NASA SP-6505

PARTS AND MATERIALS APPLICATION REVIEW FOR SPACE SYSTEMS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PARTS AND MATERIALS APPLICATION REVIEW FOR SPACE SYSTEMS

Written under contract at the Baltimore Division
of the Martin Marietta Corporation for the
Reliability and Quality Assurance Office,
NASA Headquarters

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Foreword

Parts and materials application review is one of the activities prescribed in NASA Reliability Publication NPC 250-1 entitled "Reliability Program Provisions for Space Systems Contractors." As described therein, this function calls for: (1) reviewing the applicability of each part and associated materials in each component to assure their adequacy in meeting mission requirements, (2) documenting these reviews, and (3) using them as an input to formal design reviews.

Consistent with the scope and purpose of NPC 250-1, the above provision permits latitude in selecting implementation approaches to fit specific requirements of different projects. However, there is need for some further illustration of the implementation of the application review requirement to highlight means for:

(1) Efficiently documenting the data on which the reviews will be based
(2) Conducting the reviews in a manner which will enable them to support the design review program most effectively
(3) Efficiently selecting the scope of application-review efforts to meet requirements of various projects

It is the intent of this document to provide this illustration by first describing a logical consideration of the pertinent requirements of each design and then matching appropriate review activities to meet them.

The principal author of this document is Mr. J. P. Craig, assisted by Mr. R. E. Boss and Mr. S. J. Henkel, Jr., all of the Martin Marietta Corp., and the effort has been guided and the material edited by Mr. D. S. Liberman of this office. In addition, significant assistance in arriving at the final version has been provided through the constructive comments of NASA Headquarters offices and NASA field installations, and this is gratefully acknowledged.

It is emphasized that the particular method shown here for applying application-review activities, while valid and useful, is only an illustration of one approach and is not to be considered mandatory. However, the descriptions of the <u>elements</u> of review activity should be considered basic in their general aspect, although various implementation schemes may require variations in specific details.

John E. Condon, Director
Reliability and Quality Assurance
Office of Industry Affairs
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CHAPTER 1

Introduction

PURPOSE

Through contract requirements which reference NPC 250-1 (ref. 1), NASA causes its space systems contractors to implement a program to select, reduce in number of types, specify, qualify, and review the application of parts and materials in all hardware in their systems. This effort is called the parts and materials program. NASA also requires a program of design reviews, extending down to the component (black box) level. The parts and materials application review provides an assurance input to design review that the basic parts and materials have been correctly applied in the system hardware design.[1]

The purpose of the present document is to define the parts and materials application-review activity for project management and to provide a guide for the performance of effective reviews by parts and materials specialists and design engineers.

BRIEF DISCUSSION OF APPLICATION REVIEW

The parts and materials application review is intended to assure that the parts and associated materials in each component of the system hardware are adequate for their use. This review constitutes a documented, item-by-item verification that each such usage meets specified design requirements with adequate margins of safety based on mission requirements for the component in question. Although identified as a task under the parts and materials program, the application review serves functionally as an element of design review and is conducted by technical-level contractor personnel prior to each design review meeting for each component. Its purpose is to facilitate the examination of the soundness of each part and material usage in the component without burdening the formal design review meeting with this exhaustively detailed activity. The report of each application review, which identifies parts and materials problems in the design, is an essential input to the corresponding formal design review. Decisions on disposition of any problems are made in the design review of the component. Although the basic techniques of application reviews are potentially applicable to any component, most projects will find application review to be of most use with electronic components.

In practice, application review will be the primary tool for achieving detailed scrutiny of parts applications but will usually be only a secondary means of reviewing materials applications. This does not imply that the proper application of materials is less important but that it is usual to perform a significant portion of the review of materials applications in the design review meeting itself, rather than as a separate activity. Nevertheless, a certain amount of materials review is logically an integral element of the review of parts applications, particularly in regard to:

[1]Both the parts and materials program and the design review program are elements of the complete contractor reliability program called for in NPC 250-1 (ref. 1). The purpose, functions, and techniques of design review are described in a companion document (ref. 2). For further information on design review, refer to these publications.

(1) Flammability and outgassing properties of the parts
(2) Compatibility of leads with metals-joining processes
(3) Compatibility of parts surfaces with coatings and encapsulants
(4) Environmental resistance and physical and electrical properties of coatings, encapsulants, and insulating materials

CONTENTS OF THIS PUBLICATION

Chapter 2 describes briefly the parts and materials program which bears directly upon the design function and is the basis for application review. This chapter emphasizes those aspects of the parts and materials program which have the greatest impact on the application-review activity. A more detailed discussion of the parts and materials program is given in the appendix.

The application review is considered independently in chapter 3. The discussion therein describes the factors affecting the depth of application review as well as the phasing of reviews and their content in relation to project milestones. The elements of review activity also are defined and documentation methods are suggested which support the normal part-selection process in a manner which is also readily useable for application review.

Finally, chapter 4 discusses the structuring of a program of application reviews and describes a method for selecting the scope of review activities appropriate to various levels of project requirements. This method is illustrated by examples of activity appropriate to the character of several different types of projects and their hardware.

CHAPTER 2

Related Parts and Materials Program Activities

The parts and materials program selects and guides the application of parts and materials in the system hardware. This is the basic "action" activity which application review scrutinizes. Two aspects of the parts and materials program are particularly important in this regard:

(1) For the application-review activity to have meaning, the parts and materials program must have a reasonably high level of effectiveness and adequacy in performing its design support function.
(2) The parts and materials program must generate or obtain all pertinent data for selection and application of the parts and materials. For efficiency, it should also plan its normal selection guidance and application documentation to present these data in a form readily useable in application review.

This chapter briefly summarizes some of the more pertinent activities of the parts and materials program relating to the factors cited above. A more detailed treatment is given in the appendix.

The parts and materials program comprises a number of activities among which are selection, specification, qualification, testing, source selection and control, documentation, applications guidance, application review, and field support. The first six of these activities support the process of selecting and assuring the capability of a list of parts suitable for applications on the project. The function of application guidance includes not only the provision of lists but also direct consultation with designers to assist them in selecting parts with optimum capability for specific design requirements. Application review is a doublecheck and provides assurance that all these activities have resulted in satisfactory use of parts in the design. Finally, field support is a followup function providing support to the project in its later phases for solving parts and materials problems that arise in operational use of the system and for accumulating field experience data for follow-on tasks or for future programs.

PROJECT PHILOSOPHIES AND CONTROLS

The foundations of the parts and materials program activities stem from the project guidelines and controls and cover such areas as:

(1) The scope of the parts program
(2) Overall rules for derating
(3) Parts and materials requirements for components built by subcontractors
(4) General project data requirements
(5) Configuration control of hardware
(6) Parts and materials tests and handling disciplines
(7) Parts and materials procurement practices

PRELIMINARY PARTS AND MATERIALS LISTS

The first step in parts and materials selection, following establishment of project philosophies and controls, is the preparation of preliminary parts and materials lists. These lists are prepared and used during early design and breadboarding and are refined through the various parts and materials program activities into project approved parts and materials lists for use in the final design- and flight-approved hardware.

The preliminary parts list for the project is generated by observing environments, reliability apportionments, and design approaches during the conceptual phase of design and using these requirements to select an appropriate list of parts, usually from those appearing on previous parts lists. Previous lists might include other project lists, company-preferred lists, or customer-preferred parts lists; frequently the contract will cite the specific lists to be used. Only parts with good histories and substantial background data should be included on the project preliminary parts list. One of the prime functions of the parts program is to qualify these parts on the preliminary list or to justify the selection of available alternates. A typical format for a project preliminary parts list is shown as exhibit A-1 in the appendix.

A preliminary materials list (PML) identical in purpose to the preliminary parts list should be generated simultaneously with it. Parameters much the same as those that affect parts selection (i.e., stress, loads, environment, fatigue, failure probability, and, of course, function) should be considered in its preparation. Although the use of a single project format is generally accepted practice for the preliminary parts list, projects will frequently provide the PML data by supplementing the standard materials selection data form (see exhibit A-2 in the appendix) with a separate listing which identifies each material with its suitability for specifically defined application categories within the system hardware.

Early activities of the parts and materials program center largely upon the selection of parts and materials and verification of their capability to meet part specification requirements and to perform in particular applications. Initial selections should be made directly from the preliminary parts and materials lists wherever possible, although this restriction may require early trade-off in such matters as whether to use a promising design concept which will involve the risk of using parts of less known capability.

Later, when the functional design breadboard is complete, a final choice of parts and materials for each component will be made and then verified by qualification testing of each component[2] in which they are used. This final selection will in turn evolve into the project approved parts and materials lists which will be the basis for control of parts and materials usage for the project hardware.

SPECIFICATIONS

Each listed part or material must be identified and fully described by means of a drawing or specification which prescribes physical, environmental, and functional attributes and quality controls for the item. These specifications or drawings provide the bases for procurement and the standards for part qualification. Existing specifications should be used wherever they are adequate, since this will result in considerable economies in several areas; however, where they do not satisfy project or system requirements, either modified or completely new specifications and/or specification control drawings must be prepared.

TESTING

The performance capability as well as the quality of parts and materials must be supported by test data. However, wise use of existing data from established data banks, previous inhouse tests, and vendor tests is necessary to restrain costs and to keep the total test effort within manageable proportions. If existing data are inadequate, evaluation or qualification tests will be necessary to establish parts and materials capability for selection and procurement. Once

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[2]Qualification testing of the component does not preclude qualification testing of the parts. See the discussion entitled "Specification" in the appendix.

the capability of the parts and materials has been established, acceptance testing is required to assure that the inherent capability is retained throughout manufacture and delivery. The extent and method of testing are dependent upon the prevalent failure mode of the part or material, the quantity being procured, the level of reliability required, and the acceptable risk.

APPLICATION GUIDANCE AND DERATING

The selection and qualification of "good" parts and their inclusion on a parts list does not assure proper application of these parts in the hardware design. Parts qualification only assures that the part design can meet the requirements of the part specification. Proper application of the parts requires that the parts be employed safely within components for tasks where the anticipated usage stresses are somewhat less or much less than the rated performance and environmental capability of the part itself. The extent of this difference between rating and usage stress (called "derating" or "safety margin") will depend on:

(1) The expected variability of the actual part parameters from rated values
(2) The expected variability of the stresses in use
(3) The confidence placed in the calculations or measurements of part or material capability and of use stresses (the less well they are known, the more margin is needed)
(4) The reliability required of the part in the application

One of the most important functions of the parts and materials program is to stress a derating philosophy, policy, and associated practices for the parts on the preliminary parts list and to assess the factors listed above for all use applications in order to provide application guidance to designers. This guidance can be provided in various ways; the following steps are typical:

(1) Establish a small number of use categories into which all parts and materials applications may be classified. Each of these categories implies specified ranges of each important environmental parameter and some performance parameters.
(2) Identify parts and materials as to the use category for which they are generally applicable.
(3) Provide general derating guides for obtaining different levels of reliability for each part in various use categories.
(4) Provide consulting service to designers by parts and materials specialists to give specific application guidance to supplement the general application guidance above.

Generally, the provision of application guidance for materials is handled somewhat differently from that for parts because capability data are available for most materials for most of a project's environmentally defined use (or application) categories (e.g., refs. 3 and 4). This, in turn, simplifies preparation of a materials selection list which designers can use with little additional consultation for the majority of the applications. This list also reduces the material-suitability aspect of application review in these cases to a simple checkoff function.[3] It is true that special environmental or functional problems will frequently make necessary a materials selection and test program of considerable proportions. But, even under these conditions, completion of the test program is followed by a listed approval or disapproval of each material on the project approved materials list (AML) (see second section following) for the difficult use category. Most

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[3]The functional capability aspect of materials application is rarely considered to be other than a mainstream design function. Therefore, any detailed application review requirements in this area would take the form of special stress or compatibility analysis reports specially requested by the design reviewers.

projects tend to conduct any further questioning of the application suitability in the design review itself.

DOCUMENTATION

A large volume of data pertinent to the parts and materials program must usually be accumulated and organized during the life of a project. In general, these data deal with:

(1) The performance and environmental capability of parts and materials
(2) The usage stresses under which the parts and materials must function in the system hardware

These two classes of data represent the basic information which application review must scrutinize in order to assure that each part and material in each component is applied correctly. It is therefore of particular importance for effective and efficient application review that the parts and materials program plan for the normal documentation of its activities from the outset is in a form which is readily adaptable to—or directly useable in—application review. The general application guidance data cited in the foregoing paragraphs can be of some use in conveniently summarizing parts and materials capability. Well-devised project-approved parts and materials list formats can be even more helpful in this respect; these are discussed in a subsequent paragraph.

The part selection worksheet should be used to summarize usage requirements for each part and associated material application in a component. This item, which is a primary tool used by the designer, displays on a part-by-part basis the pertinent part capability data alongside the corresponding application requirement data (e.g., design parameter limits, stress and dissipation levels, environmental limits, reliability levels, and derating factors or safety margins). Typical formats of these worksheets are shown in exhibit 1.

A well-devised selection worksheet format (and good project discipline regarding its use) is of significant value, not only later in application review but immediately in reducing the number of misapplications in the initial design of the component. This is accomplished by helping the designer keep specific use requirements fully visible while making his part selections.

As the development cycle proceeds, the data pertinent to parts and materials capabilities and their applications must be updated to incorporate new test results and refined estimates of application stresses and requirements. Failure and failure-analysis information must be a part of this updated data. For the later application reviews all this new information must be included in the documentation to be reviewed.

PROJECT APPROVED PARTS AND MATERIALS LISTS

The approved parts and materials lists (APL and AML) for a project summarize the results of a large portion of the activity of the parts and materials program. Entering an item on an APL or AML for the project certifies that all engineering requirements for the specific uses have been met; qualification tests, failure rate investigations, and manufacturer and vendor determinations are satisfactorily completed (or, if not, that a decision has been made to accept some defined risk from this source); and that drawings and/or specifications for the part or material are satisfactory. Ideally the format for the project APL and AML should reflect these items of information specifically. A typical APL format is shown as exhibit 2. It may be noted that this sample format is also useful for configuration control, since it provides broad traceability to the applications of each part and lists the governing specification and revision letter for it. (See also the discussion under this same heading in the appendix.) An AML format, though differing in detail, would be designed to provide materials information analogous to the parts information provided by the APL.

The APL and AML can also serve as basic controls over accepting changes in specifications and part drawings and can reveal areas for further standardization. From a project standpoint,

PARTS APPLICATION RECORD—RESISTORS

PROGRAM ____________ "NAME" APPORTIONED FR & CONF. 150/10⁶HR.@60% CONF

COMPONENT ____________ 263-425-4623 APPORTIONED FR & CONF. 30/10⁶HR.@60% CONF.

