

SAVE PROCEEDINGS 1994
DESIGN-TO-LIFE-CYCLE-COST IN AEROSPACE

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ABSTRACT

This paper describes the application of Design-to-Cost (DTC) principles in a total life cycle cost (LCC) environment for aerospace products in a process known as Design-to-Life-Cycle-Cost (DTLCC). The description encompasses responsibilities of the government as well as those of aerospace contractors. The paper offers useful advice in assigning responsibilities, organizing for effectiveness, and creating the often-inadequate documentation.

INTRODUCTION

DTLCC is an especially effective technique in a down-sizing market when limited labor and material resources must assume greater responsibilities for cost management and cost control. Program survival depends on our success in implementing the DTLCC principles described here.

Experience for this paper was gained by Management Consulting & Research, Inc. through numerous consulting assignments to establish, implement, and evaluate DTLCC programs for major aerospace organizations.

Design-to-Life-Cycle-Cost (DTLCC) can be defined (reference DoDD 4245.3)¹ as "an acquisition management technique to achieve defense systems designs that meet stated cost requirements. Cost is addressed on a continuing basis as part of a system's development and production process. The technique embodies early establishment of realistic but rigorous cost objectives, goals, and thresholds and a determined effort to achieve them".

DTLCC can also be defined (reference AR 70-64)² as "an Army cost control program that establishes parameters as program sponsor's objectives to be achieved through system engineering design".

DTLCC differs from DTC only in scope, DTLCC considers total lifetime cost, going beyond those costs attributed to the acquisition phase (development and production) and including operation and support (O&S) and disposal.

Designers consider the window of opportunity, shown in Figure 1, a dramatic representation of the diminishing opportunity to influence lifetime costs.

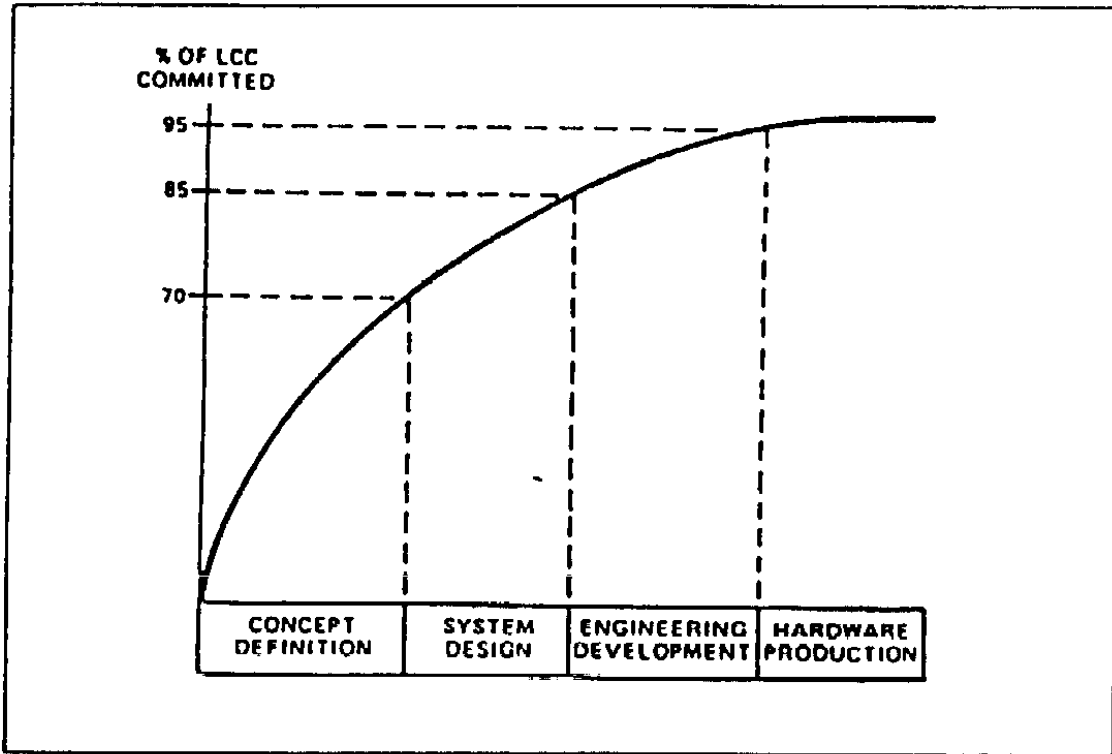


Figure 1. DTLCC Window of Opportunity

Figure 1. DTLCC Window of Opportunity

There are actually two levels of DTLCC which are of interest to the aerospace community, that of the buyer of services (typically the federal government agency) and that of the provider

of those services (typically the aerospace contractor or aerospace laboratory). Both levels are discussed in this paper.

