COST MODEL FOR COMMERCIALIZATION AND STANDARDIZATION

Final Technical Report
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1.0 INTRODUCTION

In June 1994, former Secretary of Defense William Perry issued a memo that called for the increased use of commercial off-the-shelf (COTS) parts in military systems. The rationale for this change was the almost complete reliance of military weapon systems on military standard (Mil Std) parts. In the past, Mil Std parts have been readily available from commercial contractors who supported the Department of Defense (DoD) in supplying weapon system spare and repair components. Increasingly, however, the DoD has had greater difficulty in obtaining Mil Std parts because the DoD is no longer a major customer in industrial sectors such as electronics.

As the DoD continues to shift to an acquisition policy that utilizes greater numbers of commercial grade components, there is increased pressure for the engineer and logistician to understand the ramifications of implementing non-military parts into existing weapon system designs. One area of utmost concern when shifting from Mil Std to commercial-off-the-shelf (COTS) technology is that of microelectronics. Not only has the acquisition reform movement steered DoD in this direction, but also the growing problem of obsolescence has made many Mil Std microelectronic parts impossible or cost prohibitive to obtain. Increased demands from the commercial sector for advanced microelectronics have driven many manufacturers away from the defense sector. Estimates of the military share of the microelectronics market now stand at less than one half of one percent. This has translated into an environment where most manufacturers are unwilling to adapt their product lines to meet the rigorous specifications of the military.

While utilizing commercial microelectronic parts in newly designed equipment can result in significant cost savings, the process is not so simple when commercial parts are substituted into legacy systems. It is rarely possible to implement a direct substitution, mainly due to the environmental constraints of commercial parts.

This standardization effort is an attempt to develop a structured methodology for evaluating various schemes for replacing required microelectronic parts in legacy systems. All reasonable solutions to the parts replacement problem were evaluated with respect to the overall costs associated with the solution. In the course of this analysis, no viable solution to the part replacement problem was rejected. Although cost is one of the most important parameters, there exists no standardized methodology for evaluating the various costs associated with inserting commercial technology into legacy systems.

The purpose of this research and development effort was to develop a methodology to aid the engineer or logistics specialist in identifying the most cost-effective method for replacing an unavailable military electronic part with a COTS item. To the experienced engineer or logistics specialist, this analysis may not be necessary. There is no substitute for day-to-day real-world experience. However, there are many people who have little or no experience in determining cost-effective solutions to parts replacement problems. It is for these people that this standardized analysis was developed.

To complete this effort, an engineering practice was established to document and standardize the method by which a military electronic part could be analyzed for potential COTS replacement. Because cost was the dominant parameter, other solutions to the problem, e.g., redesign, were considered as possible solutions.

In order to guide the user through the evaluation process, a software model has been developed that asks pertinent questions regarding the system and the environment in which the new part must operate. The methodology and supporting software should not only assist the user in selecting cost-effective solutions to the replacement of military parts with commercial technology, but should also provide a mechanism to facilitate standardization of spare parts in the weapon system modernization and sustainment process.

The software model that embodies the methodology supports the user in a logical approach to deciding on the most cost-effective solution to implementing commercial technology in military applications. It analyzes a number of factors that must be considered to minimize any electronic system degradation that would have an impact on weapon system readiness. At the same time, it should assure the user that the cost of the solution is as reasonable as can be expected.

2.0 PURPOSE

Because this effort concentrated on the cost of any solution, the study was not limited to replacing a military part with a commercial version. A full range of solutions was consider as follows:

a. Replace the parts using Mil Std parts from the inventory.
b. Find equivalent COTS parts. Perform any necessary screening, testing, or modifications to the circuit card assembly (CCA) and/or the environment.
c. If the required parts are integrated circuits, have new parts manufactured using the Government-funded Generalized Emulation of Microcircuits (GEM) process.
d. Have the CCA redesigned and built.

It would appear that all the user must do is to proceed down the steps until the parts problem is solved. However, this is not the case. Except for replacing the parts with military components, the decisions that must be made can become quite complex. The analysis of this complexity is the reason for this research project. It is hoped that this report and the associated software model will serve as a guide to lead the logistician or procurement specialist to make an informed choice in solving the problems. More important, it should prevent the implementation of improper approaches based on myths that continually circulate the logistics community.

A weapon system's readiness is extremely dependent upon the flawless functioning of its associated electronics. Hence, the objective of this effort was to outline for the novice engineer, logistician or procurement specialist the procedures required before a replacement can be made.

The approach of this cost analysis program was:

- To investigate the various solutions to solving the problem of replacing unavailable military parts in legacy Army weapon systems by utilizing commercial technology.
- To identify the total costs associated with each solution.
- To identify the interaction of the various solution parameters that determines the final costs.
- To develop a mathematical model of the cost parameters so that reasonable estimates can be made when determining the cost of a particular solution.
- To develop a software interface to lead the user to a cost-effective solution to a particular parts replacement problem.

3.0 ASSUMPTIONS AND GROUND RULES

A widely accepted assumption within the DoD electronics community suggests that the cost of solving non-availability problems follows a simple pyramid, as shown in Figure 1. The steps corresponding to the pyramid are discussed in detail in Section 5.0. The model developed under this effort does not contradict that assumption; in fact, the cost analysis generated under this project lends both creditability and a degree of quantification to that generic graphic. Since this effort concentrated on the replacement of Mil Std parts with COTS items, the categories of life-of-type (LOT) buy and aftermarket suppliers, as depicted in Figure 1 were not pertinent.

