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A PRIME CONTRACTOR'S RELIABILITY PROGRAM FOR COMPONENTS/PARTS FOR THE DOUGLAS S-IVB STAGE PROJECT

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Abstract

Douglas conducts parallel reliability program activities: Supplier Surveillance for special purchased components, and a Standard Parts program.

Hardware items, whose single failure can cause loss of the mission, are identified by analysis and designated "flight critical." For the Supplier Surveillance activity, special flight critical items that are developed by suppliers have a complementary reliability engineering program plan structured to Douglas Reliability Requirements Specifications that are a part of the contractual obligations extant between Douglas and NASA. The plan becomes a contractual instrument between Douglas and the supplier. Progress on the plan is monitored and fostered by Douglas Supplier Reliability Surveillance Engineers.

Periodically, status of the special hardware development and its complementary reliability engineering plan is recapitulated. The Standard Parts program activity develops and maintains Approved Parts Lists, with a supporting list of qualified parts suppliers.

Management control forms and charts for the above are described in the paper.

Credit

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Introduction

Vital activities of the Douglas S-IVB Reliability Engineering Plan cover Supplier Surveillance for the development of special purchased components and an adequate Standard Parts program. Supplier Surveillance provides guidance to the network of suppliers in their conduct of systematic and orderly project management techniques in order to foster development of system-unique hardware reliability within the constraints of project cost and time schedule. This is the responsibility of the S-IVB Reliability Engineering Branch. The Standard Parts program provides approved lists of supplied parts for selection by the designer. Responsibility for the S-IVB parts program is assigned to the Component Standards Branch, a design organization for the Missile and Space Systems Division of Douglas.

Douglas regards an overall project reliability program as consisting of two major portions. In the normal course of development, the first major portion, the Reliability Engineering Program, is followed by the second major portion, the Reliability Assurance Program. Of course, there is considerable overlap. Activities during the former are directed towards achievement of desired design reliability by the focusing of all available experience on the technical development problems at hand. A number of techniques are employed for this purpose, such as design analysis, design review, collection of failure history from both sources within and sources external to the project for application to design improvement, numerical evaluation of development progress, and testing to appropriate environmental criteria. Activities during the Reliability Assurance Program are directed towards maintenance of the designed level of reliability during manufacture and use of the hardware. Reliability Assurance activities that are oriented towards suppliers, such as metrology control, source inspection, and incoming inspection and acceptance testing, are not discussed in this paper.

The objective of this paper is to present a description of what we believe to be successfully managed components/parts cost-effective programs, integrated into development of the Douglas Saturn S-IVB Stage. Procedures, controls, and techniques are described. Forms and charts are illustrated.

Supplier Surveillance

Douglas Reliability Engineering Program

Douglas's Reliability Engineering activities, that complement the development of the Saturn S-IVB Stage, concentrate on "flight critical" items. These are items whose single failure can cause loss of the mission. Activities on these items are pace-setting for the development of the rest of the stage hardware, i.e., product assurance requirements set for these items tend to pull along (in a "Pied Piper" fashion) development of reliability in the rest of the stage hardware. Determination of flight critical items has been described previously; it is sufficient to state that the determination is the result of a careful design analysis, taking into account the effect on stage performance of the various generic failures that the items can experience without regard to the causes of the failures.

After determination of the list of flight critical items, further analysis is carried out to rank the items in order of highest criticality first. Those critical items that are to be purchased are identified, and come under cognizance of the Supplier Surveillance Group within Douglas Reliability Engineering for execution of appropriate reliability development requirements. In the majority of cases, these items are made up of several parts.

Specifications

During definition of the Saturn S-IVB Stage contractual Reliability Program Plan with NASA, Douglas included two Reliability Requirements

Specifications for describing special supplier reliability engineering activities. One specification is termed for "Major Critical Items," and the other for "General Critical Items."

These specifications are for appropriate callout in the item procurement Specification Control Drawings. It was felt that the topmost dozen or so items on the ranked criticality list, the Major Critical Items, deserved detailed and thorough reliability development attention, but that there was no need to confront a potential general critical item supplier with a requirement for an extensive reliability program for preparation of his cost proposal. More about this later.