MODULE ____________ 263-425-4623-2

THIS FORM IS PARTIAL
PARTS APPLICATION RE
SIMILAR MANNER.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CIRCUIT DESIGNATION	MFR	MFR P/N	GOVT SPEC	GOVT P/N	RESISTANCE	TOLERANCE	TYPE	RATED PWR	RATED VOLTAGE	RATING TEMP	ESTABLISHED OR GENERIC FR & CONF. LEVEL	APPLICATION TEMP a	% RATED PWR	% RATED VOLTAGE	VIBRATION
R1	IRC	GEM			1K	1%	METAL FILM	1/10	200	125°C		60°C	50	20	

MIL-R-55182

RNR55C1001FM

1%/1000 HRS (ESTABLISHED)
AT 60% CONFIDENCE

20g FROM 0 TO 2000 HZ

50g, 11 MILLISEC

(THIS COLUMN FOR SPECIAL ENVIRON
SUCH AS STERILIZATION, NUCLEAR RA
OR HARD VACUUM)

a- limit or range

PARTS APPLICATION RECORD—CAPACITORS

PROGRAM ____________ ____________ APPORTIONED FR & CONF. ____________

COMPONENT ____________ ____________ APPORTIONED FR & CONF. ____________

MODULE ____________ ____________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CIRCUIT DESIGNATION	MFR	MFR P/N	GOVT SPEC	GOVT P/N	CAPACITANCE	TOLERANCE	TYPE	RATED DC VOLTAGE	RATED AC VOLTAGE	RATING TEMP	ESTABLISHED OR GENERIC FR & CONF. LEVEL	APPLICATION TEMP	DC VOLTAGE	AC VOLTAGE	AC FREQ

Exhibit 1. Typical parts application worksheet forr

...LY FILLED OUT FOR DESCRIPTIVE PURPOSES. THE REMAINING ...CORD FORMS IN THIS EXHIBIT ARE TO BE USED IN A

17	18	19	20	21
SHOCK	OTHER	VERIFIED BY TEST	USE FR & CONF. LEVEL	PARAMETERS FOR TYPE SELECTION
		YES		STABILITY REQUIRED

0.44%/1000 HR (BASED ON APPORTIONMENT AT 60% CONF.)

...ENTS ...IATION

(THIS COLUMN CITES WHICH OF THE PARAMETERS OR CRITICAL PART PROPERTIES ARE OF FIRST IMPORTANCE IN SELECTING THIS PART.)

...PLICATION REQUIREMENTS DATA

17	18	19	20	21	22
VIBRATION	SHOCK	OTHER	VERIFIED BY TEST	USE FR & CONF. LEVEL	PARAMETERS FOR TYPE SELECTION

...s.

Legend: FR, failure rate; CONF., confidence; MFR, manufacturer; P/N, part number; PWR, power; DSGN, designation of individual input or output to a specific circuit on a microcircuit chip; TOL, tolerance; COND., electrical-condition (e.g., bias); Θ_{JC}, thermal resistance, junction to case; Θ_{JA}, thermal resistance, junction to ambient; AMB, ambient; PIV, peak inverse voltage; VZ, zener voltage; T_J, junction temperature; V_{CB}, voltage between collector and base; V, voltage; BV_{CBO}, breakdown voltage between collector and base with emitter open.

6B -1

PARTS APPLICATI

PROGRAM ________ ________

COMPONENT ________ ________ APPORTIONED FR & CONFIDENCE ________

MODULE ________ ________ APPORTIONED FR & CONFIDENCE ________

1	2	3	4	5	6	7	8	9	10	11	11A	12	13	1
IDENTIFICATION							ELEC SUPPLY		INPUT			OUTPUTS		
DESCRIPTION	MFR	MFR'S P/N	GOVT SPEC	GOVT CIRCUIT NO.	TYPE	LOGIC SCHEME	V_{DC}	PWR AT 25°C	NO.	DSGN	LEVEL & TOL	DSGN	LOGIC	LE &

PARTS APPLICA

PROGRAM ________ ________

COMPONENT ________ ________ APPORTIONED FR & CONFIDENCE ________

MODULE ________ ________ APPORTIONED FR & CONFIDENCE ________

1	2	3	4	5	6	7	8	9	10	11	12	
IDENTIFICATION						ELEC SUPPLY		FREQ. RESPONSE	GAIN	INPUT IMPED-ANCE	OUTPU	
DESCRIPTION	MFR	MFR'S P/N	GOVT SPEC	GOVT CIRCUIT NO.	TYPE	V_{DC}	PWR				DESCRIPTION	V

PARTS A

PROGRAM ________ ________

COMPONENT ________ ________ APPORTIONED FR & CONFIDENCE ________

MODULE ________ ________ APPORTIONED FR & CONFIDENCE ________

1	2	3	4	5	6	7	8	9	10	11	12
CIRCUIT DESIGNATION	TYPE	PWR RATING 25°C	THERMAL θ_{JC} RESISTANCE θ_{JA}	MAX FULL LOAD TEMP (AMB OR CASE)	ZERO LOAD TEMP (AMB OR CASE)	PIV (VZ FOR REGULATORS)	MFR	MFR'S P/N	GOVT SPEC	GOVT P/N	ESTABLISHED OR GENERIC FR & CONF. LEVEL

PARTS AP

PROGRAM ________ ________

COMPONENT ________ ________ APPORTIONED FR & CONFIDENCE ________

MODULE ________ ________ APPORTIONED FR & CONFIDENCE ________

1	2	3	4	5	6	7	8	9	10	11	12
CIRCUIT DESIGNATION	TYPE	PWR RATING 25°C	THERMAL θ_{JC} RESISTANCE θ_{JA}	MAX FULL LOAD TEMP (CASE OR AMB)	ZERO LOAD TEMP (CASE OR AMB)	GAIN OR SWITCHING SPEED	BREAKDOWN V BV_{CBO} & AS APPLICABLE	MFR	MFR'S P/N	GOVT SPEC	GOVT P/N

Exhibit 1. Typical parts a

N RECORD-DIGITAL/LOGIC MICROCIRCUITS

A	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
		SPEED			OPER. TEMP. RANGE	TYPE PACKAGE	ESTABLISHED OR GENERIC FR & CONF. LEVEL	APPLICATION DATA							
VEL TOL	FAN-OUT	CHARACTERISTIC	TIME OR FREQ.	COND.				V_{DC}	PWR	MAX TEMP.	USE FR & CONF. LEVEL	VIBRATION	SHOCK	OTHER	PARAMETERS FOR TYPE SELECTION

TION RECORD-LINEAR MICROCIRCUITS

13	14	15	16	17	18	19	20	21	22	23	24	25
JT		OPER. TEMP. RANGE	TYPE PACKAGE	APPLICATION DATA								
ALUE	COND			V_{DC}	PWR	MAX TEMP	ESTABLISHED OR GENERIC FR & CONF. LEVEL	USE FR & CONF LEVEL	VIBRATION	SHOCK	OTHER	PARAMETERS FOR TYPE SELECTION

PPLICATION RECORD-DIODES

APPLICATION DATA				CALC. DATA								
13	14	15	16	17	18	19	20	21	22	23	24	25
AVERAGE POWER	PEAK POWER	PEAK INVERSE VOLTAGE	TEMP-MAX (AMB OR CASE)	PEAK FWRD CURRENT	JUNCTION T_J TEMP (MAX)	% RATED PWR	NORMALIZED TEMP	USE FR & CONF. LEVEL	VIBRATION	SHOCK	OTHER	PARAMETERS FOR TYPE SELECTION

PLICATION RECORD-TRANSISTORS

APPLICATION DATA					CALC. DATA								
13	14	15	16	17	18	19	20	21	22	23	24	25	26
ESTABLISHED OR GENERIC FR & CONF. LEVEL	AVERAGE POWER	PEAK POWER	PEAK VOLTAGE V_{CB} & AS APPLICABLE	TEMP-MAX (CASE OR AMB)	PEAK COLLECTOR CURRENT	JUNCTION T_J TEMP (MAX)	% RATED PWR	NORMALIZED TEMP	USE FR & CONF. LEVEL	VIBRATION	SHOCK	OTHER	PARAMETERS FOR TYPE SELECTION

pplication worksheet forms (Continued).

6-C-1 6-C-2

APPROVED PARTS LIST

APL REVISION DATE ____________

PART NAME	PART DESCRIPTION	PART NUMBER	STATUS CODE (2)	MANUFACTURER	MANUFACTURER'S PART NUMBER	APPLICATION (1)	SPECIFICATION AND REVISION SYMBOL (3)
CAPACITOR, FIXED	PAPER 200 VDCW 0.047 10% MAX DIM 0.047 10% MAX DIM 1.21 X 0.415	CPV08A1KC473K	C MMEN	SPRAGUE ELECTRIC COMPANY	195P	GENERAL	MIL-C-14157B
CAPACITOR, FIXED	ELECTROLYTIC TANTALUM, POLARIZED, 50 VDCW MAX DIM 1.34 X 0.391	90B24-2	C CSEQ	ITT COMPONENTS DIVISION	CS1009	GUIDANCE 424-7497010 4§4-7560020	90B24C
DIODE, SEMICONDUCTOR DEVICE	SILICON POWER RECTIFIER, 200 VDC, 20 AMPS STUD MOUNTED	USA 1N250B	E MMEQ	WESTINGHOUSE ELECT. CORP.	CWL	424-7560020	MIL-5-19500E
RELAY, ARMATURE	200 AMP SPST NO-AUX SPDT, 28 VDC COIL 520Ω, BASE MTG, HERMETIC	MS24 14 2D2	D MMEQ	CUTLER HAMMER, INC.	604 2H152	424-7562050 424-7497020	MIL-R-6106B
RESISTOR, FIXED	FILM, INSULATED 1/4W AT 70°C AMB, ±200 PPM PER DEG C, 1K, 2%	92B4-1	0 CSEP	CORNING GLASS WORKS	CO7	GENERAL	92B4C
TERMINAL, LUG	CRIMP TYPE, RING TORQUE, INSULATED, AWG-22-18, 8 STUD	58A8-12	22CPEP	AMP, INC.	--	424-7497020	58A8 REV. 22
TRANSISTOR	SILICON, NPN, LOW LEVEL, LOW NOISE	JAN 2N930	A GSEQ	GENERAL ELEC. CO.	--	GUIDANCE	MIL-S-19500/253A
WASHER, LOCK (SPRING)	CARBON STEEL, 0.255 ID 0.493 OD X 0.062 THICK	MS35338-3	A MΦEQ	NATIONAL LOCK WASHER CO.	MS35338-3	GENERAL	FF-W-84A

(1) NOTES:
1. GENERAL - DENOTES GENERAL USAGE THROUGHOUT SYSTEM HARDWARE
2. GUIDANCE - DENOTES PART USED IN A NUMBER OF APPLICATIONS IN THE GUIDANCE SUBSYSTEM
3. DRAWING NUMBER - DENOTES PART IS USED IN A SPECIFIC COMPONENT
4. SEE APPENDIX FOR A FURTHER EXPLANATION OF APPLICATION

(2) STATUS CODE

XX X X X X

1. PART DRAWING REVISION
2. DOCUMENTATION CLASS
3. PROCUREMENT RESTRICTIONS
4. USAGE RESTRICTIONS
5. TEST STATUS

(1) PART DRAWING REVISION (1 OR 2 SPACES)

- Φ — NONE
- A TO Z, 1 TO 99 OR AS APPLICABLE — CONTRACTOR DRAWING, MILITARY DRAWING, INDUSTRY STANDARD, GOVT. DRAWING

(2) DOCUMENTATION CLASS

- F FEDERAL STANDARD
- M MILITARY STANDARD
- G OTHER GOVT SPECS
- I INDUSTRY STANDARD
- C COMPANY STANDARD
- V VENDOR DOCUMENTATION

(3) PROCUREMENT RESTRICTIONS

- M MULTIPLE SOURCE DRAWING
- S SINGLE SOURCE DRAWING
- P PATENT OR PROPRIETORY DRAWING
- Φ OPEN BID DRAWING

(3) WHERE NECESSARY TO COMPLETELY DEFINE PART, SHOW SUPPLEMENTARY OR SPECIAL REQUIREMENTS AND INDICATE SPECIFICATION CONTROL DRAWING NUMBER AND OTHER DOCUMENTS DETAILING REQUIREMENTS (SUCH AS FOR SCREENING AND NONDESTRUCTIVE TESTING).

(4) USAGE RESTRICTIONS

APPLICATION CLASS	CODE LETTER	TEMPERATURE °C	PRESSURE TORR.	ACCEL-ERATION	SHOCK	VIBRATION	ACOUSTIC NOISE
LAUNCH VEHICLE-UPPER STAGE	A	-55 TO 125	760 TO 10^{-10}	50g 40 sec	250g (10 ms sawtooth)	SINUSOIDAL 20-2000 cps - 35g peak Below 40 cps - 0.6 in. displacement, double amplitude RANDOM 200-800 cps 0.64 g^2/cps 800-2000 cps 0.15 g^2/cps	165 dB
LAUNCH VEHICLE-LOWER STAGE	E	-55 TO 125	760 TO 10^{-6}	20g 200 sec	50g (10 ms sawtooth)	SINUSOIDAL 20-200 cps - 25g peak RANDOM 20-200 cps - 0.15 g^2/cps	165 dB
OPERATIONAL GROUND EQUIPMENT	G	-55 TO 85	760 TO 400	–	30g (10 ms sawtooth)	SINUSOIDAL 10-2000 cps - 10g peak	–
GROUND SUPPORT EQUIPMENT	H	-55 TO 85	760 TO 530	–	30g (10 ms sawtooth)	10-55 cps 10g peak	–
RESTRICTED USE-(EACH USE MUST BE JUSTIFIED IN WRITING AND APPROVED BY PARTS ENGINEERING GROUP)	X	–	–	–	–	–	–

(5) TEST STATUS

- Q EVALUATION TEST COMPLETE
- P EVALUATION TESTS IN PROGRESS
- S SAFETY MARGIN TEST COMPLETED
- R SAFETY MARGIN TEST IN PROGRESS
- N TESTING NOT REQUIRED
- F TEST RESULTS UNACCEPTABLE
- T PREVIOUS PROGRAM OR DATA BANK TEST RESULTS USED

Exhibit 2. Typical project approved parts list format.

it is highly desirable to place the APL under drawing-change control and require that it indicate active revision symbols. The importance of the APL to control of hardware design justifies its inclusion under the broad disciplines of configuration and data management. This step will simplify configuration control at part and material levels and improve the traceability of system hardware. The data management and configuration control system established for the project must be followed in establishing part numbers, status codes, and revision symbols.

EFFECTS OF APPLICATION REVIEWS

Application reviews, as design assurance functions, identify problems at an early stage and foster economic corrective action. They are an important element in a closed-loop parts and materials program. The parts and materials program, disciplined at the outset by the requirement for application review, emphasizes thoroughness and the development of proper documentation for each phase of its activities to serve as an adequate basis for part selection and application. Application reviews are discussed in greater detail in chapter 3 which follows.

