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AN INVESTIGATION OF SUBSTITUTING CLASS
S PARTS FOR CLASS B PARTS IN AIR
FORCE ELECTRONICS SYSTEMS

THESIS

David B. Francis
Captain, USAF

AFIT/GLM/LSQ/87S-27

DEPARTMENT OF THE AIR FORCE
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THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
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In Partial Fulfillment of the
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Master of Science in Systems Management

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Abstract

The current emphasis on increasing the Air Force's war-fighting capability has pushed reliability to the forefront. One successful method used to increase the reliability of satellite systems is the use of expensive, but highly reliable, class S electronic parts as opposed to the class B parts normally used in avionics and ground electronic systems. Using MIL-HDBK-217D, the author predicted range of potential gains in reliability caused by substituting class S parts for class B parts for five avionics systems. Then the cost versus quantity relationship was used to calculate potential costs for quantity buys of class S parts. MITRE's Milstar life cycle cost (LCC) model was used to calculate the change in LCC due to the higher reliabilities and new acquisition costs. The research found that significant LCC savings were possible when class S parts were substituted for class B parts.

AN INVESTIGATION OF SUBSTITUTING CLASS S PARTS FOR CLASS B PARTS IN AIR FORCE ELECTRONIC SYSTEMS

I. Introduction

General Issue

High states of equipment readiness are needed for the limited numbers of system units available to operational commanders to maintain their deterrent force capability. However, a trade-off exists between system reliability, and the costs incurred by increasing system reliability. Improving parts reliability above current levels is one way of improving a system's reliability. The challenge is to increase part reliability without greatly increasing system costs.

Background

The F-4 Phantom II was going to be the best all around fighter-bomber in the US military inventory and out-class all others in the world. It included state-of-the-art avionics, weapon systems, and engines. While it turned out to be a good aircraft, the F-4 had one very serious problem, something malfunctioned every time it left the ground. The F-4's reliability was less than one flight hour between failures (2:29). On the other hand, the USSR turns out large numbers of simple aircraft which have low-unit cost, low operations and maintenance costs, high reliability and maintainability, high degrees of commonality, and high supportability. The U.S., unable to match the numbers of units, has tried to use advanced technology to get the highest possible performance as a "force multiplier." Unfortunately, "high tech" systems that are not reliable sometimes result, eg., the F-4. This means to get an effective and reliable combat weapon system, logistics considerations require as much thought, and as early, in the design as do the operational requirements (3).

For logistics, and other reasons, Deputy Secretary of Defense Frank Carlucci published his 32 Initiatives in April 1981 to improve the acquisition process. Five of these initiatives were concerned with improved reliability, availability, and maintainability (RAM). In 1983, Mr. Paul Thayer replaced Carlucci and organized six broader goals. One of these goals consolidates the five RAM initiatives into "Improved Support and Readiness" (3:8). Along with this high level executive support came a recognition by AF leaders that logistics considerations impacted system effectiveness. Weapon system effectiveness equates to "damage expectancy," i.e., can the target be expected to be destroyed from a single sortie.

Damage expectancy is the product of four factors: (1) launch success, (2) weapon system reliability,

(3) probability of penetration, and (4) the probability of kill. Using today's technology, including precision guided munitions, the probabilities associated with factors one, three, and four, are very close to 1.0 (about .98 each). However, due to low weapon system reliabilities, commanders must assign up to three aircraft to do the job one could do with higher reliabilities. As stated by Gen Mullins:

> That's why the single greatest limitation to our having combat capability we need today is logistics. That's why the single greatest impediment to our having the kind of logistically supportable systems we must have is the lack of system reliability. That's why our real leverage in generating combat capability comes first and foremost in the area of reliability improvement [4:15].

To that end, the Air Force Chief of Staff and the Secretary of the Air Force initiated the Reliability and Maintainability (R&M) 2000 program. Until R&M 2000, the primary focus of R&M has been cost efficiency. But operational necessities and logistics support considerations, such as mobility, vulnerability, and manpower have caused that focus to shift. There are now five goals for R&M 2000. In order of priority, they are:

1. Increased warfighting capability.

2. Increased survivability of combat support structure.

3. Decrease mobility requirements per deploying unit.

4. Decrease manpower requirements per unit of output.

5. Decrease costs.

The goals now focus on operations and operations support (note cost, is the lowest priority). Increased R&M allows us to meet these goals. For example, goal one could be reached by doubling weapon system reliability which would increase the number of sorties generated under surge conditions by 70 percent for an F-16. With doubled reliability, goals two, three and four are reached since fewer spares, test equipment, and maintenance personnel are required by a squadron which leads to more squadrons deployed using the same number of MAC transports. Also, maintenance facilities are smaller, a less attractive target, and the aircraft are less dependant on them to maintain their sortie rates. Fewer spares, test equipment, people, aircraft, etc., leads inevitably to achievement of goal five (5:2; 6:163).

In support of the five goals, AF policy is to double system level operational measures of reliability and halve the system level operational measures of maintainability compared to like predecessor systems (7). Additionally, there is another policy of reaching a 2000 hour MTBF per 0.56 cubic foot volume for electronic systems. (R&M 2000 got its name from this policy.) This objective would provide a 90 percent probability that a specific component will not need to be removed from an aircraft during the first 30 days of combat. As a bonus, in peacetime, there would only be one or two removals of faulty components per month for an entire 72 aircraft fighter wing (6:164).

To meet the five goals and the specific policies, the following principles for the acquisition process have been identified:

1. Management Commitment: ensures R&M goals are met by getting senior operational and acquisition officers enthusiastic support.

2. Motivation: to get and keep the contractors and project officers committed to R&M.

3. Needs and Requirements: specified by user and acquisition agency to indicate R&M priorities are as high as other operational requirements.

4. Design and Growth: demand increased R&M requirements in Air Force documentation and insist the contractor use good design practices which includes room for the inevitable changes in operational performance.

5. Preservation and Maturation: identify and correct deficiencies in fielded systems.

While all of these principles are important, it is the fourth principle where the design of actual hardware and software of the system/sub-system determines what the reliability will be. The Air Staff states that "good, reliable equipment begins with the designer selecting reliable parts and then derating them to extend part life and improve reliability" (8:9-11). The selection of high quality parts is an integral part of achieving high system reliability.

Specific Problem Statement

There is a need to determine if the use of high quality parts can sufficiently raise the reliability characteristics of Air Force electronic systems such that the increase in production costs due to higher quality parts are offset by decreases in operations and maintenance costs.

Limitations of Study

1. There are no studies which relate part reliability to system reliability with any recognized accuracy. Therefore, all other factors which might impact system reliability, i.e., process, people, and design, are assumed to remain constant.

2. The data base selected does not contain the system acquisition costs, system logistic factors, etc., needed by the LCC model. Therefore, these factors will be determined for the class B system based on the specific aircraft type predominately used (eg., B-52, F-15, C-141) and will be held constant for the class S system, unless in the judgement of a logistics expert, the increase in system MTBF is sufficient to justify changing the factors.

3. It is assumed the AF will require all parts used in electronic systems class S and that industry will respond with the wider varieties needed.

Research Questions

1. What are the potential increases in predictied MTBFs using class S parts vice using class B parts?

2. What are the potential decreases in costs due to quantity buys of class S parts?

3. What is the the change in Life Cycle Cost (LCC) using class S parts vice class B parts?

II. Review of Literature

Reliability

The reliability of a system is defined as "the probability that the system will adequately perform its intended function under stated environmental conditions for a specified interval of time, number of cycles of operation, or number of kilometers (29:8-9). Thus, the reliability of a given system depends on its design (how it performs its function), and its operational environment (eg., fighter, ground command post, etc.) over some period of time or other relevent measure. This means that an identical system operating on both a fighter aircraft and a ground site will have two totally different reliabilities. Further, over the life of the system, the system may have different probabilities of performing its intended function. For example, as redundant subsystems fail, the probabilities decrease even though the system continues to function (29:9). It is therefore not adequate to describe a systems' reliability as only a probability of functioning, since a comparison of system reliabilities is conditional on knowing each systems' dependence on time, environment, and design.

A commonly used reliability measure is the mean time between failure (MTBF). Mathematically, MTBF is equal to the integral of a system's reliability function, so reliability probabilities and MTBF are directly related (29:10). Additionally, MTBF is a useful measure in cases where maintenance and/or repairs are integral to the total system concept. Maintenance (and repair) brings the system back up to its initial probability (or very close to it) after some failure has reduced the systems' probability of functioning.

Currently, many high reliability systems require a large degree of redundant subsystems. The failure of one subsystem, the result of one component failure, does not impact the ability of the system to perform its basic function. But without repair the system no longer has its high reliability. For example, a brake system on an aircraft is composed of two identical, independent hydraulic subsystems. The reliability function is: $R(sys) = 1 - (1 - R(sub))(1 - R(sub))$. If the reliability of the subsystem is .9, then the system reliability, from a mission perspective, is equal to .99. A failure of one subsystem during a mision would reduce the systems' reliability to .9 if not repaired at the end of the mission (29). If the high reliability is required for operational reasons, then the failure of the subsystem will force a maintenance action to repair it. Therefore, for systems which use redundant subsystems to provide high reliability, all failures result in maintenance actions, but not all failures result in the loss of mission or function.

The amount of maintenence capability an organization requires, including the manpower, spares, tools, test equipment, transportation, warehouses, etc., depends more on the systems' MTBF than it does upon its probability of functioning. All life cycle cost (LCC) models in the AF which consider system reliability as a parameter use MTBF as the measure rather than probabilities of functioning (30). The cost of a systems maintenance over its projected life is then determined using its MTBF.