The Reliability Requirements Specifications include the following topics; the entire list is for the "majors," those topics asterisked are generally required for the "generals" (other topics may be added as appropriate):

*Preparation of Supplier's Reliability Program Plan

*Description of Supplier's Reliability Organization

Failure Mode Cause Analysis (FMCA)

Failure Mode Frequency Analysis

Preventive Evaluation

Quantitative Reliability

*Similar Item Failure History

Design Review and Procedure

Material Control Procedure

Change Control Procedure

Failed Part Review Procedure

*Failure Analysis and Corrective Action Procedure

Test Program

*Progress Reports and Documentation

The Reliability Requirements Specifications are outlines to which suppliers' reliability program plans are structured, together with calendar milestones for task accomplishment. The reliability effort complements the design development effort.

Douglas Supplier Reliability Surveillance Engineers evaluate each supplier on an individual basis with respect to the requirements of the appropriate Reliability Requirements Specification for establishment of his reliability engineering program plan. To derive the most benefit from the supplier's reliability engineering effort, action should begin with the design-development phase of the item. However, if the supplier's design analysis should occur after the design-development phase of the item, it still has value in that it confirms or supplements design analytical prediction of performance for the critical item. The supplier Reliability Engineering Program Plan covers technical efforts up to finalization of the item drawings and specifications. Thereafter, Reliability Assurance techniques take over to the degree specified in the item specification drawing.

Major Critical Items-Program

Program plans for Major Critical Items will usually encompass all the tasks described in the requirements specification. Supplier reliability program plans, submitted to the General Reliability Requirements Specification, will have more variation than program plans meeting the requirements of a major critical item. Reasons are:

a. Relative item design complexity.

b. Off-the-shelf versus new design concept.

c. State of development at the time reliability requirements are invoked.

d. Supplier's relative reliability engineering capability versus item criticality.

For example, little or no emphasis should be placed on tasks that would tend to influence the early basic design of an item if the supplier's design is an off-the-shelf item with minor adaptations to Douglas requirements. In this case, the supplier's reliability engineering program should be structured to concentrate on the item development test phase, including the submittal of available design and test data, historical similar parts data, and applicable reports. Likewise, the same kind of a reliability program plan should apply if late introduction of reliability requirements is applied to an item already into the test phase.

In this fashion, plans are tailored to complement individual hardware developments, with an eye to minimizing inappropriate effort and unnecessary cost. Thus, for money expended, reliability and system effectiveness are optimized.

The plan becomes the contractual instrument between Douglas and the supplier. Progress on the plan is monitored and fostered by Douglas Supplier Surveillance Engineers.

Supplier's Reliability Program Assurance

During the initiation of the supplier's reliability program plan, frequent contact and visits are in order to assure that the plan is well structured and progresses in a manner benefiting the overall program. Otherwise, visits are made only when nonconformance to the supplier's reliability program plan milestones is evident and, in addition, the hardware development to which the plan applies is in difficulty.

Supplier Surveillance personnel are instructed to avoid expressing opinions or recommendations to supplier personnel pertaining to any aspects of design, test, or concomitant procedures, though questions about these subjects may be asked. Guidance to the supplier is limited to clarification or interpretation of Reliability Engineering Requirements contractually imposed on the supplier. Any matters that have cost or schedule impact are unofficial until covered by proper contractual documentation from Douglas Procurement.

Conversations with supplier personnel are covered by internal reports. All cognizant Douglas technical sections receive copies of the report, whether or not they participate in the supplier conversation. Any suggestions or recommendations by Supplier Surveillance to any of the cognizant Douglas Sections, on matters other than the Reliability Engineering Requirement, are discussed and coordinated with the cognizant section, which authorizes and takes appropriate implementing action through Douglas Procurement.

Periodically, status of the development and its complementary reliability engineering plan is recapitulated. The recap forms, figures 1 and 2, are used to assist in this. These are working pieces of paper, and provide a place for systematically recording the facts which aid in making a decision as to whether or not the reliability plan activities need augmentation or diminution. These also aid in determining whether or not a supplier contact is in order by Supplier Surveillance. Status of qualification testing is reviewed and recorded; if there is difficulty manifested therein, as evidenced by functional failure records having been written against the item, this is cause for additional Supplier Surveillance effort. Current criticality ranking is verified and noted. A change in criticality ranking, as a result of a specific one-time mission requirement, can cause renegotiation of reliability program requirements. Accomplishment of reliability requirements to date is noted on the form, figure 2, and summarized for entry on the form, figure 1. Note that there is a place on form, figure 1, for a forecast of manhours effort to carry on surveillance; thus, the form aids administration of both Supplier Surveillance effort and travel.