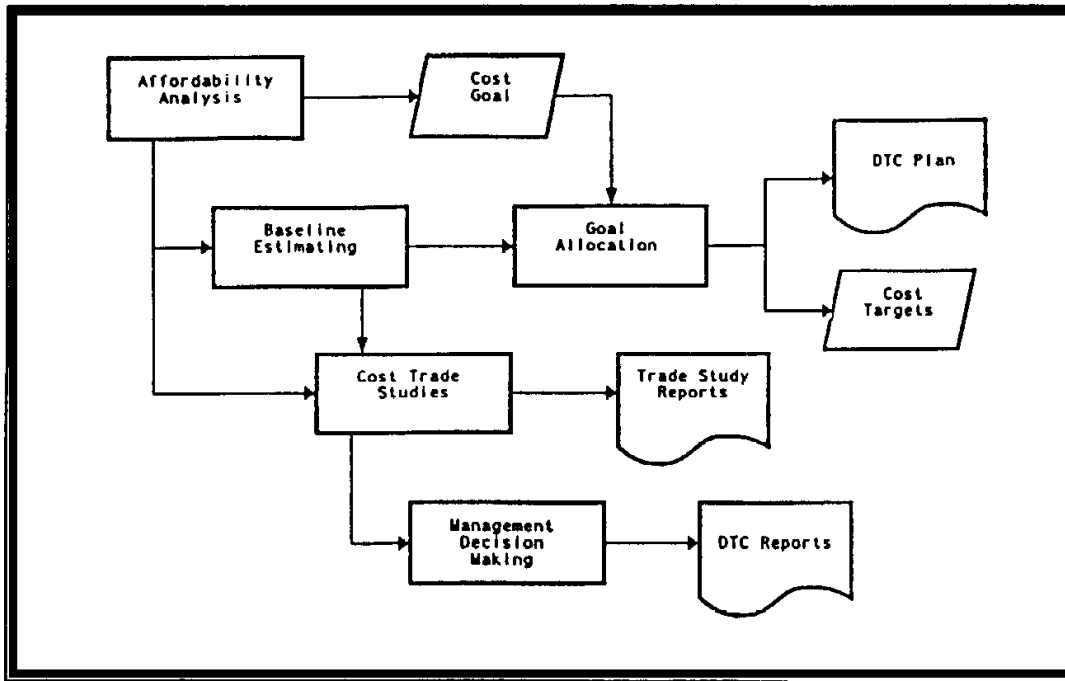


Figure 2. DTLCC Process

Figure 2 illustrates the DTLCC process as practiced by the Government/Contractor team. Major activities are described in subsequent paragraphs.

Affordability Analysis

The buyer (typically the DoD, NASA, DoE, etc.) determines the functional worth of an aerospace system and of its discretionary functions using parametric life cycle cost models or operations. The buyer (typically the DoD, NASA, DoE, etc.) determines the functional worth of an aerospace system and of its discretionary functions using research techniques. The buyer's cost analysis team can assist by evaluating costs of similar aerospace systems and functions from its historical hardware and software databases. The buyer establishes initial system level production and O&S cost goals for the baseline architecture. A range of cost estimates that relate to alternative design values will permit flexibility to stimulate contractor innovation.

Baseline Estimating and Goal Allocation

The selected contractor typically prepares his own proposal production and O&S estimates (based on the initial baseline) and allocates the buyer's top level cost goals to lower level cost targets in accordance with the program work breakdown structure (WBS). Contractor targets should be difficult, but achievable. The contractor also prepares a DTLCC Plan for the buyer, describing his DTLCC organization, estimating methods, program design and assumptions, planned cost trade studies, and reporting procedures.