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CHAPTER 3

Functions of Application Review

As r .inted out briefly in the foregoing chapters, the application-review activity, although called .or as a task in the parts and materials program, serves functionally as an adjunct to the des' n review of each component in the system hardware. (This applies primarily to electronic components.) Because of its detailed nature, the application review is conducted separately from and prior to the formal design review which it is to support. Also, because most projects tend to review materials applications to a large extent in the design review proper, the application-review function devotes more intensive attention to parts than to materials. (See also section entitled "Application Guidance and Derating" in chapter 2.) At lower levels of component "design challenge" (difficulty and criticality), the application review takes the form of a desk-type document study, with questions raised by the reviewer(s) and answered from appropriate sources (documents or individuals) as they arise. At the higher levels of design challenge, this study is conducted in a working group or small conference activity, with a somewhat better organized method for questioning of discrepant items.

In all cases the review's objective, which is to determine the soundness of usage of the parts and materials in the component, is approached functionally by the following steps:

(1) Consideration is given to the completeness of data upon which each part and material selection has been made
(2) Safety margins represented by the latest design data or measurements (e.g., breadboard, prototype, etc.) are evaluated, and performance characteristics and operating environments are reviewed, item by item, to confirm uses of derating and safety factors for the part or material in its application
(3) All discrepancies, omissions, or data estimates which are considered unlikely or not sufficiently verified are noted

The structuring of an efficient program of application reviews for any project is more than the simple scheduling of a "standard content" application review to precede each component design review. The necessary frequency, depth, and approach of application review are determined by the design challenges of the hardware in question. The term "design challenge" is used here to denote the degree of technical difficulty associated with the design of an item and the degree to which mission failure might be influenced by unsatisfactory performance of that item.

The remainder of this chapter discusses three basic aspects of the application-review activity:

(1) Factors which characterize the design challenge of the component (these factors are called "component indicators" for purposes of this publication)
(2) Elements of review activity (or "review elements") which form a basis for describing the scope of review effort appropriate for any component; this discussion also covers the role of application review at the principal milestones of the project cycle
(3) Cost considerations

The "component indicators" and "review elements" are first identified and then broken down for discussion purposes into categories to show a logical gradation of severity of design challenge and logical gradations of level of review effort. This is a necessary first step in selecting levels of review activity appropriate to various kinds of designs. The particular categories and gradations presented here are logical measures of the design challenge and were the basis for development of the method shown in chapter 4 for planning an application-review program for a project. Any other consistently logical gradation scheme used to support another planning method would probably be equally valid.

COMPONENT INDICATORS AFFECTING INTENSIVENESS OF REVIEW

DESCRIPTION OF INDICATORS

Design challenge is the key influence upon the intensiveness and emphasis of the parts and materials program and the application review. For purposes of categorizing the degree of challenge, a component design can be described in terms of the following four criteria or "component indicators":

(1) Complexity
(2) State of the art
(3) Extent of testing requirements
(4) Packaging conventionality

Complexity

For a given component, the necessary depth of application review is dependent upon:

(1) Part complexity
(2) Total number of parts and materials
(3) Number of different types represented
(4) Reliability levels which must be achieved, including the indirect influence of redundancy

For purposes of this publication, the effects of these factors are collectively considered as "complexity."

The criticality of individual parts, components, or subsystems to mission success is of importance but, like redundancy, applies indirectly through its effect upon the part and material reliability level. Determination of all these factors to an initial order of accuracy is a partial output of the conceptual phase of design.

Other factors implied in the reliability level include environments, performance ranges, and tolerances. These enter indirectly into the application assessment as elements of the component reliability requirement. Where a reliability requirement or goal has not been specifically identified, one should be estimated by analyzing program objectives, optimum cost considerations, and other factors.

As a first approximation, the gross part count and the component or system reliability goal (reduced to failure-rate terms) can be used to calculate average required failure rates at part levels. This average allowable failure rate is an effective index of component complexity since it considers not only the number of parts in the component but also a numerical measure of the reliability level that the parts must achieve, and thus reflects the ease or difficulty of providing suitable parts.[4]

[4]The indication is made more precise, of course, if the part count identifies the numbers of each part type.

State of the Art

Strange environments, nuclear exposure, sterilization requirements, micrometeorite bombardment, extreme temperature, shock, or vibration also pose special parts and materials problems which relate directly to the depth of application review necessary. This category differs from the environmental considerations affecting complexity in that a large store of experience in terms of part capabilities has not been built up; we are working in areas relatively new and unknown. New technologies, processes, or materials assume prominence and present problems in the evaluation of the sparse data. In like manner, long-life achievement requires close, detailed attention, not only during application review and specialized parts and materials activities but also in every design discipline.

The state-of-the-art challenges can be placed in the following ascending order of severity:

(1) Conventional design and environments (may include space environments; this class implies adequate prior experience)
(2) Harsh environments beyond those previously experienced by the conventional classes of component design (i.e., usual parameters, but at values above the conventional levels of part testing)
(3) "Strange" environments such as nuclear exposure, sterilization requirements, or other conditions for which part survival data are not generally known
(4) New or radical design techniques, particularly in circuitry or technological approach; this gradation also includes extremely low part-failure rate requirements
(5) Additive combinations of these factors

Testing Requirements

The extent of the testing requirements reflects the degree of evaluation deemed necessary to give assurance of adequate component performance capability. These requirements are based on the severity of use conditions and criticality of the component's function. As these requirements become more extensive, more exacting application review is needed to obtain design assurance via the "review route" as early as practicable in the project cycle (i.e., to minimize test failures and make possible orderly and scheduled progress through the test cycle).

Gradations of testing requirements are:

(1) Conventional qualification testing
(2) Special evaluation testing of a new design concept
(3) Special evaluation testing to assure ability to operate under unusually severe or strange environments (or simultaneous evaluation of two conventional environments at a moderately severe level)
(4) Formal (statistical) reliability demonstration testing
(5) Long-life verification testing where mission-life requirements are so great that reliability demonstration within available real time is not possible

Packaging

Experience with the hardware packaging technique provides a measure of the predictability of interactions between the hardware elements themselves and between the elements and the external environment. This affects the level of review activity necessary. Assessment of this indicator can be graded as follows:

(1) A standard, well-understood package for which previous experience is available or such a package with only minor modifications (minor dimensional changes, etc.)

(2) A new package design that is significantly, but not radically, changed from a previously used technique (package changes which depart significantly from previous designs in such areas as dimensional configuration, material, or mounting)
(3) Radical packaging; an entirely new approach or technique for which data are scarce or nonexistent, probably adopted because of a severe design problem or to gain some particular design advantage

EFFECTS OF EXTREMES OF DESIGN CHALLENGE

The details to be covered during application review multiply greatly as the component complexity indicator approaches the best known performances for the parts in question. Cost tradeoffs are of little influence after the failure-rate requirement has become so severe that confidence in the part capability is in question. The application review then serves as a tool to identify dangerous failure risks, and the cost of review in such cases can hardly be compared with the cost of failure.

At the other end of the spectrum, components of low complexity will generally base the parts and materials effort primarily on special characteristics (extreme environments or new techniques) or on contractual requirements not necessarily related to technical problems. The application review will follow this pattern and perhaps be included simply as a part of the component design review.

APPLICATION REVIEW ELEMENTS

The foregoing discussion of component indicators gives a general indication of the characteristics of a component which affect the intensiveness of application review needed. For any case, the scope of review activity can be described in terms of review elements.[5] Six are selected here as representing adequate review definition for early program planning. These are:

(1) Number of reviews
(2) Sophistication of documentation
(3) Parameter coverage
(4) Independence of the review
(5) Test influence (to what extent the review team can require verification of a point from the project test program)
(6) Skill required of the review team

The paragraphs which follow discuss each of these elements in greater detail.

NUMBER OF REVIEWS

One of the first elements to be considered in planning the extent of the parts and materials application-review effort is the number of reviews that is appropriate for each component. Although this number will be related in a general way to the number of design reviews scheduled for the item in question, there will not necessarily be a direct one-for-one relationship.

The following discussion treats application reviews in the order of recommended priority of selection, rather than in chronological order of project milestones at which they occur. However, the functions and requirements of the review at each milestone are also covered.

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[5]All the levels of effort within these review elements are guided in a general sense by the component indicators and, therefore, are somewhat interdependent. However, despite this broad interdependence, considerable latitude exists between the levels of effort from element to element even for the same component.

One Review

If the component indicators for the component in question dictate a minimum of review effort, the one review selected may be either the breadboard (also called "prepackaging") review or the prerelease[6] review. The decision as to which of these is the more appropriate depends on a trade-off for the specific design. The basic trade-off factors are: The breadboard review occurs earlier, thereby fostering earlier and more economical correction of circuit deficiencies; the prerelease review, on the other hand, affords the opportunity to review a complete design—the package as well as the circuit. Where packaging and power dissipation requirements are minimal, the choice would lean toward the breadboard review. The following discussion of the activities of each of these reviews will lend a better understanding of these trade-offs.

Prerelease review. The most complete single application review that can be accomplished in advance of hardware fabrication is the prerelease review. This is also the first opportunity to review the detailed package design as well as the circuit. This point, just preceding engineering release, coincides with the predominant design review.

Functions of the prerelease review are to examine the latest available data and to:

(1) Assess the status of parts and materials (i.e., specification, test, qualification, vendor selection); report where these are incomplete or inadequate; and recommend schedules for their completion
(2) Examine calculated and measured (where available) values of data on local environmental and functional stresses
(3) Identify conditions with a low margin of safety (adequacy of derating)
(4) Assess the compliance of parts and materials capabilities to application stresses; also, examine adequacy of testing requirements at subassembly (module) or higher levels to obtain further data needed to verify low-confidence data used in the assessment

Since all features of the design can be assumed to be firm at the prerelease milestone, or at least nearly so, it is theoretically possible to assure by examination that a part or material application is satisfactory and will accomplish the intended purpose. In practice, however, the review is constrained by the same realities as the design program, including its normal uncertainties, schedule pressures, continued (although diminishing) changes, and test data limitations. If the review does not attempt to duplicate or extend the design effort (which it should not), it serves in reality as a doublecheck upon the latter as it was planned and accomplished; it also serves as a check upon the adequacy of the parts and materials application activity associated with design. It is true that the review's judgment will be based generally upon the same measurements and historical data available to, or developed by, the design group. Even so, it effectively reduces the chance of overlooking pertinent facts necessary to support decisions and allows varied special talents to be brought to bear on the subject.

Breadboard review. The common disadvantage of a single prerelease application review is its delayed discovery of discrepancies. Although the prerelease review gives more confidence of mission accomplishment, earlier detection of problems provides a much more direct benefit to the design team and offers the possibility of economic gains. The earliest practical review can be conducted, although not so rigorously, at the breadboard stage of development, just after initial performance measurements are completed.

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[6]The term "prerelease" refers to the decision milestone just preceding release of engineering drawings for fabrication of flight-configuration hardware. As used here, it refers to one component; release does not usually occur at the same time for all components.

Functions of the breadboard review are to:

(1) Make a first assessment of the status of parts and materials used in this component (i.e., specification, test, qualification, and vendor-selection status)
(2) Examine calculated (or measured) values of performance stresses (in all operating modes) in relation to capabilities of parts in order to make a first assessment of derating adequacy
(3) Review parts specifications to detect omissions of needed requirements
(4) Review preliminary part selections for all components for the purpose of reducing total number of part types; the cost of reducing the number of types increases rapidly after this milestone

If tolerances, stability with time, and other performance characteristics are the predominant problems of the design—rather than packaging problems—breadboard application review, instead of prepackaging review, would be the logical selection if only one review is to be conducted.

Two Reviews

If the design problem warrants two reviews, these should be the breadboard and prerelease reviews and should coincide with the design reviews conducted at these stages. The cost of the two reviews is not so great as it may appear because data developed for the breadboard review would have to be developed in any event for the later review. The practical result is a two-part prerelease activity offering the advantages of both timeliness and increased assurance with minimal duplication. In fact, this means that there is little economy gained by a single, prerelease review that is not preceded by a breadboard review.

Three Reviews

Components of sufficient sophistication to warrant more extensive review effort can be expected to experience real difficulty in achieving design goals. In such cases, added emphasis upon planning for the breadboard and prerelease reviews is required in a review at the conceptual design stage. This conceptual review is closely related to the reliability as well as to the design effort. It is intended to plan for extracting and coordinating with maximum convenience the data developed or assembled by all these activities to a schedule consistent with later reviews. Primary functions of this conceptual (or "preliminary") review are to:

(1) Define the levels of review to be performed through the development cycle
(2) Assign responsibility for specific data inputs for each component
(3) Define documentation requirements and schedules for their delivery

Four Reviews

The fourth review to be considered is the postqualification review. These reviews provide further extension of application reviews to later development stages to cover changes in design and failure-analysis activities and will be necessary in those cases where project characteristics are such that design reviews are also required at this later stage of the project life. Reviews following the qualification test phase provide the same benefits in assessing changes introduced between release and qualification as those gained in earlier reviews from assessing corresponding changes at earlier phases. They also permit local simulated environments to be spot-checked and unexpected effects to be assessed independently. The postqualification review, by comparison with earlier reviews, is an updating activity which presents a very light workload.

Five Reviews

The fifth review is the postmission review. The ultimate application review can be held after actual mission use of the hardware to assess changes, problems, and failure experience subsequent to postqualification review in relation to the knowledge developed in earlier efforts. Because of the attention upon failures at this stage, the principal value of the additional review effort is in documenting failures at part levels for future design use. Again, the workload is light so that the benefits to the organization and to later projects are usually well worth the investment.

DOCUMENTATION

Application reviews, in all cases, are based on project data. All such data must be documented as generated or extracted in the normal project cycle. Generally, they include such items as the component specification, parts and materials application worksheets, vendor data specifying and describing capability of the parts, and parts data bank information (user data). In general, application review output documentation reduces functionally to:

(1) A record of the items and parameters checked
(2) Identification of the data used to establish a decision
(3) A statement of results

If the quantities of the input data are manageable, the output documentation can be evolved from it directly. Otherwise, some degree of summarization is needed to provide the reviewer with clearer visibility of the vital elements to be reviewed.

Input Data

The different levels of summarization or preparation of input data are:

(1) Check list
(2) Data package
(3) Summarized data
(4) Summarized data with confidence indication

Checklist. Except for the most simple case of direct data review described above, the minimum level of summarization of input data to the review is a checklist with data references, such as that shown in exhibit 3. This form extracts key items of the worksheet type of data shown in exhibit 1. For convenience, the use of symbols is indicated in the checklist to identify parts and materials parameters being reviewed. These parameters and their selection are discussed in the following subsection. If this checklist procedure is followed in successive reviews, later entries can simply reflect revisions or additions by identifying the line number of the original item. Discrepancies and a statement of the review's conclusions should be presented in a separate report.