To follow progress of the respective suppliers in meeting their milestones, an office chart is maintained. This is illustrated in figure 3. When a scheduled milestone is met, its symbol on this calendar chart is flagged. The current date line is moved with passage of time. Symbols signify appropriate topics in the supplier's reliability program plan.

In describing the Douglas S-IVB project Reliability Engineering Supplier Surveillance program, features that are believed of interest have been highlighted. All details of the program by no means are covered. The activities are controlled to optimize design reliability achieved per program dollar expended, which optimizes cost effectiveness.

S-IVB Standard Parts Program

Common Deficiencies of Early Space Projects

Early national space projects had suffered a common deficiency: a lack of firm parts management programs. This had resulted in much unnecessary testing, increased logistics problems, and use of unreliable parts. It had also prevented the accumulation of reliability data which could have been obtained had there been organized parts programs. Further, it should be noted that parts program elements contributing to reduce cost, such as standardization, reduction in part types, and selection of qualified suppliers, also contribute to reliability.

MSSD Components Standard Parts Program

The Douglas MSSD Components Standards Branch has an efficient, well organized program that results in the selection and application of reliable parts at minimal cost, to help achieve the high level of reliability required for the S-IVB Program.

Features of the parts program are to:

a. Develop and maintain Approved Parts Lists (APL's) for program usage.

b. Provide consultation to the designers on the proper application of parts.

c. Maintain a list of qualified parts suppliers.

d. Perform part failure analysis and initiate corrective action.

e. Prepare and implement standard part procurement specifications.

f. Establish part test requirements and monitor tests.

g. Anticipate future part requirements and maintain a continuing part research and evaluation program.

h. Participate in government and industry part standardization programs.

i. Maintain standard manuals.

j. Monitor parts usage to insure the use of approved parts.

A listing of all parts which are acceptable for the S-IVB Program has been accumulated and incorporated into the Douglas S-IVB APL's (one for stage and one for GSE). Only those parts for the categories covered, that are on these lists, may be selected for use in design. In compiling the APL's, NASA-Marshall Space Flight Center (MSFC) documents were used as basic guide lines. Other parts were added, selected from military, industry, and Douglas standards, or from other Douglas programs. Listing of these parts is substantiated by test and/or operational data.

Parts Selection

The parts selection for the actual part application is the combined responsibility of: the Component Standards Branch, the S-IVB Reliability Engineering Branch, and the cognizant S-IVB Design Branch. The Reliability Engineering Branch identifies those items that are considered critical from a reliability standpoint and the Design Branch selects the part that will achieve the highest system reliability. Every effort is made to limit the number of different types of parts in order to expend maximum effort on reliability improvement of those selected.

Approved Parts Lists Changes

The Approved Parts Lists (APL's) are updated in order to be responsive to design needs and remain in stride with advancements in technology. These changes are made with the approval of the part

specialist and the cognizant S-IVB Design Branch Supervisor. Changes are brought about either by a designer endeavoring to justify the need for a new part, or by the parts specialist offering a better solution to the design problem. The specialist reviews the APL Change Request for adequacy of justification. An approved request sometimes results in a Douglas specification to develop the new part, or the upgrading of a part to meet higher performance and reliability requirements. The new specification is prepared only when the part specialist cannot satisfy the design requirements with an existing part, or when it has been determined that an adequate specification does not already exist. This new specification is issued to potential parts manufacturers for competitive bids. A detailed evaluation for each competitive bid is recorded on the Proposal Evaluation Form, figure 4. These forms provide for comparative ratings of the part being evaluated with respect to such things as detailed design, available test data, workmanship, conformance to Douglas specification requirements, and cost. Past performance of the manufacturer as to quality and delivery is included. The availability of the manufacturer's facility to produce parts of the desired quality and reliability is also evaluated.

Parts Specialist's Responsibilities

The parts specialist is sometimes required to visit the potential suppliers to discuss the specifications and evaluate each manufacturer's suggestions, comments, or deviations to the specification. Visits to the potential suppliers also aid the parts specialist in evaluating the manufacturer's capabilities.

The preparation of parts specifications such as semiconductors, resistors, capacitors, wire or cable, transformers, relays, switches, fluid fittings, fasteners, bearings, etc., is the responsibility of the part specialist. When a part is qualified to the new specification, it is added to the APL.