Cost Trade Studies

The heart of the DTLCC process is the development and documentation of trade studies, by both the buyer and its contractors, in accordance with established priorities. The purpose of cost trade studies is to compare alternative designs and manufacturing processes within the acceptable performance bands on a disciplined basis. Documentation is a requirement, as described later.

There are two objectives of a trade study:

- (1) to identify the design and production process alternative which meets minimum performance requirements at the lowest average unit production cost and
- (2) the lowest O&S cost per operating hour for the same design and process. Parametric cost estimating methods are effective because the technical parameters being traded are also the model cost drivers.

Management Decision Making

The ultimate goal of the DTLCC program is a series of enlightened and objective decisions based on logical and auditable estimates which are carefully documented. Periodic DTLCC Reports establish the important audit trail.

A DTLCC objective will normally be established for a major acquisition program, beginning at Concept Demonstration. DTLCC is normally applied to DoD and NASA programs wherein the production cost is anticipated to exceed an established threshold. A primary DTLCC objective is proper balance between cost, performance, and schedule.

DTLCC Goals

DTLCC goals are typically established separately for Design-to-Unit Production Cost (DTUPC) and Design-to-Operating and Support Cost (DTOSC) as described below.

Design to Unit Production Cost (DTUPC) goals are defined as cost to the government stated in base-year dollars, lot size, and production rate and are equivalent to flyaway or rollaway cost. The buyer also needs to specify approved escalation rates and procedures, learning curve slope, and production schedule. These goals need to be demonstrated, or reliably predicted, during engineering development. The DTUPC goal is typically defined as in Table 1.

Included in Contractor DTUPC	Excluded from Contractor DTUPC
<ul style="list-style-type: none"> - Recurring unit production labor, material, and associated overhead - Allocated nonrecurring production (factory engineering, setup, quality control, initial tooling, sustaining tooling, inspection, supervision) - Software development - Integration and test - Project Management - Contractor fee and G&A costs 	<ul style="list-style-type: none"> - RDT&E - Initial spares - Technical data and publications - Support equipment - Training equipment and training - Operations and maintenance support - Facility construction - GFE - First destination transportation

Table 1. DTUPC Goal Definition

Included in Contractor DTOSC	Excluded from Contractor DTOSC
<ul style="list-style-type: none"> - Repair costs at all levels of maintenance, including labor for military, government civilians, and contractors plus replenishment spares. - Operating costs to include crew labor, POL, etc. - Support equipment repair 	<ul style="list-style-type: none"> - Modifications - Training

Table 2. DTOSC Goal Definition

Threshold cost may also be represented as a value slightly below the DTUPC goal, such that whenever the threshold cost is

exceeded, a program review is automatically triggered.

Design to Operating & Support Cost (DTOSC) goals are typically defined as cost (to the government) in base year dollars per weapon system operating hour at a specified deployment scenario (quantity, location, environment) and maintenance concept (number of levels, repair locations, and supply locations).

To the extent possible, DTOSC should be defined in design-controllable factors measurable or predictable during system test and evaluation. Recent changes to most life cycle planning guides (such as AR 70-64) have placed greater emphasis on DTOSC. When flowed down to the contractor, the DTOSC is further typically defined as in Table 2. The buyer will typically allow each prime contractor to allocate system level DTUPC and DTOSC goals to lower work breakdown structure (WBS) level cost targets.

Prime contractors typically allocate subsystem targets to subcontractors, along with other requirements and incentives.

STUDY PROCESS

The purpose of the trade study is to achieve adequate

(minimum specified) performance at the lowest possible cost. No advantages are gained by designing a better product if unit production or annual maintenance cost escalates.

Responsibility for implementing and documenting the trade study rests with the Concurrent Engineering Teams. Concurrent Engineering Teams are discussed later.

The best cost evaluation tool is the calibrated parametric cost estimating model, whose cost drivers emulate the designer's technical parameters based on actual prototype and limited rate initial production (LRIP) costs.