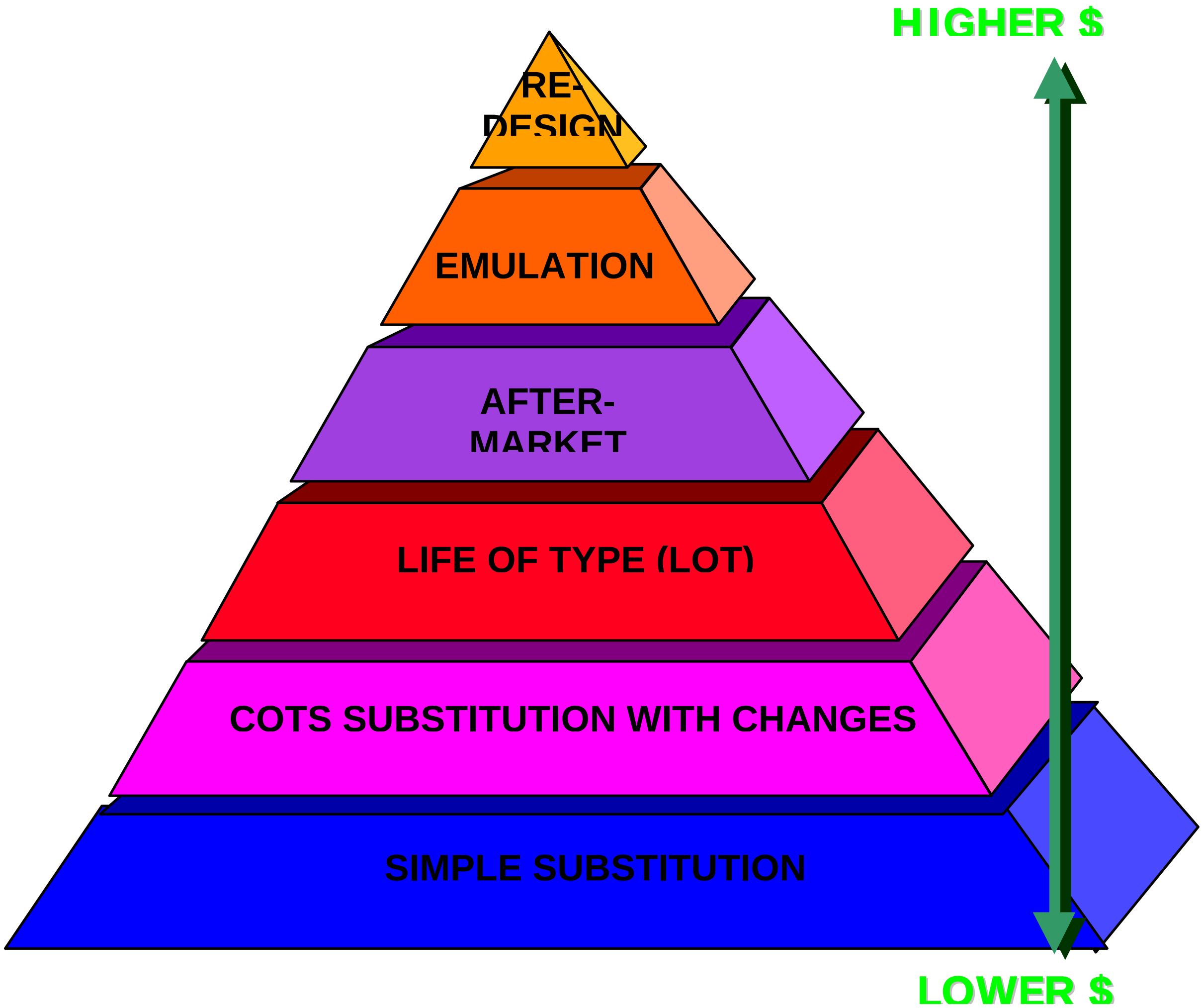


Figure 1. Non-Availability Cost Pyramid

Since there are a large number of considerations to evaluate, and many of them are continuously changing, e.g., estimated life, parts demand, usage requirements, etc., recommendations found in this report will sometimes be necessarily vague. In order to provide meaningful information in this initial analysis of a very complex problem, basic ground rules were established to bound the problem set and make the task manageable. The following is a list of the foundational constraints and assumptions the authors used during the construction of the cost model

a. Only circuit card assemblies (CCA) will be considered.
b. It is assumed that COTS parts will be obsolete and not obtainable after 5 years of manufacturing. However, there will probably be some available from inventory and after-market suppliers.
c. The replacement rate of parts will be at 5 percent a year.

4.0 BACKGROUND

For years the Army could support its weapon systems by readily purchasing parts that met military specifications. This was partly because the DoD was a major customer in the electronics component field. However, starting around the late 1970's, an explosion of electronics goods in the commercial sector attracted many manufacturers away from supporting the military. Also, due to the end of the cold war, military budgets were reduced significantly. This resulted in the decision to keep weapon systems in the field longer. As the century came to an end, the military became an insignificant customer for the electronics industry.

To illustrate this point, in 1970 the military commanded about 10 percent of the electronics market share. Thirty years later, in the year 2000, it is projected that the military share will be about 0.03 percent. Driven by the profitability of the private sector, electronics manufacturers concentrate their sales on the commercial market. The military integrated circuit (IC) expenditures in the year 2000 are estimated to be $1.1 billion. This is insignificant compared to the consumer market of approximately $300 billion.