Additional duties of the parts specialist require him to perform part failure analysis, and to document these analyses by formal reports. These failure analyses are frequently performed at the supplier's facility, and sometimes result in redesign of the subsystem in which the part is installed, or definition of a new part specification.

Parts Program Effectiveness Assurance

To assure effectiveness of the parts program, a controlled sequence of monitoring checks is carried out. The first check is during Formal Design Review, which is conducted by the S-IVB Program Design Office, and in which both the Component Standards Branch and the Reliability Engineering Branch participate to provide consultation on the application of parts. The second check is made when advanced material orders are submitted to the Component Standards Branch for signoff prior to release. The third check is made by the Engineering Drawing Check Section prior to the engineering drawing release. The fourth check is made by the Component Standards Branch by reviewing the "mechanized list of material", a computer printout of all parts used on the S-IVB Program. These four monitoring operations assure the use of approved parts in S-IVB equipment.

Conclusions

Vigorous exercise of the parts program techniques results in both reduction of part types, and standardized parts procured from qualified suppliers. This brings about selection and application of reliable parts at an optimum cost, thus enhancing the probability of achievement of the high reliability goals in the S-IVB Program.

Techniques that Douglas employs for optimizing reliability development, per supplier's program dollar expended, have been emphasized. Each supplier's reliability engineering activities are tailored to the hardware and to its reliability requirements. Followup activities are administered with an eye to the dynamics of the technological development picture as the program unfolds, as well as on the Douglas travel budget. Continuous management surveillance of the pertinent factors is provided, benefiting both Douglas and the customer.

References

1. R. L. Parkhill and J. Pauperas, Jr., "Component Failure Effect on Systems: An Analytic Model," IEEE Fourth Annual Seminar on Reliability For Space Vehicles, December 1963.

PART NO. VENDOR NOMENCLATURE Date FLIGHT CRITICAL

STAGES 201 202 203 204 501 SUBS.

1. CRITICALITY:
2. QUAL. TEST STATUS: AT: DAC/VENDOR
3. RELIABILITY ANALYSIS OPINION OF DESIGN ADEQUACY
4. FAILURE ANALYSIS RECORDS
5. SUPPLIER ACCOMPLISHMENTS TO IRPP REQUIREMENTS
6. JUDGMENT:
   a. Suppliers Plan Remaining To Be Accomplished
   b. Additional Items In Supplier Data Acquisition
7. SET JUDGMENT REQUIREMENT CALENDAR

SHOW ALL VISITS "V"

Hours Spent Est.	1964						1965												1966											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

8. RECOMMENDED CATEGORY

FIGURE 1

MAJOR FLIGHT CRITICAL ITEMS SPECIFICATION REVIEW

1B 54556		1	2	3	4	5
3.1.2	ADDITIONAL REQUIREMENTS (SCD)					
3.1.3	PREVIOUS REQUIREMENTS (400-2)					
3.1.4	VARIATIONS AND SUBMITTALS (VIR-DDR)					
3.2.1	INSPECTION RIGHTS					
3.2.2	TEST SCHEDULING ADVANCE NOTICE					
3.3	RELIABILITY PROGRAM PLAN (SEE 3.5.1-6)					
3.4.1	ORGANIZATION STATUS AND AUTHORITY					
3.4.2	ORGANIZATION CHART					
3.4.3	ORGANIZATION FUNCTIONS					
3.5.1	FAILURE MODE ANALYSIS					
3.5.1.1	FAILURE MODE CAUSE ANALYSIS					
3.5.1.2	FAILURE MODE FREQUENCY ANALYSIS					
3.5.1.3	PREVENTIVE EVALUATION					
3.5.2	QUANTITATIVE RELIABILITY					
3.5.3	BLOCK DIAGRAM					
3.5.4	FAILURE ANALYSIS PARTICIPATION					
3.5.5	SIMILAR ITEM FAILURE HISTORY					
3.5.6	DOCUMENTATION					
3.6.1	DESIGN REVIEW DESCRIPTION					
3.6.2	PROCEDURE					
3.6.3	TECHNICAL CONSIDERATIONS					
3.7.1	DOCUMENTATION LIST SPECIFICATIONS STANDARDS PROCEDURES					
3.8.1	DESIGN EVALUATION					
3.8.2	SECOND TIER SUPPLIER SURVEILLANCE PROCEDURE					
3.8.3	MATERIAL SELECTION & QUALIFICATION					
3.9	CHANGE CONTROL					
3.10	FAILED ITEM REVIEW PROCEDURE					
3.11	SUPPLIER INITIATED FAILURE ANALYSIS					
3.11.2	FAILURE ANALYSIS OF RETURNED PARTS					
3.12	IDENTIFICATION					
3.13	SUPPLIERS TEST PROGRAM & DOCUMENTATION					
3.14	RELIABILITY PROGRESS REPORTS					