A sample trade study report for an electronics module is shown in Figure 3. This sample illustrates the impact of five different alternatives in relation to program objectives. In this sample, a \$1,500 unit production cost target is assumed. Development cost is important, but there is no target and risk is to be avoided. However, the customer is willing to trade weight and reliability for cost. The PRICE H parametric estimating model was used to predict the resulting costs from established technical parameters.

Alternative Objective	Design/Process/Program Alternative Parameters				
	A Baseline	B Risk	C Weight	D Reliability	E Cost
Meets specification?	Yes	Yes	Yes	Yes	No
Overlapping schedule	No	No	2 mos	3 mos	No
Weight (spec is 0.95)	0.95 lb	0.95 lb	0.76 lb	1.10 lb	0.95 lb
MCPLXE (derived)	6.950	N/A	7.270	6.760	6.850
MCPLXS (derived)	5.300	N/A	5.300	5.200	5.300
MTBF (spec is 1750) hrs	1750 hrs	1750 hrs	2300 hrs	1500 hrs	1500 hrs
MTTR (spec is 1.5) hrs	1.5 hrs	1.5 hrs	1.0 hrs	2.0 hrs	2.0 hrs
Development Cost	\$70 K	N/A	\$120K	\$40K	\$25K
Tooling Cost	\$10K	N/A	\$10K	\$10K	\$10K
Unit Fabrication Cost	\$1350	0	\$1945	\$1050	\$1200
Unit Material Cost	\$ 350	\$2350	0	\$ 450	\$ 175
Total Unit Production Cost	\$1700	\$2350	\$1945	\$1500	\$1375
Conclusions and Recommendations	Proposal can't meet cost target	Purchase unit can't meet cost target	Pay more for light weight?	Risky but meets cost target	Relax spec?

Figure 3. Sample Trade Study Report

SUBCONTRACTOR FLOW DOWN

Despite all planning and control activities implemented by the buyer and the prime contractor, DTLCC goals could be missed because of subcontractor commission or omission. Subcontractor and supplier costs should become an integral segment of target costs. Prime contractors need to "flow down" through the subcontracting process suitably tailored requirements and incentives. It is insufficient to just copy the DTLCC clause from the prime contract to each subcontract.

Flow down begins with a critical evaluation, including independent cost assessment, of each subcontractor proposal. Fact finding teams, combining contract specialists, engineers, and cost analysts representing the buyer and the prime contractor typically conduct on-site evaluations to determine capability to meet cost goals. Consideration should be given to **cost** drivers rather than **price** drivers. Observing Pareto's Law (the most expensive 20% of the WBS elements contribute 80% of the product's cost), the prime contractor DTLCC Manager should

continually monitor the subcontractor's evolving estimate as well as his evolving design.

THE DTC ORGANIZATION

DTLCC responsibilities are typically assigned to existing organizations. However, small adjustments can be made to existing aerospace contractor organizational responsibilities to assure effective assimilation of supporting cultures and successful DTLCC activities. Refer to the traditional organization chart in Figure 4 and note the added functions relative to DTLCC.

Organizational Responsibilities

Specific assignments related to a successful DTLCC program may be identified for each aerospace contractor functional entity, as follows:

- DTC Manager
- Develop DTLCC Plan and establish DTLCC procedures,
 - Prepare DTLCC Reports,
 - Supervise cost target allocation,
 - Maintain cost audit trail, and
 - Train.

- Engineering
- Review and challenge specifications,
 - Identify alternative designs, and
 - Conduct trade studies.

- Manufacturing
- Identify alternative processes,
 - Support trade studies, and
 - Support cost model calibration.