While redundancy improves a system's MTBF, it hurts its owner in terms of the cost of maintenance capability. But other factors make up the reliability function. One of the obvious ones, apparent in the equation above, is part quality.

Part Quality

System reliability is difficult to explain and quantify since the concept means different things to different people. For example, an MTBF of 2000 hours for a radio system as defined by the system program office (SPO) may mean an average of 2000 hours between actual hardware failures, while to the user, it means an average of 2000 hours between any removal of the equipment. Since removals include software errors, human error, or equipment abuse, the user may experience a mean time between removal (MTBR) of only 200 hours in actual use. Given the previous mathematical definition of MTBF, the objective is to find what causes the system failures and eliminate them. There are several sources which provide approaches on the cause of system failures.

MIL-STD-781C, Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution, divides failures into six categories. These range from equipment design through part manufacture to inappropriate repair procedures (9).

Mr. Joe Capatano, a reliability engineer for Gould, Inc., divides system reliability into four categories; people, process, parts, and design. That is, the time and effort people put into the design and manufacture of the system (workmanship), the quality of the manufacturing processes, the quality of the parts, and the correct system design to meet the expected environment. This division was developed to explain in general terms why items fail and allows Gould engineers to focus their attention on these major causes providing preventative and corrective action.

At the 1981 Air Force Systems Command R&M Workshop, the Design Engineering Emphasis Panel ranked the following tasks as the most cost effective to improve system reliability: (1) parts derating, (2) parts selection and control, (3) failure analysis and corrective action, (4) parts screening, and (5) parts burn-in. The major emphasis was on parts quality (2:25).

According to Anthony Feduccia, Chief, System Reliability & Engineering Division, Rome Air Development Center (RADC), an electronic system/subsystem initially has about an equal number of failures due to people/process/design and to parts. During the first two to three years, most of the people/process/design problems are worked out and fixed (eg., manufacturing processes are changed, the design is changed, etc.) while many part problems remain (2:28). In the development of a particular "moderately complex" electronic system at General Dynamics, after working out the bugs of a production line they discovered the major causes of failure at top assembly tests were electronic parts from suppliers, (in particular; bad internal connections and contamination by conductive particles). They were forced to redesign their subassembly tests, where it was easier to find and replace defective parts, to become effective in removing parts which failed due to "infant mortality," (the early failure of parts as a result of a percentage of manufactured parts having a lower quality than what they are rated at) (10:214).

All of these sources have divided the cause of failures into somewhat different slices. But they all mention the quality of piece parts as a major factor in system reliability.

The DOD defines and controls part quality through the use of two main specifications, MIL-M-38510 for microcircuits and MIL-S-19500 for semiconductors. These specifications define the design process and tests required for specific quality levels and require appropriate levels of manufacturer certification for corresponding part quality levels (21:22). The tests and specific test procedures required for microcircuits and semiconductors are specified in two specifications, Test Methods and Procedures for Microelectronics, MIL-STD-883C, and Test Methods and Procedures for Semiconductors, MIL-STD-750 (23;24). To be able to label their parts as meeting MIL-SPEC, part manufacturers must have their production lines certified by the Defense Electronics Supply Center (DESC). The requirements for certification of parts and production lines are specified in MIL-STD-976A, Certification Requirements for JAN Microcircuits. To be certified, the manufacturer must submit parts and documentation to DESC. If necessary, the manufacturer must make the parts while government inspectors are watching (25).

For certified microcircuits, class S has the highest quality certification, class B is next, and then a series of lower commercial part classifications (class C). Class D parts are commercial parts which are uncertified by the government, but they are not marked by their manufacturers as class D parts. For certified semiconductors, JANS is the highest, JANTXV is next, and then JANTX and JAN level parts (21;22;25). Uncertified commercial parts are not permitted to use the JAN marking and are rated as "lower than MIL-SPEC." MIL-HDBK-217 rates all uncertified parts as having lower quality than certified parts without reguard to the quality of the manufacturers production line or the tests conducted on the parts due to historical data (11). (For future brevity, class S will refer to class S microcircuits and JANS semiconductors while class B will refer to class B microcircuits and JANTXV and JANTX semiconductors.)

The classification of certified parts is achieved through progressively higher requirements on the manufacturer in three areas; part design, part production, and part testing. Requirements on part design limit the designer's choices of materials and specifies certain internal dimensions, eg., spacing between the leads. Structure design requirements aim to eliminate inherent design failures, make the part easier to produce, and start the manufacturing processes with high quality materials.

Requirements for Part production specify quality control measures the producer must use to insure a uniformly high quality product, eg., the use of process control charts to monitor the thickness of the substrate (base layer). Part testing requirements verify the parts meet minimum quality goals. In theory, well designed and manufactured parts should not need to be tested, yet the lines are run by people, and in practice, the tests do screen out a small percentage of parts which do not meet the quality goals.

Each different screen test has its own unique percent defective allowed (PDA), or a one part failure, which ever is higher. If failures exceed the PDA limit, the entire inspection lot is rejected and the manufacturer must conduct an analysis to determine what went wrong, decide how to fix it, and determine what other lots may have been affected (25).

Class S parts are intended for use in space applications (21:7). Given the inability to repair systems in space the DOD and NASA have chosen to use parts of very high quality as one method of achieving high system reliability (26;27).

The increased reliability of class S parts over the next lower quality level, class B, is due to the DOD's increased control in the design of the parts, the increased control and monitoring of the manufacturing process, and to a lesser extent, an increased number of tests. For example, the producer is not permitted to use laser scribing, must maintain a minimum lead separation of 1.0mm, and must be able to measure and monitor the desired characteristics of design to high tolerances, eg., substrate thickness, pinholes, and cracks (21;25). While not required, DESC is available for consultation on the design of class S parts to help the manufacturer improve their producibility (28).

Production requirements for class S parts include monitoring internal water vapor levels, particle contamination, the effects of time, temperature, and current on the parts, and the use of quality control charts to show the status of each of the manufacturing steps. A big difference between class S parts and class B parts is the serialization requirement for class S parts. Each part must be traceable to its inspection lot, sub-lot, and production lot so failures can be traced to production processess and input materials. During sample parts testing (some tests require 100% participation) if one part fails, the entire lot can be checked for similar problems which, if found, could lead to correction or improvement of manufacturing processes or monitoring.

Higher level test requirements include increased burn-in time (from 160 hours for class B to 240 or 320 hours for class S depending on part type), a particle impact noise detection (PIND) test (to check for contamination which could cause shorts), reverse bias burn-in of 72 hours, radio-graphic examination of samples, a nondestructive, 100 percent lead bond pull test, and higher levels of government representation during testing and failure analysis (see Figure 1) (21;25).

The result of the controls on design, manufacturing, and testing of class S parts is to narrow the distribution of part strength, primarily by reducing the distribution to the left of the part's nominal rating. Part strength is the ability of the part to continue to operate normally after experiencing a stress, also known as its "stress resisting

Requirements	Class S Microcircuits	Class S Semiconductors	All Class B
Internal Visual +	required	required	required
Stabilization Bake +	required	required	required
Temperature Cycling and/or Thermal Shock +	required	required	required
Constant Acceleration +	required	required	required
Particle Impact Noise Detection +	required	required	---
Instability Shock Test Diodes Only +	---	required	---
Serialization +	required	required	---
Hermetic Seal + not applicable to microcircuits	---	optional	required
Interim Electrical +	required	required	---
Burn-In +	240 hrs*	240 hrs*	160 hrs**
Interim Electrical + (reverse bias)	required	required	***
Reverse Bias Burn-In +	72 hrs	48 hrs	***
Interim Electrical +	required	required	required
Seal (fine and gross) + not applicable to semiconductors	required	---	required

Figure 1. Product Assurance Test Requirements for Class S and Class B Parts (21; 22)

Requirements	Class S Microcircuits	Class S Semiconductors	All Class B
Final Electrical +	required	required	required
Hermetic Seal + not applicable to microcircuits	---	required	optional
Radiographic 100% for semiconductors	required	required	---
External Visual +	required	required	required
Nondestructive Bond Pull Test + not applicable to semiconductors	required	---	---

* 320 hours for hybrid microcircuits
** Transistors 160 hours; diodes, rectifiers, and thyristors 96 hours
\+ 100 percent tested, all others are samples
*** Required for Semiconductors

Figure 1. (CONTINUED)

capacity." Parts which have a wide distribution of part strength, may receive a stress well below the parts nominal rating and yet a percentage of parts will fail. The study of part strength distributions with stress distributions is called probabilistic design (29:74-85). Using probabilistic design, MIL-HDBK-217, Reliability Prediction of Electronic Equipment, quantifies the reliability of parts (11).

MIL-HDBK-217, produced by the Rome Air Development Center (RADC) rates the quality of certified and uncertified parts. It assumes a constant failure rate for solid state electronic part, an exponential failure distribution, on the basis of extensive test data (11:5.1.1-1 - 5.1.2.4-2). According to MIL-HDBK-217D, class C parts have failure rates which are twenty times higher than class B parts and class B parts have failure rates which are two times higher than class S. Using the failure rate and other data found in MIL-HDBK-217, system reliabilities and MTBF values can be calculated using simple equations (11). While the equations are simple, the calculations can be quite cumbersome and time consuming since even a moderately sized electronic system can contain thousands of parts (19).

