producibility, Engineering and Planning
PIP	Product Improvement Program
POL	Petroleum, Oil and Lubricants
PV	Product Verification
RAM	Reliability, Availability, and Maintainability
R&D	Research and Development
R&M	Reliability and Maintainability
RDTE	Research, Development Test and Evaluation
SAE	Society of Automotive Engineers
WBS	Work Breakdown Structure
WRA	Weapon Replaceable Assembly
WUC	Work Unit Code

9.2 Glossary:

Acquisition Cost: Acquisition cost is the sum of investment or procurement costs, recurring and non-recurring.

Alternative: One of several different ways of achieving a desired capability.

Cost Element: A cost element is the lowest level identified cost for a given LCC analysis. A cost element is further broken down into variables, rates, factors, or constants related mathematically which produce a money amount corresponding to an aspect of the product under investigation.

Cost Factors: A cost per unit of resource; hence, a value established on a per unit basis which, when multiplied by the number of units or program factor, yields the estimated cost.

Cost Growth: Cost growth is a term related to the net change of an estimated or actual amount over a base figure previously established. The base should be relatable to a program, project, or contract and be clearly identified including source, approval authority, specific items included, specific assumptions made, date, and amount.

9.2 (Continued):

Cost Model: An ordered arrangement of data and equations that permits translating physical resources into costs. A mathematical device used to develop estimates and output formats for presentations. The model consists of an input format to specify the problem; information, including both system description data and estimating relationships; and an output format.

Cost of Ownership: Ownership costs encompass the cost elements within the operating and support cost category exclusively. (See Reference 3 of paragraph 10.2, Government Documents.)

Cost Parameters: Cost parameters are cost thresholds and cost brackets or bands. Cost threshold is the upper boundary value of cost which should not be exceeded. Cost brackets or band is the acceptable range of cost for the performance band.

Cost Tracking: Generally, a process which collects and evaluates data in determining the reasons for variances between successive cost estimates or between planned or projected versus actual costs.

DELPHI Technique: A polling technique often used to make expert opinion estimates. The experts in a given technical area are polled by letter. They are asked to estimate the cost for a system displaying certain specified characteristics. Their responses are summed and a mean, standard deviation or range established. This data is fed back to the experts in another letter and they are allowed to change their estimates, if they desire. After several interactions, an order of magnitude estimate (the mean) results.

Design to Cost [Design to Unit Production Cost (DTUPC)]: Design to cost (DTC) and design to Life Cycle Cost (DTLCC) are management techniques to achieve system designs that meet stated cost requirements.

Disposal Cost: Disposal cost is the sum of all contract and government in-house costs required to remove the system or equipment from the inventory, and which may be offset by some residual value (e.g., salvage or resale).

Economic Analysis: A systematic approach to the problem of choosing how to employ scarce resources and an investigation of the full implications of achieving a given objective in the most efficient and effective manner. The determination of efficiency and effectiveness is implicit in the assessment of the cost effectiveness of alternative approaches.

Equipment: Refers collectively to an item, component, or sub-system procured for installation in a system or to support a system.

Expert Opinion Estimating: Estimating costs based on the opinion of the experts in the field. Especially useful when estimating costs for "state-of-the-art" technology or systems. Involves a DELPHI polling of the experts. (See DELPHI Technique.)

9.2 (Continued):

Force Structure: Fleet size structure. (See paragraph 6.4.)

Goal: Normally a firm number (sometimes interchangeable with "target")

Industrial Engineering Estimate: Used primarily to estimate recurring production or investment costs and involves the build-up of costs by detailed analysis of work processes and material. It involves an examination of separate segments of work at a low level of detail and a synthesis of the many detailed estimates into a total (bottom-up estimate).

Investment Cost: Investment (development and/or production) cost is the sum of contractor and government in-house costs, both non-recurring and recurring, required to transform the results of R&D into a fully deployed operational system or equipment.

Learning Curve: The cost-quantity relationships for estimating costs of equipment. Generally used to predict or describe the decrease in the cost of a unit as the number of units produced increases.

Life Cycle Cost: LCC is the sum total of the direct, indirect, recurring, non-recurring, and other related costs expended, or estimated to be expended in the design, research and development (R&D), investment, operation, maintenance, and support of a product over its life cycle, i.e., anticipated useful life span. It is the total cost of the R&D, investment, O&S and, where applicable, disposal phases of the life cycle. All relevant costs should be included regardless of funding source or management control.

Mean-Time Between Failures (MTBF): For a particular interval, the total functioning life of a population of an item divided by the total number of failures within the population during the measurement interval. The definition holds for a time, cycles, distance, events, or other measures of life units.

Mean-Time-To-Repair (MTTR): The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time.