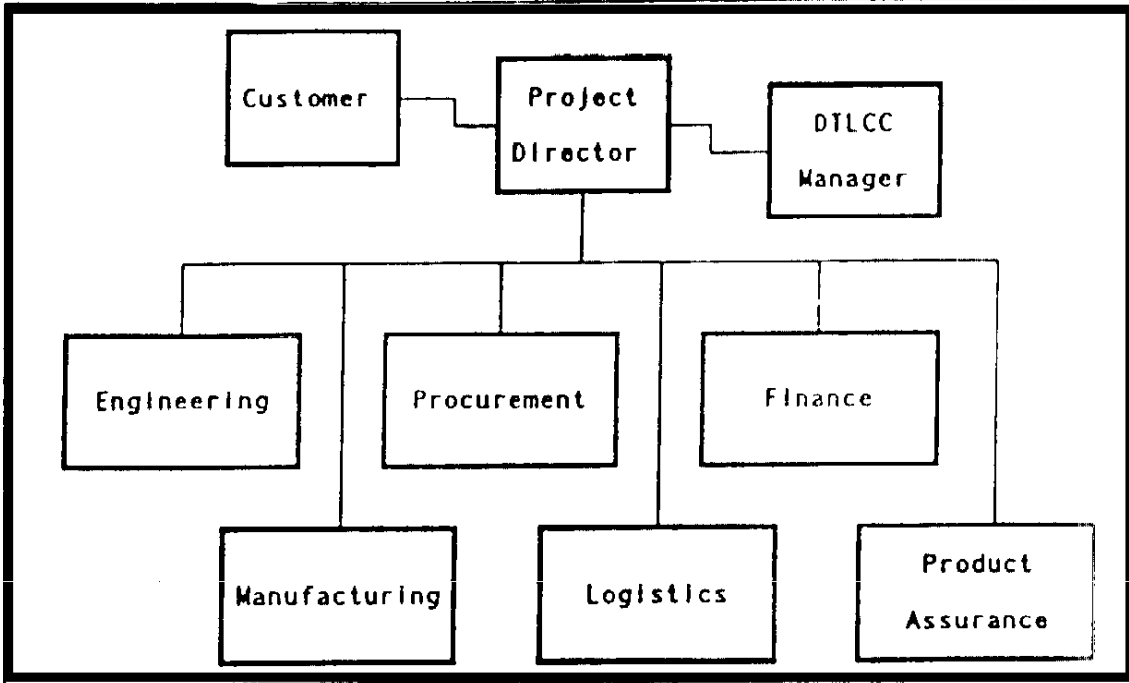


Figure 4. Transitional Organization with Additional DTLCC Responsibilities

- Procurement
- Flowdown DTLCC requirements and targets,
 - Evaluate and monitor subcontractors and suppliers,
 - Lead fact finding teams, and
 - Initiate DTLCC training for suppliers.

- Logistics
- Review and challenge support requirements,
 - Identify alternative maintenance concepts,
 - Support trade studies, and

- Support cost model calibration.

- Finance
- Provide approved models, calibration factors,

- Product Assurance
- Evaluate cost and sensitivity of the quality function, and
 - Assure lowest cost for acceptable quality.

Concurrent Engineering Teams

DTLCC benefits from a team approach. Design teams can effectively treat DTLCC issues as part of their overall design responsibility. Cost engineers, assigned to each team, can provide real time review of evolving designs in their embryonic stage and can work cost/benefit analyses with the designer. Many more options can be analyzed in a less formal environment, characterized by mutual benefit and accomplishment.

Concurrent Engineering Teams improve productivity and efficiency, often shortening design schedules, because team representation includes engineering as well as manufacturing skills. Teams "own the process" and are more likely to consider peripheral design issues, such as cost. Teams typically are assigned total responsibility for selected work breakdown structure (WBS) elements and then assume responsibility for all aspects, including cost.

Concurrent Engineering Teams are typically responsible for allocating broad cost goals into specific cost targets, for interfacing with subcontractors and suppliers, and maintaining the baseline cost estimate. Team members quickly absorb additional skills due to the team environment, improving their contribution to the team.

REPORTING

Good DTLCC programs die from two causes: negligent management and poor reporting. Government references provide a good basis for documenting the DTLCC program, whether for the government buyer or other buyer. A distillation of their recommended format and content is useful to the DTLCC Manager for planning.

The DTLCC Plan

The DTLCC Plan should be prepared initially by the buyer to establish DTLCC feasibility. A later version should then be developed (and frequently updated) by the aerospace contractor to document his game plan; his version may actually help in his being selected for the design responsibility. Specific topics in either version include:

- A concise statement of goals and targets structured to the work breakdown structure (WBS);
- Organizational responsibilities;
- The accepted process for allocating or reallocating cost targets;
- Summary of the baseline estimate with discussion of the estimating method and assumptions; and
- A list of planned trade studies with procedure for initiating, controlling, and documenting them.