In recent years the AF has advocated the use of class B parts in weapon systems due to the higher reliabilities they have over commercial parts. Often, however, certified parts are not used in the design or production of systems. Design engineers either can't design a system using only the existing certified parts or else they fail to consider the availability of certified parts ahead of time. Non-availability of certified parts makes the use of many commercial parts mandatory (10;14). To achieve the reliability required, designers must then add redundancy to critical functions. The end result, are systems which have high reliabilities, but low MTBF values, since the maintanence concept for most earth based systems is to repair every component failure, maintaining the high system reliability.

Reliability Prediction

Classification and quantification of part quality has made it possible to predict the reliability of systems and sub-systems. Reliability prediction is useful to provide a rational basis for doing comparisons and trade-offs. There are two methods of reliability prediction at the piece part level. Both use probabilistic design, but the first is a simple parts count method and is used early in a program when little design information is available. The second and more powerful tool is called part stress analysis. It takes into account the actual hardware design and the environmental stresses applied to the system. RADC has shown that part quality has a direct effect on the part failure rate, and thus, system failure rate (11:4.2-5.1.1.1).

Using parts stress analysis for predicted reliabilities, (measured by MTBF) does not guarantee the final, actual field reliabilities. People, process, and design also affect the system reliability and they are difficult, if not impossible, to quantify. Further, the methods used to accumulate test data in the laboratory; ovens, vibration and shock tables, bench sets, etc., do not usually simulate many of the stresses the parts will be exposed to in the field. However, parts have been identified as the single most important consideration.

In a study conducted by the Reliability Analysis Center (RAC), a survey was taken of a very large number of systems of various types (eg., radar, communication, etc.) applied to various environments (air, ground, and naval). Actual field MTBF was compared to systems' predicted MTBF. While there was a large variance observed, there was a strong correspondance between the two, and in general, the higher the predicted MTBF, the higher the field MTBF (12). In a second study, RAC showed the higher the part quality (class S versus class B versus commercial), the smaller the variance of the relationship and the better predicted MTBF indicates field MTBF (13).

Part Cost

Higher quality parts cost more money, due to the extra process controls and testing, together with lower yields and higher administrative costs. While prices vary, on average class B parts cost twice as much as commercial parts and class S parts cost 15-20 times as much as class B. It's easily shown that since class B parts have failure rates which are 20 times lower than commercial parts, class B parts are very cost effective (28). What is not easily shown is whether class S parts are as cost effective, or more cost effective, as class B.

There are four reasons class S parts cost so much. First is the very low production rates of the parts. A parts supplier may get an order for as few as 50 parts from a satellite manufacturer. If none are in stock, the supplier will make one production run from a mold (about 750 parts) to get a yield of 450 parts. That will leave 400 parts requiring storage in a very controlled environment against the day, hopefully, a future order comes in. A second reason is the relatively low variety of class S parts available due to the effort required by the supplier to get certified for that part. With such low demand, suppliers have no incentive to try to get parts certified. That leads to reason three, there is very little competition in the class S market due to low demand. For most class S parts, there is only one supplier for each part. Finally, the extra tests and controls that class S requires raises the price (14).

However, there are three considerations which could lower the cost of class S parts. First, as parts are standardized and procurred in large quantities the price drops dramatically due to production efficiencies and increased competition. Just considering increased production efficiencies, Albert Caquot developed an empirically derived relationship which shows as production doubles, the price drops by 16 percent. Using this relationship, if production increases ten times, the price drops 43.8 percent (14:443).

Second, the screens required for class S parts eliminate a large number of bad parts. The O&M cost savings resulting from eliminating additional bad parts may make up for the higher initial acquisition costs. Higher system MTBFs mean fewer spare parts, test equipment, maintenance personnel, intermediate repair shops, etc. are required. With a field repair currently estimated between $5,000 to $15,000, O&M savings could significantly impact the total LCC picture (2:28; 15).

Finally, there are opportunity costs which are not easily measured, but are exactly the point of R&M 2000. Higher reliability systems using class S parts will make the limited number of systems more useful, generate higher sortie rates, decrease mobility requirements, etc. If the increase in system reliability is significantly improved due to the use of class S parts, perhapes a slightly higher price for them is worth it.

Related Studies

In 1984 Space Division (SD) advocated a more widespread use of class S parts. They emphasized the higher quality aspect and cost reduction through standardization of parts and increases in production quantities. However, their prime argument for class S parts centered on a hypothetical case where class B parts would fail 60 times more often then class S parts, rather than the 2 times specified in MIL-HDBK-217. SD then used the 60:1 figure to show that repair costs, at $20,000/repair, more than made up for the higher part acquisition cost. Both assumptions are flawed. The use of the dubious 60:1 failure ratio shows a best case class S system versus a worst case class B system, but it is not indicative of the average quality of class S and class B parts. Secondly, the $20,000/repair figure may be the average cost of rework on satellite or booster systems, but it's not indicative of average AF wide repair costs (16).

A study was begun by engineers at AFALC in response to the SD briefing. They concluded there weren't sufficient varieties of class S parts to increase system reliabilities. That is, they only looked at the currently available class S parts rather than assuming more varieties would become available. AFALC questioned the impact of part reliability to system reliability and thought that processes had a greater impact than parts. They did not finish the study and did not publish or document any findings (17).

The Reliability Analysis Center (RAC), a DOD information center run by the IIT Research Institute, conducted a study to investigate the claimed advantages of lower cost and greater availability of commercial microcircuits over class B microcircuits. They surveyed eight manufacturers and three distributors on four part classes: (1) plastic commercial (unscreened), (2) plastic (screened), (3) hermetic commercial (unscreened), and (4) class B. The survey asked each manufacturer and distributor to supply cost and availability information for each part number at procurement quantities of one, 100, and 1,000 in each of the four levels. RAC followed up the survey with an intensive literature review, interviews with part reliability experts, and data from the RAC mircociruit data base.

RAC reached the following conclusions:

1. While manufacturers have different pricing structures, prices decrease logrithmically with order quantity (which is consistent with Caquot).

2. There is a definite increase in cost going up in quality level (about 1.5 times increase between each successive level).

3. There is no average difference in lead time for part acquisition based on quality level.

4. Plastic commercial parts have considerable variation in the quality from different manufacturers and even between lots from the same manufacturer. They have problems with humidity and temperature due to the permeability of the plastic coating, imperfect seals around leads, and variations in raw material. Plastic commercial parts, therefore, have a poor long term storage performance and high stress environments. Their reliability for military applications is highly questionable.

5. To get low failure rate plastic commercial parts requires a 100 percent stress screening program, but this will still not alleviate problems due to humidity and corrosion (i.e., long term use, extensive periods with power off, and long storage).

6. Hermetically sealed parts (hermetic commercial and class B) have lower failure rates and withstand mechanical stress better than plastic parts due to their construction,

i.e., lower permeability of sealant to moisture and stronger casings. Class B parts (all hermetically sealed) are significantly better than hermetic commercial parts.

7. After defining a generic system, class B parts were generally found to be much cheaper in the long run over all commercial parts due to costs associated with part inventory, field repair costs, and production line rework (31).

III. Research Methodology

The approach taken in this study consisted of five steps. The first step was to select representative electronic systems which use class B parts, and which were in, or could be put into the format required by the selected model, ORACLE, for reliability predictions. Class S parts were then substituted in the systems for existing class B parts and evaluated using MIL-HDBK-217D. New system MTBFs were calculated and the range of MTBF increase determined. The potential cost savings of class S parts using large volume purchases were determined using contractor and DESC supplied data, and the Caquot relationship. The range of MTBF increase and the calculated costs of class S parts were used in the LCC model of a system currently in full scale development (FSD) to determine the impacts on life cycle cost. Finally, a qualitative comparison and assessment was made of the results.

Population

There were hundreds of electronic systems in the AF inventory to choose from, but not all had the detailed parts descriptions necessary for this study. Since a reliability prediction is usually required for system acquisition, RADC had a large data base of systems in the ORACLE format. ORACLE is a computerized software version of MIL-HDBK-217 used for obtaining reliability predictions of electronic systems/equipment (18).

Unfortunately, much of the data base was not appropriate. Prior to 1980, many of the SPOs used commercial quality parts and did not provide a full system profile, ie., they used a lot of system defaults instead of specifying the entire circuit layout. For example, ORACLE will assume a part has a minimum number of connections to other parts unless all the connections are specified. If a microcircuit is connected to five other parts, but ORACLE is defaulted to two parts, the default will minimize the number of solder joints assumed to be in the system. This leads to unrealistic best case predictions which are inappropriate for valid comparisons.

Since 1980, SPOs have not often used ORACLE at RADC, but have relied on in-house contractor capabilities. Since November 1986, RADC has been providing free copies of ORACLE to contractors and other government offices. The managers of ORACLE at RADC have studied their data base on several occasions to determine its usefulness for reliability studies sponsored by RADC. As a result, they found only five systems resident on ORACLE which are representative of modern electronic systems, i.e., extensively use microcircuits, and have not relied on system defaults, but have specified the layout of the components in detail. All five of these systems were used in the study (19). Appendix C contains a description of some problems with using ORACLE on the VAX.

Reliability Predictions

First the systems were run on ORACLE to generate a reliability prediction using the existing class B parts. Then, for each system, the part quality for all microcircuits and semiconductors were raised to class S. All other parameters remained constant. Each system was re-run on ORACLE to generate new reliability predictions for the new part level. A range of MTBF increases were found.