Data package. In order to meet more complex requirements, documentation for review should be enhanced by assembling actual data reports. The latter, in addition to the checklist, will permit convenient detailed examinations of specific entries during the design review or subsequent application reviews. Such data reports might include:

(1) Calculated values of expected environmental stress levels for the application (early program stages)
(2) Observed values of environmental stress levels of the application (later stages)

APPLICATION REVIEW CHECK LIST FORM

Project: "NAME"

Component: UNIT 3 OGE RECEIVER

Component data and source: DESIGN SPECIFICATION-"OGE RECEIVER" A-111-B

Environmental ranges: USE PROJECT STANDARD OGE ENVIRONMENT

Safety and derating factors: DERATING FACTOR 0.5 FOR CRITICAL PARAMETERS; 0.7 FOR OTHERS

Reliability requirements: MTBF 500 HR. AT 60% CONFIDENCE

Line no.	Schematic/ drawing no.	Part designation and identification	Parameter/Operating-to-rated ratio (a,b,c)						Manufacturer	Lot no.	Data source/location
			A	B	C	D	--	--			
1	XXXX	Q23 (2N915)	V_{CB} / 0.5	V_{CE} / 0.5	V_{EB} / 0.7	I_C / 0.5	P_C / 0.5	T_A / 0.7	ABC CO.	6705B	NOTEBOOK 2054 / J. SMITH
2											
3											
4											
5											
6											

NOTES: a. The symbol entered above the diagonal line in each box identifies the part parameter reviewed. The number below the diagonal line in each box records the operating-to-rated ratio for the given parameter.

b. Users of this check list form should identify the parameters applicable to the part type being reviewed, assign appropriate symbols and list the symbols and their definitions on a separate sheet.

c. A special identifying symbol should be used to indicate those operating-to-rated ratios which are based on actual measurements of application value.

Exhibit 3. Typical application review checklist form. MTBF is mean time between failures; OGE is operational ground equipment.

(3) Measured values of performance parameters in use (as they become available)
(4) Parts reliability test data (later stages)

The data package also provides an excellent parts and materials experience file for reference by other programs. The check list and data package are used, for the most part, for reviews that can treat environments as constant throughout the component or consider local environmental variations in only a few key instances.

Summarized data. As design sophistication grows, the examination of the application of each part or material involves more extensive documentation. In general, when the design challenge is greater, correspondingly larger quantities of data are generated among the design disciplines. Under these circumstances, special data summaries are needed to bring the appropriate pieces of information together in proper perspective. When this level of project activity is reached, it is especially important that test reporting formats established in the planning stage should be devised so that pertinent application data can be extracted readily for application-review summaries.

Exhibit 4 is a suggested format for the type of summary data needed in an actual review. In this expanded listing:

(1) Line numbers identify particular part positions within the assembly
(2) A group of lines (a, b, and c) below these numbers permits entries to be made for the same part during successive reviews, so that changes in data for each part are readily detectible
(3) Four columns record the pertinent data for each principal parameter of a part under review (note that these four columns, columns 5, 6, 7, and 8 for the first parameter, are repeated as columns 9, 10, 11, and 12 for the second parameter, etc.)

The four columns identify the specific parameter by symbol, the part capability, the derating factor, and the application requirement. The last requirement is normally the most severe condition to be encountered throughout the mission. Parameter symbols must also distinguish between average or peak values and, perhaps, the mission time phase being considered. Failure-rate entries, as parameters, should be related to specific conditions defined by other entries which influence the failure rate (temperatures, power dissipations, etc.); or they may be defined by a preestablished ground rule so that comparisons will be valid.

The remaining columns to the right of the application requirements (columns 17 through 20) are optional. They should be designed as a checklist of items to be considered in a specific case. Here, they are associated with:

(1) An assessment of actual test failures
(2) Review of qualification test requirements
(3) The criticality of the specific application
(4) Final approval of a selected supplier

Summarized data with confidence indication. The same format can be used for the next higher requirement or level of review documentation by adding a coded notation to indicate the confidence value of the capability entry and the usage requirement entry. Such information is appropriate if the design review, at some early phase, expects to consider specific part parameter verification in the test program. Low-confidence entries may be interpreted as a need for test verification of a parameter, especially when the application is critical to the success of the design. Documentation with confidence coding, therefore, is represented as the most intensive order of documentation activity for application review.

PARTS APPLICATION REVIEW DATA SUMMARY

PROJECT: "NAME" COMPONENT: COMMUNICATIONS TRANSMITTER A

DATE: X-XX-XX

SHEET 2 of 10

1 LINE NO.	REVIEW ENTRY	3 SCHEMATIC AND OR DRAWING NO.	4 PART DESIGNATION & IDENTITY	PARAMETER - CAPABILITY VS. APPLICATION: 5 SYMBOL	6 DERATE OR SAFETY FACTOR	7 CAPABILITY (adjusted)	8 APPLIC-REQ'T.	9 SYMBOL	10 CAPABILITY (adju	17 FAILURE REPORTS	18 QUALIFICATION APPROVAL	19 CRITICALITY RANKING	20 APPROVED MANUFACTURER
1	a	X XXX	Q-10(2N930)	V_{CB}	0-5	23 V	20 V	V_{EB}	0.7	NONE	OK, B-26	2	ABC Co.
	b												
	c												
2	a												
	b												

NOTE: A series of these forms should be filled out to cover all parts in the component being reviewed. This set of forms should be accompanied by a series of appendices to explain all symbols and numerical references to data. Typically, Appendix 1 would identify symbols, Appendix 2 would reference data sources, Appendix 3 would index and describe failures referenced by report numbers in column 17, and Appendix 4 would list and index all planned and completed qualification tests referenced in column 18.

ENTRIES:

- Col. 1 Line number: For reference purposes, use sequential numbers for each part.
- Col. 2 Entry: Letters designate reviews to be conducted. This permits subsequent changes and additions at later reviews to be entered on separate lines (a, b, and c) for comparison with original entries.
- Col. 5 Symbol: Parameter designation. Attach Appendix 1 to identify symbols used.
- Col. 6 Derating or safety factor required. Derating factor <1; safety factor >1.
- Col. 7 Part capability after appropriate derating or safety factors have been applied. With the capability value, add appropriate symbols to denote: (a) Whether the value is measured or calculated, (b) the confidence value, and (c) the data source reference number. Identify symbols and references in the appendices; see note.
- Col. 8 Application requirement (not adjusted). Add symbols and references to give the same kinds of descriptive data given in column 7.
- Col. 9-16 Second and third parameter listings. Use more columns if more parameters are involved.
- Col. 17 Failure reports: List report index number and identify in Appendix 3.
- Col. 18 Qualification approval: Indicate approved or not approved and add report index number from Appendix 4.
- Col. 19 Criticality ranking: Symbol or short title identifying importance of part to component performance.
- Col. 20 Approved manufacturer: Name, abbreviation, or federal identification number of approved manufacturer.

Exhibit 4. Typical form for parts application review data summary.

Reporting of Reviews

The foregoing paragraphs deal with the degree of preparation of data inputs for the application review. In all cases, the review output is a report presenting the results of the review, thus completing the necessary documentation. Reports should highlight discrepancies and problem areas, such as data omissions and safety-factor violations, even though corrective action (including test) is being taken to clear them. Most important, the organization and presentation of the report should support the associated design review. Ideally, reported items will be dealt with specifically at that time, and corrective action or a decision to accept the additional risk will result.

PARAMETER SELECTION FOR REVIEW

The selection of parameters to be reviewed for each part or material type is important in achieving product assurance. A choice must be made between the extremes of checking <u>all</u> parameters, which is normally both impractical and unnecessary, or <u>none</u>, which would make the review meaningless. The skills and experience of the review team and designer are of particular value in determining the scope of review and identifying specific parameters.

The component specification itself is the first guide to the selection of parameters. Specific parameters among the various parts which should be checked are suggested, for example, by:

(1) Need for exceptionally high accuracies
(2) Need for stability over a broad temperature range or long time interval
(3) Unusual environmental conditions (high temperature, shock, vibration, vacuum, sterilization, etc.)
(4) Stringent reliability requirements

Familiarity with the parts and materials themselves will identify parameters which are ordinarily of principal concern to the designer. The extent of parameter coverage may be categorized as:

(1) Major parameters only
(2) Major plus selected minor parameters
(3) Major plus all significant minor parameters

Major Parameters Only

When a low-order application review is planned, only the major characteristics of the part or material for each application will be reviewed, such as stability with time or environments, power dissipation, and operating temperature. As a minimum, factors known to cause a variation in failure rate should be considered. In general, this approach is used when environments can be considered to be of uniform magnitude throughout a component or where there are only a few isolated local variations from the uniform value. If reliability is numerically stated, derating and safety-factor requirements as well as failure rates should be evaluated and confirmed as an independent review function. This gradation includes cases where some parts and materials are omitted entirely from the review, on the basis of a prior establishment of clear ground rules for such omissions.

Major Plus Selected Minor Parameters

The next order of review effort should consider separately each stress (voltage, tensile force, power), each environment (local to the part rather than conditions external to the component), and each failure rate under the best estimated operating conditions. Many of these parameters need not be carried beyond a brief look, provided the capability has an unquestionable margin over the application stress. Safety factors must, of course, be considered. This gradation includes the major parameters of the previous grade and any other parameters desirable or included by the task definition.

Major Plus All Significant Minor Parameters

The greatest depth of application review requires a review of all major and all significant minor parameters. This highest level of review differs from the intermediate level in two respects. A review at this level will consider more of the minor parameters (performance and environmental stresses) than will the intermediate-level review, and, most important, a review at this level will require greater in-depth consideration of each parameter reviewed.

Also, at this level of review, the failure-report history of the component is given an additional and independent scrutiny by the applications-review team to ascertain whether any of the reported failures in testing or use are the result of part or material misapplications. This requires that each open and closed failure report be reviewed, the former for the obvious purpose of examining the history while failure analysis is in progress, and the latter for the purpose of reexamining the analysis and closure of each closed failure report from an "applications" viewpoint.

It is emphasized that a review of failure-report history of the component is always a key item for consideration at design reviews. The difference in this case is that the applications-review team conducts a separate and additional parts-and-materials-oriented scrutiny of the failure reports.

DEGREE OF INDEPENDENCE

This review element describes the degree of "doublecheck" which the review exercises over the parts and materials application process. More specifically, it indicates the degree of technical authority of the application-review team to impose requirements on the project design functions (and the parts and materials program) for generation or validation of data needed for the review. It also implies the extent of direct informal communication between the reviewers and the design groups to obtain specific items of information. The special data requirements involved would include not only the area of part capability but would be particularly concerned with such matters as:

(1) The accuracy of estimation of anticipated stress levels on and within the component
(2) Reliability required of the component
(3) Criticality of potential failure modes of and within the component

For components of lesser design challenge, the design review, not the application review, serves as the instrument to control these special data requirements. However, for more severe design challenges, the need for more timely special data contributions may make it necessary to delegate to the application reviewers a certain amount of authority to communicate directly with specific design groups to request generation of needed data. For specific apportioning of review effort, the "degree of independence" may be categorized for convenience as one of the following levels.

Design Data Only

A minimum review effort makes available existing design data and calculations and associated supporting information from the data bank. No added load or requirement is imposed upon the designers and test engineers. The reviewer works independently and his findings are evaluated and acted upon at the design review. In this case, many of his findings may take the form of identifying areas where data are missing, where there is not sufficient confidence in the data, or where the data do not support the design.

Specification of Data Needed

A higher degree of independence would involve advanced planning by the review team, usually at the conceptual review, to identify the stress, reliability, or criticality data anticipated to be necessary for the application review. This degree of independence might also involve requesting verification or recalculation of certain data elements if early reviews indicate a question of application adequacy.

Independent Evaluation of Source Data

The highest degree of independence would involve a fairly extensive reexamination by the application review team of the accuracy and completeness of source data. This might involve questioning of the anticipated stresses of usage or of the degree of conservatism the parts and materials group attaches to the use of the parts reliability data. Although the principle of this examination is implicit in the review function, the extensive exercise of this avenue of investigation is an item requiring a high level of effort which can be justified only for the highest levels of design challenge.

TEST INFLUENCE

The test influence review element indicates the technical authority of the review team to impose requirements on the test program for the purpose of obtaining verification of specific parameters. In practice, the appropriate degree of test influence and the manner of exercising it are closely identified with those for the "degree of independence" element covered in the preceding discussion. It is convenient to identify the degree of test influence by the following categories:

Data Bank and Design Calculations

For the lowest level (zero level) of test influence, the application review is based on generic and data bank information on parts. Component level information is derived either from design calculations or data which are evolved in the "normal" course of the test program. There is no part level testing for the project.

Available Measured Parameter Values

The next higher level of test influence involves a parts (and components) testing effort which is preplanned for the project and is based on prior experience. The application-review team does not directly influence these testing requirements. However, it may do so indirectly and selectively through recommendation to the design review.

Specified Parameter Values To Be Measured

The third level of test influence permits the reviewers to request specific verification during a planned test, either as a result of or in anticipation of an application review. Parameter values to be verified might include low confidence estimates either in part capability, part reliability, or local operating or environmental stresses within a component.

All Significant Parameters Measured

This is the highest level of test influence and would apply usually to the most severe of design challenges. Here, maximum application assurance is offered by a completely isolated evaluation of parameters covered by the review and by their verification through direct measurement at some time in the test program. In this case, the scope of work is greatly expanded, not only by the added evaluation but also by a probable increase in the number of parameters considered for each item. Ordinarily, relatively few parameters will warrant the extra time and expense of direct verification. When this degree of influence is applied, it is necessary to define the work carefully in order to assign a review team with skills commensurate with such scope.

REVIEW-TEAM REQUIREMENTS

The review-team requirements are a review element that encompasses both the level of skill of the reviewers and their degree of objectivity. These levels are discussed below.

Designer

The minimum application review of any significance is one conducted by the designer himself. In this case, he can be reasonably expected to have the required specialized skill for review, but he may not offer the desired degree of independence and objectivity. Therefore, this type of review can be considered adequate, even for minimal requirements, only if documented specifically and defended by the designer as a part of the formal design review.

Parts and Materials Specialists

At the next level of review activity, greater objectivity and greater accumulated experience are obtained by utilizing the parts and materials group to perform the review. Although independence is still not complete because members of this group participated in the design program, their specialized knowledge of parts and materials can be sufficient to counterbalance this limitation. Again, for reasons expressed in the preceding paragraph, review documentation is essential to insure separate attention and to provide a basis for independent consideration at the design review.

Team

Full independence of review is established by selecting a separate team of engineers (or a single individual, if the amount of work is not exhaustive). In the absence of specialized skills, this approach relies upon the clarity and completeness of the design and test data. Although more time may be required for review, this technique allows more flexibility in selecting available personnel. Specific skills may be included on such a team to support critical needs for assurance.

