AEROSPACE RECOMMENDED PRACTICE

ARP4294™	REV. A
Issued 1992-02 Stabilized 2021-09 Superseding ARP4294	

Data Formats and Practices for Life Cycle Cost Information

RATIONALE

The LCLS committee discussed the ARP4294 and has decided that the best course of action is stabilization.

STABILIZED NOTICE

This document has been declared “Stabilized” by the SAE LCLS Life Cycle Logistics Supportability Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/ARP4294A

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP)4294 is directed at life cycle cost (LCC) analysis of aerospace propulsion systems and supplements AIR1939.

Specific topics addressed by ARP4294 are listed below:

a. Propulsion system LCC element structure.

b. Information exchange and relationships with:

   (1) Aircraft manufacturer
   (2) Equipment suppliers
   (3) Customer

c. The relationship of the LCC element structure to work breakdown structures.

d. The relationship between LCC analysis and other related disciplines (e.g., technical (performance analysis, weight control, component lives), reliability, availability and maintainability (RAM), integrated logistic support (ILS), production and finance).

e. Classification of the accuracy and applicability of LCC assessments.

1.1 Purpose:

ARP4294 supplements the general guidelines of AIR1939 and complements ARP4293 by providing specific data formats and data transfer procedures to increase the effectiveness of LCC evaluations. ARP4294 promotes the consistency and understanding of information exchanged at the interfaces between customers, aircraft manufacturers, engine producers, and equipment suppliers. It clarifies the relationships between LCC and related disciplines. In support of the free flow of LCC information between customers, manufacturers, and equipment suppliers, ARP4294 provides classifications governing the applicability of LCC analyses.

2. REFERENCES:

2.1 SAE Documents:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR1812 Environmental Control Systems Life Cycle Cost

AIR1939 Aircraft Engine Life Cycle Cost Guide

ARP4293 Life Cycle Cost - Techniques and Applications

SP-721 Aircraft Engine Life Cycle Cost

2.2 Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD 881A	Work Breakdown Structures for Defense Material Items, 25 April 1975
AFR 70-5	Should Cost Aug 85
AFR 80-14	Test and Evaluation
AFR 173-1	AF Cost Analysis Program Oct 75
AFR 173-2	Economic Escalation
AFR 173-9	Aircraft Fuel Conversation Data Collection
AFR 173-11	Independent Cost Analysis Program Oct 86
AFR 173-13	USAF Cost and Planning Factors Sept 86 - contains 'Core Model'
AFR 178-1	Economic Analysis and Program Evaluation for Resource Management March 88
AFR 178-1	Vol II Economic Procedures Handbook (Core Model)
AFR 400-31	Vol 1-4 AF Visibility and Management of Operating and Support Costs (VAMOSC) SE 82
AFR 800-8	ILS Element Program June 86
AFR 800-11	Life Cycle Cost Management Program Jan 84
AFR 800-11	ASD Supplement 1
AFR 800-14	Management of Computer Resources in Systems
AFR 800-18	AF Reliability and Maintainability Program
AFR 800-21	Interim Contractor Support for Systems and Equipment
AFR 800-22	AFE VS GFE Selection Process
AFR 800-28	Air Force Policy on Avionics Acquisition and Support
AFR 800-30	Life Cycle Management of Aeronautical Gas Turbine Engines AP 80
AFR 800-21	ICS for Systems and Equipment Mar 87
AFLCP 70-1	Contracting and Acquisition
AFLCP 173-3	A Guide to Estimating Aircraft LSC
AFLCP 173-4	Estimating Depot Maintenance Cost to AF Aircraft
AFLCP 173-10	AFLC Cost and Planning Factors
AFLCP 800-3	Logistics Performance Factors in ILS 6 Apr 76

2.2 (Continued):

AFLCP/AFSCP 800-19	Joint Design to Cost Guide Life Cycle Cost as a Design Parameter 15 Oct 77
AFLC/AFSC 800-4	Repair Level Analysis Procedures
AFLCM 800-1	Program Management
AFLCR 173-10	AFLC Cost and Planning Factors
AFSCM 173-1	Cost Analysis Procedures
AFSC Supplement 1, AFR 173-1	Air Force Cost Analysis Program
AFSC/AFLC	Supplement 1 to AFR 800-11. Life Cycle Cost Management Program
AFSC/AFLCP 800-19	Joint Design-to-Cost Life Cycle as a Design Parameter 15 Oct 77
AFSC/AFLCR 800-28	Repair Level Analysis Program May 81
AFSC/AFLCR 800-31	Government-Furnished Equipment/Contractor-Furnished Equipment (GFE/CFE) Selection Process, GFE Acquisition and GFE Management
AFM 400-1	Spares Requirements
AFM 26-1	Manpower Policies and Procedures
AFM 800-6	Program Control - Financial
DI-A-7088	
DI-A-7089	
DI-E-3128	Engr Change Proposals
DI-F-6000C	Cost Performance Report
DI-F-6004B	Contract Funds Status Report (CFSR)
DI-F-6010A	Cost/Schedule Status Report
DI-F-30203	Design to Cost/Life Cycle Cost Document
DODD 4245.3	Design to Cost
DODD 5000.1	Major System Acquisitions
DODD 5000.2	Major System Acquisition Procedures
DODD 5000.4	OSD Cost Analysis Improvement Group (CAIG)
	Aircraft Operating and Support Cost Development Guide
DODD 5000.28	Design to Cost
DODD 5000.33	Uniform Budget/Cost Terms and Definitions
DODD 7000.2	Performance Measurement for Selected Acquisitions
DODD 7000.3	Selected Acquisition Reports
MIL-STD 1388	LSA
MIL-STD 1390	Level of Repair (Navy)
MIL-STD 480	
MIL-STD 481	
MIL-STD 483	(USAF)
MIL-STD 490	
OMB A 109	Major Systems Acquisition
OSD	Inflation Factors
FASCAP	Fast Payback Capital Investment Program (USAF/MPM Ltr 21 Dec 78)
	Economic Analysis Handbook
	Network Repair Level Analysis Model - User's Guide

2.2 (Continued):

Integrated Logistics Support, Published by Defense Systems Management College
Product Performance Agreement Guide - Warranties
Definition of Cost Drivers

2.3 Acronyms and Abbreviations:

ARP Aerospace Recommended Practice

CCT Completion of Certification Testing

ILS Integrated Logistic Support

LCC Life Cycle Cost

O&S Operating and Support

RAM Reliability, Availability, Maintainability

R&M Reliability and Maintainability

RDT&E Research, Development, Test and Evaluation

SAE Society of Automotive Engineers

SE Support Equipment

WBS Work Breakdown Structure

2.4 Glossary:

ACQUISITION COST: The primary investment, being the sum of the total development cost (RDT&E) and the investment costs of the system.

AVAILABILITY: The ability of an item (under combined aspects of its reliability, maintainability and maintenance and support) to perform its required function at a stated instant of time or over a stated period of time.

CONSUMABLES: Those materials such as grease, safety wire, packing, etc. that are not covered by a part number, but are required in the assembly of an engine.

COST ELEMENT: 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.

2.4 (Continued):

EXPENDABLES: Those components such as standard parts found in bins (nuts, bolts, washers) which are normally not tracked, but do have part numbers.

INTEGRATED LOGISTIC SUPPORT (ILS): The management and technical process through which supportability and logistic support considerations of systems/equipment are integrated during the early phases of and throughout the life cycle of the program and all elements of logistic support are planned, acquired, tested and provided in a timely and cost-effective manner.

LIFE CYCLE COST: LCC is defined as the sum of all monies expended, attributed directly and indirectly to a defined system from its inception to its dissolution: encompassing the acquisition, ownership and disposal phases of a program.

LOGISTIC SUPPORT ANALYSIS (LSA): A structured process which includes actions to define, analyze, and quantify logistic support requirements, and to influence design for supportability, through system development.

MAINTAINABILITY: The ability of an item, under stated conditions of use, to be retained in, or restored to, a state in which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources.

OWNERSHIP COST: The sum of the Operating and Support Costs and Disposal of the system.

RELIABILITY: The ability of an item to perform a required function under stated conditions for a stated period of time.

RISK: As used in cost effectiveness analysis and operational research, it is the product of the consequence of an outcome and its probability of occurrence.

ROTABLES: Repairable parts that can be exchanged between engines, that rotate between the first engine, the repair shop, stores and the second engine.

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

SUPPORTABILITY: The degree to which system design characteristics and planned logistics resources, including manpower, meet system availability requirements.

SYSTEM: 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.

2.4 (Continued):

TRADE-OFF (ANALYSIS): The determination of the optimum balance between system characteristics (cost, schedule, performance and supportability).

3. PROPULSION SYSTEM COST STRUCTURES:

This section presents a standard LCC element structure and examines the relationship between this type of structure and a work breakdown structure.

3.1 LCC Element Structure:

The LCC of a propulsion system can be divided into its constituent cost elements to varying levels of detail. At the highest level, LCC may be considered to comprise "acquisition costs" and "ownership costs". These subdivide to four major program phases:

a. Research, development, test and evaluation costs (RDT&E) - ACQUISITION
b. Investment costs - ACQUISITION
c. Operating and support costs - OWNERSHIP
d. Disposal costs - OWNERSHIP

At the lowest level, a breakdown of LCC has very detailed costs such as the cost of updating training manuals, or the cost of the training instruction, as sub elements of the Ownership Costs. Underlying the lowest level of cost elements are the data elements used to calculate them (e.g., the number of updates of the training manuals, the average number of pages updated, cost per page of update, etc.).

The list of cost elements defining the allocation of costs within an LCC statement is called a cost element breakdown structure. Over the past few years there have been many cost structures proposed. They are often of general applicability and do not adequately address the LCC of propulsion systems. Each customer, producer, and supplier often adopt their own structure. This can obviously lead to confusion when data is exchanged between these parties unless a common structure is agreed upon beforehand. ARP4294 addresses this problem by defining a cost element structure for the propulsion system which can be used as the basis for communication between all parties involved in LCC assessments. At the lowest level, each cost element is individually defined. The structure is presented in Appendix A.

The use of the structure is intended to ensure accurate communication of LCC information among the customer, engine producer, airframe manufacturer, and equipment suppliers. It will also be of great benefit when used within joint ventures. In any particular circumstance, the structure may be tailored to suit different study types and data availability.

3.2 LCC Phases:

The four principal phases of LCC listed in 3.1 overlap as illustrated in Figure 1. Note that the project LCC includes project specific research and development cost only. The basis of definitions contained in AIR1939 have been used to allocate the costs within the phases of the structure presented in Appendix A:

a. Research, Development Test and Evaluation (RDT&E): The sum of all contractor and government-funded costs required to bring the propulsion system's development from inception to production. They include engineering design, analysis, development, test, evaluation and management.

b. Investment: The sum of contractor and government in-house cost, both recurring and nonrecurring, required to transform the results of R&D into a fully deployed operational propulsion system including elements for production tooling and setup costs.

c. Operating and Support: The sum of all costs, including contractor support, associated with the operations and maintenance of the propulsion system.

d. Disposal: The sum of all contractor and government in-house costs required to remove the propulsion system from the inventory, and which may be offset by some residual value (e.g., salvage or resale).

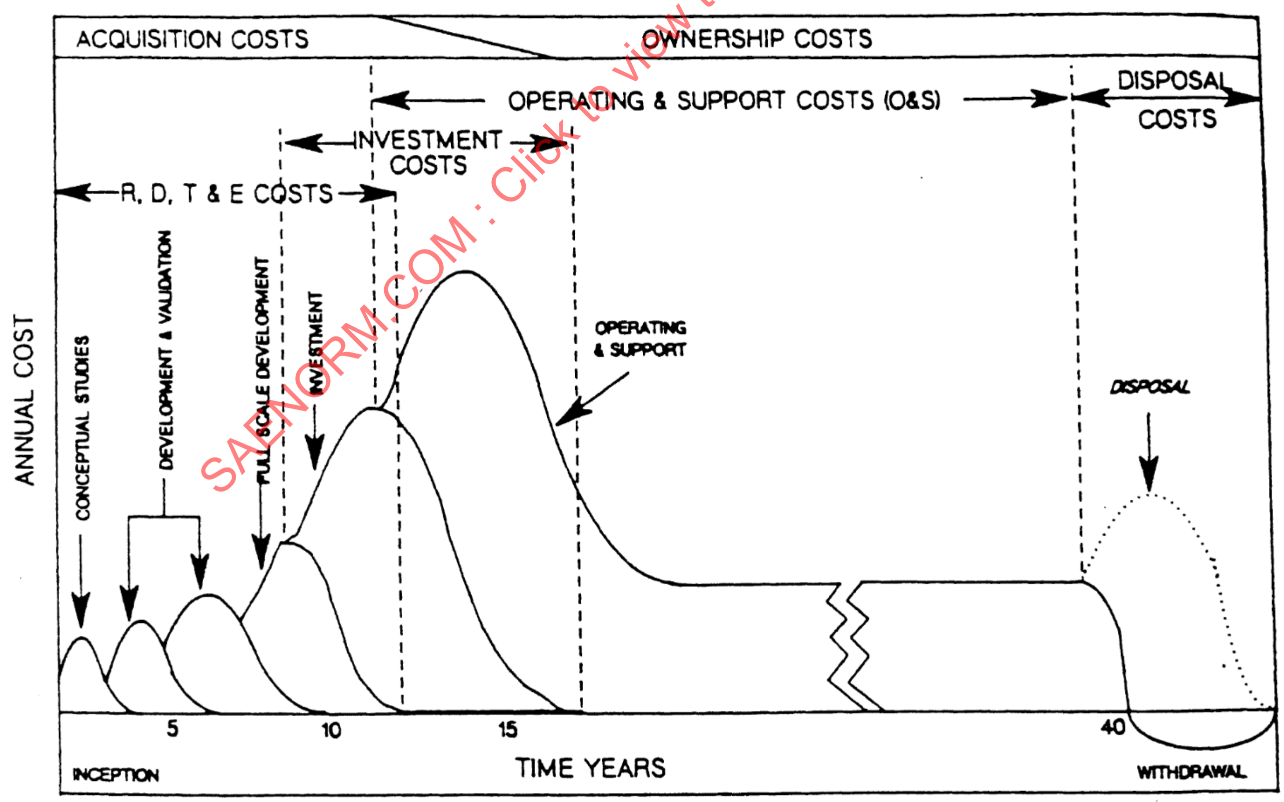


FIGURE 1 - Life Cycle Cost (Phases of the Life Cycle)

3.3 LCC Element Structure for Propulsion Systems:

This section describes the use of the LCC element structure for propulsion systems defined in Appendix A. Figure 2 illustrates the upper indenture levels of the structure. Illustrations of the complete structure can be found in Appendix A.