In this reduced-funding environment, the DoD has to find a way to keep its weapon systems supplied with electronic parts for lifetimes of 30 years or longer. This is not a trivial problem. Since the military parts market is shrinking, it is imperative that the original equipment manufacturers (OEM's) establish a means to use commercial piece part devices in weapon system design**.** These parts are not only readily available because of high consumer demand, but because of the large number being manufactured, they are also relatively inexpensive.

5.0 PROBLEM SOLUTIONS

In a typical scenario, the logistician receives a request to obtain a component that is part of a military CCA. The technician must now proceed to implement a process that will ensure that this part will be supplied in a timely manner, and at the lowest cost to the government. The logistician will typically go through a number of steps to expeditiously locate and supply the part. There will be times when the procedure will result in a higher-than-normal cost, but this may be justified by showing a significant amount of future savings.

5.1 Substitute Equivalent Military Standard Part

Finding an acceptable Mil Std part replacement is the most cost-effective solution. Searching for a substitute military part is the usual first path taken when the required part is not available. However, this is very time consuming and requires engineering knowledge. There are limited military parts that can be substituted for others. Unfortunately, even when another military part is found to be acceptable, there is a good chance that it will be available in limited quantities and it too will soon be unavailable.

5.2 Substitute COTS Replacement Part

As long as an acceptable commercial replacement part can be found, it is a satisfactory solution to the growing unavailability problem. While, in theory, replacing unavailable military parts with commercial spare parts is a good idea, the implementation is quite complex. It is not sufficient to just match the functionality of the part; environmental specifications also must be met. These concerns will be more fully explored later in this report.

5.3 After Market Suppliers

When a device is discontinued the manufacturers usually give warning and the government then has a chance to make a lifetime buy. Because of underestimating the future needs and limited budgets, these buys are frequently inadequate to meet the future demands for the part. This is where the after-market companies come in and take over the manufacturing and supply of these parts. They provide a relatively risk-free albeit expensive solution to the obsolete parts problem. However, this process only remains risk free until additional capability is required, i.e., the legacy hardware is out of processing power, out of memory, or simply too old and slow for the upgrade.

5.4 Emulating Parts

The government has recently implemented a capability that allows for the emulation of obsolete, older-technology, integrated circuits in the latest microcircuit technology. The program, Generalized Emulation of Microcircuits (GEM), allows a direct substitution of an older design onto a modern chip. The process is much more expensive than finding a commercial substitute and the new chip is usually larger in physical size than the old one. However, if the part to be replaced is a critical integrated circuit the GEM process is a viable solution. In the case of Application Specific Integrated Circuits (ASIC), it is probably the only cost effective solution.

5.5 Redesigning the Circuit Card Assembly

Board redesign is very costly and is considered only as the last solution. When a board contains many parts that are unavailable due to obsolescence, the redesign approach may be the only solution for sustainment. If this is the case, new board design should use the latest technology to reproduce the original functionality of the assembly.

Given unlimited funds, board redesign may provide the best solution to the electronic parts non-availability problem. However, since the DoD does not operate with unlimited funds, other solutions must be evaluated before board redesign is begun.

6.0 TECHNICAL APPROACH

The technical approach for this program was to develop a systematic method for determining the most cost-effective solution to replacing an unavailable part on a military circuit card assembly. It was decided, early on, that instead of just providing guidelines, the user would be given a software tool to gradually lead to the most cost-effective solution to a particular problem.

In order to follow the logic behind the development of this analysis it will be instructive to follow a typical scenario.

6.1 Typical Scenario

The logistics technician receives a request to replace a component that is part of a military CCA. Upon identifying the part, the technician would proceed through the options outlined in Section 5.0. This methodology progresses as follows:

6.1.1 Use Mil Std Parts

If the technician can locate a supply of Mil Std parts, the problem is easily solved. Since it has been previously accepted that these military parts will perform as expected in the CCA, no further work is required than to have the parts ordered and shipped.

6.1.2 Mil Std Part Unavailable

When Mil Std parts are unavailable, the usual procedure is to try to locate a substitute part. If another military part can serve as a substitute the problem is solved, but more often this is not the case. At this point the technician can try to locate a commercial part and hope that it will meet the military requirements. This is a very time consuming operation that can be greatly enhanced by using the Army's newly developed Commercialization and Standardization Evaluation (CASE) tool. (The CASE tool is available through the DLA Standardization Office.) At present the CASE tool has a database that only addresses U.S. Army Aviation and Missile Command (AMCOM) systems. In the future it may be expanded to include other weapon system types.

After making the search, either manually or with the CASE tool, the technician may find that there will be a small number of COTS parts that will meet the functional requirements. In some cases there will be none. Meeting functional requirements will not alone be sufficient. This is mainly because the COTS parts usually will not meet the military environmental requirements, e.g., the temperature range. If the CASE tool is used it will assist the user in qualifying a COTS part for substitution for a Mil Std part by providing step-by-step guidelines for the engineering activities required for COTS substitution.

The substitution of an electrically equivalent COTS part for a Mil Std part will usually require screening of large numbers of parts. This can be costly and may even be impossible. The alternative to this solution is to have the board redesigned and then all the problems are solved in one operation. As expected, this is the brute force method and is the most expensive option. It does however solve the present problems and may alleviate other future non-availability issues.