Design Specialist Team

Maximum effectiveness is realized by assigning a carefully selected team of specialists to perform the review. Ideally, this team will include capability in all specialties involved in the design and application. The specialized skills are generally identifiable within broad technology areas, such as electronic, mechanical, hydraulic, pneumatic, and structural disciplines. In addition, environmental, nuclear or stress specialists, and experts in various materials areas (metals, plastics, lubricants, etc.) may be required. Generally an impressive review capability can be achieved with such a composition when the project characteristics justify it. Highly specialized talents may also be used in consultation without the need for their participating directly in the formal application reviews.

COST CONSIDERATIONS

BENEFITS OF REVIEW

The value results of parts and materials application reviews are reflected in:

(1) Avoiding failures
(2) Providing required inputs to design reviews
(3) Formalizing, simplifying, and performing more efficiently the basic parts and materials program functions associated with an immediate project design
(4) Confidence in the system's ability to meet performance requirements
(5) Supporting subsequent design efforts
(6) Timely discovery of discrepancies leading to planned smooth conduct of the test program, thus minimizing redesign and retrofit efforts with their attendant high costs
(7) Early identification of unavailability of suitable parts and materials

It is difficult to quantify avoided cost, but the economics of virtually all reliability assurance techniques, in effect, are based upon it—the prevention of failure and the avoidance of greatly increased costs attendant upon such failure accrue inevitably from delay and replacement. Each of the results of application review is pertinent to cost avoidance.

For example, the relatively minor expense of conducting a meaningful application review can be justified by the prevention of a single critical failure or the elimination of a few minor problems during later stages of testing. In a similar manner, increased knowledge of application problems contributes to the design of more reliable equipment, so intensification of this knowledge through application review on a particular new program offers additional reliability improvement. Application reviews benefit from the consolidated record of parts and materials design parameters developed from previous programs and contribute, in a like manner, to future programs.

DIRECT COSTS

In a given program, all attributable workload in application reviews appears as time invested by the reviewers, with minor clerical requirements. Direct review cost is limited to these man-hours because the inputs to review (the data and the tasks from which they derive) are basic requirements of the parts and materials program, with or without application review. Furthermore, the functions of the parts and materials program are not additional because they must be performed anyway in a thorough design effort. Among the specific application-review functions are the collection and summarization of data for the review, evaluation in the review, and reporting of results. After a preliminary selection of review activities, the review workload can be costed by straightforward time-estimating techniques.

From a practical standpoint, review of each component is essentially isolated, both in time and in technical considerations, from that of other components of the system even though many data entries may be common. The workload is dependent upon the depth of review undertaken and is related directly to the depth of design activity. Costs are directly proportional to the number of parts applied, this value being modified by a factor representing the average number of parameters which must be considered for each part. This modifier is affected by the component indicators discussed earlier—the average part reliability requirement, harsh or unusual environments, unprecedented applications (as represented by state-of-the-art design and extensive test requirements), and, finally, the degree of past experience with the packaging technique.

COSTS OF DATA

The expense of generating data necessary to the application review is not legitimately chargeable as a review cost. All required data are properly an output of the design effort and test program. Integration of the test requirements to develop necessary part-level data is a cost of design assurance and not application review. Even historical data used in part selection should be referenced during that process. Thus, the application-review task is one of collecting and extracting for evaluation the information of interest. This task is accomplished efficiently when uniform data formats are adopted which consider, among other factors, the outputs needed for application review. The data serve review and design purposes equally, and the efficient accumulation of parts and materials data in this manner is of lasting value to the original project and those subsequent to it.

CHAPTER 4

Structuring An Application Review Program

GENERAL

The preceding chapters have described the functions of application review and discussed various gradations of review depth and design challenge. In order to put this information to use in planning a program of application reviews, it is necessary to provide some consistent and specific method for relating effort within each element of review activity to the hardware elements and the project in question. This chapter presents one method for establishing this relationship at the component level. The structuring of an overall program then becomes a matter of organizing the recommended unit levels of review effort (as modified by management considerations[7]) in relation to the project's design review program.

SELECTION OF REVIEW ACTIVITIES: A METHOD

The basic step in structuring an application review effort and defining specific activities is determination of the needed depth of review for each component in the system. Various schemes can be used for achieving this purpose, and any one of them is acceptable if it is based upon a sound consideration of the characteristics and requirements of the component being reviewed and the system requirements.

The method described here is an empirical[8] one which employs a matrix of component indicators on one scale and review elements on the other. This matrix is shown in exhibit 5. For convenience in using the matrix, exhibit 6 summarizes, in chart form, the descriptions from chapter 3 of gradations of component indicator severity and review element intensiveness.

The gradations of each component indicator matrixed against the gradations of activity within each review element are displayed in exhibit 5. By appropriate indications in the blocks where these gradations intersect—a shaded block is a prerequisite, an open block is an option (generally), and a blackened block is an exclusion—the matrix guides the "first cut" selection of level of review activity.

In order to refine the "first cut" selection, a system of weighting factors[9] is used wherein the factors for the appropriate component indicators are summed, and this total is compared with

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[7]These considerations may consist of specific contract requirements, costs, schedules, personnel availability, or other technical or business aspects peculiar to a given project. Their impact upon the parts and materials program and application review activities must be determined on an individual basis by project management.

[8]The method is flexible. For each defined level of component design challenge, there is a range of levels of review activity from which the user should select the precise level that best suits his project's needs.

[9]The weighting numbers are mechanical devices, not absolute values, serving a purpose in the use of the chart. A chart could have been constructed with different values, equally functional. Their purpose is simply to reflect arithmetically a valid relationship, based upon experience, between project requirements and the type of review activity needed to satisfy them.

the sum of the factors for the initially selected review element depths. By an empirical rule, the ratio of total review element weight to total indicator weight should be 2 to 1. If it is not, then the initially selected levels of activity for review elements are readjusted in a "second-cut" selection to arrive at ratio of weights as close to 2 to 1 as possible.[10]

USE OF THE SELECTION MATRIX

The steps to be followed in the use of the selection matrix are given below.

Step 1. The first step in the use of the matrix is to categorize the design challenge of the component in question in terms of each of the component indicators on the left side of the chart. For convenience, a checkmark or other notation should be made beside the appropriate gradation within each component indicator. (In exhibit 7, this is accomplished by circling the weighting values on selected rows.) Every subsequent step in the use of the chart for this component will be in terms of the four horizontal rows selected in this step. All other rows can be ignored.

Step 2. Add the weighting numbers for the indicator rows just selected. (These are circled in exhibit 8.) This total will be used in step 4.

Step 3. For each review element shown across the top of the chart, select the first column of blocks (first from the left) in which all the blocks intersecting the previously checked "indicator" rows are clear or open. This is the minimum appropriate level of activity for each review element. It should be noted that this procedure allows the greatest design challenge gradation (rather than the least) to be the governing factor. All activity gradations for each review element to the left of the "minimum" block just selected can be regarded as a prerequisite except elements II and VI where the higher level activity obviates the lower level one. (For elements III, IV, and V, the higher level activity includes the lower one automatically.)

Step 4. Add the weighting numbers for the "minimum" review element gradations selected in step 3. This total should be twice the total of indicator weights added in step 2.

Step 5. If the ratio of weights determined in step 4 is not exactly 2, the activity gradations for the review elements should be reexamined and adjusted (insofar as possible). If the ratio is less than 2, the minimum-level-of-activity column selected in step 3 may be moved one (or more) blocks to the right for one or more of the review element areas, in order to arrive at a new sum of weights of review elements which will give a ratio of 2 (or as close as possible to it) when step 4 is repeated.[11,12]

If the ratio from step 4 is greater than 2, there is no technical latitude in reducing the minimum review activity level (i.e., moving to the left on the chart). In these cases, the activity level

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[10]This empirical weight ratio is primarily applicable to middle-of-the-range design challenges. Usually it will not be attainable for very severe design challenges and may be exceeded for very simple ones.

[11]The readjustment to the right should always avoid levels of activity where the matrix shows a blackened block for any of the intersections involved. These blackened blocks indicate levels of effort which cannot be reasonably justified.

[12]As a first estimate, the adjustment to the right should be applied uniformly for each element available (not shaded) until the ratio is best approximated (i.e., advance each by one block and repeat step 4). High-challenge designs will usually fall short of the desired ratio.

System: ____________________

Component: ____________________

Prepared by: ____________________

Date: ____________________

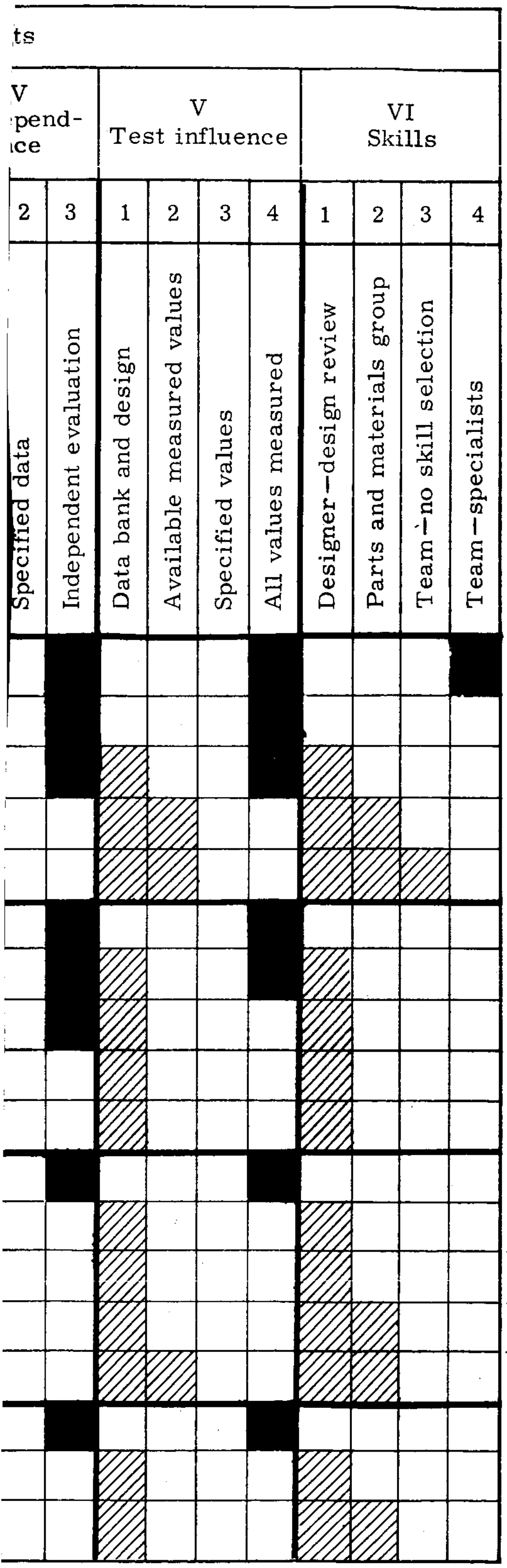
Approved by: ____________________

Date: ____________________

			Review elem													
			I Reviews						II Documentation				III Param- eters			Ir
		Weight →	1	2	3	4	5	6	1	2	3	4	1	2	3	1
	↓Weight	Component indicators	Breadboard	Prerelease	Conceptual design	Postqualification	Postmission	Data derivation	Check list and refs	Data package	Summarized data	Summary and confidence	Major only	Major plus selected minor	Major and all significant minor	Design data only
A Complexity (a)	1	10^4 failures per 10^9 hr														
	2	10^3 failures per 10^9 hr														
	3	10^2 failures per 10^9 hr														
	5	10 failures per 10^9 hr														
	7	1 failure per 10^9 hr														
B State of art	0	Conventional design														
	2	Harsh environment														
	3	Strange environment														
	4	New design														
	5	Combination														
C Evaluation test	1	Conventional qualification														
	2	New design evaluation														
	3	Strange environment evaluation														
	4	Reliability demonstration														
	5	Long life verification														
D Package	1	Standard, minor change														
	2	New design, major change														
	3	Radical design														

26A-1

Exhibit 5. Selection of



PROCEDURE

The following procedure is used to establish the proper level at which application reviews should be conducted for a given project. The procedure here is abbreviated for quick reference. A thorough discussion of the procedure is given in the text. Refer to exhibit 6 for definition of terms.

Step 1. Identify one subdivision row under each component indicator which best describes the characteristics of the component. Mark these four rows. (For all succeeding steps, the unmarked rows can be ignored.)

Step 2. Add the four weighting values (shown at the left) for the four component indicator rows just selected.

Step 3. Locate the first subdivision column (from left) under each review element in which the blocks corresponding to the selected component indicator subdivisions are unshaded. These six columns represent the minimum appropriate level of activity for each of the review elements.

Note: Observe that the highest requirement among the component indicators is the governing factor in selecting minimum levels of review activity.

Step 4. Add the six weighting values for the six identified review element columns. This total should be twice that total obtained in step 2.

Step 5. If the ratio of totals from step 4 is less than 2 to 1, the level of activity in one or more review element categories can be increased to a higher subdivision to approximate the factor of 2 in weighting totals.

Note: Implementing a selected level of activity (column) under a review element will also include lower levels of activity for that review element (with two exceptions). This does not apply to element VI, skills, or element II, documentation. In the latter case, the use of data summaries obviates the assembly of a special data package for review, but all data are subject to examination on request.

a/ The "complexity" subdivisions are expressed as average part failure rate in the component. They can also be expressed as a failure percentage per 1000 hr. In this case, the corresponding percentages for five categories are: 1, 0.1, 0.01, 0.001, and (for 1 failure per 10^9 hours) 0.0001 percent.

If failure rate is expressed in MTBF terms, the proper complexity subdivision can be determined by multiplying the component MTBF (in hours) by the number of parts in the component. This number, expressed as a power of 10, is divided into 10^9. The quotient is the number of failures per 10^9 hr for the average part. For example, a 100,000-hr MTBF requirement for a component having 10 parts is equivalent to A-2 (or 10^3 failures per 10^9 hr); the same MTBF for a 100-part component would raise the subdivision selection to A-3 (or 10^2 failures per 10^9 hr).

☐ Optional activity level ■ Excluded activity level

▨ Prerequisite activity level

plication review activities.

26A2

2G 13-1

COMPONEN

A – Complexity

Expressed as the average part failure rate determined by dividing the assembly failure rate requirement for the component by the estimated total part count. Subdivisions are cells with centers expressed as powers of 10 failures per 10^9 hrs. The logarithm of the failure rate determined should be rounded to the nearest whole number to determine the applicable cell. (See note on exhibit 5 for other terms.)

B – State of the art

This technical indicator encompasses both design techniques and environmental conditions and their combination. Subdivisions are expressed as:

(0) Conventional design and environments.

(2) Unusually harsh or severe environment, beyond that previously experienced for the equipment under development.

(3) Strange environment: nuclear exposure sterilization requirements, or, in general, conditions for which part survival data are not conventionally investigated.

(4) New design techniques, packaging, or use of recent component development or technical advances. Extremely low part failure rates fall in this category.