The standard structure results from research into other structures including those noted in Section 7. The specification of a low level breakdown provides the basis for grouping of elements at higher indenture levels. The structure may be used at the very early stages of a project to define the costs covered even though the breakdown of costs presented is at high indenture levels. The structure acts as the means of defining costs covered, but does not imply that costs are necessarily available down to the lowest level.

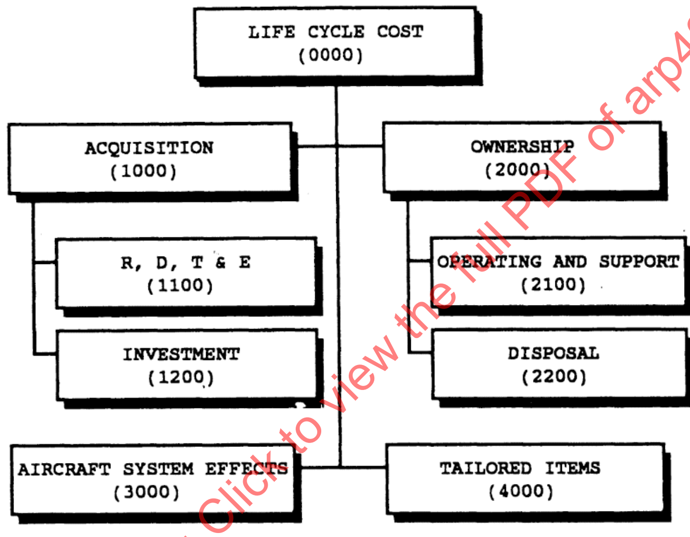


FIGURE 2 - Life Cycle Cost Element Structure

3.3.1 Rules for Cost Allocation: To assess the phase to which a particular cost belongs, refer to the definitions contained in 3.1. Within each phase, trace the cost to the lowest level definition which is applicable.

3.3.2 Indenture Levels: At each level the structure has been arranged such that definitions are sufficiently broad to ensure lower levels can be completely contained. This is to minimize the possibility of a requirement to invent new ones.

3.3.3 Tailoring of Structure: The structure may be tailored to a given application by grouping costs at required indenture levels. As noted, the structure may be used at the outset of a project simply to define the content of costs presented at the summary phase level (i.e., RDT&E, investment, operating and support, and disposal). At the other extreme, for an in-service project, all costs down to the most detailed level could be presented and supported by the same set of detailed definitions.

LCC presentations should always be made at, or above, the indenture level for which the analysis is capable of audit. If additional cost elements are to be included which are not covered by Appendix A, always add them to the lowest level cost category. At worst, this will involve adding additional categories within one or more of the four principal phases.

Provisions have been made to include cost elements for aircraft system effects (line item 3000) and other tailored items (line item 4000) that can be directly attributed to the propulsion system, and which can not be included in other parts of the structure. For example, improving the specific fuel consumption (SFC) of the propulsion system of an aircraft might result in an overall reduction in the aircraft size required to meet a given mission requirement. The savings associated with this would be included under line item 3000.

An example of a LCC presentation based on Appendix A is given in Figure 3. This is the recommended format for summary LCC presentations.

3.4 Cost of Infrastructure:

The optimization of the design of a new propulsion system is usually guided by a set of 'rules' prescribed by the customer (e.g., minimize LCC, or maximize performance - or more usually: minimize LCC and maximize performance plus improve supportability). Sometimes a parameter, such as maintainability, may not rate as a deciding influence between competing design options when expressed in LCC terms. This might be because the contractor does not have access to other high cost secondary effects which are part of the customer's support infrastructure. For example, there may be a ratio of 1:5 between people directly involved in maintenance activity and those in supporting roles.

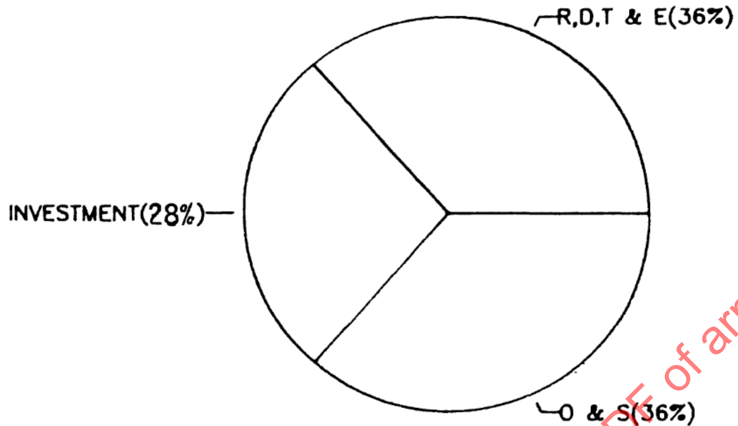
The cost structure contained in Appendix A, contains cost elements which have traditionally been considered directly attributable to the propulsion system. Examples of other factors which should be considered by the customer when requesting design-trade activity are listed below:

a. Ratio of direct to indirect maintenance personnel
b. Costs of direct/indirect personnel including support (e.g., accommodation)

c. Impact of performance and/or reliability on fleet size required to meet a given requirement

LCC SUMMARY STATEMENT
ADVANCED TRAINER-POWERPLANT ONLY

FLEET SIZE:	200 AIRCRAFT
OPERATIONAL PHASE:	25 YEARS
TOTAL ENGINE FLYING HOURS:	2.5 MILLION
ECONOMIC CONDITIONS:	JANUARY 1989



	$M	%	DEFINITION - LINE ITEM NO
R, D, T & E			
CONCEPTUAL STUDIES, + D&V	5		1110 + 1120
FULL SCALE DEVELOPMENT	195		1130
TOTAL R, D, T & E	200	36	
INVESTMENT			
PRODUCTION INVESTMENT	25		1210
ENGINE INVESTMENT	100		1220
ENGINE SUPPORT INVESTMENT			
- SPARES	20		1231
- INITIAL SUPPORT	5		1232
TOTAL INVESTMENT	150	28	
OPERATING AND SUPPORT			
FUEL, OIL AND LUBRICATION	90		2110
MAINTENANCE LABOR	20		2121
MAINTENANCE MATERIAL	85		2122
SUSTAINED ENGINE SUPPORT	5		2130
TOTAL O & S	200	36	
TOTAL LIFE CYCLE COST	550	100	

FIGURE 3 - Example of Tailored LCC Statement

3.4 (Continued):

Where applicable, underlying data must be supplied to contractors so that the effects can be included in the design trade process.

3.5 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". (Reference AIR1939, Section 2.1)

The contractor's extension of the WBS should reflect what contract work is to be done and the way it is to be managed and performed. It may be linked to technical milestone achievements and contractual payment profiles. It must include the level at which required reports are to be submitted to the customer, major subcontractors, intermediate level, and cost accounts. The lower level elements should be meaningful products or task oriented subdivisions of a higher level element.

The LCC element structure is similar to a WBS but not necessarily the same because WBS element breakouts can be different than LCC line elements. Each structure fulfills a different function. The WBS provides a detailed definition of monitorable tasks which comprise a given program. Consequently it does not, necessarily, cover all aspects of a project (e.g., operational fuel and oil consumed are unlikely to be included). The LCC element structure, however, presents a breakdown of costs incurred over the entire life of a project.

It is important that relationships between the two structures are understood since certain facets of LCC will often need to be monitored using data from systems collecting data against a WBS (e.g., elements of R&D, ILS). This demands close cooperation between the LCC analyst and program management team.

4. INTERFACES:

The large volume of data required to support the calculation of LCC is likely to be obtained from many different sources by the LCC analyst. Some of these data sources will exist in the analyst's own company or organization, and others will be external to it. To ensure speed, accuracy, and consistency of LCC assessments the suppliers of data should be conversant with their data supply responsibilities including the definition of each data element to be supplied.

This section examines the range of LCC studies performed at different stages in the life cycle of a project and identifies the associated communication requirements and responsibilities of participants. Formats to support data exchange are presented in Appendices A through E.

4.1 Study Types at Different Program Phases:

The types of LCC study performed over the life of a project depend on the status of evolution of the design of the aircraft system and propulsion system. The following considers each principal phase, briefly describing the studies which might be undertaken and the role of the four major participants:

a. Customer
b. Aircraft manufacturer
c. Engine producer
d. Equipment supplier

AIR1939 provides a more detailed description of LCC study types. Figure 4 illustrates the external communication paths.

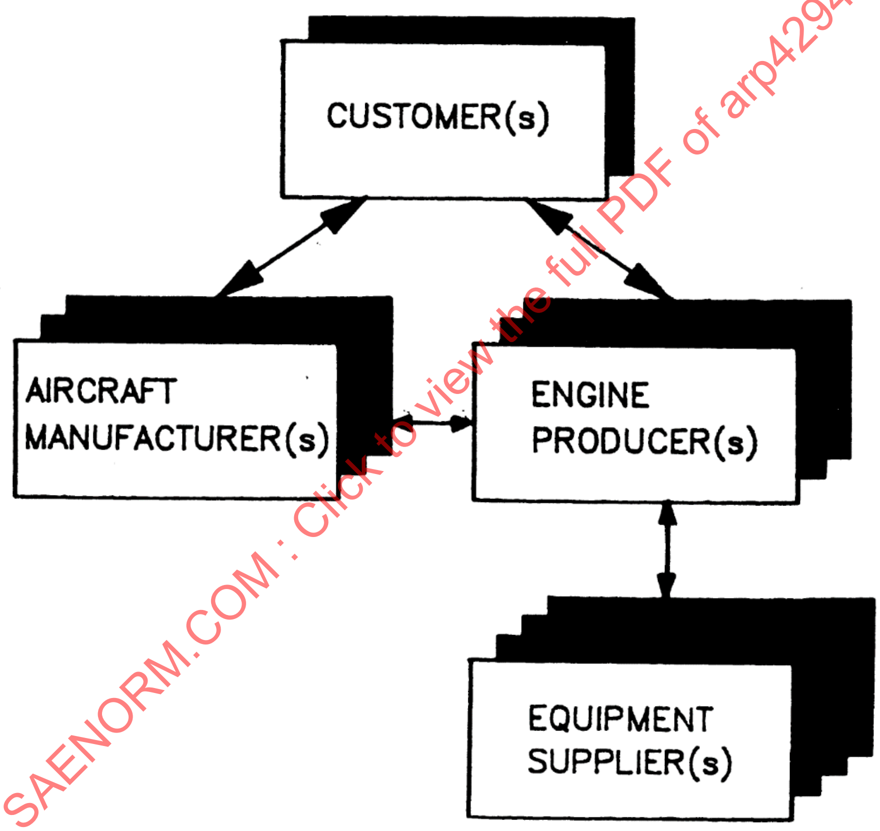


FIGURE 4 - LCC Communications Between Major Participants

It should be noted that the following commentaries are concerned with LCC analyses applied to the propulsion system only. They do not discuss remaining aircraft system studies and influences unless they are directly impacted by differences in, or changes to, the propulsion system.

4.1.1 Conceptual Studies: The objectives of this phase are to identify a propulsion system type and optimum thermodynamic cycle for a baseline aircraft and set of missions. LCC studies are, therefore, used to support the selection of propulsion system and/or aircraft system concept from a range of engineering options. A baseline LCC is established for one of the concepts and the others are measured relative to it in rank order. Data at this stage are only sufficient to assess major LCC elements. Sensitivity analysis and risk assessment should be undertaken to assess high cost drivers and major areas of uncertainty.

4.1.1.1 CUSTOMER INVOLVEMENT: The customer provides the aircraft manufacturer and engine producer with assumptions (ground rules) to be used in the LCC analyses. The customer also provides a definition of the requirements to be met by the aircraft system and an indication of any constraints to be imposed on the final solution. The latter must include the relative importance to be attached to LCC, reliability, maintainability, supportability and performance.

The range of LCC studies may be formulated following consultation between aircraft manufacturer and engine producer, and sometimes the user.

The customer will review and discuss the results of the studies with the aircraft manufacturer and engine producer and the preferred concept(s) will be selected for the next phase.

4.1.1.2 AIRCRAFT MANUFACTURER INVOLVEMENT: In certain circumstances the aircraft manufacturer will represent the customer and so in addition to what follows, the manufacturer will also provide the information and support described in the previous section.