While the technician would be tempted to have the CCA redesigned, there would have to be a good cost savings justification and a budget to implement it. Also, if the required parts are integrated circuits, the use of the government's GEM technology to replace these parts must be explored. In the case of replacing application specific integrated circuits, there are no COTS replacement parts and a GEM replacement would be the next logical approach to identifying a solution.

6.1.3 GEM Solution

If the required parts are integrated circuits, they may be candidates for redesign using the GEM technology. This technology emulates older parts in a new technology and can provide chips that will meet military standards. It is excellent for emulating application specific integrated circuits (ASICs) since these cannot be found in the COTS market. However, there are some drawbacks to using this solution and these are:

a. Expense of design and testing
b. The GEM package may be physically larger than the original package and may not fit in the space of the original part.
c. Only very small integrated circuits can be emulated at this time.

6.1.4 Redesign Solution

While redesign of the CCA appears to be a simple solution to all the individual parts replacement problems, there are many important steps to this solution that must be seriously considered. First, the documentation package must be complete. Even if the original manufacturer is to perform the redesign, it is no guarantee that the information is complete and accurate. One of the problems associated with the redesign of a complex board is the loss of the original designer's intent in placing some components in the circuit. It is not simply a matter of following the original schematic and building a new board with new technology. For one thing, the new chips usually perform faster so new timing problems must be solved. In addition, the new chips will probably be packaged in plastic and require fan cooling as opposed to heat sinks.

Secondly, even after the board is redesigned and tested, it still must operate properly in the higher-level system. It must fit exactly and it must operate properly with all the interface signals. Lastly, all technical documentation must be updated to reflect the new board.

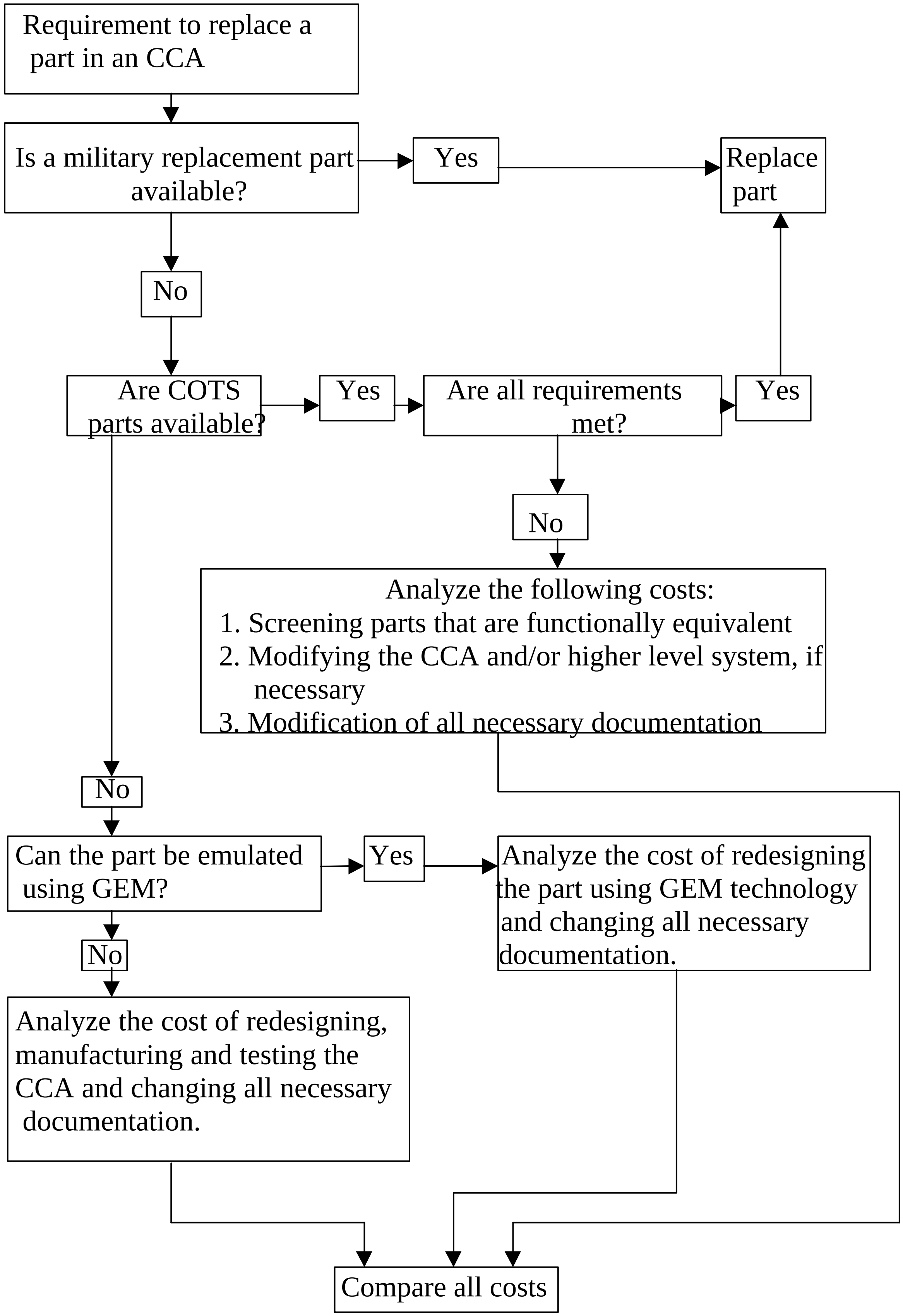
To reiterate, the design characteristics of the original CCA must be faithfully captured. One should not automatically assume that faster chips are better. And finally, the interfaces to the CCA must be analyzed to ensure that the design margins are met.