Class S Parts Cost Determination

Class S parts suppliers, SD, Aerospace Corp., and DESC were contacted to get current prices. These prices were adjusted for quantity buys using the Caquot relationship and savings estimated by DESC. The objective was to determine new part acquisition costs given the production of sufficiently large quantities of class S parts. It is possible that extremely large production increases could reach large price reductions, for example, a 1000 times increase in production reduces prices by 80 percent, while a one million times increase in production would reduce prices by 97 percent. This study limited the price decrease of class S parts to 44 percent, the decrease expected for a ten-fold increase in production.

LCC Cost Determination

The range of MTBF increases could be applied to any system with a good LCC model, along with the estimated increased production cost, to determine the impact on the systems' LCC. The system selected for this analysis is the Milstar Terminal program. Milstar is a family of airborne/ ground satellite communications terminals which are being developed at ESD. The program is currently in FSD and uses an interactive LCC model to explore the impacts of proposed changes (what-if exercises) and as a tool for budgeting O&S costs. The Milstar LCC model has been approved by ESD/ACC, the cost estimating division, as an appropriate method to calculate O&S costs for budgeting and estimation purposes. The model is operated by the MITRE Corp. for the SPO and runs on a MITRE owned mainframe. Since the model cannot be run on any AFIT system, the Milstar SPO agreed to have MITRE run the model and provide the results.

The baseline costs for Milstar had been determined (production costs using class B parts and MTBF) and was used as the baseline for this analysis. The model was then run three additional times with the production figure adjusted as required for class S part costs. In the first run, the lowest increase in MTBF was used, in the second run the highest increase in MTBF was used and the last run used the average increase in MTBF of two systems which were very close together. The output for each run was a percentage increase or decrease in the O&S and total production costs over the projected 15 year life of the program.

Comparison of Differences

The use of statistical tests to determine whether the differences in MTBFs and LCCs are statistically significant is not warranted for this study. Firstly, changing parts from class B to class S will positively increase the system MTBFs. How much depends on the relationship of the number of microcircuits and semiconductors which were changed to the total number of parts in the system and other system factors (eg., junction temperatures, environment, etc.). The higher this ratio, the closer the MTBF increased by a factor of two since the class S parts are rated twice as reliable as class B parts (MIL-HDBK-217D). Secondly, class S manufacturers were resistant to providing cost data, particularly since a major contract for the sale of class S parts was being negotiated. Therefore, accurate cost data on price decreases was difficult to get and the study resorted to the Caquot relationship. Also, the LCC data base for the Milstar system did not go into the detail required to distinguish between microcircuits/semiconductors and all other parts needed for production. It just listed a total parts and materials cost. Therefore, the researcher performed a simple qualitative assessment of the results obtained.

IV. Results

Selection of Systems

A TDY trip was made to the Rome Air Development Center (RADC) at Griffiss AFB to select systems from their ORACLE data base, receive training on operating ORACLE, obtain a historical perspective of the ORACLE data base, and to get magnetic tape copies of the ORACLE program and data bases of the five systems.

As discussed in Chapter II, program offices stopped using ORACLE at RADC in 1980. Only a fraction of the systems in their data base use only class B parts. Of those, only the five systems selected (Table I) have sufficiently documented the system configuration to make

Table I

Systems Used in Calculation of MTBF

ORACLE Identifier	System Name	Product Division
MTD (1)	JTIDS	ESD
GPU5A (2)	PAVE CLAW	AD
VAR-3 (1)	MEECN/DRE	ESD
TAS (3)	SEEK TALK	ESD
VAN-ST (3)	Enhanced JTIDS (EJS)	ESD

(1) System in development
(2) System operational
(3) Program cancelled

reasonably accurate reliability predictions. The RADC ORACLE office made these conclusions on the basis of studies they have conducted on their data base to determine it's make-up and use for other RADC studies (19).

Calculation of New MTBFs

Table II shows the parts available to use in the construction of an electronic system in ORACLE. Only the electronic parts indicated were changed from class B to class S. (Mechanical parts, such as switches, tubes, printed circuit boards, etc. are not being considered in this research.) For each system, the parts data base was accessed and all possible electronic parts were changed from

Table II

Parts Available in ORACLE (32)

Integrated Circuits *	Transistor *
Diode, General Purpose *	Diode, Zener *
Diode, Voltage Reference *	Diode, Veractor *
Transistor, Microwave *	Thyristor *
Resistor *	Capacitor *
Inductor	Rotating Device
Relay	Switch
Connector	Tube
Laser	Quartz Crystal
Fuse	Neon Lamp
Incandescent Lamp	Meter
Wirewrap Connection	Hand Soldered Connection
Reflow Solder Connection	Circuit Breaker
Hybrid Circuit *	Light Emitting Diode
Heater	Opto-Electronic - LEDs *
Printed Board Connector	Isolators and Display

* Electronic parts upgraded from class B to class S

class B to class S (Table III). All other parts and parameters (eg., environment, junction temperatures, etc.) were left unchanged.

Table III

Identification of Parts Changed Per System

System	*Total Number Parts	Percent of Parts Changed
JTIDS	2,826	95.0
PAVE CLAW	334	62.3
MEECN/DRE	3,538	87.7
SEEK TALK	1,142	76.3
EJS	2,555	90.5

* Does not include solder connections as a part count, but they are included in the MTBF calculations.

Table IV shows the results of the MTBF calculations. As expected, no MTBF doubled and all but one system experienced large gains. MTBFs increased over a range of 12.1 percent to 78.3 percent.

Table IV

Comparison of Original and New MTBFs
(MTBF in hours)

System	Original MTBF	New MTBF	Percent Increase
JTIDS	2,287.2	3.631.9	58.8
PAVE CLAW	5,952.7	10,615.4	78.3
MEECN/DRE	4,988.5	6,469.2	29.7
SEEK TALK	6,510.0	8,456.5	29.9
EJS	9,481.0	10,627.3	12.1

Cost of Parts

The current manufacturers of class S parts (Table V) were all contacted and requested to provide pricing information. All but one declined due to a competitive procurement action by DESC and SD to buy selected class S parts for inventory. The name of the company providing information is withheld by request and will be called Company A for this research.

Table V

Class S Manufacturers (16)

US Micro Tek	RCA
Microsemiconductors	San Fernando Electric
Motorola	Signetics
National Semiconductors	Teledyne Crystalonics

Col B. Jones, SD, and Mr. J. Wiesner, the Aerospace Corp., were contacted for the costs of class S parts. They said that no central repository for purchased class S parts costs existed. But long lead times in acquiring class S parts (up to a year and getting longer) had caused SD to initiate a centralized procurement of class S parts. SD had surveyed class S manufacturers to determine expected prices for each part. DESC was contacted to get the price list since the information was considered competition sensitive by SD and DESC was running the procurement (33; 34).

Mr. C. Borchers, Chief of the Technical Support Section at DESC, was contacted to get a copy of the government estimated price list (Appendix B). The government price list was then compared to the price list provided by the one manufacturer. Most of the parts produced by the manufacturer that were on the government price list were within the range of prices quoted by the manufacturer. Since the manufacturer only makes one type of device, the government price list was used in the research as it included a much wider range of part types. However, the comparison did provide some confidence that the government price list is accurate (35; 37).

The government price list was then cross checked against files at DESC to obtain the equivalent class B part number and price. A total of 331 parts were checked. Of the 221 microcircuits, 47.5 percent had class B equivalents, and of the 110 semiconductors, 75.5 percent had class B equivalents. (A few of the class B equivalent parts did not have prices for them and they were not included in the research (Appendix A)) (36).

The ratio of class S cost to class B cost was then computed by adding up the total cost of class S parts for microcircuits and semiconductors, and dividing by the total cost of cla s B microcircuits and semiconductors (see Table VI).

Note: The government price list for class S parts included 65 radiation hardened microcircuits. These parts have no radiation hardened class B equivalents and were not used in these computations. However, examining their prices does not show them to be, on average, more expensive than other class S microcircuits (37).

Table VI

Class S to Class B Cost Ratio
(cost in dollars)

Mircrocircuits:

$$\frac{\text{class S total cost}}{\text{class B total cost}} = \frac{7{,}808}{1{,}013} = 7.71$$

Semiconductors:

$$\frac{\text{class S total cost}}{\text{class B total cost}} = \frac{2{,}213}{671} = 3.30$$

All:

$$\frac{\text{class S total cost}}{\text{class B total cost}} = \frac{10{,}021}{1{,}684} = 5.95$$

New Cost Ratio:

$$\text{Ratio} = 5.95 - (5.95 * .44) = 3.3$$

Many of the class S parts are being purchased in reasonably large quantities (for class S parts). As mentioned previously, the prices received from Company A are within the government price estimates. For example, part 0020lSDA, a digital microcircuit, is on the government price list at $75.00 each, with a total of 200 required for purchase. The manufacturer quotes this part at $78 to $58, depending on quantities. Most parts are being purchased in quantities of 200 to 600, although some parts have purchase quantities in the few thousand. Prices of parts with large purchase requirements also fall within the manufacturers quoted prices (Appendix A and B) (37).

With no other data available on production efficiencies, the Caquot relationship discussed in Chapter II was used. The maximum decrease in price this research used was 44 percent which would result from a ten fold increase in production. Table VI shows that the average cost ratio of class S to class B parts is 5.95. Reducing the cost of class S parts 44 percent and calculating a new class S/class B ratio for all parts derives a new average cost ratio of 3.3 for all parts (Table VI). This figure was used to increase the electronic parts cost in the production cost of the LCC model.