The details of joint trade-off studies, including common ground rules, and deliverables of each party will be agreed between the aircraft manufacturer and engine producer. Maintainability issues concerning engine installation should also be addressed. A baseline study for measurement of design options will be agreed upon. The interface boundary between the LCC of the propulsion system and that of the rest of the aircraft system will be stipulated by all participants. This will usually be aligned with that used to define boundaries between the propulsion system and remainder of the aircraft system in the group weight (mass) statement.

The aircraft manufacturer must supply the engine producer with data agreed to be exchanged (e.g., installed fuel burn data). The latter will be derived from the engine performance deck supplied by the engine producer used in conjunction with the aircraft system performance model, for the agreed range of trade-off studies.

The aircraft manufacturer will coordinate with the engine producer to ensure any published results of studies by each party are compatible. When the aircraft manufacturer and engine producer each submit results of the LCC analyses to the customer, the results should be capable of integration by the latter when necessary.

4.1.1.3 ENGINE PRODUCER INVOLVEMENT: At the outset of the studies, the engine producer will coordinate the detailed common ground rules with the aircraft manufacturer and customer, plus any data to be exchanged between parties, and the timetable to be followed.

The engine producer will provide the aircraft manufacturer with performance decks for the propulsion concepts to be evaluated and undertake the agreed range of LCC trade-off studies. For each propulsion concept a risk assessment will be undertaken and cost drivers identified. This analysis will be limited by the data available at this stage of the program and should concentrate on establishing major differences (if any) implied by each design concept.

Initial goals for component lives, engine reliability characteristics, maintainability, and cost must be set.

The degree to which coordination with other subsystem suppliers should take place in this phase is determined by the conventionality of the mission/application. The more demanding or unusual that an application is, then the more care must be exercised in dealing with suppliers and predicting LCC for their components (because it will be higher due to the greater risk involved or the higher level of technology demanded).

The engine producer will compile reports showing the results of the trade studies on the engine concepts for issue to the customer. These will include the LCC of each concept in rank order, commentaries on the risks associated with each of them, (quantified where possible), and recommendations on the preferred option. Prior liaison with the aircraft manufacturer must ensure that results presented for the propulsion system, including the baseline study, are compatible with those for the rest of the aircraft system.

4.1.1.4 EQUIPMENT SUPPLIER INVOLVEMENT: Equipment supplier components generate more maintenance actions than do those built by the engine producer. Engine producers should exchange data with them early in the program so that trade studies and component improvements can be accomplished. The suppliers should provide LCC information on their components at a level of detail consistent with the project phase. These must be based on meeting cost and technical specifications which are compatible with the engine requirements.

4.1.2 Development and Validation: The objectives for this phase are to determine the optimum thermodynamic cycle and overall configuration for the propulsion system, and to generate a design specification as the basis for full scale development (FSD). The specification will include values for performance, reliability, component lives and maintainability.

Propulsion system studies focus on sizing the aircraft system. Trade studies include assessments of the effect of cycle choice on aircraft performance, cost, and size.

4.1.2 (Continued):

More detailed information is usually available for the engine in this phase allowing the use of accounting or simulation models on the propulsion system. Since the airframe design usually has not yet been selected, it is important that the parametric sizing models still be used to show engine effects on aircraft system size and cost. These models should estimate aircraft system cost as a function of the driving propulsion system parameters.

4.1.2.1 CUSTOMER INVOLVEMENT: The customer must supply the aircraft manufacturer and engine producer with updated LCC ground rules, requirements specification, and design mission mix for the propulsion concepts selected from the previous phase. Again, these must include the relative importance to be attached to LCC, reliability, maintainability, supportability, and performance.

4.1.2.2 AIRCRAFT MANUFACTURER INVOLVEMENT: Comments similar to those made for the previous phase apply.

The aircraft manufacturer and engine producer must agree on any joint studies to be undertaken in this phase and the ground rules to be used. A definition of the baseline study for measurement must be established.

The aircraft manufacturer must supply the engine producer with installed fuel burn data, based on the performance deck supplied by the engine producer and the aircraft system model, over the range of agreed trade studies. More detailed assessments can be made of supportability issues concerned with installation.

The aircraft manufacturer and engine producer must ensure that published documents are consistent.

4.1.2.3 ENGINE PRODUCER INVOLVEMENT: The engine producer will coordinate with the aircraft manufacturer to agree upon the range of joint trade studies to be performed and supply appropriate performance decks. The engine studies will include allowances for airframe effects using trade-off factors supplied by the aircraft manufacturer. Joint studies will support the selection of engine cycle and characteristics of any thrust augmentation (e.g., reheat) required. Internal studies will include selection of major design features and the overall engine configuration.

Cost drivers will be identified and a risk analysis undertaken. Consideration must be given to how risks can be reduced in the FSD phase.

Design targets for component lives, reliability, maintainability, supportability and performance will be set.

If not already in existence, communication links with potential equipment suppliers must be established to support inputs to design optimization and engine LCC assessments.

4.1.2.3 (Continued):

The principal output from this phase will be the engine design specification to be used as the basis for FSD. Reports will be generated on the trade-off studies undertaken to support the selection of parameters contained in the specification document.

4.1.2.4 EQUIPMENT SUPPLIER INVOLVEMENT: At this stage of the program it is essential that suppliers are involved in the supply of data to support the LCC analysis. The aim must be to allow them to contribute to design optimization. Ways of reducing risks associated with equipment design must be sought.

4.1.3 FSD: Almost all of the propulsion system configuration and most of the aircraft system configuration will have been selected by the time FSD starts. This phase is dominated by detailed trade studies to optimize component features. Since the airframe is frequently not yet fully defined, parametric models for aircraft system size need to be used. These will usually be more detailed with respect to airframe characteristics.

4.1.3.1 CUSTOMER INVOLVEMENT: Detailed ground rules on fleet deployment, customer support infrastructure, and missions should be supplied to the aircraft manufacturer and engine producer. An update of all ground rules is to be provided including the mission mix and performance to be met by the engine specification.

Using the more detailed customer ground rules on how the aircraft system will be used, predictions can be made of how operation and support costs will vary for different uses of the system. Simulation or accounting models will be used to focus on the effects of the mission(s) on the engine (or aircraft system). When the aircraft system offers a major improvement in capability from the customer's previous experience, all parties involved should anticipate significant new problems, failure modes, and costs to arise. These will have been brought about by new ways of using the aircraft system.

Reporting requirements during this phase must be specified. These are likely to be contractual deliverables.

Changes required to the engine specification (e.g., as a result of changes to the mission requirement), must be specified.

4.1.3.2 AIRCRAFT MANUFACTURER INVOLVEMENT: Common ground rules for joint studies must be agreed upon by the engine producer including the definition of the baseline assessment. Fuel burn data must be supplied to the engine producer together with other parameters to support design trade-off studies of the propulsion system.

Aircraft ground rules (e.g., aircraft delivery schedules), which affect propulsion system LCC must be supplied to the engine producer. Detailed maintainability assessments can now be made at the engine/airframe interface, and maintenance support policies developed.

4.1.3.2 (Continued):

Once again, reports to the customer must be coordinated to ensure consistency of presentation and compatibility of content with those generated by the engine producer.

4.1.3.3 ENGINE PRODUCER INVOLVEMENT: The engine producer will undertake trade studies on detailed design features to assess the most cost-effective way of meeting the design specification.

LCC analysts will be closely involved in the selection of equipment suppliers. System and supportability requirements must be specified in the request for quotation (RFQ) against which suppliers are to quote. The aim of the LCC analyst will be to acquire LCC assessments of a given equipment from competing suppliers. The basis of selection will be influenced by engineering, product support, contractual, and LCC considerations. Credibility, and the ability of the supplier to manage the achievement of LCC goals, must be taken into account in the LCC assessment.

An LCC management and control program will be invoked, which will include traceability across the propulsion system and supplier equipment. Requirements will be placed on the latter to support this process including agreement to design targets for reliability, maintainability, supportability, and cost. Engine producer personnel will monitor supplier effort towards meeting LCC goals and ensure LCC assessments of supplier equipment are consistent with those for the engine.

Engine producer LCC analysts will coordinate closely with other specialists (e.g., ILS, R&M, costs, weight, sfc) to provide a LCC input to the management of the program.

LCC assessments will be undertaken for changes in requirements specified by the customer.

4.1.3.4 EQUIPMENT SUPPLIER INVOLVEMENT: Suppliers will be expected to provide LCC data during the tendering and selection process plus report on the management and control processes to be used to achieve stated goals. Milestones must be proposed against which progress towards LCC goals can be measured and demonstrated throughout the program.

Selected suppliers will undertake LCC trade-off studies and provide evidence of these to the engine producer. Reports will be generated to support the LCC management and control program for the propulsion system. Liaison will take place with the engine producer to ensure LCC assessments and data are consistent with studies being undertaken for the propulsion system.

LCC assessments will be supplied to the engine producer for any changes required to the equipment specification.

4.1.4 Investment: The objective of this phase is to transform the results of R&D into a fully deployed operational system. The transition to production will begin with advanced purchase of tooling and long lead time components well before the conclusion of the FSD phase. The initial engine price will be established based on manufacturing costs, delivery schedules, production learning, and stability of the design. Initial spares provisioning will be a major part of early investment costs. Configuration will be more rigidly controlled by the customer than during the FSD phase.

4.1.4.1 CUSTOMER INVOLVEMENT: The customer supplies detailed production quantities/schedules and provides a detailed specification of deployment emphasising timing, physical location and resources. The customer generates a detailed definition of the support plan including initial requirements for training, training equipment, technical manuals, and support equipment. Support manpower requirements will have been established through maintenance analysis and prior experience.

The customer updates the definition of mission and mission mix as new information becomes available. Warranties and guarantees are specified and negotiated by the customer.

The customer exerts complete control of the engine configuration.

4.1.4.2 AIRCRAFT MANUFACTURER INVOLVEMENT: The aircraft manufacturer updates the engine power and fuel burn estimates as a result of test flying and supplies this information to the engine producer. Detailed maintainability assessments of the engine/airframe interface are undertaken. The aircraft manufacturer coordinates the support policies on engine/airframe equipment and support equipment. The flow of data on the complete system is controlled by the aircraft manufacturer.

4.1.4.3 ENGINE PRODUCER INVOLVEMENT: The engine producer optimizes the design and manufacturing processes to meet the production cost target. Detailed assessments of production tooling and manufacturing costs are established. The engine producer generates the program for improving the engine logistics, reliability, availability, and supportability based on detailed deployment and support requirements provided by the customer. Detailed spares provisioning recommendations are made.

The LCC assessment of the engine is refined using the above together with updated mission and fuel burn data supplied by the customer and airframe manufacturer respectively. LCC tracking continues using the latest production cost data and test data.

Forecasts of costs associated with offers of warranties and guarantees are made in support of negotiations with the customer. Detailed budgetary LCC assessments are undertaken for the customer.

4.1.4.4 EQUIPMENT SUPPLIER INVOLVEMENT: The supplier refines LCC input to the engine producer including production prices. Equipment support policies are optimized, consistent with engine and aircraft needs.

The supplier continues LCC tracking, participates in design trade study activity, and provides evidence of progress towards LCC design goals to the engine producer. The suppliers participate in cost reduction team activities with the engine producer.

The supplier provides warranties and guarantees to the engine producer.

4.1.5 Operational Deployment: In the operational phase, there is much detailed information available for the entire aircraft system, so that any cost estimation to be done will use accounting and simulation models. When an existing engine is placed in a new airframe, or an existing aircraft system is given a new mission, it is important that mission severity analysis be used to establish new maintenance cost estimates.

4.1.5.1 CUSTOMER INVOLVEMENT: Once in-service, the customer will supply the engine producer with operational data including parts usage, maintenance manhours consumed, reliabilities achieved, mission mix etc. Parameters supplied will be subject to mutual agreement with the engine producer. The latter will use the information provided to advise on improvements to the management of engine maintenance and to assess the value of engine/component improvements.

The customer may sponsor a component improvement program to further reduce operational costs.

4.1.5.2 AIRCRAFT MANUFACTURER INVOLVEMENT: The aircraft manufacturer will supply the engine producer with fuel burn data to support assessments of the effect of mission changes, or installation of the propulsion system in a different airframe. Again, this will be based on engine producer supplied performance deck and aircraft simulation models.

4.1.5.3 ENGINE PRODUCER INVOLVEMENT: The engine producer will utilize in-service data to provide guidance to the customer on how the maintenance philosophy can be optimized.

LCC assessments will be made of any proposed component improvements/modifications to the engine. LCC predictions of the new design will be compared with those based on in-service data of the existing design to determine whether a design change is cost-effective.

For new applications and/or new missions, the engine producer will supply performance decks to the aircraft manufacturer. Assessments of LCC will be made of new applications of the propulsion system based on customer/aircraft manufacturer data.

4.1.5.4 SUPPLIER INVOLVEMENT: In this phase, the supplier will be expected to prove that the equipment has met design goals and will need to collect data and undertake appropriate LCC assessments to support this.

The supplier should recommend improvements to maintenance philosophy and/or design, which will improve LCC.