(5) A combination of any two or more of these conditions.

This indicat
contractual
Such testing
higher asser
(1) Conv
(2) Spec
(3) Spec
an unusually
of conventic
(4) Form
(5) Long
can be demc
testing or te
use time

REVIEV

I – Number of reviews

Except for "conceptual design," which represents a higher level requirement, the reviews are listed in order of occurrence. Selection of activity at any level also includes those listed as lower subdivisions.

(1) *Breadboard:* This application review is the lowest order and most logical starting point when low-level activity is indicated and significant impact of package design is not anticipated. (See chapter 3)

(2) *Prerelease:* This application review occurs when the design is ready for release. It *may* be used alone as the lowest level of review where packaging problems are significant and the circuit design is routine. However, even at low levels of review requirement, it is normally preceeded by a breadboard review, since the total effort of these two is not much greater than for prerelease review alone, and the timing advantages of breadboard review are significant.

(3) *Conceptual design:* This level of activity includes detailed advanced planning, in addition to the two previous review requirements. In point of time, it occurs first.

(4) *Postqualification:* This review adds the evaluation, at part level, of qualification test experience to the previously cited reviews.

(5) *Postmission:* This review considers failure experience in relation to earlier review background. It is applicable to hardware which has a clearly defined "start" of the use phase and is not intended for easily maintainable items.

(6) *Data derivation:* This activity is indicated when circumstances warrant processing of collected data for future use in the data bank. It does not contribute directly to the current program.

II – Degree of documentation

Subdivisions of the documentation requirement indicate increasing depth corresponding with greater review activity. Succeeding data types or content are similar but are more complete and subject to finer analysis.

(1) *Checklist and references:* The minimal requirement consists of a simple listing of those items which have been checked, including applicable references to the source of the data – data bank, designers notebook, evaluation test reports, etc. – and results.

(2) *Assembled data package:* In addition to an index of items checked, the referenced data are assembled for immediate and future review.

(3) *Summarized data:* This level involves a more complete presentation of review results. The documentation will show, in each instance, the particular part capability adjacent to the applied stress; derating and safety factors as well as failure rate determination may be included.

(4) *Summarized data and indicated confidence:* An indication of the confidence placed in the estimates is added to the summary. This evaluation draws attention to those items requiring measurement (low confidence entries) and facilitates integration of the measurements into the test program.

III – Parameter

Parts and materia
to be checked in
tion review are ic
scope and select
(1) *Major only*
parameters affect
ment performance
are checked. Th
identified as tho
with important kr
ships to failure r
ature, dissipatio
environment is c
usually at compo
than local level.
(2) *Major and*
minor: Principal
include stress, e
failure rate, and
tors. Individual
given to performa
environments, et
for both major an
minor parameters
must be exercise
selection.
(3) *Major and*
icant minor: Thi
sider a larger nu
parameters than
sidered in parag
requires that all
be reviewd in gr
Also the applica
team makes its c
amination of all
ports on the com
seek out possibl
tions of parts or

Exhibit 6. Definition of Term

26B-2

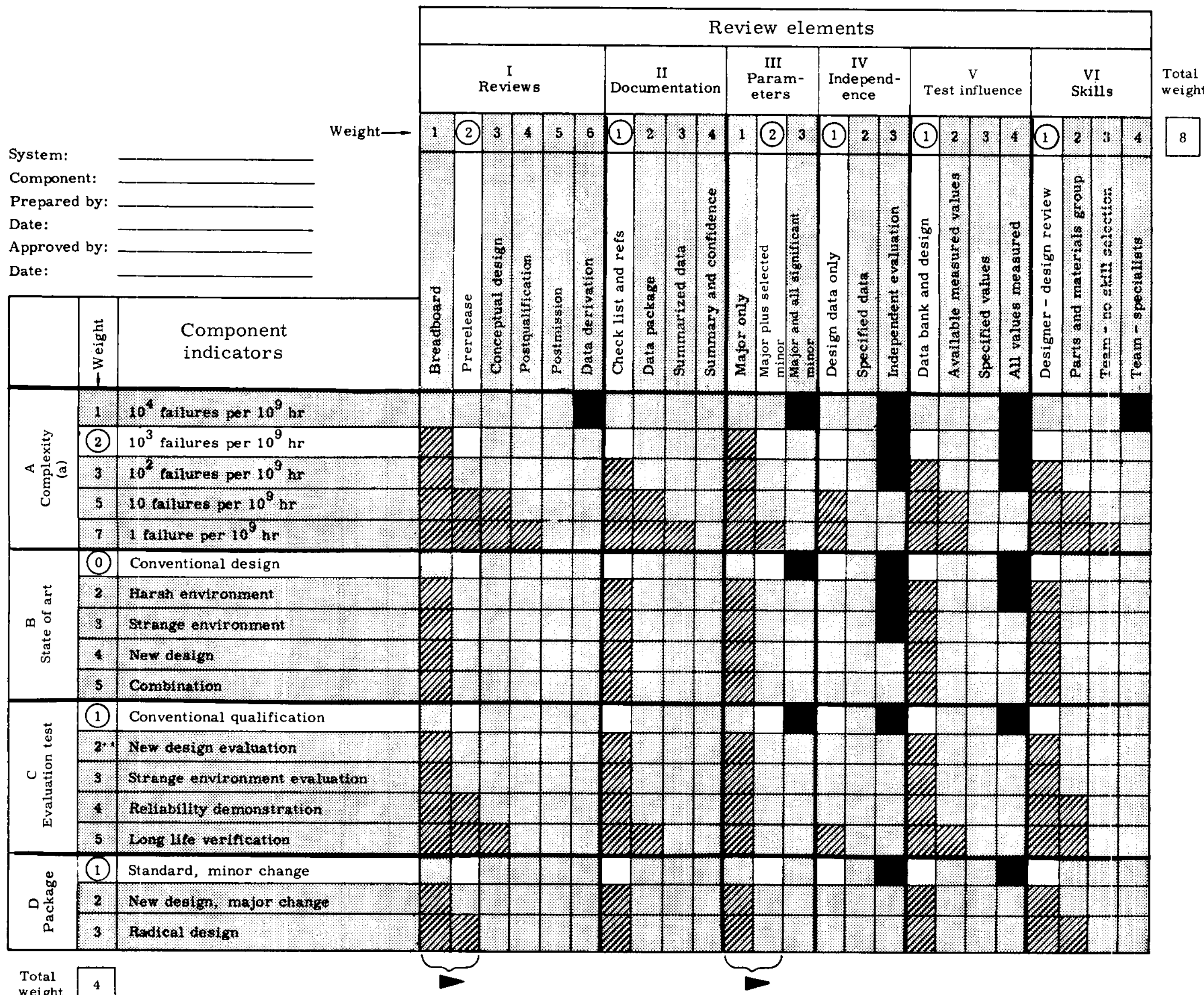
INDICATORS

C – Evaluation test	D – Package
reflects design efforts in which technical uncertainties or quirements produce a need for parallel evaluation testing. ay occur at component levels in breadboard stages or at ly levels in prototype stages. Subdivisions include: tional qualification testing. evaluation testing of a new design concept. evaluation testing to ensure operational capability under severe or strange environment or simulate test of combination l environments at a moderately severe level. reliability demonstration testing fe verification testing for mission lifetimes beyond that which trated with any certainty by real-time testing; i.e., accelerated s truncated in time at or less than the anticipated mission or	The degree of experience with the hardware packaging technique provides a measure of the predictability of interactions between the hardware elements themselves and between the elements and the external environment. Subdivision are: (1) Standard, well-understood package for which previous experience has been gained. Minor modifications to such a package, (dimensional changes, etc) are included in this subdivision. (2) New package design. Not a radical approach, but significant changes in dimensional configuration, material, mounting, etc. (3) Radical packaging: an entirely new approach or technique for which data are scarce or nonexistent, probably adopted because of a severe design problem or a particular advantage.

ELEMENTS

verage	IV – Degree of independence	V – Test influence	VI – Skill requirements
arameters applica- tified by detail. The major equip- reability re loosely arameters n relation- (temper- tc.) idered t rather *lected* rameters onmental, ety fac- ntion is , local n detail elected dgement the *signif-* vel con- r of minor e con- (2) and meters r depth. s review reex- re re- nt to sapplica- erials.	This element refers to the degree of "double check" afforded by application review, particularly in terms of its independence from the data source groups. (1) *Design data only:* The reviewer uses the data resulting from the design program and available historical (data bank) sources without any direct influence upon the data generated. (2) *Specify data needed:* Reviewers specify (usually at conceptual phase) anticipated data needed for review so that design and test can be planned to provide them. Selected verification data can also be requested at later phases. (3) *Independent evaluation of source:* Reviewers evaluate data sources to their own satisfaction to assure accuracy and completeness of source data. In addition to parts performance data, this might include questioning of design estimates of anticipated usage stresses or questioning the conservativeness of parts reliability activities.	A measure of the degree of availability of the test program for producing data needed for application review, and thus a measure of the certainty of the data being compared. (1) *Data bank and design calculations:* Only historical data and "normal" design and test data from the program are used. Testing will not concern itself with part level determinations. (2) *Available measured parameters:* The test program part level outputs will be predetermined by the "normal" design effort but will not be influenced directly by the application review. (3) *Specify parameters measured:* The reviewers will request certain test data during early test program planning. Also, during progress of the program they will influence remaining tests directly so that questionable or low-confidence estimates may be verified. (4) *All parameters measured:* Values used for comparison in the review will be verified by measurement. This level of activity does not mean that *all* parameters will be measured, but only those determined to be necessary in the review. (Implies a significant increase in workload.)	The selection of the reviewer of the composition of the review team is adapted to the level of project difficulty and its specific requirements. (1) *Designer – design review:* The designer himself reviews his applications and defends them at the design review with his supporting documentation. (2) *Parts and materials group:* Members of the parts and materials group who have contributed to the project conduct the application review, thereby increasing the variety of specialized skills and the level of documentation (from (1)). (3) *Team – no skill selection:* An independent review is conducted by one or more technically competent individuals, but they may not be specialists in the precise design and application disciplines. (4) *Team – Design specialists:* A selected team of specialists in disciplines directly pertinent to the component design and application performs a completely independent review.

r application review activities.



The total review program will also include all of the review element subdivisions in each category which are lower than the selected level.

Exhibit 8. Selection of review elements.

(Note: Only one subdivision, or level of review activity, will be finally selected in each review element category. The bracketed weights indicate the range of options available.)

System: ______________

Component: ______________

Prepared by: ______________

Date: ______________

Approved by: ______________

Date: ______________

			Review elements: I Reviews						II Documentation				III Parameters			IV Independence			V Test influence				VI Skills			
		Weight →	1	(2	3	4	5	6)	(1	2	3	4)	1	(2)	3	(1	2)	3	(1	2	3)	4	(1	2	3	4)
	Weight	Component indicators	Breadboard	Prerelease	Conceptual design	Postqualification	Postmission	Data derivation	Check list and refs	Data package	Summarized data	Summary and confidence	Major only	Major plus selected minor	Major and all significant minor	Design data only	Specified data	Independent evaluation	Data bank and design	Available measured values	Specified values	All values measured	Designer—design review	Parts and materials group	Team—no skill selection	Team—specialists
A Complexity (a)	1	10^4 failures per 10^9 hr																								
	(2)	10^3 failures per 10^9 hr																								
	3	10^2 failures per 10^9 hr																								
	5	10 failures per 10^9 hr																								
	7	1 failure per 10^9 hr																								
B State of art	(0)	Conventional design																								
	2	Harsh environment																								
	3	Strange environment																								
	4	New design																								
	5	Combination																								
C Evaluation test	(1)	Conventional qualification																								
	2	New design evaluation																								
	3	Strange environment evaluation																								
	4	Reliability demonstration																								
	5	Long life verification																								
D Package	(1)	Standard, minor change																								
	2	New design, major change																								
	3	Radical design																								

Exhibit 7. Initial selection of component indicators and optional ranges among review elements.

originally selected is usually "forced" by an exceptionally exacting design requirement in one "indicator" (especially the fourth or fifth row under A, complexity, or the fifth row under C, evaluation test).

In all cases, it should be borne in mind that the levels of application review activity selected by this or any other technically based method are subject to readjustment on the basis of overall project management factors. For example, in practice an originally planned post-mission review on a component may frequently be eliminated for reasons of personnel unavailability, schedule, or failure experience (few failures in test or use).[13]

BASIC EXAMPLES

The remainder of this chapter presents hypothetical examples to illustrate the use of the matrix for selecting the proper level of application review for five typical components of different degrees of design challenge.

Case 1

Consider the design of a power inverter which has unique input/output ratings. It is not off-the-shelf equipment, but it is well within the range of previously applied design techniques. Package shape or size and mounting arrangement may also be unique but constitute only a minor modification over earlier designs and do not involve new techniques. Use and test environments for the component are fully defined in terms of standard test conditions (also within the limits met in the past). Reliability has been expressed by an operating requirement for mean time between failures (MTBF) and total shelf life, but demonstration testing to a statistically significant level is not required.[14]

These conditions are reflected in the following component indicator category subdivisions, which are illustrated in exhibit 8:

Complexity . . . . . . A-2 (assuming 10,000 hour MTBF, 100 parts)
State of the art. . . . B-0
Evaluation test. . . . C-1
Package D-1

(Total component indicator weight is 4.)

As illustrated previously (exhibit 7), the <u>review element</u> ranges from the chart are:

Reviews . . . . I-2 to I-6
Documentation . . . . II-1 to II-4
Parameters. III-2
Independence . . . . . IV-1 or IV-2
Test influence . . . . V-1 to V-3
Skills . . . . VI-1 to VI-4

(Review element weight range is 8 to 21.)

[13]Schedule restraints can also preclude the highest gradation of II, documentation, IV, independence, and V, test influence. Personnel unavailability can preclude the assembly of a review team of specialists independent of the actual design effort.

[14]The "Note" to the "Complexity" category of component indicators in exhibit 5 explains the conversion of MTBF terms to the terms of the chart.

Indicator weights total 4. Choosing the low end of the optional range throughout will give an element weight total of 8, which conforms to the 2:1 ratio (exhibit 8).[15]

The resulting review, if a weight of 8 is assumed to be adequate, entails reviews at breadboard and engineering release (or a single review at engineering release incorporating the data developed by breadboard). Documentation consists of a checklist of parameters considered with references to the data sources used. Major and selected minor parameter areas are considered (operating stress levels, environments, and failure rates, with attention to suitable safety factors). Design and historical data are examined, and no review requirements are imposed upon the test program. Finally, it is the designer who will accomplish the review and defend it at the overall design review.[16]

Case 2

The equipment for case 2 is equivalent to that of case 1 except that the MTBF or number of parts, or both, are increased to the extent that the part average failure rate falls in the 10-failure-per-10^9-hour category. In addition, reliability demonstration is required. Therefore, the indicators are:

Complexity A-5
State of the art. B-0
Evaluation test. C-4
Package D-1

(Total component indicator weight is 10.)