Life Cycle Cost Evaluation

The selected system was the Milstar Terminal Program, currently in FSD. The Milstar communications terminals are highly complex electronic systems. Each terminal contains up to 11 line replaceable units (LRUs) and will be available in ground or airborne, command post or force element configurations. The Milstar SPO has developed a LCC model which has been approved by ESD/ACC to use as a basis for budgeting O&S costs and for making what-if and trade-off studies. The

LCC model is based on the entire system of terminals and users. That is, it contains the aircraft and ground sites, standard mission durations, total number of terminals, number and make of LRUs in each terminal, and other pertinent facts that make up the Milstar system. This model was used to calculate new costs using the range of increased MTBF values and the increased cost of class S parts (38; 39).

The Milstar LCC model uses a given, fixed value for production costs. The production cost consists of 70 percent materials cost and 30 percent labor. The materials cost breaks down into 10 percent overhead, 30 percent for mechanical parts (eg., antennas, LRU boxes, switches, etc.) and 30 percent for electronic parts. This breakout was confirmed by Mrs. M. Weech, head of ESD/ACC, as appropriate for this type of system (40; 41).

The model was run three times. In all cases the production cost of prime mission equipment (PME) was increased by 1.93 times, (.3P * 3.11) + P, where P equals the original production cost. For the first case, the system MTBF was increased by 12.1 percent (the minimum increase in MTBF) and in the second case MTBF was increased by 78.3 percent (the maximum increase). In the third case, the MTBF was increased by 29.8 percent to correspond with an average increase of two systems' MEECN/DRE and SEEK TALK, MTBF increase (Table IV). These two systems had increases in

MTBF with only .2 percent difference. Since both systems have a fairly large number of parts and both are communications terminals with airborne and ground application, like Milstar, their increases in MTBF may be more representative of the increases that could be expected in similar systems. The results of the LCC model run are given in Table VII.

Table VII

LCC Analysis on the Milstar System
(based on a total of 15 year life span)
(increase or decrease over baseline system)

MTBF Increase In Percent	*Total Production In Percent	+Recurring O&S In Percent
12.13	↑ 8.1	↑ 38.0
29.8	↓ .5	↓ 9.7
78.3	↓ .8	↓ 18.6

* Includes test equipment, investment spares, inventory, and modification kits to ground sites and aircraft as well as prime mission equipment (PME).

\+ Includes recurring cost of replacement spares.

V. Conclusions and Recommendations

Conclusions

Research Question 1. What are the potential increases in predicted MTBF using class S parts vice using class B parts? This question was very specific in nature and given the tools, MIL-HDBK-217D and ORACLE, an increase in MTBF was guaranteed for each system. The unknown element was the magnitude of the increases and if all five systems' increases in MTBF would cluster within a narrow range or if a wide range would result. Remember the MTBFs generated are not field MTBFs, what the systems actually experience in practice, but predicted MTBFs based on defined environments, manufacturing, and operating conditions in MIL-HDBK-217D. While these predicted MTBFs may not be experienced in the field, the literature review has shown that increases in predicted MTBF are indicative of increases in field MTBF. The range of the predicted MTBFs was applicable in predicting what would happen to another systems' field MTBF should class S parts be substituted for the class B parts.

The results obtained indicate a wide range of increases is possible, 12 to 78 percent. However four of the five increases were greater than 29 percent. Twenty-nine percent is a significant improvement in any systems MTBF, yet it was achieved by just changing to different parts with no technological risk. (Since the magnitude of the increases is not linear with the number of parts in the system, or percentage of parts changed, it was impossible for any conclusions to be reached concerning the specific reasons for increase in each system. It would be possible to manually go through the computations in MIL-HDBK-217D to determine the reasons, but that was outside the scope of this research.)

Research Question 2. What are the potential decreases in cost due to quantity buys of class S parts? No data exists which indicates specific cost reductions for class S parts given large production of parts. A few of the government estimated prices for parts are much lower (greater than 20% lower) than Company A's prices for the same parts. However, they were just 8 out of the 33 parts that Company A had on the government price list. Of the 33 parts in common, 18 parts on the government price list were within Company A's quotes, and 7 parts had price differences that were less than $10 per part (less than 20%) and for most of those, the difference was only $2. It was concluded that there was insufficient data, both in price of parts and quantity of purchase, to indicate any quantity price differences from the government price list. No research indicated that the Caquot relationship was not valid, therefore, the Caquot relationship was used to decrease class S prices due to quantity buys.

Research Question 3. What is the change in Life Cycle Cost (LCC) using class S parts? The data indicates that life cycle costs go down as MTBF increases, despite the increased acquisition costs due to the cost of class S parts. Relatively small increases in MTBF do not produce any recurring or production cost savings which would make up for the cost of class S parts. But, as MTBF increases sufficiently, fewer test sets are required, a smaller inventory of spares (Line Replacement Units (LRUs), Shop Replacement Units (SRUs), and parts) is needed, the need for recurring parts purchases decreases, and personnel costs drop due to a reduced need for maintenance. Surprisingly, as the percentage increase in MTBF goes from 29.8 percent to 78.3 percent, production costs hardly change indicating there is a need for minimum levels of test equipment. However, recurring costs continue to fall. Conditionally then, the increased reliability out-weighs the increased costs of class S parts. But, the increase in MTBF must be large enough to affect support equipment and spare levels.

Initially, the high relative cost of class S parts dominates the LCC analysis. Relatively small percentage increases in MTBF do not change the need for support equipment or spares levels (LRUs, SRUs, or component parts) at the base or intermediate repair level. The reduction of 0.1 of a test stand or 0.2 of each spare LRU (for example) cannot change the need for them since the base must maintain minimum readiness and availability rates. Since it is impossible to reduce 0.1 of a test stand (they must reduce requirements of material in whole numbers at the base level) no savings accrue for the increase in MTBF and the cost of class S parts is additive to the LCC of the system.

However, when the MTBF rises above a minimum level, the need for support equipment and spares levels are reduced by a whole number. Some bases may not need test stands at all, to maintain readiness and availability rates. For example, a central intermediate facility may service several bases. The bases without the test stands no longer need SRU spares, only LRUs to support the remove and replace maintenance concept (Milstar has very effective built-in-test (BIT) software and it is considered in the LCC model). The depot requires fewer component parts since fewer LRUs and SRUs are being received for maintenance. As MTBF continues to rise above the minimum point for a LCC break-even, the recurring costs associated with maintenance personnel and component parts level replacement at the depot also drop. (Production costs do not change within the range of MTBF increase.)

Four of the five systems analyzed for increases in MTBF did have percentage increases large enough to derive cost savings when compared to the results of the LCC model for Milstar. While the Milstar LCC model is not specific for any of them, the indication is that many systems (if not most) could get a sufficient increase in MTBF to benefit from the use of class S parts despite the higher initial cost.

Recommendations

This research covered a broad area and does not presume to have answered all the questions related to the use of class S parts in military systems. It did not examine all the issues as closely as they should be examined and there are many topics which require further investigation to substantiate the results of this research. The following three topics are recommended as the next steps in validating the concept.

Unlimited Availability and Cost of Class S Parts. This research assumed that there was an unlimited availability of class S parts. As noted in Chapter III, this isn't the case today. In fact, there is a very limited supply of class S parts, which means that designers of electronic systems would be severely limited in their use of parts for their designs if limited to class S parts today. Therefore, further work on determining the future availability of class S parts is needed. Could the Air Force and/or DOD mandate the use of class S parts in electronic systems? Would the current commercial manufacturers respond with greater numbers of class S parts and a wider availability of part types?

The other area of interest concerning class S parts is the price. The object of this research was to use a conservative approach in pricing class S parts given an unlimited availability. As production increases, economies of scale are achieved and prices decrease. This forms the basis of the Caquot relationship discussed in Chapter III (15). However, there are other factors which could realize cost savings to the AF, both in terms of the cost of class S parts, and other areas. First, if the AF/DOD mandated the use of class S parts, the demand for class S parts would increase dramatically. This might induce other manufacturers not currently producing class S parts to enter the market which would further reduce prices. Second, as the AF/DOD switched to class S parts, all other parts (classes B, C, and commercial) would be eliminated from military inventories, significantly reducing the management effort required to maintain and store them (standardization). Finally, the lower intangible and opportunity costs of systems due to low MTBFs, the expense of highly trained maintenance personnel (which are harder to keep in the military), the cost of military airlift for mobility of systems with poor MTBFs (requiring a large amount of spares and test equipment, etc.) should all be included in a study of cost impac's of class S parts on the military.

Make-Up of Predicted MTBF. This research did not attempt to determine why the five systems used to calculate new MTBFs had such a wide range of percentage increase. Since over 90 percent of the parts in the EJS system were changed, yet the MTBF only increased by 12.1 percent, an analysis of the determining factors which drive the failure rates in MIL-HDBK-217D is warranted.

Sensitivity Analysis. No attempt has been made to do a sensitivity analysis on the results. Sensitivity analyses need to be performed on: (1) the range of percentage increase in MTBF, (2) the price of class S parts, and (3) the level of percentage increase in MTBF required to break-even, that is, for the cost of class S parts to be outweighed by the savings in production and recurring costs. These would establish boundaries by which decision making could take place with more quantitative data.

Final Comments

Class S parts are not the sole, or even primary method, for Air Force to achieve its goal of high reliability systems. Before committing to the investment costs that would be required, the Air Force should thoroughly investigate all ramifications of a policy of purchasing class S parts.