Operating and Support Cost: O&S cost is the sum of all costs, including contractor support, associated with the operations and maintenance of a system or equipment.

Parametric Estimating: An estimate made by using an expression relating cost to selected system parameters, performance requirements or goals.

Procurement Cost: See Investment Cost.

Product: Refers to the system or equipment being acquired or modified.

Production Cost: Cost associated with manufacturing, assembly and test. Includes recurring cost and tooling.

9.2 (Continued):

Regression Analysis: A statistical technique for expressing functional relationships between quantities that can be measured or observed, and quantities that are to be predicted on a probabilistic basis.

Research, Development, Test and Evaluation: RDT&E cost is the sum of all contractor and government-funded costs required to bring a product's development from concept to production including engineering design, analysis, development, test, evaluation, and management.

Risk: As used in cost effectiveness analysis and operations research, the product of the consequence of an outcome and its probability of occurrence.

A risk profile considers many possible outcomes.

Sensitivity Analysis: Repetition of an analysis with different quantitative values for cost or operational assumptions or estimates such as hit-kill probabilities, activity rates, or R&D costs, to determine their effects for the purposes of comparison with the results of basic analysis. If a small change in an assumption results in a proportionately or greater change in the results, then the results are said to be sensitive to that assumption or parameter.

Simulation: The construction of a working mathematical or physical model presenting similarity of properties or relationships with the natural or technological system under study.

Statistics: Concerned not only with the collection and interpretation of large masses of data, but also with scientific techniques of analysis for drawing valid conclusions about phenomena operating under uncertainty or under probabilistic conditions.

Sunk Cost: The costs expended in the past and which are not relevant to present and future decisions (might be included in total LCC).

System: Refers to a composite of equipment, facilities, and services which make up an entity. The complete system includes the prime and all support related equipment, materials, facilities, and personnel required for obtaining, operating, and maintaining the system.

Target: Used in a contract to define the customer's objective. It is sometimes used as the basis for an incentive arrangement, is normally more ambitious than a goal, but sometimes used interchangeably with "goal".

Time-Phased Cost: A presentation of the cost results broken down by the time period in which the costs occurred rather than a single total cost figure.

Uncertainty: A situation is uncertain if there is no objective basis for assigning numerical probability weights to the different possible outcomes or there is no way to describe the possible outcomes.

9.2 (Continued):

Work Breakdown Structure (WBS): A WBS is a product-oriented family tree composed of hardware, services, and data which result from the identification of acquisition tasks during the development and production of a system or equipment, and which completely describes the program or project. A WBS displays and defines the product to be developed or produced and relates elements of work to be done to each other and to the end product.

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11. ILLUSTRATIONS: To clarify and condense the narrative, these illustrations, as listed in the Table of Contents, are included.