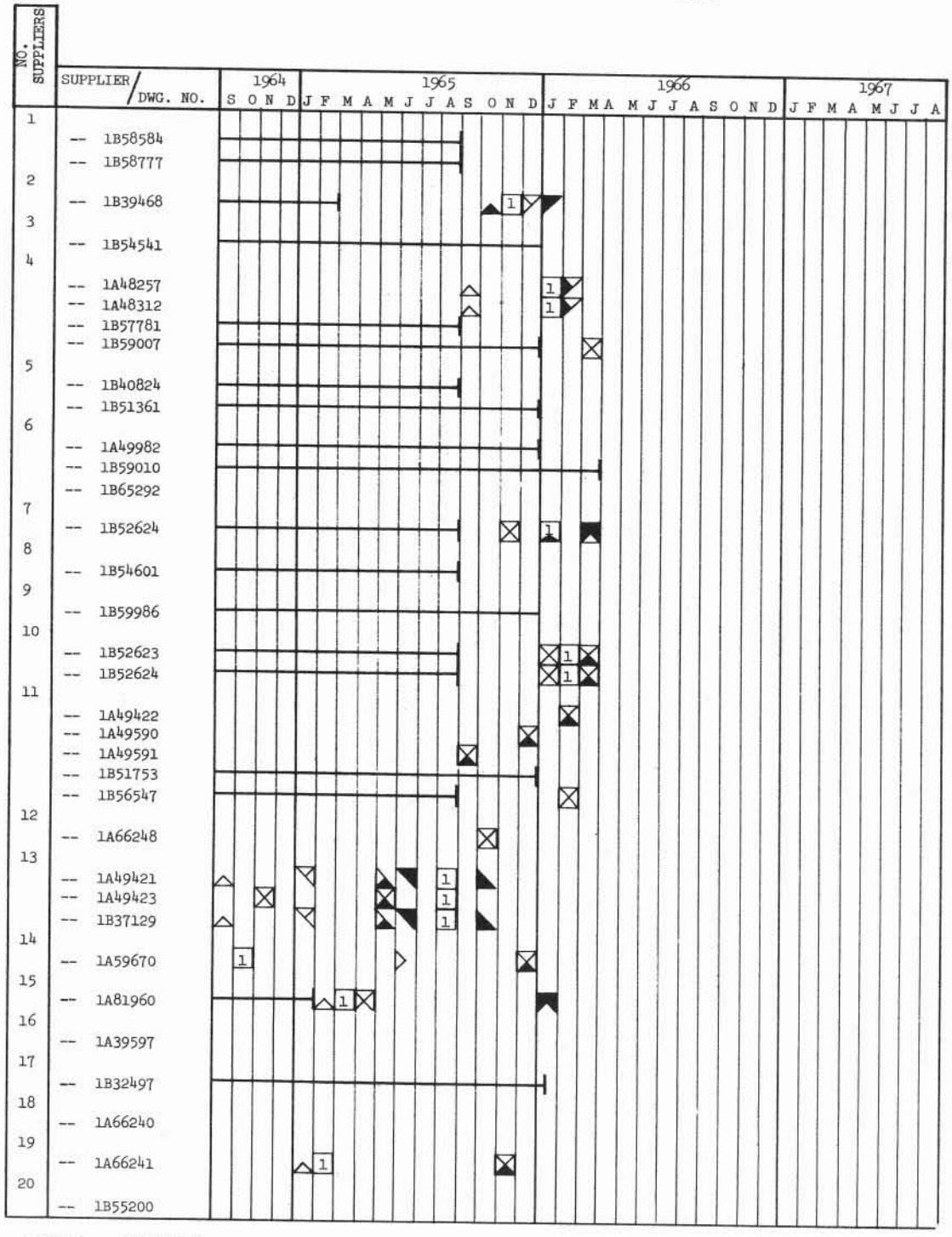
FIGURE 2
(SHEET 1)