My concern is that many people dismiss the use of class S parts out of hand, without looking at the total system impact. Even if the Air Force can break-even (from a cost point) using class S parts, the higher reliability measures afforded by the use class S parts could help achieve the Air Force goal of increased warfighting capability. The use of class S parts to help the Air Force achieve that goal should be explored, rather than be dismissed out of hand due to apparent high acquisition costs.

Appendix A

Company A Class S Parts and Costs
Quoted 18 November 1986
(Prices in dollars)

Part Number	Price Range	Part Number	Price Range
00103SCA	78/58	00103SCB	78/58
00103SDA	78/58	00103SDB	78/58
00201SCA	78/58	00201SCB	78/58
00201SDA	78/58	00201SDB	78/58
00302SCA	78/58	00302SCB	78/58
00302DSA	78/58	00302SDB	78/58
00401SCA	78/58	00401SCB	78/58
00401SDA	78/58	00401SDB	78/58
00801SAC	78/64	00801SCA	78/64
00801SCB	78/64	00801SDA	78/64
00801SDB	78/64	00803SCA	78/64
00803SCB	78/64	00803SDA	78/64
00803SDB	78/64	01306SEA	78/64
01306SEB	78/64	02001SCA	98/82
02001SCB	98/82	02001SDA	98/82
02001SDB	98/82	02002SCA	98/82
02002SCB	98/82	02002SDA	98/82
02002SDB	98/82	02003SCA	98/82
02003SCB	98/82	02003SDA	98/82
02003SDB	98/82	02004SCA	98/82
02004SCB	98/82	02004SDA	98/82
02004SDB	98/82	02005SCA	98/82
02005SCB	98/82	02005SDA	98/82
02005SDB	98/82	02103SCA	140/97
02103SCB	140/97	02103SDA	140/97
02103SDB	140/97	02105SCA	140/97
02105SCB	140/97	02105SDA	140/97
02105SDB	140/97	02502SCA	120/100
02502SCB	120/100	02502SDA	120/100
02502SDB	120/100	02601SCA	120/100
02601SCB	120/100	02601SDA	120/100
02601SDB	120/100	02701SCA	98/79
02701SCB	98/79	02701SDA	98/79
02701SDB	98/79	02801SCA	140/100
02801SCB	140/100	02801SDA	140/100
02801SDB	140/100	10101SGC	240/150
10101SGA	240/150	10101SHA	240/150

Part Number	Price Range	Part Number	Price Range
10101SPA	240/150	10102SIC	240/150
10103SGC	220/138	10103SHA	220/138
10103SGA	220/138	10104SGC	220/175
10104SHA	220/175	10104SPA	220/175
10107SGC	245/175	10201SIC	200/168
10304SGC	230/170	11005SCA	230/170
11005SCB	230/170	11201SCB	230/170
11201SDA	230/170	11401SHA	298/180
11402SGA	288/170	11402SGC	288/170
11703SXA	300/198	11704SYA	300/210
20302SEA	397/286	20302SEB	397/286
30001SAC	72/57	30001SCA *	72/51
30001SCB	72/57	30001SDA *	72/51
30001SDB	72/57	30002SCA	72/57
30002SCB	72/57	30002SDA	72/57
30002SDB	72/57	30003SAC	72/57
30003SCA *	72/51	30003SCB	72/57
30003SDA *	72/51	30003SDB	72/57
30004SAC	72/57	30004SCA *	72/51
30004SCB	72/57	30004SDA *	72/51
30004SDB	72/57	30005SAC	72/57
30005SCA *	72/51	30005SCB	72/57
30005SDB	72/57	30006SCA	72/57
30006SCB	72/57	30006SDA	72/57
30006SDB	72/57	30007SCA *	72/51
30007SCB *	72/51	30007SDB *	72/51
30007SDA *	72/51	30008SAC	72/57
30008SCA	72.57	30008SCB	72/57
30008SDA	72/57	30008SDB	72/57
30009SCA *	72/51	30009SCB	72/57
30009SDA *	72/51	30009SDB	72/57
+ 30103SEA *	72/51	+ 30103SEB	72/57
+ 30103SFA *	72/51	+ 30103SFB	72/51
+ 30106SEA *	89/51	+ 30106SEB	89/57
+ 30106SFA *	89/51	+ 30106SFB	89/57
+ 30109SEA *	72/51	+ 30109SEB	72/57
+ 30109SFA *	72/51	30201SCA *	77/62
30201SCB	77/68	30201SDA	77/68
30201SDB *	77/62	30203SAC	77/70
30203SCA *	77/62	30203SCB	77/70
30203SDA *	77/62	30203SDB	77/70
30302SAC	72/57	30302SCA *	72/51
30302SCB	72/57	30302SDA *	72/51
30302SDB	72/57	30303SAC	72/57
30303SCA	72/57	30303SCB	72/57
30303SDA	72/57	30303SDB	72/57

Part Number	Price Range	Part Number	Price Range
30401SCA	77/68	30401SCB	77/68
30401SDA	77/68	30401SDB	77/68
30501SAC	77/68	30501SCA *	77/51
30501SCB	72/57	30501SDA *	72/51
30501SDB	72/57	30502SAC	72/57
30502SCA *	72/57	30502SCB	72/57
30502SDA *	72/57	30502SDB	72/57
30605SAC	77/68	30605SCA *	77/57
30605SCB	77/68	30605SDA *	77/57
30605SDB	77/68	30701SEA *	77/57
30701SEB	77/68	30701SFA *	77/57
30701SFB	77/68	30702SEB	77/68
30702SFA	77/68	30702SFB	77/68
30703SEA	77/68	30703SEB	77/68
30703SFA	77/68	30703SFB	77/68
30901SEA *	77/62	30901SEB	77/68
30901SFA	77/68	30901SFB	77/68
30902SEA *	77/62	30902SEB	77/68
30902SFA *	77/62	30902SFB	77/68
30903SEA *	77/62	30903SEB	77/68
30903SFB *	77/62	30904SEA *	77/62
30904SEB	77/68	30904SFA *	77/62
30904SFB	77/68	30905SEA *	87/65
30905SEB	87/68	30905SFA *	87/68
30905SFB	87/65	30906SEA *	87/68
30906SEB	87/65	30906SFA *	87/60
30906SFB	87/65	31001SCA	72/57
31001SCB	72/57	31001SDA	72/57
31001SDB	72/57	31002SCA *	72/51
31002SCB	72/57	31002SDA *	72/51
31002SDB	72/57	31003SAC	72/57
31003SCA	72/57	31003SCB	72/57
31003SDA	72/57	31003SDB	72/57
31004SCA *	72/51	31004SCB	72/51
31004SDA *	72/51	31004SDB	72/57
31101SEA *	72/57	31101SEB	72/62
31101SFA *	72/57	31101SFB	72/62
31202SEA *	98/62	31202SEB *	98/62
31202SFA *	98/62	31202SFB	98/62
31507SEA	98/71	31507SEB	98/71
31507SFA	98/71	31507SFB	98/71
31508SEA *	98/66	31508SEB	98/71
31508SFA *	98/66	31508SFB	98/71
31509SEB *	98/66	31509SEA *	98/66
31509SFA *	98/66	31509SFB	98/71
32201SEA *	77/62	32201SEB	77/66

Part Number	Price Range	Part Number	Price Range
32201SFA *	77/62	32201SFB	77/66
32202SEA	77/66	32202SEB	77/66
32202SFA	77/66	32202SFB	77/66
32203SEA *	77/62	32203SEB	77/66
32203SFA *	77/62	32203SFB	77/66
32204SEA *	66/62	32204SEB	77/62
32204SFA *	77/62	32204SFB	77/62

+ While still on the Quality Parts List (QPL), these parts have not been made in three years. Prices are estimates only.

* Competitors for these parts identified.

Appendix B

Comparison of Part Costs
(Prices in dollars)

Microcircuits:

CLASS S PARTS NUMBER 1	PRICE	Company A Price	CLASS B PARTS NUMBER 2	PRICE
11401SGC	260.00		01-108-4744	13.00
11405SGC	260.00		01-168-0960	43.62
10103SGC	160.00	220/138	01-072-4073	3.19
10104SCA	205.00		01-095-4885	34.67
10104SGC	185.00	220/175	01-072-4074	17.36
10701SXC	260.00		01-104-5439	10.56
10304SGC	180.00	230/170	01-072-4075	12.75
11703SXC	220.00		01-156-7241	27.29
10107SGC	210.00	245/175	01-040-6377	9.49
11005SCA	210.00	230/170	01-238-5501	5.95
11201SCA	210.00		01-088-3862	6.31
10201SCA	190.00		01-089-8069	4.09
10201SIC	180.00	200/168	00-197-3361	8.21
10101SGC	175.00	240/150	00-167-6330	3.24
10101SCA	190.00		00-762-0633	3.39
10102SCA	190.00		00-007-4079	3.50
10102SIC	175.00	240/150	00-274-0200	3.47
10901SPA	190.00		01-069-3045	8.95
00104SDA	75.00		00-374-9916	4.57
00401SCA	75.00	78/58	01-078-7524	1.43
00105SCA	75.00		01-076-8391	1.77
00105SDA	75.00		00-434-1544	4.39
00801SCA	75.00	78/64	00-361-8732	3.89
00803SCA	75.00	78/64	00-369-9839	5.45
00803SDA	75.00	78/64	01-044-5797	19.77
00103SCA	75.00	78/58	01-076-8390	1.31
00205SDA	75.00		00-574-4361	4.66
33001SDA	75.00		01-235-3483	5.85
33301SDA	75.00		01-235-3485	6.29
33002SDA	75.00		01-235-3484	5.91
34001SDA	75.00		01-234-8716	4.68
33003SDA	75.00		01-231-5886	70.05
34002SDA	75.00		01-235-3486	5.56
33701SFA	75.00		01-192-8768	11.38