DTLCC Reports

Periodic reporting ensures management attention and appropriate action for the design process as well as a basis for determining incentive award values. DTLCC rewards are typically earned long before the true production and support costs can be known. The contractor DTC report typically includes the following topics:

- Summary of the current production and support baseline;
- Comparison of the current estimate to DTLCC targets, by WBS, to identify cost variances;
- Evaluation of major variances and trends with a plan to control the variances;
- Identification of cost drivers, particularly those under design control;

- Description of cost (parametric) models, cost estimating relationships (CERs), cost data base, and pricing factors used by the estimators;
- Discussion of risk analyses performed in conjunction with the "point estimates"; and
- Confirmation of design, schedule, and requirements changes since the last DTLCC report; and
- Summary of design/cost trade studies completed since the last DTLCC Report; and
- Discussion of cost reduction initiatives in process.

LESSONS LEARNED

Experiences vary between government agencies and aerospace companies. However, a core set of "lessons learned" has emerged which is worth considering by organizations newly implementing the DTLCC process. These may be stated, as follows:

1. Plan early. This includes preparation of a DTLCC Plan to be followed by a DTLCC Handbook. Engineers and other members of design trade study teams need familiarization training in estimating and need to become sensitive to the cost drivers in your product.
2. Organize around DTLCC goals. Establish accountability for program success. Assign company cost targets to individual design engineers and design managers. Determine organizational responsibility for target allocation, trade study management, and DTLCC reporting.
3. Flow down DTLCC requirements to subcontractors and suppliers. Incentivize them in the same way that the buyer incentivizes the prime contractor. Institute fact finding and periodic reviews early in the procurement cycle in order to hold them to the same standard as for the prime contractor.
4. Adopt proven tools. Parametric cost estimating models enjoy a distinct advantage over other estimating tools because the model cost drivers (independent parameters) closely match the design variables under control of the designer. Don't overlook the risk dimension in estimating; include uncertainty in all estimates.
5. Maintain the audit trail. Since DTLCC payoff must be predicted long before the accounts will be paid, it is imperative that the history of estimates be maintained. DTLCC Managers must practice good documentation skills to assure that the estimating audit trail can be preserved along with the associated design evolution history.

CONCLUSION

DTLCC works. Aerospace management has proven the effectiveness of early attention to unit production cost and annual support cost. Designers understand cost issues. The new positive attitude toward cost control is being manifested by those with the most to gain - the aerospace designer.

REFERENCES

- estimate which reflects the current design
1. ¹DoDD 4245.3, Design-to-Cost (now canceled and incorporated into Part 6, Section K, of DoDI 5000.1)
 2. ²AR 70-64, Design-to-Cost
 3. DoDD 4245.8, DoD Value Engineering Program
 4. DoD Handbook 4245.8-H, Value Engineering

5. DoDD 5000.1, Defense Acquisition
6. DoDD 5000.4, OSD Cost Analysis Improvement Group
7. DoD Manual 5000.2-M, Defense Acquisition Management Documentation and Reports
8. DoD Instruction 5000.2 Defense Acquisition Management Policies and Procedures
9. MIL-STD-337, Design to Cost
10. DI-F-30203, Design-to-Cost/Life Cycle Cost Development
11. Michaels, Jack V. and William P. Wood, *Design to Cost*, John Wiley & Sons, 1989
12. DoD Guide LC-1, Life-Cycle Costing
13. DoD Guide LCC-2, Life-Cycle Costing Casebook
14. DoD Guide LCC-3, Life-Cycle Cost for Systems
15. DoD Manual 4120.3-M, Defense Standardization Manual
16. DoD Manual 4245.7-M, Transition from Development to Production Manual
17. Seldon, M. Robert, *Life Cycle Costing: A Better Method of Government Procurement*, Westview Press, 1979
18. Sissons, Leslie G., *Cost Estimating for Defence Contracts*, Longman Group UK Ltd., 1986
19. Defense System Management College, System Engineering Management Guide, 1982