4.2 Data Exchange at Interfaces:

LCC assessments, and optimization studies for the development of the design and operational procedures, can only succeed if the flow of LCC information can be effectively coordinated and communicated across boundaries within industry and between the customer and industry. Methods employed must be responsive to varying LCC personnel and organization capabilities. Many LCC coordination requirements can be performed by more than one LCC participant. To reduce duplication and to improve LCC data exchange and functional relationships at the interfaces, it is essential that each LCC participant establish and concur with coordination arrangements.

This section promotes the use of standard formats for communicating data.

4.2.1 With Customer: The starting point of an LCC assessment is a statement of ground rules (e.g., performance requirements, planned fleet disbursement, mission mix) by the customer. These should be registered with the airframe manufacturer and engine producer simultaneously.

The frequency of these inquiries, and often great similarity between them, suggests that a standard format could be developed through which the customer requirement could be specified. Apart from the improved ease of communication and enhanced understanding of data transmitted by this means, the added advantage of the use of this standard format is that contractors and customers can gear procedures to its use with consequent reduction in support resource. The recommended standard format for exchange of this type of data is contained in Appendix B.

The communication of LCC between contractors and the customer, including the results of design trades, will be supported by the use of the standard LCC element structure of Appendix A. In addition, the classification procedure contained in 5.1 should be used to qualify the accuracy of data exchanged.

4.2.2 With Aircraft Manufacturer: In early phases, the aircraft manufacturer should use engine LCC models (or be supplied data) that are sensitive to the configuration differences between the engines under consideration. The engine producer should supply data in a form that will isolate these differences to the lowest possible LCC element consistent with data accuracy.

4.2.2 (Continued):

In later phases, after engine selection has been made, engine LCC data can be aggregated to levels established by the aircraft system LCC model. Engine maintenance cost models need to be sensitive to power levels demanded, since the aircraft system power needs frequently increase after the engine design has been fixed. The engine producer should structure input to the aircraft system model in a manner that ensures consideration of this cost penalty.

To appreciate the influence of design decisions on the overall aircraft system, the developer of the propulsion system will require data to be supplied by the aircraft manufacturer together with an indication of the range of applicability. A standard format covering the principal data requirements is contained in Appendix C.

4.2.3 With Equipment Supplier: Earlier discussions of the role of the supplier at different stages of the engine project have identified the key contributions that can be made by the supplier in the achievement of a cost-effective product. To maintain productive exchange of LCC information at the supplier interface, the engine producer should provide, or accept from the supplier, the model and methodologies to be used to assess the LCC of the equipment. In most cases a suitable model may be developed on a microcomputer spreadsheet and used as the medium for conveying suitable ground rules to the supplier and the return of meaningful results. The complexity of the model used will depend on the stage the project has reached and the complexity of the equipment. In particular, it should be noted that if the equipment design embodies maintenance modules (LRU's/WRA's), then their sparing will need careful consideration.

The model can evolve from that used in the assessment of supplier LCC for selection purposes, to use for tracking the LCC of the equipment of selected suppliers.

An example of the categories of data, which will form input to the assessment of supplier equipment, is contained in Appendix D together with a list of other requirements to be addressed by the supplier.

4.2.4 Applicability of Standard Data Formats: LCC practitioners must always be aware of the dangers of misusing supplied information. A range of applicability must always be agreed upon by all parties at the point of exchange.

4.3 Managing LCC:

This section addresses the role of the LCC analyst in LCC studies and the relationship between LCC analysis and other related disciplines.

4.3.1 The Role of the Analyst: LCC studies can be divided into three principal areas:

a. Baseline Studies: Establishing a datum LCC against which others can be measured.

b. LCC Trade-Offs: Assessment of differences in LCC between competing options embodying design change, alternative maintenance concepts, etc.

c. LCC Tracking: Forecasting and monitoring LCC through different phases of the life cycle and influencing decisions over design, development, operation, and disposal.

Further details of study types can be found in AIR1939.

In each type of study, the analyst must play a leading role from identification of study objectives, through data collection and analysis, to the documentation of studies and formulation of recommendations. The difficulties associated with ensuring that LCC receives appropriate attention in a given program are significant. Relevant specialists involved in the design, development, and support of the propulsion system are already faced with increasingly demanding challenges in their individual fields. Against this background the analyst must ensure that, in addition, due attention is given to the LCC implications of change proposals at each stage of the program.

To facilitate the role of the analyst, it is essential that the LCC activities receive visible support from senior personnel. The LCC effort must be perceived to be an integral part of the management of the program. This philosophy must be maintained at all levels of the organization, across boundaries with other disciplines, and with external participants such as suppliers. It must be actively fostered to ensure it remains effective.

The wide range and complexity of data to be collected in LCC studies requires dedicated resources to coordinate and drive LCC assessments and ensure data consistency. Personnel needed to undertake these tasks must have an appreciation of a wide range of disciplines including the terminology employed. The LCC analyst must be prepared to challenge the data supplied for consistency and accuracy.

The diversity of LCC input data is illustrated by Figure 5. This shows the principal stages in processing the customer requirements into major LCC elements. The added difficulties of communicating with a wide range of contributors to the LCC assessment is illustrated in Figure 6. Those in the outer circle are external to the engine producer and those in the intermediate level are internal company contacts.

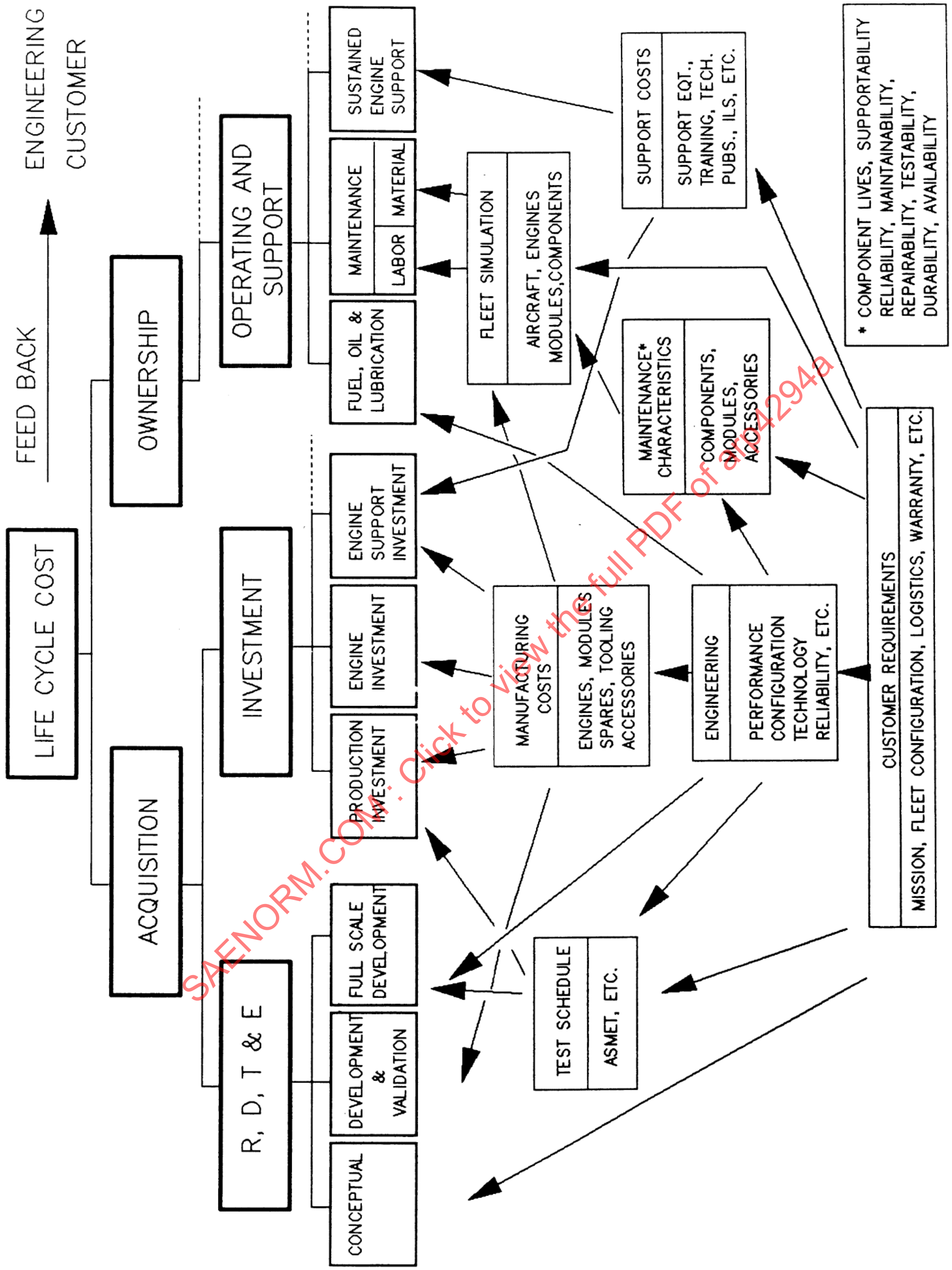


FIGURE 5 - Sourcing of Data Elements

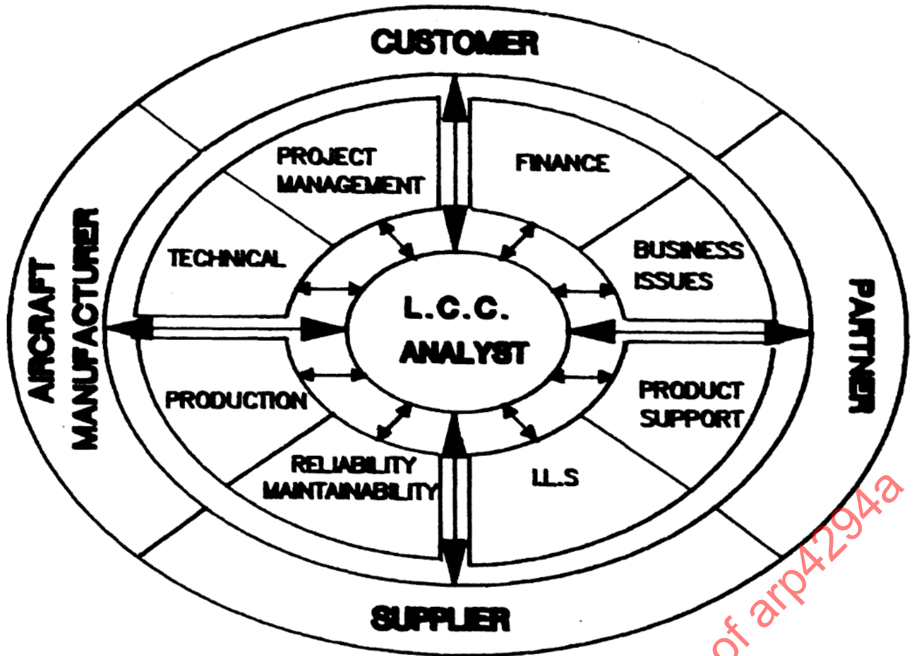


FIGURE 6 - Managing LCC

4.3.1 (Continued):

In addition, the LCC analyst must have the necessary knowledge and skills to determine the appropriate LCC tools and methodologies to use at a given stage in the program to meet a specific requirement. Finally the analyst must have the skills and knowledge to interpret the results of LCC analyses and summarize them in an understandable format.

In summary, the LCC analyst is a key communicator and coordinator, and must be prepared to spend a significant amount of time in this role. The following sections review the role of the LCC analyst at the interface with specialist functions.

Liaison with external contacts is described in 4.1.

4.3.1.1 TECHNICAL: The LCC analyst must be thoroughly conversant with engine design, development, usage, and maintenance. As engine design parameters are extended to take advantage of new materials or design techniques, the analyst should anticipate life and reliability problems, performance deterioration issues, and difficulty in manufacture and repair. Therefore, a continual dialogue is necessary between the LCC analyst and the engine designers.

4.3.1.2 PRODUCTION: The LCC of an engine is very much affected by the producibility of the design and the capability of the production organization to achieve cost learning. Unforeseen difficulty in this area can affect development cost and maintenance cost as well as production cost. Therefore, new designs must be thoroughly coordinated with the production organization, and the LCC analyst must be aware of all high-risk areas in the design.

The purchasing organization has an important influence on engine LCC through its interface with suppliers. It must be kept informed of the LCC requirements to be placed on suppliers and ensure these form an input to the supplier selection process and to the procurement contract. Exchange of information with suppliers is necessary to affect management and control of the contribution of supplier equipment to engine LCC and reliability.

4.3.1.3 RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM), INTEGRATED LOGISTICS SUPPORT, (ILS), PRODUCT SUPPORT: RAM and support aspects of an engine design are significant LCC drivers. Therefore, initial analyses of these drivers should occur with conceptual design, and should be a part of trade studies for the optimization or selection of a design. Government emphasis is on simple maintenance procedures and improved diagnostics. Consequently, engine design is evolving towards modularity and accessibility. The LCC analyst should, therefore, search out these refinements in new designs and include them in cost estimates.

4.3.1.4 FINANCE: Good communication channels are essential with personnel maintaining financial accounts as the latter are important sources of data for:

a. Development of cost estimating relationships (CER) used in parametric analyses.

b. Use in tracking LCC elements.

The definition of data must be carefully matched to those required in each case.

4.3.1.5 BUSINESS ISSUES: The analyst must be aware of the rules for pricing of engines, spares, support etc. to ensure that the appropriate level of input is included in the LCC analysis. There will also be a requirement to assess the implications attached to incentive schemes offered by the customer, and to support the development of incentive schemes for equipment suppliers.