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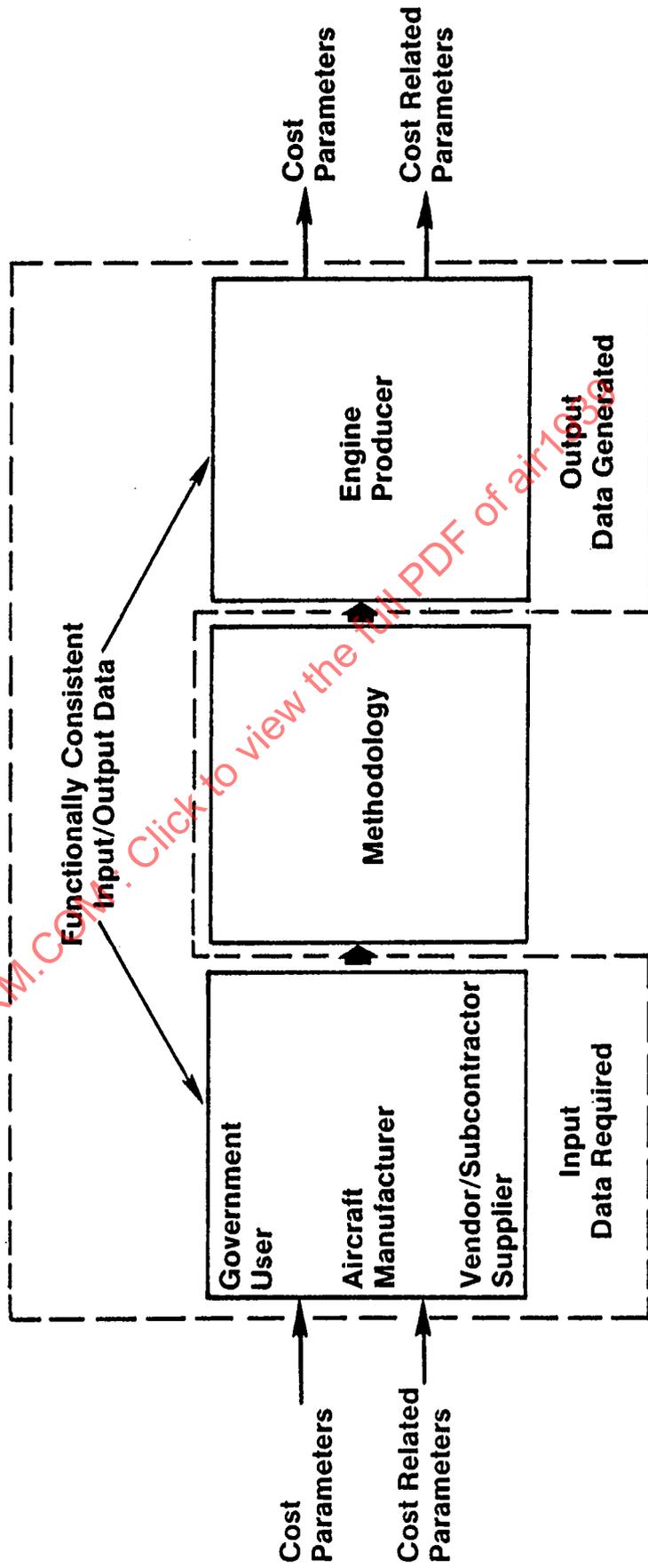
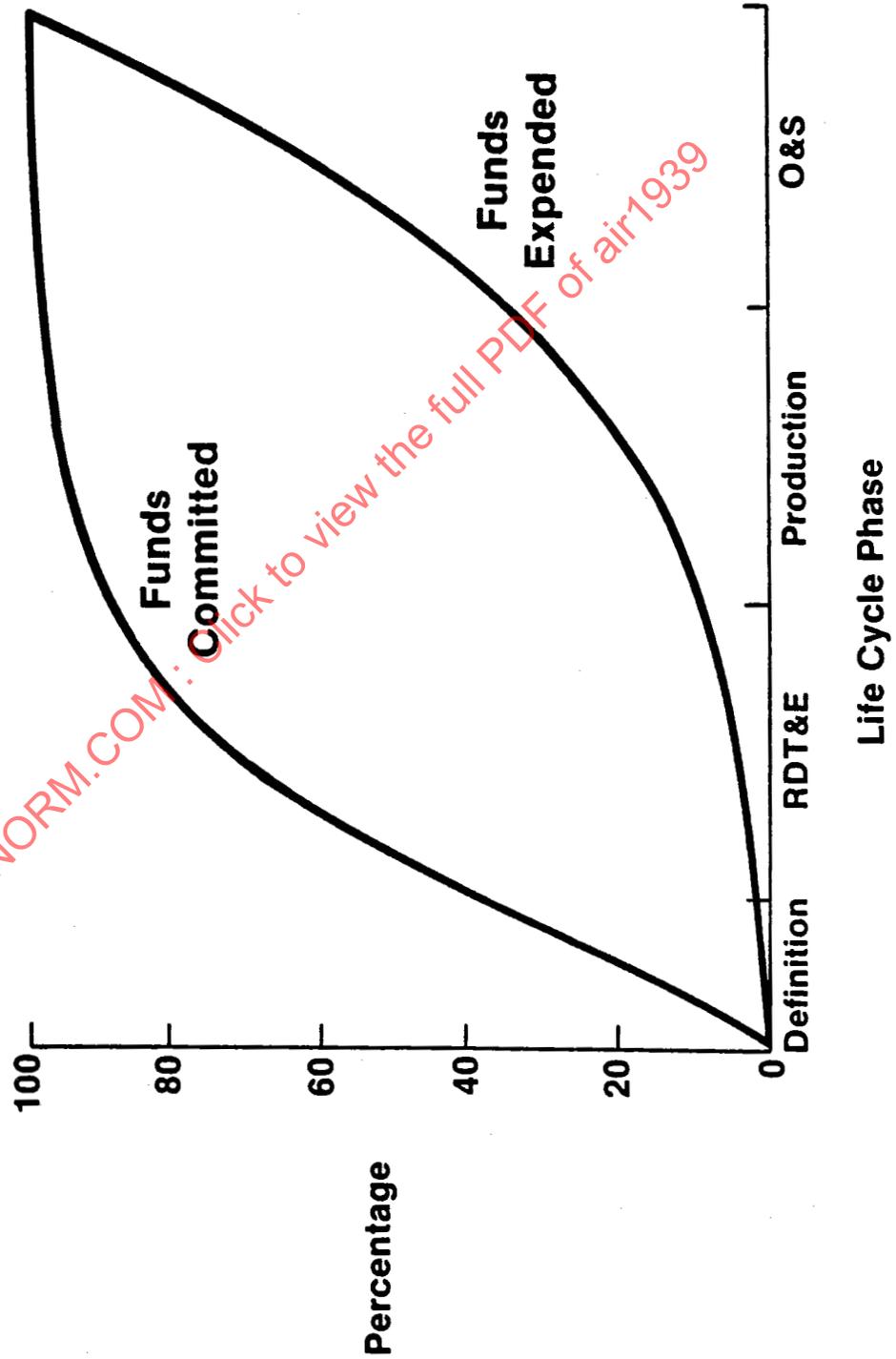


Figure 1. Data Requirements Flow Chart.