6.2 Solution Tradeoffs

If Mil Std parts are available then the problem is solved and no analysis is required. However, it is when one or more of the required Mil Std parts is not available that an analysis is required. The logistics technician must decided between three choices, which should be investigated in the following order:

a. Replace parts with COTS technology by screening COTS parts to identify those that will meet the environment requirements. It may also be necessary to perform modifications to the CCA and the higher-level system.
b. If the parts are integrated circuits, have new parts designed and manufactured using the GEM technology. Modify all required documentation.
c. Redesign and test the CCA and modify all required documentation.

As stated before, it is not a simple matter of going down the list and implementing the first process that works. There must be an extensive analysis of tradeoffs that include lifecycle costs and extent of engineering costs. The cost model developed and described in this report is an attempt to address all the considerations necessary to take an intelligent course of action. The following flowchart was constructed to illustrate the logic employed in this methodology.


Requirement to replace a part in an CCA
Is a military replacement part available?
Yes
Replace part
No
Are COTS parts available?
Yes
Are all requirements met?
Yes
No
Analyze the following costs:
1. Screening parts that are functionally equivalent
2. Modifying the CCA and/or higher level system, if necessary
3. Modification of all necessary documentation
No
Can the part be emulated using GEM?
Yes
Analyze the cost of redesigning the part using GEM technology and changing all necessary documentation.
No
Analyze the cost of redesigning, manufacturing and testing the CCA and changing all necessary documentation.
Compare all costs

6.3 Cost Comparison

It was demonstrated above that there are two processes that result in an easy replacement of parts, i.e., availability of Mil Std or COTS parts that meet all government requirements. The three other options consist of screening COTS parts to find those that meet military requirements, utilizing a GEM replacement (if the part is an integrated circuit), or redesign of the CCA. It is not obvious that any one of these solutions will always be the best and, therefore, a tradeoff study must be performed.

6.3.1 Functionally Equivalent COTS Parts

If functionally equivalent COTS parts are available they will usually not meet some of the military requirements. The main shortcoming is the small temperature range. However, there are other important considerations. If the COTS part operates at a faster speed its effect on the operation of the CCA must be considered. Other usual considerations are resistance to radiation and moisture and the possibility that the new parts will not fit properly in the old part's space. To aid in the selection of a COTS replacement part, the reader is advised to read the report entitled, "Commercial and Standardization Evaluation Tool (CASE)," and use the associated CASE tool for guidance.

First the technician must analyze the problem to determine if the COTS part can be used; only then can the cost analysis be made. The first step is usually to determine whether there will be some parts in a batch that will operate in the range of military requirements. If there are, then the cost of screening out these parts must be determined (or estimated).

If the screening process reveals that adequate parts cannot be screened out, the technician must determine if the environmental conditions can be modified to accommodate the functionally correct COTS part. This would require modification of the board or higher-level assembly to cool or heat the part in situ as required. This can usually be done if there is available space on the board. However, this would require modification of the CCA with all the associated redesign and manufacturing costs.

Even if parts that meet the temperature requirements can be screened out, they must be tested for radiation and moisture. Because some will not pass, there must be enough screened parts to provide for this eventuality.

If an adequate supply of COTS parts that appear to meet military requirements can be located, they must be inserted into the CCA and the CCA must be tested to ensure that the board will operate in accordance with military requirements. Assuming that one has been able to find COTS parts and, after modification of the CCA, the parts are found to be acceptable, remaining costs must be tabulated. For example, there are parts that must be purchased in order to restock the supply. One must also consider the yearly replacement rate when determining the number to purchase. Also included in this cost analysis must be the cost of modifying the required documentation.

6.3.2 GEM Redesign

The GEM process only applies to the replacement of integrated circuits that cannot be supplied by any other method. If the part to be replaced is an ASIC, there is no choice since there are no COTS replacement parts. Also, if the part were to be redesigned and manufactured by conventional means the cost would be much more than the cost of a GEM replacement. The GEM process consists of implementing existing older technology designs in a chip that can emulate the design using a new technology. This is a valid solution to the redesign problem providing the chip is not too large and the final package will fit properly on the CCA. As in the case of using a screened COTS chip, all the costs of restocking, testing, and modifications to the required documentation must be determined.

6.3.3 CCA Redesign

When all reasonable solutions fail, redesign of the CCA may be the only possible option. It is usually the most expensive procedure, but the avoidance of future costs must be considered in the analysis. It may be the most cost effective or, at least, the least objectionable solution to the problem.

The most important consideration in redesigning a CCA must be the existence of a complete data package. While it is hard to believe, sometimes the documentation does not even exist. Also, just having a schematic is not sufficient. It is not a simple matter of doing a part-for-part replacement on the new board. The company that gets the job must have as much documentation as possible to determine the design intent of the original designer. The company will also need sample boards that are deemed to be “typical”. Even after all this, it may take several design iterations before the new board will test properly in place of the old one.

There are several factors to consider in determining the cost of redesign. The following is the estimate of expected costs in redesigning a CCA that was used as guidelines for the cost model development.