FLIGHT CRITICAL ITEMS SPECIFICATION REVIEW

1B 55245	1A 86975		1	2	3	4	5
	3.1	MEANTIME BETWEEN FAILURE					
3.1.1		RELIABILITY REQUIREMENTS					
	3.1.1	RELIABILITY ESTIMATES					
	b.	SERVICE LIFE					
	c.	SERVICE LIFE & ACCEPTANCE TEST ENVIRONMENT					
	d.	DATA CENSORING CRITERIA (What is a Failure)					
	e.	SIMILAR ITEM FAILURE HISTORY					
	f.	ENVIRONMENTS EXISTING WHEN FAILURES OCCURRED					
3.1.2		PREVIOUS REQUIREMENTS (RCS 400-2)					
	3.1.2	SUBSTANTIATION-RELIABILITY ESTIMATES					
	a.	SIMILAR PART FAILURE RATES					
	b.	TOTAL NO. FAILURES THIS ITEM DURING TEST					
	c.	EXPECTED & EXISTING FAILURE MODES AND FREQUENCY-OCCURRENCE					
	d.	EXISTING OPERATING TIME TOTAL ALL ITEM OR SINGLE ITEM REPORTS					
3.1.3		VARIATIONS & DATA SUBMITTALS (VIR)					
3.2.1		INSPECTION RIGHTS					
3.2.2		TEST SCHEDULING NOTIFICATION					
	3.2	REPORTS AND DATA REQUIRED					
	a.	ESTIMATE (3.1.2) UPDATED WITH PROGRESS REPORT					
	b.	TEST RESULTS					
	c.	ACCEPTANCE TEST PROCEDURES					
	d.	OPERATING TIME AND ENVIRONMENT					
	e.	TEST PLAN					
3.3	f.	PROGRAM PLAN - ANTICIPATED TASKS, MILESTONE CHART					
	g.	IN-HOUSE REJECTIONS AND FAILURE ANALYSIS					
	h.	FAILURE ANALYSIS OF ITEMS ON FORM 60-732 and 60-7321 AND DISASSEMBLY OBSERVATION OF FAILED ITEM					
3.3		FAILURE MODE CAUSE ANALYSIS					
3.3		RELIABILITY PREDICTIONS					
3.3		FAILURE RATE SUBSTANTIATION					
3.3		BLOCK DIAGRAM					
3.3		FAILURE REVIEW PROCEDURES					
3.4.1		ORGANIZATION STATUS AND AUTHORITY					
3.4.2		ORGANIZATION CHART					
3.4.3		ORGANIZATION FUNCTIONS					
3.5		SIMILAR ITEM FAILURE HISTORY					
3.6		DOCUMENTATION					
3.7		FAILURE ANALYSIS					
3.8		SUPPLIER RELIABILITY PROGRESS REPORT					

FIGURE 2
(SHEET 2)

ACTIVE FCI SUPPLIER SURVEILLANCE CALENDAR



LEGEND: MILESTONES: ANTICIPATED APPROVED

1 INITIATE PROCUREMENT
2 RELIABILITY PLAN
3 FAILURE MODE CAUSE ANALYSIS
4 FAILURE HISTORY - SIMILAR PARTS
5 PREDICTIONS
6 FIRST PROGRESS REPORT

FIGURE 3

COMPONENT STANDARDS BRANCH

EVALUATION OF PROPOSALS FROM VENDORS

PART NUMBER	NAME		
DESCRIPTION			
CODE	PROSPECTIVE VENDOR	ORDER OF PREFERENCE	REMARKS
A			
B			
C			
D			
E			
F			

EVALUATION

CHARACTERISTICS		POSSIBLE POINTS	VENDOR						REMARKS
			A	B	C	D	E	F	
REPORT EVALUATION	DAC REPORTS								
	IDEP REPORTS								
	OTHER REPORTS								
TECHNICAL REVIEW OF PROPOSAL									
FACILITIES									
SCHEDULING									
PAST PERFORMANCE									
LOCAL REPRESENTATION									
VENDOR COOPERATION									
PRESENTATION OF PROPOSAL									
COST									
TOTAL									

SPECIALIST: DATE:

FIRST ISSUE: REVISION:

FIGURE 4