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Figure 2. Phased LCC Funding Trends.

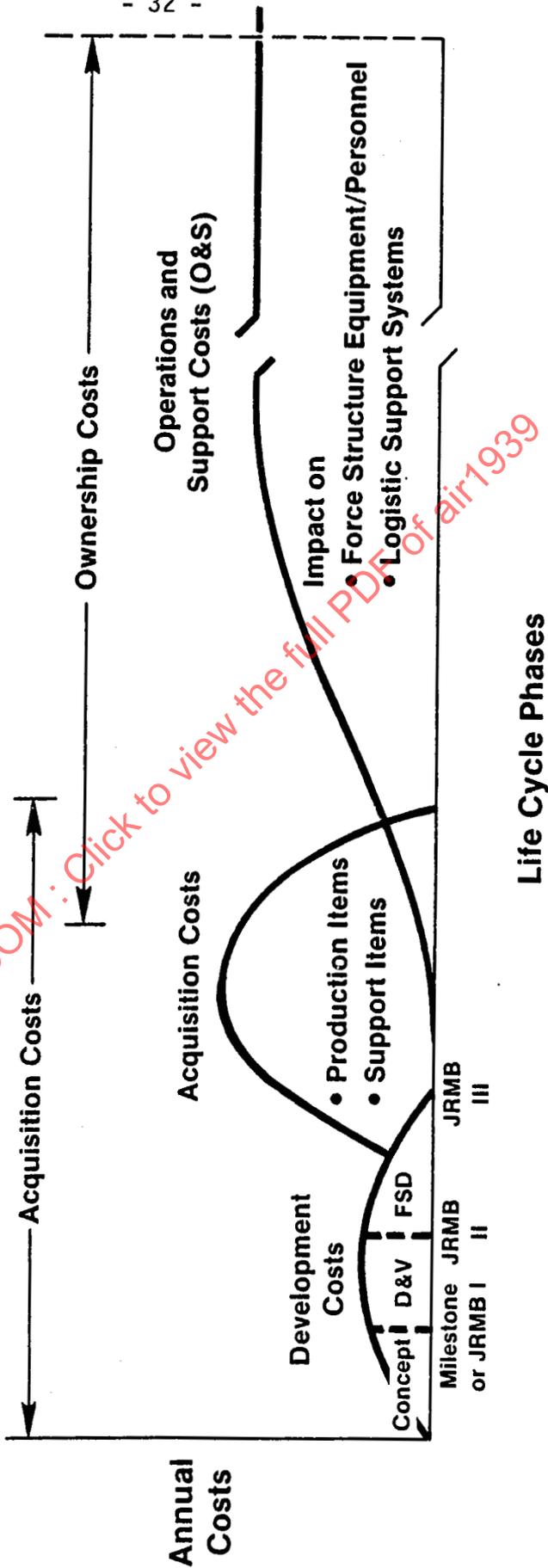


Figure 3. Life Cycle Costs.

Life Cycle Cost Presentation Requirements			
Program Phase	Calculation Method	Level of Detail	Typical Data
Conceptual	Parametric	System/Engine	Program Timing Fleet Size Aircraft Type Mission All Above - Plus Engine Operating Characteristics Production Quantity/Rate Life Limits Maintenance Plan FMECA (Failure Modes, Effects and Criticality Analysis) LSAR (Logistic Support Analysis Record)
Validation	Parametric or General 'Bottom Up'	Engine/Module	Tooling Make/Buy Support Equipment General Routings All Above - Plus Final Routing Timed Block Buys Warranty Contractor Support Training CIP
Full Scale Development	General 'Bottom Up'	Module/Component	Consumption Rates Rework/Salvage Schemes Performance Deterioration All Above - Plus Inventory Levels Asset Assignments Market Conditions/ Constraints
Production	Detail 'Bottom Up'	Part	Service Related Deficiency Actual Mission Mix
Operating & Support	Detail 'Bottom Up'	Part	
Disposal	Detail 'Bottom Up'	Part	

Figure 4. LCC Input Data By Phase.