4.3.2 Procedures to Support LCC Assessments: As previously described, all studies require the effort and commitment from a wide range of participants across many disciplines from within the analyst's own company or organization and often from others external to it. The analyst must be capable of managing these resources to best effect.

4.3.2 (Continued):

An important characteristic, which pervades all studies, but is particularly relevant in decision support activities (e.g., design trade-offs), is the need for a fast response to study requests. If results are not available when recommendations can be acted upon, then the benefits of undertaking the study will be lost. There is, therefore, a need for the analyst to balance the effort and accuracy of the study against the timescale to achieve results, which can form an input to the direction of the program.

Against the background described, there are a number of common procedural stages which can be followed to support any type of LCC study. It is important that these are properly documented and available to all participants to enable them to appreciate the significance of their role. The following provides a guide to the principal stages of the procedure. The LCC analyst manages its execution and usually acts as the chairman of key meetings:

a. STAGE 1:

The LCC analyst formulates the objectives of the study, including timescales, through discussions with study sponsors and senior personnel governing areas responsible for providing inputs to the study.

Appendix E provides a typical checklist to be used by the analyst in support of design trade studies. Initial estimates of the impact of a given design change are made by specialists to determine whether a more detailed assessment is necessary. The form can be employed directly at design review meetings with specialists present and act as a catalyst for identification and communication of LCC drivers.

b. STAGE 2:

The LCC analyst communicates study objectives defined during Stage 1 to data providers and requests the information needed for the study. It might be possible to create standard formats for the request and response for certain categories of data. In practice, however, to meet time constraints, each exercise will usually require a different emphasis to be placed on the level of detail of individual types of data to be acquired. This obviously makes the creation of generalized formats difficult. This is particularly so in the area of data to support operating cost evaluations. As a minimum, the analyst should use a checklist of standard data elements to guide data requests.

4.3.2 (Continued):

To accomplish this stage most effectively, and with minimum duplication of effort, it should commence with a meeting between the LCC analyst and all parties involved in providing data. The specific data required is arrived at through discussion and included in the minutes of the meeting as actions placed on data providers. Further meetings may be held with individual data providers to clarify requirements, as required. Timescales for data supply must be compatible with the date specified for the meeting to be held at Stage 4.

c. STAGE 3:

The LCC analyst undertakes the LCC analysis and prepares a draft presentation of results to be used at Stage 4.

d. STAGE 4:

A meeting is arranged by the LCC analyst to discuss results with all data contributors (or their representatives) to gain final commitment to their contribution to the analysis and discuss the conclusions and recommendations which can be supported by the analysis. If necessary, refinements to data will be made and the analysis revised.

e. STAGE 5:

The LCC analyst prepares a report based on the analysis and presents recommendations together with a summary of assumptions and data sources. It must also contain guidance on limitations of use of the information presented. The content of the report should be communicated to interested parties (internal and external to the analyst's own organization, as appropriate) including data providers. The LCC analyst must provide a sufficient level of detail to support the decision making process.

f. STAGE 6:

Project management must ensure that the recommendations of the LCC report are given appropriate weight in the decision making process (e.g., design changes, additional investment in development, changes to operating policies).

The degree of formality attached to the use of the procedure will vary according to the circumstances surrounding the request for the LCC studies and the time available to undertake them. In all cases, however, it is essential that results are accompanied by a statement of the limitations of the analysis and the assumptions used (including sources of data).

5. USE AND APPLICABILITY OF LCC ANALYSIS:

5.1 Classifications for Use of LCC Input and Output:

The degree to which LCC information is freely exchanged is influenced by the commercial and proprietary nature of cost and related technical data. Without exchange of essential information, attempts to influence design for optimal LCC will be severely limited. This section proposes the use of standard classifications for the use and applicability of such data exchange. The classification is intended to accompany all data exchanged.

Proposed classifications are listed below:

a. CLASS 3: Rough order of magnitude accuracy, valid for comparative assessments with greater detail, where available, in certain areas (e.g., assessment of production cost). The estimate may be derived from several techniques which may include parametric assessments.

b. CLASS 2: Reasonable level of accuracy with most of indents in cost structure addressed. Detailed account taken of customer logistics and support requirements.

c. CLASS 1: Contractually binding capability for certain elements, depending on current phase. Lower indents calculated.

PREPARED BY SAE COMMITTEE E-35,
PROPULSION ECONOMICS FOR
ACQUISITION AND OWNERSHIP

APPENDIX A
LIFE CYCLE COST ELEMENT STRUCTURE FOR PROPULSION SYSTEMS
(DEFINITIONS ARE GIVEN FOR THE LOWEST LEVEL COST ELEMENTS ONLY)

The cost element structure contained in this appendix is intended to be used to define the content of an LCC assessment of a specific project or application. It should be noted, however, that estimating procedures used in a study will be dependent on the phase the project has reached and will not necessarily isolate costs to the lower levels of detail shown in the structure. A high level view of the structure is presented in Figure A1:

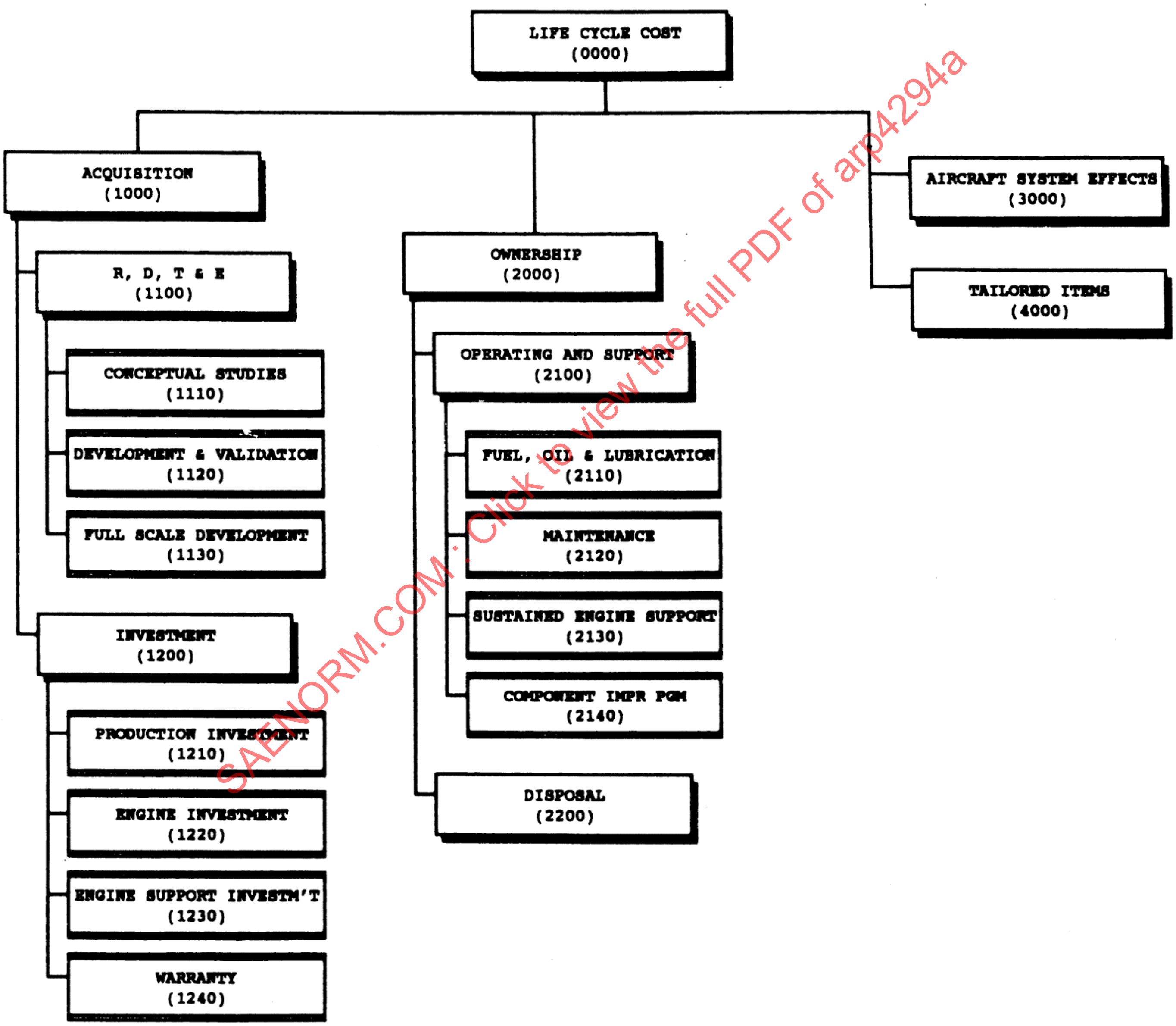


FIGURE A1 - Life Cycle Cost Structure for Propulsion Systems

The numbering system indicates the indenture level of a given cost element eg:

1100 RESEARCH, DEVELOPMENT, TEST AND EVALUATION

1110 CONCEPTUAL STUDIES

1120 DEVELOPMENT AND VALIDATION

1130 FULL SCALE DEVELOPMENT
1131 BENCH DEVELOPMENT TO COMPLETION OF QUALIFICATION/CERTIFICATION TESTING (CCT)
1132 BENCH DEVELOPMENT PROGRAM, POST CCT
1133 SUPPORT OF A/C FLIGHT DEVELOPMENT PROGRAM

In the above, "1100" comprises "1110", "1120" and "1130", while "1130 comprises "1131", "1132", and "1133".

"1000" and "2000" series elements relate to the major division of LCC into "acquisition" and "ownership" respectively. To support maximum flexibility, two additional categories have been defined at this level. These are "aircraft system effects" and "tailored items" which are numbered "3000" and "4000", respectively.

"1100", "1200", "2100" and "2200" series elements relate to the four phases of LCC (see Figure A2) (i.e., research, development, test, and evaluation, investment, operating and support, and disposal, respectively). Life cycle cost is coded "0000".

Definitions are provided for the lowest level cost elements in each part of the structure. The definitions at higher indentures should be derived from these.

A pictorial representation of the cost structure precedes the detailed descriptions of cost elements for each of the principal phases.

0000 LIFE CYCLE COST

1000 ACQUISITION

1100 RESEARCH, DEVELOPMENT, TEST AND EVALUATION (See Figure A2)

1110 CONCEPTUAL STUDIES

The sum of all contractor and government funded costs required to complete the feasibility studies of, and assess the subsequent definition of, any system or equipment conceived in response to meet a mission requirement. These include project related research, theoretical studies, hardware, material, tests, tooling, and other supporting activities (e.g., LCC and ILS studies).

1120 DEVELOPMENT AND VALIDATION

The cost of all engineering effort, including theoretical studies and design, hardware, tooling, rig and engine testing, management, and other supporting activities including LCC and ILS considerations, to transform the results of conceptual studies into design proposals suitable for full scale development.

1130 FULL SCALE DEVELOPMENT

1131 BENCH DEVELOPMENT PROGRAM TO COMPLETION OF QUALIFICATION/CERTIFICATION TESTING (CCT)

All engineering activity, engine hardware procurement, tooling hardware procurement, accessory development and procure-ment, rig testing, bench engine testing, engine repair and overhaul, and all ancillary activities to support the bench test program to CCT. Other supporting activities such as LCC studies and ILS assessments are included.

1132 BENCH DEVELOPMENT PROGRAM, POST CCT

All engine bench development activity to support the engine development from CCT to full operational clearance/initial operational capability (FOC/IOC); to investigate and resolve any problems or maintenance events arising during aircraft flying; to develop improvements in engine reliability, maintainability, and component/module lives. Included are engineering, hardware procurement, validation of alternative production sources, continuing accessory development, bench and rig testing etc. Other supporting activities such as LCC studies and ILS assessments are included.

1133 SUPPORT OF AIRCRAFT FLIGHT DEVELOPMENT PROGRAM

Engine support of the flight development program for the period up to FOC/IOC. The activities include engineering, hardware and tooling procurement, acceptance testing, engine and module repair and over-haul, service engineers support, development and provision of support equipment, including software, and all ancillary activities (e.g., installation mock-ups, technical publications for prototype engines and logistic support of the flight test centers).

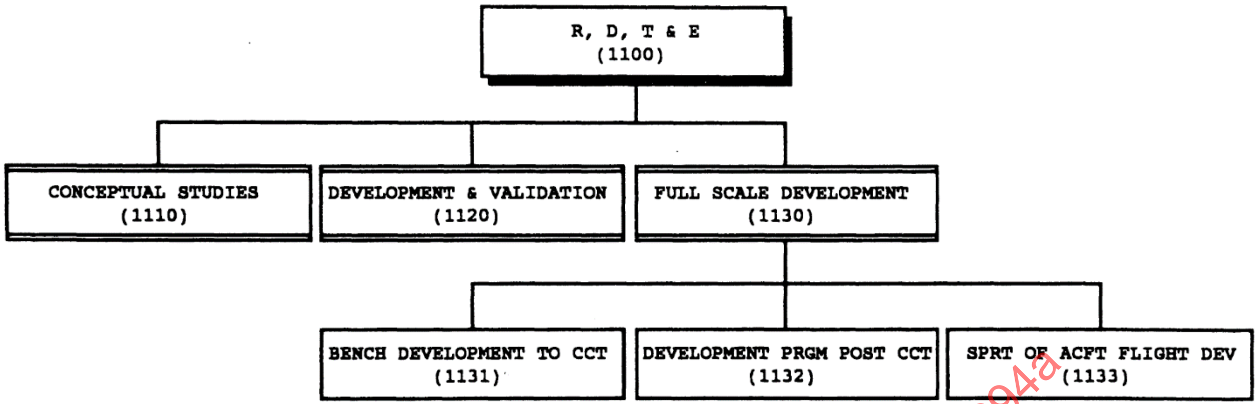


FIGURE A2 - Research, Development, Test and Evaluation

1200 INVESTMENT (See Figure A3)

1210 PRODUCTION INVESTMENT

1211 PROGRAM MANAGEMENT

All effort associated with management and control of the overall program plus LCC management, configuration management, and quality assurance management.