6.3.3.1 Engineering Costs

Engineering costs vary greatly depending on the CCA function. For example, a microwave radar digital signal processor (DSP) or flight control computer motherboard costs significantly more to design, develop, qualify and support than does a simple power supply CCA. Today's systems will likely be designed with complex programmable logic device (CPLD) digital chips or their equivalent FPGA devices, and some may have application-specific integrated circuits (ASIC)’s.

Assuming an engineering rate of about $ 60 per hour:

Simple (power supply):

Circuit Design and Development:	$ 30 K
Software Design and Development:	$ 0 K
Development tools cost including OS and support services:	$ 0K
Total Engineering Costs for Simple Redesign	$ 30 K

Moderate Complexity (for an embedded system controller card using a DSP or 32 bit RISC chip):

Circuit Design and Development:	$ 50 K
Software Design and Development:	$ 70 K
Development tools cost including OS and support services:	$ 30 K
Total Engineering Costs for Moderate Redesign	$150 K

Highly Complex (cell phone motherboard with processor and wireless systems on one PCB using chip scale packaging):

Circuit Design and Development:	$ 240 K
Software Design and Development:	$ 360 K
Development tools cost including OS and support services:	$ 100 K
Total Engineering Costs for Complex Redesign	$ 700 K

The above estimates are for truly commercial parts. However, specific examples can vary widely as to their final costs. To illustrate, consider a highly complex CCA such as a hybrid microcircuit built by Chrysler to replace a conventional engine controller. It cost several million dollars, including a research phase in which a couple of prototypes were completed.

6.3.3.2 Fabrication Costs

Piece part fabrication costs for the model were based on following. The baseline quantity in deriving fabrication costs was for production of 10,000 parts. It should be noted that a smaller order could increase costs by 50 to 100 percent.

Simple =	$ 15 per part
Moderately Complex =	$ 40 per part
Highly Complex =	$ 120 per part

The above are OEM costs and do not reflect a price markup for distributors, retailers, etc. This is typically 30 percent up from the OEM to the store. There is also a 30 percent markup from the store to the end user.

6.3.3.3 Testing Costs

Testing costs are heavily influenced in the commercial world by Federal Communications Commission (FCC) Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) development and qualification costs. In some cases, the CCA is also environmentally tested. Brother, Inc., for example, has multiple temperature chambers (including walk in), an EMI chamber big enough for a TV, a 3-axis shock and shake table, drop tester, ESD testers, etc. That equipment represents a large investment that must be recaptured from future sales.

Simple =	$ 20 K
Moderate =	$ 60 K
High =	$ 150 K

The above cost estimates do not include the cost of a formal government qualification of a commercial CCA. For those costs, one would have to multiply by a factor of between 5 and 15 for the additional environmental and life testing for the ruggedized military environment.

6.3.3.4 Procurement Costs

Cost of procurement is greatly dependent on the following factors:

- Patent protection
- Software royalties
- Shipping costs
- Taxes and tariffs
- Memory costs at time of purchase, depending upon whether the company can or cannot buy chips directly from the manufacturer
- Costs of float (cost of warehousing and overhead in general)
- Profit for the OEM (in this case the military systems integrator)

There is usually a price break at 10,000 parts and 100,000 parts. The model assumes:

- Very low volume
- No NRE recovery
- A 30 percent profit for the OEM
- A 5 percent patent protection
- A 20 percent overhead
- A 5 percent cost of shipping
- A 5 percent float and cost of product sales
- A 30 percent penalty for low volume
- A 10 percent cost of after sale technical support (example: people who constantly call the 1-800 number.)

These percentages are added to the piece part cost shown previously to get to the final per part cost:

Simple =	$ 15	x (1 + 1.05)	=	$ 30.75
Moderate =	$ 40	x 2.05	=	$ 82.00
High =	$ 120	x 2.05	=	$ 246.00

6.3.3.5 Additional Costs Due to Military Requirements

The above estimates are for strictly commercial devices, like consumer electronics, where costs have to be kept low. They have to be scaled for the specific technology and cost of the application. To meet the military reliability or warranty requirement using commercial grade parts, the commercial costs have to be multiplied by the following factors:

Design costs for military applications have to be multiplied by a **factor of 4** (more design simulation, systems integration modeling, prototyping, documentation, design QA, software verification and validation, technical publications, etc.)

Fabrication costs for military applications have to be multiplied by a **factor of 3** (soldering practices, qualified technicians, parts cost, additional QA.)

Testing costs for military applications have to be multiplied by a **factor of 6** (EMI and environmental testing - for example, commercial parts seldom require explosion or altitude testing, etc.)

Procurement costs for military applications have to be multiplied by a **factor of 4** (parts tracking databases, limited volume premiums, increased per unit overhead costs, etc.)

Note: The cost factors just given were the result of a best guess developed from different information gathered from the commercial world.

Because of the technical details that must be addressed in the redesign and manufacturing of a new CCA, the costs will be high, especially in the restocking costs. There will also be costs associated with modify the required technical documentation.

6.3.4 Remaining Life of System

The estimated remaining life of the weapon system is an important parameter. If the system will only be in the field for less than five more years it is obvious that you would not want to implement a board redesign unless the system is extremely critical for fighting the battle. On the other hand, if the remaining system life is estimated to be approximately 30 years then some up-front investments can be made to avoid future large expenses. These may be very large inventory buys due to the fact that COTS parts start becoming obsolete in about 3 years.