Review element ranges are:

Reviews . . . . I-4 to I-6
Documentation . . . . . II-3 or II-4
Parameters. III-2
Independence IV-2
Test influence V-3
Skills . . . . VI-3 or VI-4

(Total review element weight range is 17 to 21.)

Selection of minimums within the range of options in each review element category yields a weight of 17. This selection is illustrated in exhibit 9. In this case, number of reviews, documentation, and skills may be upgraded above the minimum to achieve a better weight ratio.

The minimum application review is then seen to be upgraded from case 1 by requiring conceptual design (preplanning in detail) and assessment of qualification test results in addition to breadboard and engineering release. Documentation summaries are required because the volume of data is quite large; each applicable parameter affecting failure rate is to be covered, and design data with test verification should be provided where the review indicates a critical need. Finally, the review should be conducted by an independent team, but special skills are optional.

In this example, reconsideration may be given to increasing the review activity in one or two categories to approximate more closely the standard review factor of two. Such a decision could result in raising the levels of "Reviews," "Documentation," and/or "Skills." However, as noted previously, a review activity whose weight sum is not quite double that of the component indicators is usually adequate for projects with higher requirements. The increase should be made only if justified.

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[15]Project management may still elect to increase the review activity to any of the higher options. Experience with the part or component and additional details of the program should identify which, if any, review element may require more or less depth of treatment.

[16]These activities, suitable to the selected review element levels, are defined in exhibit 5. They are discussed more comprehensively in chapter 3.

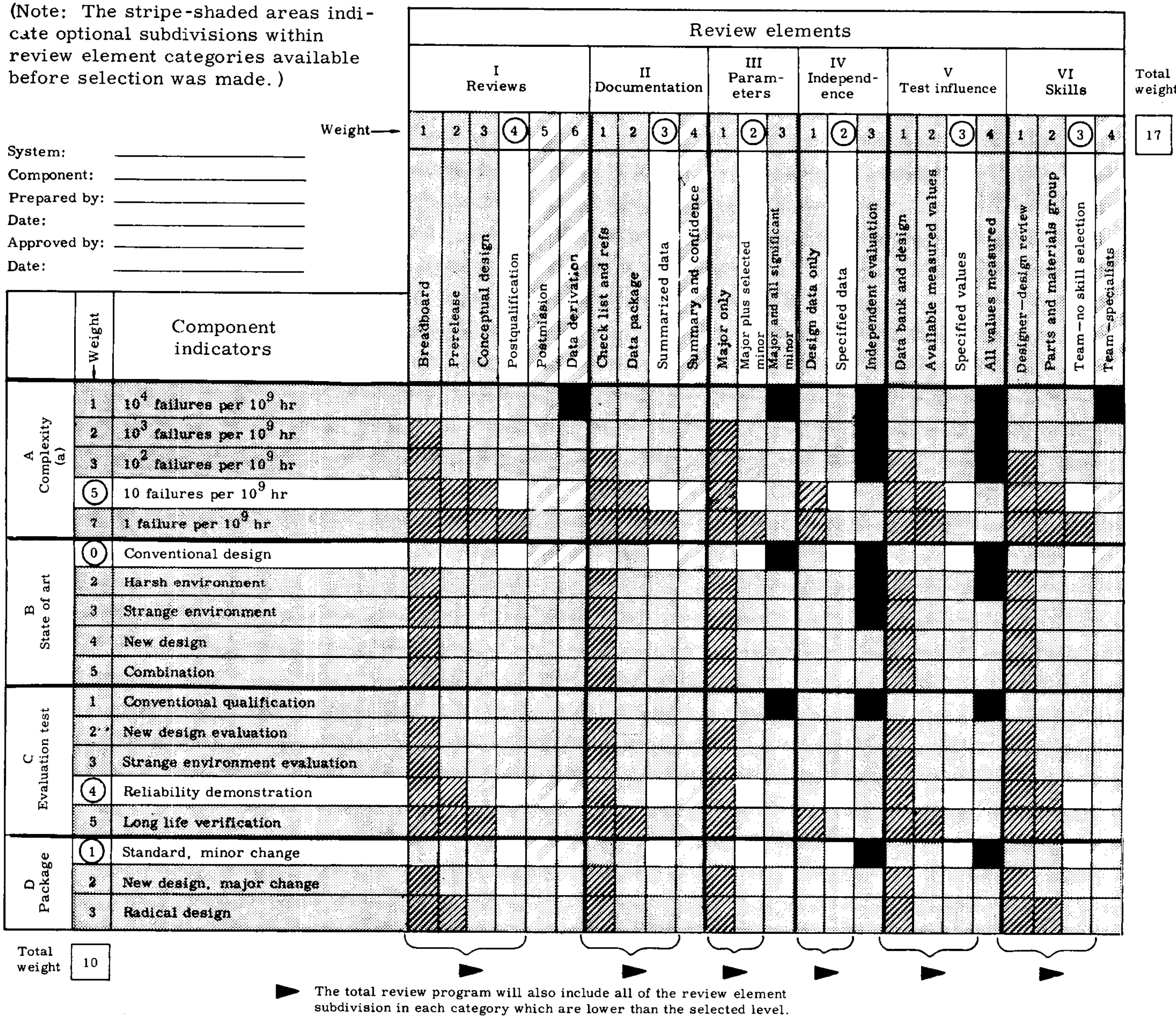

Exhibit 9. Completed selection for case 2

Case 3

The design of a large booster for space missions illustrates the effects of harsh environment and high reliability requirements. The reliability, expressed as a probability of successful launch, must be reduced to a complexity factor by some subsidiary technique, such as a constant part failure rate assumption. Under these conditions, a black box component of some criticality within the system design might be defined by such indicators as:

Complexity	A-5	
State of the art.	B-2 (vibration)	(Total component indicator weight is 12.)
Evaluation test.	C-3	
Package	D-2	

Element ranges are then:

Reviews	I-4 to I-6	
Documentation	II-3 or II-4	
Parameters.	III-2 or III-3	(Total review element weight range is 17 to 22.)
Independence	IV-2	
Test influence	V-3	
Skills	VI-3 or VI-4	

The available options are plotted in exhibit 10. In this case, a forced restriction at the upper range occurs only in "Independence" and "Test Influence," and the options are nearly identical to those of case 2.[17]

Selection of review elements at the minimum ranges would produce a review weight sum of only 17, considerably less than twice the component indicator total. On the other hand, selection of the maximum ranges available would result in a weight of 22 which approximates (although is still less than) the "factor of two." The design challenge of this project (reflected in the higher component indicator weight sum) appears to justify the greater depth of review activity. Therefore, unless other project considerations make it advisable to reduce the activity in one (or more) categories, the maximum review effort within the range would be selected; that is, one which excludes only completely independent data source evaluation and the requirement that all values be verified by measurement.

Case 4

As an extreme illustration, a highly critical component in a space probe or satellite system will illustrate the extreme requirement for review. For example, the appropriate indicators may be (exhibit 11):

Complexity	A-7 (long life requirements)	
State of the art.	B-4 (new design)	(Total indicator weight is 16.)
Evaluation test.	C-3	
Package	D-2	

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[17]Case 2 did not permit review of all significant minor parameters because of the state of the art was conventional. In case 3 the harsh environment does allow consideration of the higher review level. This is not to be construed as prohibiting failure analysis as part of the parts program in case 2, but rather as an unjustified activity for an independent review, since parts are applied under customary conditions and failure causes will generally be quite obvious (usually poor part quality). In view of the reliability demonstration required, management may decide to upgrade the review in this instance, subject to past experience.

(Note: As explained in the text, a suitable weighting factor ratio can be obtained in this case only by selection at the high range of each review element category.)

System: ____________
Component: ____________
Prepared by: ____________
Date: ____________
Approved by: ____________
Date: ____________

			Review elements																						
			I Reviews						II Documentation				III Parameters			IV Independence			V Test influence				VI Skills			
		Weight →	1	2	3	4	5	6	1	2	3	4	1	2	3	1	2	3	1	2	3	4	1	2	3	4
	Weight	Component indicators	Breadboard	Prerelease	Conceptual design	Postqualification	Postmission	Data derivation	Check list and refs	Data package	Summarized data	Summary and confidence	Major only	Major plus selected minor	Major and all significant minor	Design data only	Specified data	Independent evaluation	Data bank and design	Available measured values	Specified values	All values measured	Designer—design review	Parts and materials group	Team—no skill selection	Team—specialists
A Complexity (a)	1	10^4 failures per 10^9 hr																								
	2	10^3 failures per 10^9 hr																								
	3	10^2 failures per 10^9 hr																								
	5	10 failures per 10^9 hr																								
	7	1 failure per 10^9 hr																								
B State of art	0	Conventional design																								
	2	Harsh environment																								
	3	Strange environment																								
	4	New design																								
	5	Combination																								
C Evaluation test	1	Conventional qualification																								
	2	New design evaluation																								
	3	Strange environment evaluation																								
	4	Reliability demonstration																								
	5	Long life verification																								
D Package	1	Standard, minor change																								
	2	New design, major change																								
	3	Radical design																								

Exhibit 10. Optional review element range for case 3.

(Note: The stripe-shaded areas indicate optional subdivisions within review element categories available before selection was made.)

System: ______________
Component: ______________
Prepared by: ______________
Date: ______________
Approved by: ______________
Date: ______________

			Review elements																							
			I Reviews						II Documentation				III Parameters			IV Independence			V Test influence				VI Skills			
		Weight →	1	2	3	4	5	6	1	2	3	4	1	2	3	1	2	3	1	2	3	4	1	2	3	4
	Weight	Component indicators	Breadboard	Prerelease	Conceptual design	Postqualification	Postmission	Data derivation	Check list and refs	Data package	Summarized data	Summary and confidence	Major only	Major plus selected minor	Major and all significant minor	Design data only	Specific Data	Independent evaluation	Data bank and design	Available measured values	Specified values	All values measured	Designer—design review	Parts and materials group	Team—no skill selection	Team—specialists
A Complexity (a)	1	10^4 failures per 10^9 hr																								
	2	10^3 failures per 10^9 hr																								
	3	10^2 failures per 10^9 hr																								
	5	10 failures per 10^9 hr																								
	7	1 failure per 10^9 hr																								
B State of art	0	Conventional design																								
	2	Harsh environment																								
	3	Strange environment																								
	4	New design																								
	5	Combination																								
C Evaluation test	1	Conventional qualification																								
	2	New design evaluation																								
	3	Strange environment evaluation																								
	4	Reliability demonstration																								
	5	Long life verification																								
D Package	1	Standard, minor change																								
	2	New design, major change																								
	3	Radical design																								

Total weight: 16

Total weight: 24

► The total review program will also include all of the review element subdivisions in each category which are lower than the selected level.

Exhibit 11. Completed selection for case 4.

The resulting element ranges are:

Reviews . . . . I-5 or I-6
Documentation II-4
Parameters. III-3
Independence . . . . . . IV-2 or IV-3
Test influence . . . . . V-3 or V-4
Skills VI-4

(Total review element range is 21 to 24.)

The different requirements of the project have forced the review activity to the highest level in four of the seven categories. No upper restrictions have been imposed. The only options are the highest and next highest subdivisions in three review element categories. Obviously, the maximums should be selected, although the weight will still be less than the 2-to-1 ratio. (Actually it is 1.5 to 1.) As shown in exhibit 11, this represents the maximum depth of review available. The fact that the design is approaching an area of very high risk is forewarned by the absence of techniques for the part program to effectively cope with the project challenge. More effective techniques, deserving of higher weighting factors, are not known at this time. The state of the art in application review has been reached.

Case 5

A servoactuator used in a space-mission launch vehicle is an illustration of a highly critical mechanical component. It alines the thrust vector to keep the vehicle on its planned trajectory. The appropriate component indicators may be A-5, B-2, C-3, and D-2 for a total weight of 12 (exhibit 10). Element ranges would then be I-4 to I-6, II-3 or II-4, III-2 or III-3, IV-2, V-3, and VI-3 or VI-4 for a total range of element weights of 17 to 22. The maximum here is slightly short of the standard 2-to-1 ratio. However, as in case 3, only the completely independent data source evaluation and the requirements that all values be verified by measurement are excluded.

APPENDIX

Elements of Typical Parts and Materials Program

A general discussion of the objectives, functions, and problems of the parts and materials program is presented herein to provide additional insight into the relationship between this activity and the parts and materials application review function.

BACKGROUND

Historically, the function of the parts and materials program has been to assist designers in selecting parts and materials for a project. With the increase in system complexity and operating requirements, however, this function has evolved from a convenient or economical form of project assistance to a critical influence on mission success, particularly in electronics and aerospace applications.

Today, the selection, specification, and qualification of parts and materials, as well as the preparation of approved lists, are encompassed within a comprehensive program conducted by identified specialists whose primary objective is the support of mission requirements. The application review provides for evaluation of the effectiveness of this program at principal design milestones for each component. The review contributes, in turn, to formal design reviews at component levels in which critical audits of all aspects of the design are conducted.

Basically, the requirements for part selection are derived from the requirements of the overall mission which the system hardware is to accomplish. The derivation starts with the establishment of a mission concept and selection of a concept of hardware design which can accomplish it; this permits environmental and performance requirements for subsystems and components to be derived from those of the system (by accounting for actions by the components, interactions between the components, and their effect upon the system profile itself). By a similar process, the component requirements can be further evolved to a set of idealized part requirements.

This seems simple and direct. In practice, however, the basic logic remains valid, but the simplicity disappears. Complications are caused by the following factors which characterize most aerospace development efforts:

(1) The evolution of hardware design is an iterative process with a complex pattern of trade-off decisions and feedback loops. The result is a series of readjustments in requirements at the lower levels of assembly.

(2) The existence of a requirement for a part having certain performance and environmental capabilities does not mean that such a part is available. If it is not available, the resulting action may be another cycle of design adjustments through part of the system.[1]

(3) Procurement problems may be encountered even when suitable parts are apparently available. For example, small quantities may not attract a vendor's interest sufficiently for him to accept reliability requirements or stringent control procedures and policies.

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[1]This factor is also complicated by the early need for preliminary parts and materials lists that will provide minimum selection guidance for designers and lead time for procurement.

Because of these constraints, the parts and materials program is forced into an iterative process of its own. In the beginning, requirements are simply matched with the known capabilities of generic parts and materials. Later, the selection, specification, and qualification of parts are refined to optimize the acceptable risk to the total project effort. Application reviews follow this same pattern and serve to unify the iterative selection process and to assure that it is complete, without error, and acceptable.