1212 ENGINEERING SUPPORT TO PRODUCTION

Preparation and update of the production engine build standard master parts lists and the preparation and implementation of modification procedures (i.e., configuration control). Also included is all cost reduction and value engineering activity.

1213 PRODUCTION TOOLING

1213.1 Initial Tooling

The initial package of jigs and fixturing tools required to manufacture engine components (including the accessory package) to the given standard and at a given rate of production. This includes all in-house casting tooling but excludes any tooling for material suppliers (i.e., casting and forging) if amortized into their prices. Also included are assembly jigs and fixturing tools required to build the given engine and accessory package at a given rate.

All engine and accessory industry test bed equipment capable of handling all the required engine and accessory testing in order to sustain the production program. Included are the costs of converting available test beds, but excludes the cost of new test beds. The latter would be included in 1214 INVESTMENT IN PERMANENT FACILITIES AND EQUIPMENT. The accessory test equipment has to cover all test equipment, test rigs, calibration equipment, etc. required by the accessory manufacturers, but excludes any development tooling which is included in the development costs.

The preparation and maintenance of all production, assembly and test tool design, test schedules and drawings.

1213.2 Replacement/Modification Tooling

The maintenance of, and replacement of, tooling covering the elements described in 1213.1 INITIAL TOOLING, necessary to maintain the engine and accessory manufacturing program along with the assembly and test program over the complete operational phase of the engines.

Any jigs, fixture tooling, calibration equipment etc. required to produce any modification kits for either the engine or accessory package, along with any changes to tested equipment and any new tool designs, test schedules, and drawings.

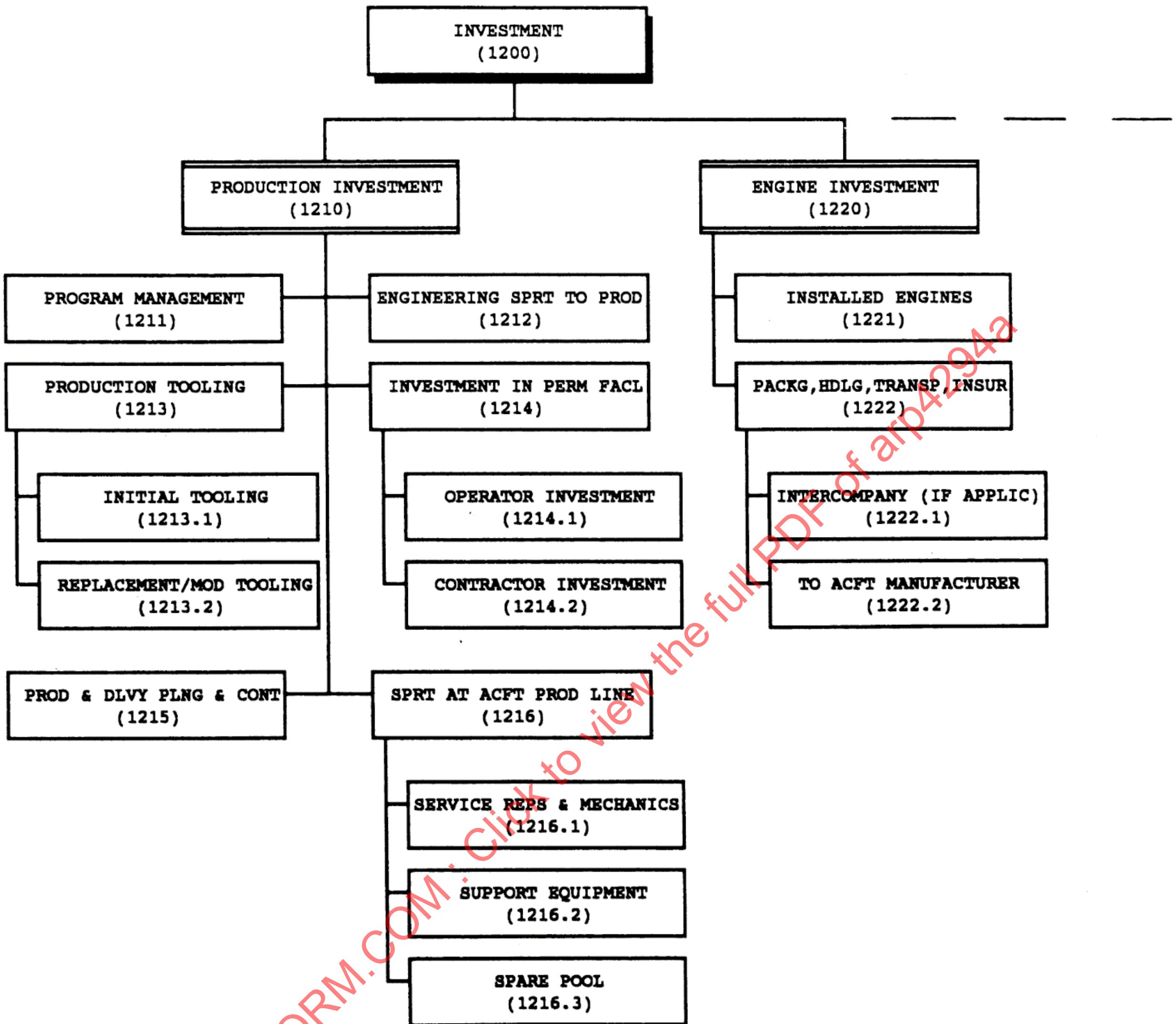


FIGURE A3 - Investment (1)

1214 INVESTMENT IN PERMANENT FACILITIES AND EQUIPMENT

1214.1 Operator Investment

Any project specific capital investment by the customer in manufacturing hardware and equipment (e.g., base facilities).

1214.2 Contractor Investment

As 1214.1 OPERATOR INVESTMENT, but for capital investment by the contractor which is not amortized into internal cost rates or overhead structure (e.g., test beds).

1215 PRODUCTION AND DELIVERY PLANNING AND CONTROL

Manufacturing/production planning, including the preparation and maintenance of operation drawings, operation sheets, quality assurance planning, raw material drawings and production assistance, the preparation and update of delivery programs, and the planning of all transport and packing.

1216 SUPPORT AT THE AIRCRAFT PRODUCTION LINE

1216.1 Service Representatives and Mechanics

All service representatives and mechanics, at the aircraft construction site during the installation of engines who advise, assist and carry out modification programs and support initial ground runs.

1216.2 Support Equipment (SE)

All level 1 and 2 SE to support item 1216.1 SERVICE REPRESENTATIVES AND MECHANICS. Level 2 SE is to allow a module change or modification embodiment.

1216.3 Spare Pool

Modules, accessories, expendables and consumables to support item 1216.1 SERVICE REPRESENTATIVES AND MECHANICS.

NOTE: Category 1216 SUPPORT AT THE AIRCRAFT PRODUCTION LINE excludes all technical support planning (covered under item 1232.2.1 INITIAL TECHNICAL SUPPORT).

1220 ENGINE INVESTMENT

1221 INSTALLED ENGINES

All installed engine units including attrition buy, where appropriate, based on the given reference unit production cost plus the effects of production learning.

1222 PACKAGING, HANDLING, TRANSPORTATION AND INSURANCE

1222.1 Intercompany (If applicable)

The transportation of installation modules, between partners including all packing, handling, and insurance charges.

1222.2 To Aircraft Manufacturer

The transportation of installation engines to the airframe manufacturer including all packing and insurance charges.

1230 ENGINE SUPPORT INVESTMENT (See Figure A4)

1231 SPARES

1231.1 Spare Engines

Spare engine holdings.

1231.2 Spare Modules

Spare module holdings.

1231.3 Spare Accessories

Spare accessory holdings.

1231.4 Initial Provisioning Spare Parts and Repair Material

1231.4.1 Engine Breakdown Spares

Initial provisioning pool of spare parts and repair material for the engine.

1231.4.2 Accessory Breakdown Spares

As for 1231.4.1 ENGINE BREAKDOWN SPARES but for accessories.

1231.4.3 Support Equipment Spares

As 1231.4.1 ENGINE BREAKDOWN SPARES but for support equipment.

Categories 1231 SPARES excludes all supply support planning (covered in item 1232.2.2 INITIAL ADMINISTRATIVE SUPPLY SUPPORT and 2132.4 SUSTAINED ADMINISTRATIVE SUPPLY SUPPORT (Reprovisioning)).

1231.5 Packaging, Handling, Transportation and Insurance

Transportation of spare modules, accessories and initial provisioning spare parts between partners and, where applicable, on to the operational bases/maintenance depots, including all packing, handling, and insurance charges. The transportation of spare engines to the operational bases/maintenance depots.

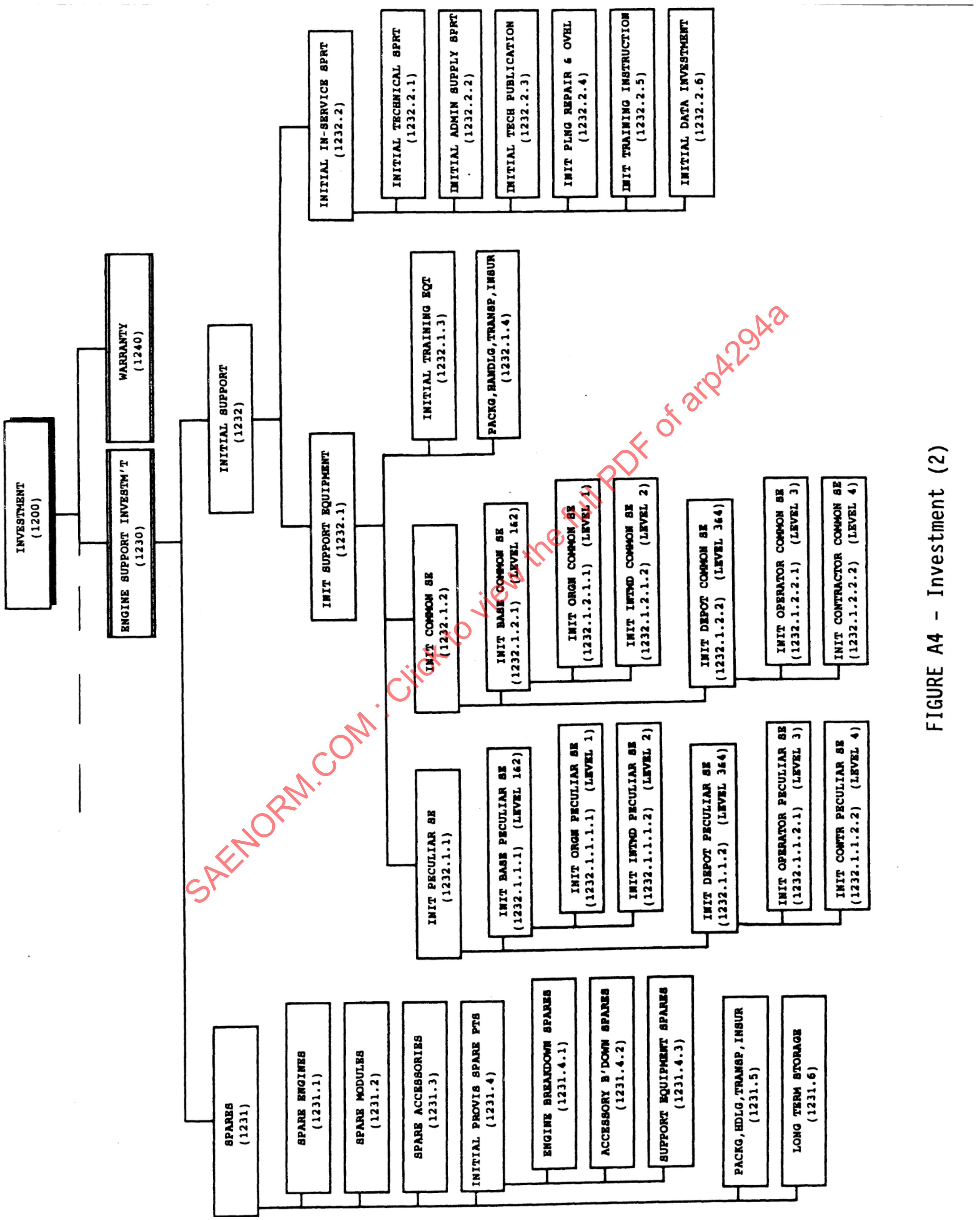


FIGURE A4 - Investment (2)

1231.6 Long-Term Storage and Corrosion Prevention

The cost of additional special protective measures and procedures to facilitate long-term storage and corrosion prevention.