6.4 Detailed Cost Analysis

The following mathematical analysis was developed in order to compare the various parameters that affect the final cost of a military parts replacement problem. The analysis is meant to be qualitative rather than quantitative because of the difficulty in using precise costs and quantities. However, some of the parameters will significantly outweigh others and will dominate the final decision.

6.4.1 Qualitative Analysis

The following analysis was developed using ratios of various costs factors associated with the design, development, and manufacturing of electronics components. The factors used are based on the experience of the authors and their associates. Therefore, since there may be other engineers with different experiences, there will be some disagreement with the conclusions. This is to be expected. However, the estimates given are for clarification of the model, and the user is encouraged to substitute numbers more applicable to his weapon system environment where appropriate.

Definitions:

P = *price* of a typical part
N = total *number* of parts on the CCA
L = remaining *life* of the system
R = yearly parts *replacement* rate
C_r = non-recurring costs of CCA *redesign*
C_g = non-recurring costs of integrated circuit redesign using *GEM*
C_c = non-recurring costs of *COTS* replacement

	MIL	**COTS**	**GEM**	**REDESIGN**
Price of part:	P	P/10	5P	N(P/10)
Spares:	2P	2P/10	2(5P)	2N(P/10)
Replacement:	RLP	RLP/10	5RLP	NRL(P/10)
NRC:	-	C_c	C_g	C_r

Mil Part: P+2P+RLP=3P+RLP=**P(3+RL)**

COTS Part:
$(P/10)+(2P/10)+(RLP/10)+ C_c =$
$(3P/10)+(RLP/10)+ C_c =$
$\mathbf{(P/10)(3+RL)+ C_c}$

GEM Part:
$5P+2(5P)+5(RLP)+ C_g =$
$5(P+2P+RLP)+C_g =$
$5(3P+RLP)+ C_g =$
$\mathbf{5P(3+RL)+ C_g}$

Redesign: $NP/10+2NP/10+NRLP/10+ C_r =$
$3NP/10+NRLP/10+ C_r =$
$\mathbf{(NP/10)(3+RL)+ C_r}$

The values of P and the quantity (3+RL) are relatively small and constant and can be represented as K. Therefore,

Mil Part: K

COTS Part: $K/10+ C_c$

GEM Part: $5K+ C_g$

Redesign: $NK/10+ C_r$

Notice that each expression is composed of a constant term added to a variable, C. C is a variable because the non-recurring charges are very complex and depend on many factors. In the case of the military standard part the variable is zero or very small. Also, it will be assumed that the dollar value of the constant term will be significantly smaller than the other variable factors. An analysis of each expression is as follows:

Mil Part: The only expense is the cost of the part. While the cost is high, if the military part is readily available, it is the most cost-effective way to replace a part.

COTS Part: If a military part is not available then a COTS replacement must be considered. As can be seen from the expression, the typical cost of a part may be one tenth of the cost of a military part. However, the non-recurring cost due to parts screening, modification of the CCA and environment (if possible) and changes that must be made to the documentation can eliminate any possible cost savings.

GEM Part: If the required part is an application specific integrated circuit it will be impossible to find a COTS replacement. Other than redesigning the CCA, a new part must be designed and built. It is assumed in the above expression for a GEM part that the cost of the part may be 5 times that of a military standard replacement. However, depending on the complexity of the integrated circuit, the C_g term can be high.

Redesign: This is the most drastic solution to the non-available parts problem. In the expression, the C_r figure is very high, however the problem is solved for N number of parts that are all possible future parts problems.

SCENARIO:

If a sample scenario that represents only one possible problem set is examined then an appreciation for the analyses that must be made is obtained. Because of the many variables involved, however, real-world solutions are not generally as straightforward.

Making the following assumptions:

1. A replacement part is needed. The military part costs \$10. (P=10)
2. A COTS replacement is less expensive (1/10th the cost) but the non-recurring cost makes the military replacement part the first choice.
3. The cost of a GEM part is more expensive (5 times) than the cost of a Mil Std part.
4. If the part is an application specific integrated circuit then the only two choices are to redesign in the GEM technology or redesign the CCA.
5. The cost of a GEM redesign is \$20K (C_g =20,000)
6. The cost of a CCA redesign is \$500K (C_r =500,000)
7. There are 100 parts on the original CCA. (N=100)
8. Non-recurring costs for COTS replacement are \$5K. (C_c =5,000)
9. The parts replacement rate will be 5 percent a year. (R=0.05)
10. The CCA has a 10-year remaining life. (L=10)

The question to be answered is whether it makes sense to redesign the CCA and solve the non-available parts problems in one operation or solve every parts replacement problem as it occurs. It is also probable that the logistics technician does not have a choice of redesign due to a limited budget. Because of funding problems, the CCA redesign may only take place when there is no other choice and the system is critical.

Applying the aforementioned formulas yields the following cost estimates:

Mil Part:

$P(3+RL)= 10(3+(.05)(10))=10(3+0.5)=10(3.5)=$ **35**

COTS Part:

$(P/10)(3+RL)+ C_c =(10/10)(3+(.05)(10))+5000=(3+0.5)+5000=$ **3.5+5000**

GEM:

$5P(3+RL)+ C_g =50(3+(.05)(10))+20000=50(3.5)+20000=$ **175+20000**

Redesign:

$(NP/10)(3+RL)+ C_r =(100)(10)/(10)[3+(.05)(10)]+500000=$
$100(3+0.5)+500000=(100)(3.5)+(500000)=$ **350+500000**

As previously stated and demonstrated above, the non-recurring costs far outweigh the other costs. Now let us look at the cost of redesign. It is approximately $500,000, but it solves a problem for 100 future parts. This makes the solution for each part:

$500,000/100=$5000 per part

If we look at the COTS substitution to the part problem the cost of the part was also approximately $5000. However, this solution would have to be repeated another 99 times, theoretically (a situation that may not be at all possible). This sample analysis shows that a complete redesign may sometimes be more cost-effective than a piecemeal solution to a problem that will continue due to the non-availability of parts.