CLASS S PARTS NUMBER 1	PRICE	Company A Price	CLASS B PARTS NUMBER 2	PRICE
33004SDA	75.00		01-235-6963	6.99
33203SSA	75.00		01-232-1109	23.68
33501SDA	75.00		01-234-9309	7.08
34101SCA	75.00		01-186-8335	6.98
34101SDA	75.00		01-245-1740	38.85
02004SDA	85.00	98/82	01-030-6353	15.14
30001SCA	35.00	72/51	01-031-7030	1.67
30301SCA	38.00		01-248-2335	20.19
30002SDA	50.00	72/57	01-230-4552	3.31
30003SDA	40.00	72/51	01-091-4186	3.50
30004SCA	35.00	72/51	01-042-0369	1.60
31001SCA	39.00	72/57	01-171-2153	2.49
32301SCA	39.00		01-069-0419	2.17
30701SFA	64.00	77/57	01-067-4994	3.15
30702SEA	60.00		01-067-9804	2.85
31302SCA	79.00		01-171-2155	2.70
36001SEA	60.00		01-222-6089	8.08
30901SEA	60.00	77/62	01-249-8047	2.92
30903SEA	60.00	77/62	01-217-7201	3.09
30904SEA	60.00	77/62	01-059-0583	2.18
31503SFA	79.00		01-147-2280	4.94
31504SFA	79.00		01-075-7787	5.98
31512SEA	74.00		01-240-0494	4.63
30605SCA	70.00		01-238-5519	16.67
30605SDA	75.00	75/57	01-067-4993	7.37
30608SFA	75.00		01-161-4550	6.64
31509SEA	70.00	98/66	01-248-8630	43.45
31508SEA	70.00	98/66	01-248-8628	45.78
30007SCA	35.00	72/51	01-238-5520	22.64
31003SCA	35.00	72/57	01-171-2154	2.86
32401SRA	76.00		01-093-8823	4.90
32403SRA	76.00		01-086-7634	4.58
32403SSA	84.00		01-247-9003	12.00
30906SEA	60.00	87/68	01-238-5522	16.90
31603SEA	60.00		01-103-0605	3.89
30302SCA	35.00	72/51	01-238-5521	2.53
32501SRA	76.00		01-248-8632	14.39
30501SCA	37.00	72/51	01-171-2152	2.82
30501SDA	40.00	72/51	01-071-1879	3.13
32201SEA	60.00	72/62	01-248-8631	41.65
32502SRA	76.00		01-249-2375	116.39
30102SCA	55.00		01-203-7282	61.42
07001SCA	46.00		01-021-5875	3.38

CLASS S PARTS NUMBER 1	PRICE	Company A Price	CLASS B PARTS NUMBER 2	PRICE
07003SCA	51.00		01-026-2489	3.74
07102SEA	58.00		01-058-7980	5.91
07006SDA	47.00		01-026-8821	1.61
TOTAL =	7,808.00		TOTAL =	1,013.24

1 - M38510 Slash Sheet Number 2 - National Stock Number

Semiconductors:

CLASS S PARTS NUMBER 1	PRICE	CLASS B PARTS NUMBER 2	PRICE
JANS1N3595	19.00	01-127-6139	1.39
JANS1N3893	25.00	01-123-2985	6.95
JANS1N4148-1	15.00	01-228-5606	2.43
JANS1N4150-1	18.00	01-074-4613	.44
JANS1N4153-1	15.00	01-251-5681	24.42
JANS1N4460	22.00	01-130-9213	7.67
JANS1N4461	22.00	01-199-0384	2.78
JANS1N4469	22.00	01-178-8252	2.78
JANS1N4954	20.00	01-123-2974	2.06
JANS1N4955	20.00	01-128-9130	2.83
JANS1N4959	20.00	01-175-5159	12.63
JANS1N4961	20.00	01-128-3821	3.08
JANS1N4962	20.00	01-023-3459	2.78
JANS1N4964	20.00	01-023-3460	2.73
JANS1N4968	20.00	01-123-2975	2.86
JANS1N4971	20.00	01-023-3446	3.23
JANS1N4973	20.00	01-123-4707	3.23
JANS1N4976	20.00	01-207-0940	3.64
JANS1N4979	20.00	01-123-4704	4.14
JANS1N5417	24.00	01-228-5605	10.80
JANS1N5418	24.00	01-023-3451	1.67
JANS1N5551	22.00	01-123-2983	1.08
JANS1N5616	19.00	01-115-7392	1.31
JANS1N5617	19.00	01-123-2990	1.19
JANS1N5618	19.00	01-101-2347	1.25
JANS1N5806	22.00	01-104-4043	3.97
JANS1N5811	25.00	01-150-1792	14.41
JANS1N746A-1	20.00	01-228-5601	13.50
JANS1N747A-1	20.00	01-193-8517	1.54
JANS1N748A-1	20.00	01-171-5830	.59
JANS1N749A-1	20.00	01-234-2938	.63
JANS1N751A-1	20.00	01-161-9490	.68
JANS1N753A-1	20.00	01-166-8991	.83
JANS1N754A-1	20.00	01-131-0261	1.06
JANS1N757A-1	20.00	01-157-0288	1.05
JANS1N758A-1	20.00	01-115-6668	1.83
JANS1N759A-1	20.00	01-175-8446	1.43
JANS1N965B-1	20.00	01-162-0470	.85
JANS1N967B-1	20.00	01-196-1755	.64
JANS1N968B-1	20.00	01-193-8530	.95
JANS1N969B-1	20.00	01-197-4194	4.46
JANS1N972B-1	20.00	01-193-8528	2.65

CLASS S PARTS NUMBER 1	PRICE	CLASS B PARTS NUMBER 2	PRICE
JANS1N972B-1	20.00	01-193-8528	2.65
JANS1N829-1	30.00	01-193-8513	9.06
JANS2N2060	25.00	01-213-4396	6.40
JANS2N2222A	15.00	01-005-9891	1.60
JANS2N2369A	17.00	01-022-6846	1.79
JANS2N2432A	25.00	01-022-6849	5.07
JANS2N2484	17.00	01-022-6847	1.90
JANS2N2605	25.00	01-123-4701	12.83
JANS2N2857	35.00	01-023-3438	2.87
JANS2N2905AL	20.00	01-181-4824	38.53
JANS2N2907A	15.00	01-019-4947	1.54
JANS2N2945A	25.00	01-022-6851	3.44
JANS2N3251A	15.00	01-245-1504	10.00
JANS2N3421	50.00	01-050-7903	4.30
JANS2N3467L	22.00	01-221-1736	4.27
JANS2N3501L	25.00	01-026-2573	3.24
JANS2N3507L	25.00	01-022-6852	6.95
JANS2N3637L	25.00	01-023-3437	3.62
JANS2N3700	30.00	01-023-3435	1.84
JANS2N3763	30.00	01-128-3812	15.37
JANS2N3741	40.00	01-051-5791	4.60
JANS2N3749	70.00	01-123-1543	9.88
JANS2N3866A	60.00	01-123-2429	2.45
JANS2N3868	40.00	00-501-0772	12.47
JANS2N3997	110.00	01-121-6695	18.93
JANS2N4033	20.00	01-183-6503	7.24
JANS2N4150	45.00	01-123-4700	6.94
JANS2N4261	30.00	01-181-4823	15.18
JANS2N4416A	25.00	01-058-6627	3.21
JANS2N4856	25.00	01-123-2966	2.96
JANS2N4857	25.00	01-050-7043	1.44
JANS2N4858	20.00	01-165-2735	6.95
JANS2N4957	50.00	01-128-9129	3.70
JANS2N5237	40.00	01-186-9423	40.14
JANS2N5664	45.00	01-132-8731	15.95
JANS2N5665	45.00	01-193-5721	20.52
JANS2N6758	50.00	01-203-1177	24.00
JANS2N6764	50.00	01-175-8438	91.28
JANS2N6766	50.00	01-179-7197	83.85
JANS2N918	50.00	01-019-4951	2.90
TOTAL =	2,213.00	TOTAL =	670.66

1 - Part Reference Number 2 - National Stock Number

Appendix C

Problems with ORACLE

The data tapes for ORACLE and the five systems data bases were loaded on the AFIT Classroom Support Computer (CSC) system to run the ORACLE program. Immediately problems arose in running the program. The VAX operating system for the CSC was not configured in a way the program could operate properly. Janet Skerkoski, the CSC system manager contacted RADC and found out what commands had to be set up for the program to run.

However, additional problems arose. First, the program and data base were very large, over 35,000 blocks. The disk allocation for the user account was raised to 50,000 blocks to hold the data and operate the program. Next, the program still wouldn't run until more trouble-shooting discovered additional changes in the users "login" file had to be made. For example, the program and the data files had to be in the same subdirectory. When these changes were made the program would run, i.e., the ORACLE program menus would appear and could be scrolled through, but two more problems occured. Calculating the original MTBFs on some of the systems took so long the Gandalfs (modems) would automatically log the user off the CSC after 30 minutes (an automatic time-out). A hard wire terminal was installed to correct this problem. However, when the parts were attempted to be changed from class B to class S the ORACLE program often did not recognize the system in question had those parts to be changed. The parts were finally changed using the VMS editor on the data base rather than the ORACLE program editor. But when the program was set to calculate the new MTBFs, either it would never calculate them (just run in an infinite loop) or it would break out of the calculations with an error message and the MTBF it had calculated would only be the MTBF up to the point of the error. Mr. Lyne of RADC attempted to fix these problems by logging in on the CSC, but was unable to find the causes.