1232 INITIAL SUPPORT

1232.1 Initial Support Equipment

1232.1.1 Initial Peculiar Support Equipment

1232.1.1.1 Initial Base Peculiar Support Equipment (Level 1 and 2)

1232.1.1.1.1 Initial Organizational (Level 1) Peculiar Support Equipment

All peculiar (project specific) initial SE for engines, modules, accessories and SE for SE, for use at the organization level (Level 1). This includes work stands, gantry adaptors, strip and build tools, lifting adaptors, containers, stillages, gauging plates, reference gauges, deadweight testers, test sets etc. as appropriate. Tooling for repair and overhaul work to be performed at this level is to be included (e.g., jigs and fixtures, fixturing tools).

1232.1.1.1.2 Initial Intermediate (Level 2) Peculiar Support Equipment

As for 1232.1.1.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) PECULIAR SUPPORT EQUIPMENT, but for peculiar equipment and tooling required at the Intermediate level.

1232.1.1.2 Initial Depot Peculiar Support Equipment (Levels 3 & 4)

1232.1.1.2.1 Initial Operator (Level 3) Peculiar Support Equipment

As for 1232.1.1.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) PECULIAR SUPPORT EQUIPMENT, but for peculiar equipment and tooling required at the operator's depot facility (Level 3).

1232.1.1.2.2 Initial Contractor (Level 4) Peculiar Support Equipment

As for 1232.1.1.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) PECULIAR SUPPORT EQUIPMENT, but for peculiar equipment and tooling required at the contractor's depot facility.

1232.1.2 Initial Common Support Equipment

1232.1.2.1 Initial Base Common Support Equipment (Levels 1 & 2)

1232.1.2.1.1 Initial Organizational (Level 1) Common Support Equipment

As for 1232.1.1.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) PECULIAR SUPPORT EQUIPMENT, but for equipment and tooling which is common to other engines already in the operator's inventory.

1232.1.2.1.2 Initial Intermediate (Level 2) Common Support Equipment

As for 1232.1.2.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) COMMON EQUIPMENT, but for common equipment and tooling required at the intermediate level.

1232.1.2.2 Initial Depot Common Support Equipment (Levels 3 & 4)

1232.1.2.2.1 Initial Operator (Level 3) Common Support Equipment

As for 1232.1.2.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) COMMON SUPPORT EQUIPMENT, but for common equipment and tooling required at the operator's depot facility.

1232.1.2.2.2 Initial Contractor (Level 4) Common Support Equipment

As for 1232.1.2.1.1 INITIAL ORGANIZATIONAL (LEVEL 1) COMMON SUPPORT EQUIPMENT, but for common equipment and tooling required at the contractor's depot facility.

1232.1.3 Initial Training Equipment

All initial training equipment including any necessary models, slide rigs, propulsion system training rigs (PSTR), training engines, facilities etc.

1232.1.4 Packaging, Handling, Transportation and Insurance

Transportation of all initial support equipment, defined in section 1232.1 INITIAL SUPPORT EQUIPMENT, between partners and, where applicable, onto the operational bases/maintenance depots. This is to include all packing, handling and insurance charges.

1232.2 Initial In-Service Support

1232.2.1 Initial Technical Support

Undertaking of programs for the initial maintainability, maintenance planning, health and performance monitoring, reliability and integrated diagnostics, serialized tracking, SE, software support, ILS, LSA, LCC, plus facilities planning for Level 2.

1232.2.2 Initial Administrative Supply Support

Initial supply support (materiel) planning and associated activities from industry covering operational bases and maintenance depots.

1232.2.3 Initial Technical Publications

All initial operator, maintenance and overhaul manuals, illustrated parts catalogues, technical documentation etc.

1232.2.4 Initial Planning for Repair and Overhaul

Initial facilities planning including repair support, support equipment requirements, repair scheme preparation, etc.

1232.2.5 Initial Training Instruction

All initial training instruction, including course notes, lecture/course fees, preparation, etc.

1232.2.6 Initial Data Investment

The provision of data required by the customer covering engineering, reprocurement, management and support. The initial setup costs of an appropriate data depository, and project specific data collection systems, are included.

1240 WARRANTY

The cost of providing warranties and guarantees not already covered under other categories (e.g., 1220 ENGINE INVESTMENT). Costs associated with the administration of warranties and guarantees including those associated with field service evaluation.

2000 OWNERSHIP

2100 OPERATING AND SUPPORT (See Figure A5)

2110 FUEL, OIL AND LUBRICATION

2111 OPERATIONAL FUEL, OIL AND LUBRICANTS

All mission fuel, oil and lubricants consumed by the fleet during the total operational phase.

2112 TEST FUEL, OIL AND LUBRICANTS

As for 2111 OPERATIONAL, but for ground running and testing.

2120 MAINTENANCE (for all levels)

2121 ENGINE MAINTENANCE LABOR

2121.1 Base Labor (Levels 1 and 2)

2121.1.1 Organizational Labor (Level 1)

Maintenance labor covering pre, inter and post flight checks, plus servicing at Level 1 and LRU remove/replace while engine is installed in the aircraft. This includes fault isolation, repair and testing plus removal/replacement of engine and modules where appropriate.

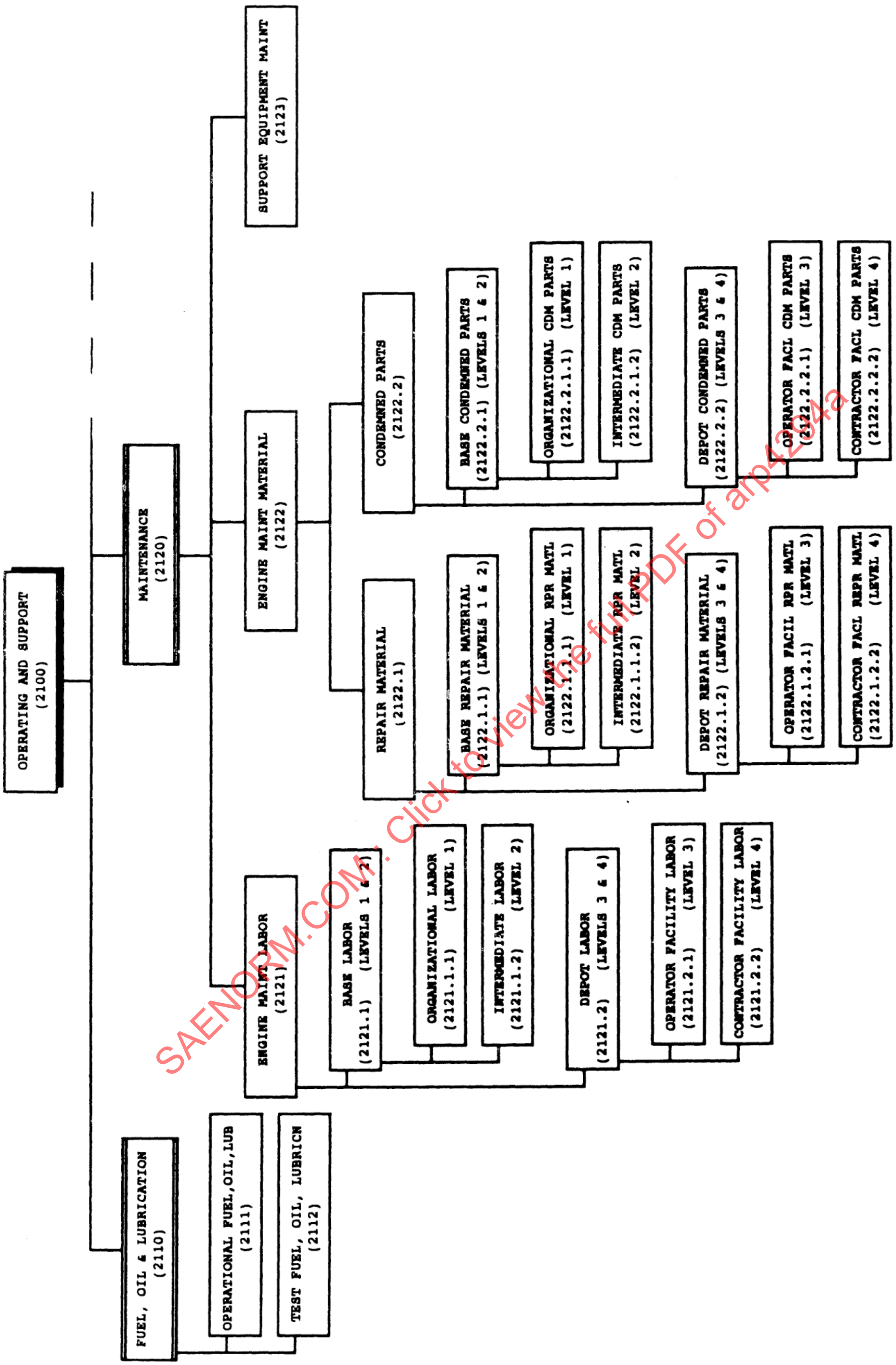


FIGURE A5 - Operating and Support (1)

2121.1.2 Intermediate Labor (Level 2)

Maintenance labor, including fault isolation, to cover removal/replacement, strip and build of engine, module, spare parts or accessory, plus servicing and repair and testing, at Level 2.

2121.2 Depot Labor (Levels 3 and 4)

2121.2.1 Operator Facility Labor (Level 3)

Maintenance labor, consumed at the operator's depot facility (Level 3) to strip, build, repair spares and test engines, modules, spare parts and accessories (including fault isolation).

2121.2.2 Contractor Facility Labor (Level 4)

As for 2121.2.1 OPERATOR FACILITY LABOR (Level 3), but for labor consumed at contractor facility.

2122 ENGINE MAINTENANCE MATERIAL

2122.1 Repair Material (Consumables, Expendables, and Rotables)

2122.1.1 Base Repair Material (Levels 1 and 2)

2122.1.1.1 Organizational Repair Material (Level 1)

All material consumed at Level 1 during activities described in 2121.1.1 ORGANIZATIONAL LABOR (Level 1), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.1.1.2 Intermediate Repair Material (Level 2)

All material consumed at Level 2 during activities described in 2121.1.2 INTERMEDIATE LABOR (Level 2), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.1.2 Depot Repair Material (Levels 3 and 4)

2122.1.2.1 Operator Facility Repair Materials (Level 3)

All material consumed at Level 3 during activities described in 2121.2.1 OPERATOR FACILITY LABOR (Level 3), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.1.2.2 Contractor Facility Repair Material (Level 4)

All material consumed at Level 4 during activity described in 2121.2.2 CONTRACTOR FACILITY LABOR (Level 4), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.2 Condemned Parts

2122.2.1 Base Condemned Parts (Levels 1 and 2)

2122.2.1.1 Organizational Condemned Parts (Level 1)

Replacement of parts condemned at Level 1 during activity described in 2121.1.1 ORGANIZATIONAL LABOR (Level 1), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.2.1.2 Intermediate Condemned Parts (Level 2)

Replacement of parts condemned at Level 2 during activities in 2121.1.2 INTERMEDIATE LABOR (Level 2), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.2.2 Depot Condemned Parts (Levels 3 and 4)

2122.2.2.1 Operator Facility Condemned Parts (Level 3)

Replacement of parts condemned at Level 3 during activities described in 2121.2.1. OPERATOR FACILITY LABOR (Level 3), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2122.2.2.2 Contractor Facility Condemned Parts (Level 4)

Replacement of parts condemned at Level 4 during activities described in 2121.2.2 CONTRACTOR FACILITY LABOR (Level 4), excluding those covered by 1231.4 INITIAL PROVISIONING SPARE PARTS AND REPAIR MATERIAL.

2123 SUPPORT EQUIPMENT MAINTENANCE

Maintenance labor and maintenance material for the repair of support equipment, including software updates.

2130 SUSTAINED ENGINE SUPPORT (See Figure A6)

2131 SUSTAINED INVESTMENT

2131.1 Replenishment Spares (if any)

Any additions to the initial spares inventory (e.g., modules, major assemblies, and accessories) required to maintain a desired level of availability.