6.4.2 Semi-Quantitative Analysis

The previous analysis was performed with assumed values for the various costs. Depending on the numbers used, the results can vary greatly. The following is an attempt to put some typical numbers into the equations. These numbers are derived from many contacts with industry.

The most important costs to be considered are those that are non-recurring. In most cases, these will consist of:

- The cost of screening COTS parts to find those that would be acceptable for military applications
- The cost of redesigning the CCA

Assuming that a direct military or COTS replacement part is not available and a GEM solution is not called for, the question remains as to whether it is more cost effective to redesign the CCA and solve the non-availability parts problems in one operation or solve every parts replacement problem as it occurs.

<u>COTS Replacement</u>

If a COTS replacement is to be used and a direct substitution is not possible (usually due to the limited temperature range of COTS parts) screening must done to find parts that are acceptable. Also, other characteristics must be evaluated, e.g., humidity, radiation, and speed.

Assuming a need for 100 parts at an average military price of $10 per unit. The cost equation for COTS parts is:

$$\mathbf{K/10 + C_c = 10/10 + 20{,}000 = 20{,}001}$$

It can be seen that the non-recurring costs far outweigh the cost of the parts. This would place the cost of each part at approximately $200. To illustrate just how important it is to consider the non-recurring costs, even if 1000 parts were needed, the cost of the parts would only represent 5 percent of the total costs.

CCA Redesign

If a CCA contains 100 parts and is of moderate complexity, the non-recurring costs are very high. These include,

Redesign

- Analysis
- Design
- Prototype testing
- Prototype assembly
- Prototype testing in subassembly
- TDP changes
- Qualification

Logistics

- Spares
- Changes to technical manuals
- Test set changes
- LSAR updates

Using the industry cost figures presented earlier, the cost equation becomes,

$$\mathbf{NK/10 + C_r = (100)(10)/10 + C_r = 100 + C_r}$$

The non-recurring costs, C_r, can be calculated as follows. The multipliers for military equivalent of commercial boards were given previously.

Stage	Commercial	Multiplier	Military
Design and development	50K	4	200K
Software	70K	4	280K
Development Tools	30K	4	120K
Fabrication of prototypes	40K	3	120K
Testing of prototypes	60K	6	360K
Total	**250K**		**1080K**

As can be seen from this analysis, a redesign of the CCA to a new CCA would cost approximately $1.08 million. If we take a very simplistic view and only consider the initial need for 100 parts (similar to the above COTS analysis) then the cost of these new parts would be $1,080. This is a very costly solution, but sometimes it may be the only solution.

If the CCA will be in service a long time and there are many components on the board that will be scarce in a short while, then a more detailed analysis must be made. Even after all this, there may be no funds available to completely replace the CCA. While the analyses of this report are valuable in making decisions, there will be many real-world constraints that will overshadow a rational, technical analysis.

The remaining life of the system is important in making the parts replacement decision even if one does not consider the large up-front cost. Redesigning a CCA that will not be used much longer may be a waste of money, while redesigning a CCA with a long future lifetime only solves the problems for about 5 years. After that time most of the components will be obsolete again. Even when all the information is analyzed, it will remain for the logistics technician to use his or her best judgement in making the final decision.

Observations

a. The cost of parts goes up linearly with the number of required parts until one hits a very large requirement, e.g., 10,000. These large buys are not usual with replacement parts.
b. The cost of redesign probably goes up exponentially as the complexity of the board increases. Therefore, redesign of very complex boards must be avoided. However, when a board is very old, the circuit is usually no longer considered complex.
c. The expense of non-recurring cost due to substituting COTS parts for military parts is not easy to quantify. Depending on the modifications necessary, the costs can go from trivial to prohibitive.

7.0 CONCLUSIONS/RECOMMENDATIONS

As expected, analyzing the costs associated with the replacement of a military part was not trivial. There are many interacting variables that have an impact on the final costs. Although it is not possible to place dollar values on all the expected costs, one can use some rules of thumb to gauge the major cost drivers. Some general guidelines include:

- The older the CCA the less chance there will be that a COTS replacement will be possible.
- If the part is an integrated circuit, a COTS replacement will probably not be available.
- Even if a COTS part is functionally equivalent, it will probably not be possible to make a direct substitution until the allowances are made for the military environment.

- Redesign and manufacture of a new CCA using COTS parts should not automatically be ruled out. There are cases where it is the most cost-effective solution.
- When replacing a part, the remaining life of the system will be an important consideration in the choice of solution.

This analysis was performed as a preliminary look at the costs associated with replacing military parts with COTS parts. It is specifically tailored to the needs of those individuals who are tasked to replace military parts but have a limited engineering background. It was also done in the hope that the Services would show an interest in expanding this effort so that a robust software tool could be developed with more accurate industry cost data. Such a tool could provide reliable guidance to making the most cost effective decisions for parts replacements.