Ms. Skerkoski and Mr. Lyne decided there were at least three sources of the problems. One, ORACLE requires a very large amount of memory to run beyond the initial space it takes up. A large number of intermediate files are created during the calculations which exceeded the block allocation and caused the CSC to stop the work. Second, the ORACLE program was coded for a mainframe and re-coded for operating on a VAX when RADC decided to give the program to SPOs and contractors. As a result, there are probably several bugs still in the code. Mr. Gill Wagner of ASD/ENSI, which runs ORACLE on a VAX, verified the large number of problems he has had trying to get ORACLE to run, including program bugs. Finally, the version of the VMS operating system ORACLE was supposed to run under was different than the CSCs version of VMS (version 4.5). VMS versions are compatible, but small differences can sometimes cause problems. Most of these were fixed, but some problems have remained.

Mr. Lyne decided with all the problems of running ORACLE on the CSC that he would do the part substitutions and MTBF calculations on the mainframe at RADC. He was able to do the work in one afternoon.

Bibliography

1. Wade, Jr., The Honorable James P. "DOD Acquisition: What the Future Holds," Program Manager, 15: 27-29 (March-April 1986).

2. Feduccia, Anthony J. "System Design for Reliability and Maintainability," Air Force Journal of Logistics, 8: 25-29 (Spring 1984).

3. Cochoy, Lt Col Robert E. "Improving System Support Readiness," Program Manager, 13: 7-10 (September-October 1984).

4. Mullins, Gen James P. (Ret). "Reliability," Program Manager, 13: 12-16 (September-October 1984).

5. "Reliability and Maintainability Action Plan (R&M) 2000," Air Force Policy Letter for Commanders, No. 2, (May 15, 1985).

6. Goodell, Br Gen Frank S. "R&M 2000--Beyond the 'Buzzwords'," 1986 Proceedings Annual Reliability and Maintainability Symposium. 163-164. New York: IEEE Press, 1986.

7. USAF/CV. "R&M Policy Letter #2: Minimum System-level R&M Requirements," Letter. 3 March 1986.

8. HQ USAF/LE-RD. Reliability and Maintainability Principles. Arlington: ANSER (October 1985).

9. Department of Defense. Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution. MIL-STD-781C. Washington: Government Printing Office, 21 October 1977.

10. Goldshine, G. D. and R. E. Martin. "Component Defects and System Reliability," 1981 Proceedings Annual Reliability and Maintainability Symposium. 214-221. New York: IEEE Press, 1981.

11. Department of Defense. Reliability Prediction of Electronic Equipment. MIL-HDBK-217D Notice 1. Washington: Government Printing Office, 13 June 1983.

12. Reliability Analysis Center. Electronic Equipment Reliability Data. EERD-2. Rome: IIT, Summer 1986.

13. Reliability Analysis Center. Microcircuit Device Reliability: Digital SSI/MSI Data. MDR-19. Rome: IIT (Spring 1984).

14. Swanson, Donald K. and Charles E. Gastineau. "Parts Control = Quality + Increased Productivity," 1981 Proceedings Annual Reliability and Maintainability Symposium. 440-445. New York: IEEE Press, 1981.

15. Dushman, Allan. "Effect of Reliability on Life Cycle Inventory Cost," Proceedings 1969 Annual Symposium on Reliability. 549-561. New York: IEEE Press, 1969.

16. Seta, Capt Donald and Jim Wiesner. "JAN Class S Electronic Parts," Briefing. Space Division (SD). October 1984.

17. Meyer, Capt Carl and others. "Class S Parts Use in Avionics Equipment," Briefing and memos. Air Force Acquisition Logistics Center (AFALC). November 1984.

18. Klion, Jerome and George W. Lyne. "RADC ORACLE," 1981 Proceedings Annual Reliability and Maintainability Symposium. 81-85. New York: IEEE Press, 1981.

19. Lyne, George W. and Florence Winter. ORACLE Reliability Predictions. Personal Interview. RADC, Griffiss AFB NY, 23 February 1987.

20. Aeronautical Systems Division (AFSC). Program LCC Documentation Version 2. TR-747-3. Analytical Sciences Corp., Reading MA, 28 April 1976.

21. Department of Defense. General Specification for Microcircuits. MIL-M-38510F. Washington: Government Printing Office, 1 December 1981.

22. Department of Defense. General Specification for Semiconductors. MIL-S-19500G. Washington: Government Printing Office, 16 February 1984.

23. Department of Defense. Test Methods and Procedures for Microelectronics. MIL-STD-883C. Washington: Government Printing Office, 25 August 1983.

24. Department of Defense. Test Methods and Procedures for Semiconductors. MIL-STD-750C. Washington: Government Printing Office, 23 February 1983.

25. Department of Defense. Certification Requirements for JAN Microcircuits. MIL-STD-976A. Washington: Government Printing Office, 5 October 1981.

26. Lindstrom, Dean L. "Reliability Achievement in High Technology Space Systems," Goddard Space Flight Center Proceedings of the 12th Annual Precise Time & Time Interval Applications and Planning Meeting. 57-67. Washington: Government Printing Office, March 1981

27. Bird, George T. and G. Ronald Herd. "Avionics Reliability Control During Development." NATO Advisory Group for Aerospace Research and Development (AGARD) Lecture Series No. 81 on Avionics Design for Reliability. I.1-I.11. New York: Technical Editing & Reproduction Ltd., March 1976.

28. Knott, Robert, Class S Parts. Telephone interview. DESC, Dayton OH, 10 March 1987.

29. Kapur, K. C. and L. R. Lamberson. Reliability in Engineering Design. New York: John Wiley & Sons, Inc., 1977.

30. Earles, Mary Eddins. Factors, Formulas, and Structures for Life Cycle Costing (Second Edition). Concord: Eddins-Earles, 1981.

31. Reliability Analysis Center. IC Quality Grades: Impact on System Reliability and Life Cycle Cost. SOAR-3. Rome: IIT (Winter 84/85).

32. ORACLE Users Manual (Draft). RADC, Griffiss AFB NY, undated.

33. Jones, Col Robert, Chief of Acquisition Logistics Division. Telephone interview. Space Division (SD/AL), Los Angeles AFS CA, 24 November 1986.

34. Wiesner, Jim, Senior Engineer. Telephone interview. Aerospace Corporation, El Segundo CA, 24 November 1986.

35. Borchers, Cyril L., Chief, Technical Support Section. Telephone interview. DESC, Dayton OH, 25 November 1986.

36. Borchers, Cyril L., Chief, Technical Support Section. Personal interview. DESC, Dayton OH, 21 & 22 August 1987.

37. Space Division, Air Force Systems Command. Memorandum to DESC. Subject: JAN Class S Operating Stock Computer Print-out (20 May 1986). Los Angeles AFS CA, 22 May 1986.

38. Lamiere, Richard, Assistant Deputy Program Manager for Logistics. Telephone interview. Milstar Program Office (ESD/SCML), Hanscom AFB MA, 18 August 1987.

39. Gorzella, Donna Marie, LCC Analyst. Telephone interview. MITRE Corporation, Bedford MA, 20 & 24 August 1987.

40. Weech, Margaret, Chief, Cost Estimating Division. Telephone interview. Electronic Systems Division (ESD/ACC), Hanscom AFB MA, 13 August 1987.

41. Del La Russo, Frank, Senior Engineer. Telephone interview. MITRE Corporation, Bedford MA, 13 August 1987.

VITA

Captain David B. Francis was born on 19 April 1955 at Nellis AFB, Nevada. In 1978, he graduated from California State University, Long Beach, with a Bachelor of Science degree in Business Administration. He received a commission in the USAF through OTS in 1979 and was assigned to Space Division (SD), Los Angeles AFS, California. At SD, he served in the Launch Vehicles directorate in program control for the AF Space Shuttle Mission Operations and Integration Program Office and as program manager for implementing security systems in the NASA Tracking and Data Relay Satellite System. While at SD he received an MBA at California State University, Dominguez Hills. In 1983, he completed Squadron Officers School and was reassigned to the Electronic Systems Division (ESD), Hanscom AFB, Massachusetts. While at ESD, he was Chief of Program Control for the Milstar Terminal Program Office and program manager of the Milstar terminal development for the Minuteman Missile Weapon System. He entered the School of Systems and Logistics, Air Force Institute of Technology, in May 1986.

Captain Francis is married to the former Mary Hennessy, of Boston, Massachusetts.

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Abstract

The current emphasis on increasing the Air Force's war-fighting capability has pushed reliability to the forefront. One successful method used to increase the reliability of satellite systems is the use of expensive, but highly reliable, class S electronic parts as opposed to the class B parts normally used in avionics and ground electronic systems. Using MIL-HDBK-217D, the author predicted range of potential gains in reliability caused by substituting class S parts for class B parts for five avionics systems. Then the cost versus quantity relationship was used to calculate potential costs for quantity buys of class S parts. MITRE's Milstar life cycle cost (LCC) model was used to calculate the change in LCC due to the higher reliabilities and new acquisition costs. The research found that significant LCC savings were possible when class S parts were substituted for class B parts.