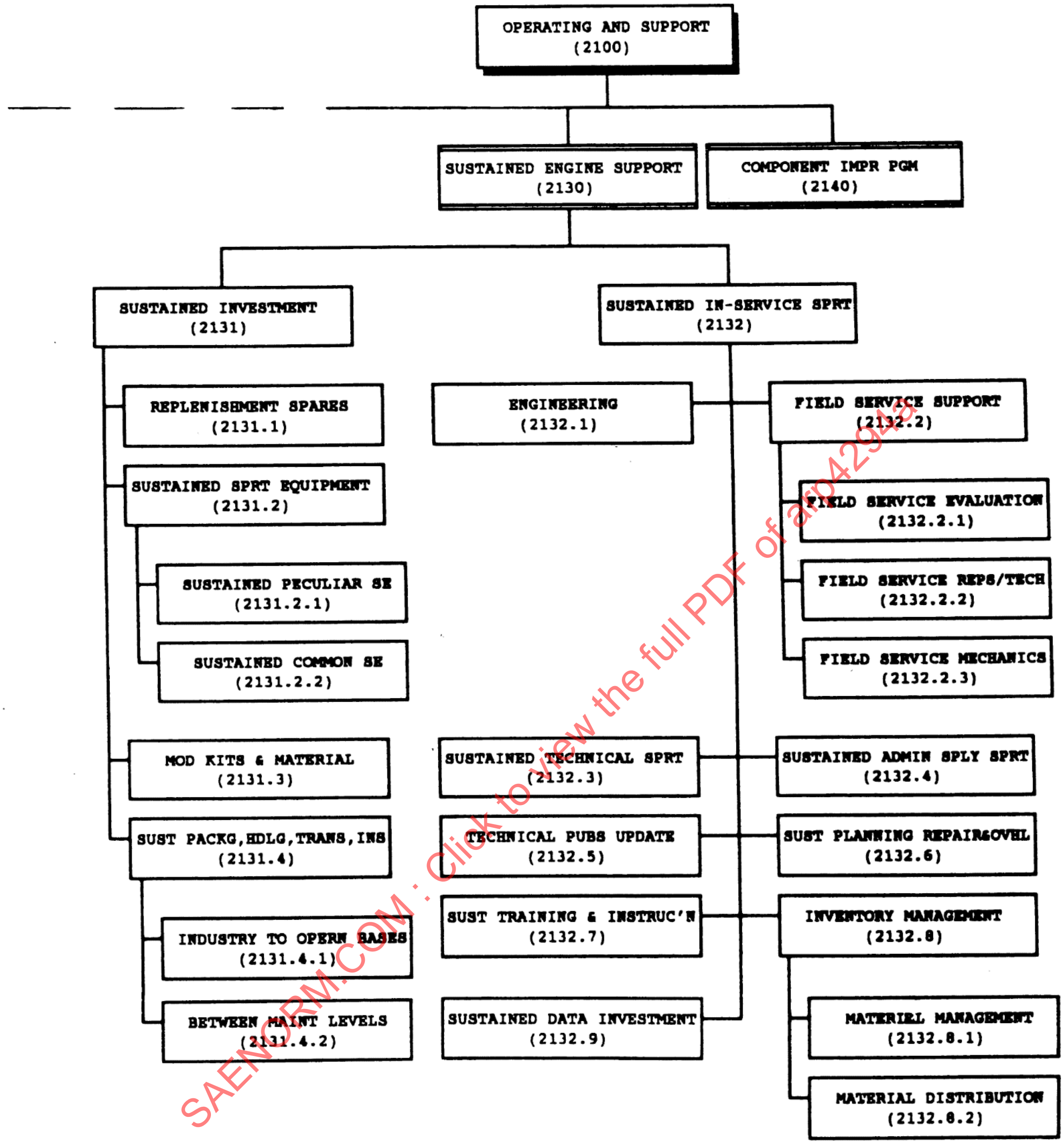


FIGURE A6 - Operating and Support (2)

2131.2 Sustained Support Equipment

2131.2.1 Sustained Peculiar Support Equipment

Additional purchase or replacement of complete, damaged or worn out equipment, as described in 1232.1.1 INITIAL PECULIAR SUPPORT EQUIPMENT, for all maintenance levels.

2131.2.2 Sustained Common Support Equipment

Additional purchase or replacement of complete, damaged, or worn out equipment, as described in 1232.1.2 INITIAL COMMON SUPPORT EQUIPMENT, for all maintenance levels.

2131.3 Modification Kits and Material

Any modification kits, excluding modification tooling (covered in section 1213.2 REPLACEMENT/MODIFICATION TOOLING), technical publication updates (covered in section 2132.5 TECHNICAL PUBLICATION UPDATES) and modification procedures (covered in section 1212 ENGINEERING SUPPORT TO PRODUCTION). This includes any change in material that the modification requires.

2131.4 Sustained Packaging, Handling, Transportation and Insurance

2131.4.1 Contractor to Operational Bases

Transportation of sustained breakdown spares and sustained support equipment, defined in section 2131 SUSTAINED INVESTMENT between partners, and their subsequent distribution from industry to the operational bases/maintenance depots. This is to include all packing, handling and insurance charges.

2131.4.2 Between Maintenance Levels

The transportation of all repair units, including engines, modules, accessories, and spare parts between operator maintenance levels. This is to include all packing, handling, and insurance charges.

2132 SUSTAINED IN-SERVICE SUPPORT

2132.1 Engineering (if any)

Any specific engineering activity, in the form of personnel, planning or hardware support, that may be required at the operational bases and is not covered elsewhere in section 2132.2 FIELD SERVICE SUPPORT (e.g., In-service sampling).

2132.2 Field Service Support

2132.2.1 Field Service Evaluation (FSE)

Efforts specifically associated with the evaluation of performance, operability and maintainability. This includes; for example, FSE specific program reviews, program planning and control, engine tracking, training, support equipment, etc.

2132.2.2 Field Service Representatives/Technicians

Continuing advice, assistance, training operator personnel, feedback to the customer support organization, the management of in-field CIP's, etc. Industry Management of field service activities.

2132.2.3 Field Service Mechanics

Project field service mechanics required at the maintenance depots or operational bases.

2132.3 Sustained Technical Support

Continuing technical support planning and associated activities as described in section 1232.2.1 INITIAL TECHNICAL SUPPORT.

2132.4 Sustained Administrative Supply Support

Continuing administrative supply support from industry covering the operational bases and maintenance depots as described in 1232.2.2 INITIAL ADMINISTRATIVE SUPPLY SUPPORT.

2132.5 Technical Publication Updates

Revisions and updates to all technical publications, manuals, etc. during the operational phase of the engines. Most revisions and updates will be the result of modifications.

2132.6 Sustained Planning for Repair and Overhaul

Continuing planning for repair and overhaul as described in section 1232.2.4 INITIAL PLANNING FOR REPAIR AND OVERHAUL.

2132.7 Sustained Training and Instruction

All continuing training and instruction commensurate with the fleet build up, the introduction of new operations, including new facilities, capability expansion, etc.

2132.8 Inventory Management

2132.8.1 Materiel Management

All provisioning conferences, feedback to supply support, stocking levels, etc.

2132.8.2 Material Distribution

Labor resources required for planning and maintaining spares holdings at different levels of the maintenance organization.

2132.9 Sustained Data Investment

Provision of data required by the customer for the Ownership Phase covering engineering, reprocurement, management and support.

2140 COMPONENT IMPROVEMENT PROGRAM (C.I.P.)

Total engine CIP costs including software over the life cycle of the engine. It includes design, fabrication and test costs associated with component improvement, once the engine is in production.

2200 DISPOSAL (See Figure A7)

The sum of all costs required to remove the propulsion system from the inventory. It may be offset by the residual value from resale or salvage.

3000 AIRCRAFT SYSTEM EFFECTS

Additional costs (or savings) in Aircraft System LCC attributable to the propulsion system, (e.g., reduction in quantity or size of aircraft required due to increased engine performance and/or reliability).

4000 TAILORED ITEMS

Any other costs (or savings) which can be attributed to the propulsion system.

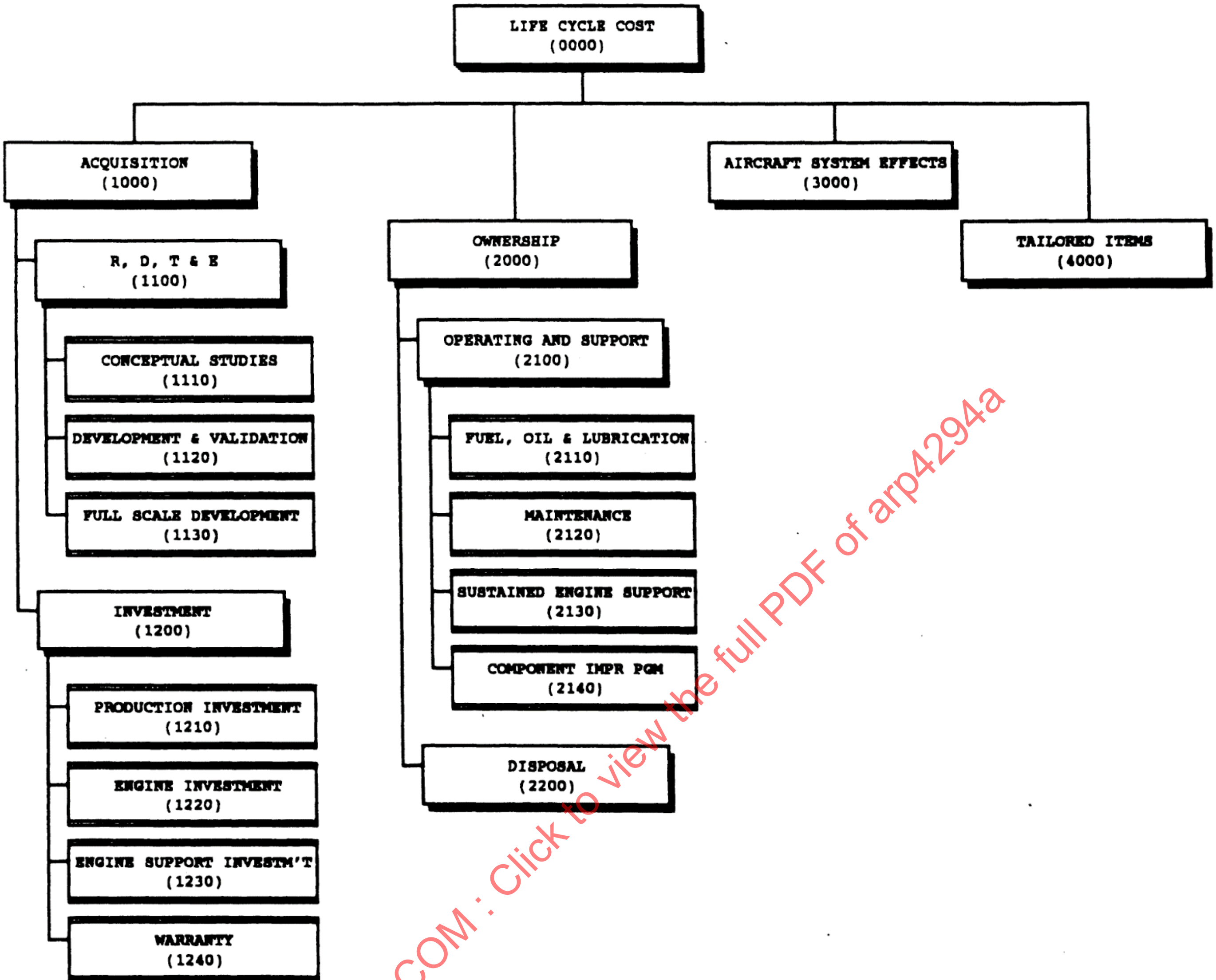


FIGURE A7 - Disposal, A/C System Effects, Tailored Items

APPENDIX B
LIFE CYCLE COST QUESTIONNAIRE FOR CUSTOMER

1. DESCRIPTION OF REQUIREMENT, AND ANTICIPATED AREAS OF RISK (e.g., planned growth, drag increase) (NARRATIVE)

		CUSTOMER REQT	EXAMPLE ANSWER
2.	GENERAL DEFINITIONS		
2.1	Aircraft		Single Engine Trainer
2.2	Engine		Advanced Trainer Engine
2.3	Period of Study		25 years from first aircraft in service
2.4	Mission Profile (Peacetime): Please complete the attached questionnaire in as much detail as possible (page 58 and 59) including scheduled operation above max rated conditions.		
2.4.1	Specify any exceptional environmental factors to be taken into account (e.g., over sea, over sand, desert missions, etc.)		
2.5	Operational Effects to be included:		
2.5.1	FOD		Included/Excluded
2.5.2	Unconfirmed failures		Included/Excluded
2.5.3	Improper maintenance		Excluded/Included
2.5.4	Others, to be specified		Excluded/Included

		CUSTOMER REQT	EXAMPLE ANSWER
3.	AIRCRAFT PROFILE		
3.1	Specify delivery program (by period) of aircraft by fleet and squadron including the following:		PERIOD YR1 YR2 YR3 YR4...YRN
3.1.1	Attrition reserve		
3.1.2	Strategic reserve		
3.1.3	Operational Aircraft in service		
3.1.4	A/C in pipeline		
3.1.5	Total Aircraft		
3.2	Specify the utilization of aircraft in service (mission hours)		500 hours/annum
3.2.1	TAC cycles per engine flying hour		6 per EFH
3.3	Aircraft/engine attrition		
3.3.1	Customer to specify if:		
3.3.1.1	Strategic reserve is rotated		Rotation
3.3.1.2	Attrition reserve is rotated		Rotation
3.3.2	Specify random aircraft attrition rate per aircraft flying hours		0.2 per 100,000 AC hours

	CUSTOMER REQT	EXAMPLE ANSWER
3.4 Aircraft retirement policy		
3.4.1 Airframe retirement age (years or flying hours)		15 years
3.4.2 Are engines retired with airframes?		Yes/No retirement
3.4.3 Type of retirement		Instantaneous
3.5 Planned growth in power requirements		Additional 10% thrust

	CUSTOMER REQT	EXAMPLE ANSWER
4. LOGISTICS ORGANIZATION		
4.1 A general description of the customers maintenance organization structures; (e.g., does customer require a facility to recover all modules at level 2?).	)	4 Bases) Level 1 and 2 1 Depot) Level 1 Industry Facility) 3 and 4
4.1.1 Specify the maintenance organization (see page 60 and 61 for definitions)	)	
4.1.2 Confidence required of serviceable engine/module availability at each level of maintenance		80% Engines) All 90% Controls) levels and Accessories)
4.2 Requirements for self sufficient dispersals - customer has to define the requirements		No
4.3 Spares stocking policy/spare supply requirements:		
4.3.1 Initial Provisioning) BY		24 months
4.3.2 Follow-on Provisioning) YEAR		6 months Constant
4.4* Transportation times and assumed modes of transportation between maintenance organizations		15 days each way
4.5* Turnround times at maintenance organization operated by customer for each level		60 days for engine 15 days for controls and accessories

* Repeat for each element of logistics pipeline and maintenance facility