FOUNDATIONS OF PARTS AND MATERIALS PROGRAM

The parts and materials program comprises a number of activities including selection, specification, qualification, testing, source selection and control, documentation, application review, and field support. Each of these activities starts early in the project cycle and continues at some level of effort throughout a large part of the life of the project. However, certain decisions must be made, and certain vital parts program activities must be instituted at the very beginning of the project (i.e., during the conceptual design phase) in order to permit the parts program to respond in a timely manner to project needs as follows:

(1) Project management must concur with a defined scope and the philosophy of the parts and materials program
(2) Uniform criteria governing derating and safety factors must be issued under project authority
(3) Preliminary parts and materials lists must be prepared by the parts and materials group in cooperation with the designers and must be maintained, updated, and eventually transformed into project approved lists

PROJECT MANAGEMENT

Project management decisions have a direct impact upon the parts and materials program. However, the project manager requires information and recommendations from his parts specialists—as well as from design, procurement, reliability, quality, and other project groups—to make these and other decisions which form the basis for execution of the project. It is essential that these specialists provide the project manager with this information early enough to enable him to make or delegate decisions in a timely manner.

Information Required by Parts Program Manager

Project management must provide direction and certain types of information to the parts and materials manager at the beginning of a project and during its following phases. Among the first and most important are data and decisions in these areas:

(1) Reliability level required for parts and materials for both flight and ground installations. Will parts and materials be selected from those with established reliability? Will each lot of procured parts require 100 percent screening tests? Are parts purchased to the lower levels of government specification adequate? Or, is it possible to use commercial off-the-shelf items?
(2) Selection criteria. To what extent will parts and materials be selected from existing preferred lists? Does the contract establish guidance here?
(3) Procurement policies. Is the program of such a nature that a large proportion of parts will require single-source, single-lot procurement, or are normal procurement practices adequate for all parts? To what extent will competitive bidding and multiple-sourcing be used?

In addition, in order to discharge his responsibilities in coordination with other project activities as the effort proceeds, the parts and materials manager must keep abreast of the following information:

(1) Continuous estimates of environments at the local level (modified as the program develops)
(2) Reliability estimates, with increasing precision if goals are difficult to achieve
(3) Functional stress levels for each application of each part or material, including the early design phases
(4) Change data, with increasing detail as the project approaches engineering release
(5) Cost limitations in part procurement and part test
(6) Project schedules
(7) Data requirements which must be fulfilled to meet contractual commitments

Control Procedures

Control procedures for parts and materials activities, based upon project guidelines, must be established and implemented during the early design phase. They include programs for designs procured from outside vendors, general data requirements, control of the actual hardware, part test and handling disciplines, traceability requirements, procurement practices, and part measures to be applied to off-the-shelf components selected for the system. Establishing these controls at an early stage is essential in order to obtain an optimum design and to permit part qualification early in the program. Certain controls will be required by the system contract (see NPC 200-2, ref. 5).

Even in the early phase, reliability estimates at the component level are necessary in judging the feasibility of attaining the system goal. Tentatively selected components often can be further subdivided into part types and quantities with reasonable accuracy at this time. Such data are adequate to establish a first approximation of the failure-rate requirements acceptable for part types. When compared with the failure rates demonstrated by parts in similar application environments, these estimates indicate the feasibility of a conceptual design and aid materially in choosing among competing concepts, components, and parts. Timely activity in all these areas will have a significant benefit to the technical, fiscal, and schedule aspects of the project.

DERATING AND SAFETY FACTORS

The consistent use of derating and safety factors is a prerequisite to reliability achievement and the proper application of parts and materials and is important to design as well as to the parts and materials program. Early in the design phase, selected derating and safety factors (with conditions of their intended use) should be assembled for the project in a manner convenient for the various design groups and promulgated with project management authority. Originally, such factors will probably be derived from the experience of designers and application specialists; later during the project cycle, empirical values will be refined by analysis, testing, and the explicit requirements of a specific part or material application. However, it is essential that the groundwork for derating and safety factors be laid early in the project cycle to forestall unnecessary application problems in later phases.

It is particularly important that the inevitable trade-offs among design parameters be accomplished at the system level under overall project control, and not at the detail level. Derating and safety factors affect the complexity, size, weight, cost, power, and other characteristics of hardware; for this reason, their use cannot be left to the sole discretion of individual designers.

Influences Upon Derating

In general, derating and safety factors are used to account and compensate for:

(1) The statistical distribution of part capability (lot to lot and by type)
(2) The effects of environmental stress on part performance
(3) The specific system life requirements (failure-rate adjustment)

Their consistent use, however, is complicated by the different practices that have evolved in various design disciplines, the unknowns in manufacturers' ratings, and the particular problems of a given part or material application.

An experienced electronics designer, for example, will state that he derates a wire-wound resistor to 50 percent of its rated power, or a transistor to 20 percent of its rated power. He means that his experience shows the statistical variations of part capability and of usage stresses to be such that this derating is necessary for a high probability of successful performance. The capability (rating) of parts is based on criteria (sometimes arbitrary) which differ among manufacturers and are not always known to the user. If distribution functions for these variables were available, the probability of success could be cited as a function of the derating factor. But, in practice, they are seldom known, and the designer is forced to apply a generic factor based upon his experience with similar parts.

A second derating is associated with the definition of part performance capability as a function of some environmental stress. Such derating factors for broad classes of electronic parts are available in military and industry documents (e.g., ref. 6). However, these factors in no way protect against the variabilities of parts capabilities and usage stresses. The rates of degradation for many parts and materials are functions of thermal, electrical, radiation, or mechanical stresses, and they must be determined for the specific system environment and life requirements. Reliable application requires that the generic derating of a part type also be derated for environment.

A third derating occurs when the reliability engineer selects the failure rate for use in analysis. This factor is some function of the other two, that is, those associated with distribution and environment. It is usually based on generic instead of specific failure-rate data and therefore adds a degree of conservatism in design which contributes to long life.

Safety Factors

The structural or mechanical designer traditionally applies a safety factor to his applied loads and then compares this increased load to the allowable loads. The safety factor provides reliability by protecting against statistical variations of applied loads and allowable loads.[2] For instance, normal aircraft practice and specifications require a factor of safety of 1.5 from applied load to ultimate load, with additional factors of 1.15 for fittings, 2.0 for castings, etc. The ultimate load is then compared with the allowable load, the basis being the material properties in the particular environment.

Many attempts have been made to establish exact values for probability of failure of structures under static loading. The familiar Warner analysis is normally used, but distribution data are seldom available for a meaningful prediction. When the relationship between safety factors and reliability is not known, the recourse is to treat the safety factor as an evolutionary number previously successful in similar use.

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[2]Allowable loads are reduced as a function of various environments; ref. 7, for example, describes the effects of temperature on the allowable stresses for many materials.

Conditions which cannot be accurately foreseen and require dependence on safety factors include, for example, hotspots in resistors, ac ripple effects in capacitors, voltage spikes on transistors, nonhomogeneity in castings, and nonuniformity in Fiberglas-reinforced plastics. The safety introduced is clearly dependent upon a detailed knowledge of the rating basis, capability, load, application, and recorded statistics from prior use.

In summary, the basic logic of derating in the application of parts and materials requires that the capability of a part (rating) or material (allowable) be decreased as a function of environment and that an additional arbitrary factor be applied to the rating (derating) or to the applied load (safety factor) to protect against variations of load and capability. However, in order to follow through in applying this logic on a project-wide basis, the following steps must also be stressed:

(1) Verification of manufacturers' ratings and critical examination of rule-of-thumb derating and safety factors
(2) Continued refinement of the factors as the design progresses in order to reflect new values for explicit conditions of use
(3) Consideration of combined loads or environments, particularly where two or more factors may apply simultaneously, in order to avoid an unnecessary penalty to the design

PARTS AND MATERIALS LISTS

The proper selection and utilization of parts and materials as well as the minimization of the number of part and material types are always important to the project, and this importance increases as missions become more difficult. The former contributes to mission success and the latter to maximum procurement and handling economies, minimum test costs, reduced data requirements, and minimum specification preparation. Like the consistent use of derating and safety factors, this general problem requires project-level attention and coordination.

Parts Lists

Parts lists are used to achieve the objectives of proper part selection and utilization and minimization of part types. Although there are some variations in terminology within the industry, the parts and materials list can be identified as of two types corresponding to normal project design phases:

(1) Preliminary lists are prepared and used during conceptual design and during breadboarding
(2) Approved lists are evolved in the process of detail design

The preliminary parts list must be prepared as early in the project life as feasible. This list can be generated by observing environments, reliability apportionments, and design approaches during the conceptual phase of design. Then, as a joint effort by parts specialists and designers, a minimum number of part types of known performance can be selected. Even in these early stages, the associated data should be as complete as possible; they should include a procurement specification, if available, for each part type and the identification of a manufacturer and source for specific parts when appropriate. The project preliminary parts list is the basis for the project approved parts list (APL) which begins to take shape after the functional design breadboard is completed. The type of information normally recorded is shown in exhibit A-1, which is a sample page from a preliminary parts list.

The project parts list is evolutionary in nature, as it is based largely upon previous part knowledge and experience. On occasion, the customer will state parts requirements in terms of a customer's preferred parts list for the system he is procuring. These lists are available

1.0 Resistors

Note: a. Resistance values shall be selected from the 10% tolerance decade of values listed at the end of this section, regardless of the actual tolerance used.

b. Use carbon composition types only for resistance values outside the range of metal film, RNR types. In such cases derate power an additional 50%.

	SPEC	TYPE DESIGNATION	RESISTANCE RANGE (OHM) a	POWER (WATTS)	MAX CONT. VOLTAGE	APPROX. SIZE (IN.)
1.1	Metal Film, MIL-R-55182. (Tol. 1%(F), T.C. 50 ppm/°C, T_{max} 125°C full load, 175°C zero load)					
	/1	RNR55C----F-	49.9 - 100K	1/10	200	9/64d x 9/32 (max)
	/4	RNR63C----F-	49.9 - 1M	1/4	300	1/4d x 21/32 (max)
	/6	RNR70C----F-	29.9 - 1M	1/2	350	21/64d x 7/8 (max)
1.2	b Carbon Composition, MIL-R-39008. (Tol. 5%(J), T.C. 2000 ppm/°C approx., T_{max} 70°C full load)					
	/1	RCR07G---J-	10 - 22M	1/4	250	3/32d x 9/32 (max)
	/2	RCR20G---J-	10 - 22M	1/2	350	5/32d x 27/64 (max)
	/3	RCR32G---J-	2.7 - 22M	1	500	1/4d x 19/32 (max)
1.3	Metal Film, Glass, MIL-R-22684A. (*Tol. 2%(G), 5%(J), T.C. 200 ppm/°C, T_{max} 70°C full load, 150°C zero load)					
	/1	RL07S---*	51 - 150K	1/4	250	.098d x 9/32 (max)
	/2	RL20S---*	51 - 470K	1/2	350	.161d x .416 (max)
	/3	RL32S---*	51 - 1M	1	500	.250d x .593 (max)
	/4	RL42S---*	10 - 1.5M	2	500	.328d x .640 (max)

RLR series is preferred but is not available at this time. Use RL series as substitute temporarily.

Exhibit A-1. Sample page from a preliminary parts list.

to contractors either for reference or mandatory use in part selection as required by contract. In addition, contractor lists previously developed for a similar project can be useful.

Only parts with good histories and substantial background data should be included on the preliminary parts list. This is the reason for utilizing other sources of information, such as previous contractor lists and customer and industry lists, in the initial preparation. One of the prime functions of the part program is qualification of these parts on the preliminary list or justification of selection of available alternates. Qualification of these parts followed by qualification of the component designs in which they are applied is the basis for finalization of the project APL, which in turn will be the basis for control of parts usage for the project hardware.

Materials Lists

A project preliminary materials list (PML) similar in purpose and method to the project preliminary parts list should be generated simultaneously with it. Designers concerned directly with materials (structures, pressure tanks, etc.) consider parameters much the same as those that affect parts selection: stress, loads, environment, fatigue, failure probability, and, of course, function. In general, except for strange environments (e.g., nuclear exposure) and special properties (e.g., outgassing), the properties necessary for selection and application are available in standard references (e.g., refs. 3, 4, and 7).

Choice of specifications, stock sizes, and other pertinent limitations should be made and included in the PML in order to promote standardization. It is also convenient and desirable to include in the PML the principal material properties, types, forms, and sizes, and even suitable fabrication processes, although a simple identification fulfills the basic intent of the document. Environmental properties of importance should be noted or a plot or curve of the affected properties should be included (see refs. 3, 4, and 8). Materials for selected application only, such as flight or ground equipment, should be so identified.

Often these data are not provided within a single format. In such cases, a project may accomplish the purpose of the PML by using a standard materials selection format (a typical format is shown in exhibit A-2) and supplementing it with a separate listing which identifies each material with its suitability for specifically defined application categories within the system hardware.

The project PML evolves to the project AML in a manner analogous to the evolution of the project APL.

PROGRAM ACTIVITY AREAS

Once the basic project and program guidelines are established, the activities of the parts and materials program center largely upon the selection of parts and materials and their verification in particular applications. This process, extending through the life of the project, necessarily involves control of sources (vendors), specification, and documentation as well as testing and support. Of these, selection is functionally the most important, and documentation is procedurally the most extensive. Application reviews, of course, provide surveillance over all activities and serve as a formal interface with design through their contribution to corresponding design reviews. These activities will be described under appropriate topics in the following subsections.

PARTS AND MATERIALS SELECTION

Selection of parts and materials is based upon:

(1) The functional requirements of the design (derived from system analyses)
(2) Environmental data reduced from mission to local level
(3) Reliability estimates of the desired part performance
(4) Evaluation of the criticality of individual functions

1100 ALUMINUM SHEET AND PLATE		ALUMINUM ALLOYS DESIGN DATA - SHEET AND PLATE
CURRENT SPECIFICATION QQ-A-250/1c	OTHER SPECIFICATION	SUPERSEDED SPECIFICATION: QQ-A-561

DESCRIPTION

Low strength non-heat treatable commercially pure aluminum sheet and plate.

USES

Non-structural and electrical applications where excellent formability, good corrosion resistance, good electrical conductivity, or any combination of these is required and where high strength is not necessary. EC grade is available where electrical conductivity is prime requirement.

PROCUREMENT

Sheet normally procured in -O and -H14 tempers.
Plate normally procured in -F temper.

Note: -H24 temper is considered interchangeable with -H14 and may be supplied at the option of the producer unless the -H24 temper is specifically excluded. Engineering documentation (Material Substitution or DCN) is not required. -H22, -H26, and -H28 tempers are similarly interchangeable with -H12, -H16 and -H18 respectively.

MECHANICAL PROPERTIES [a]

Material Specification	Thickness In.	F_{tu}	F_{ty}	F_{cy}	F_{su}	F_{bru}	F_{bry}	El in 2" % Min.
						e/D = 2		
		1000 psi minimum						
QQ-A-250/1 -O	0.006-3.000	L11	3.5[b]					15-30[c]
-H12/H22	0.017-2.000	L14	11.[b]					3-12[c]
-H14/H24	0.009-1.000	L16	14[b]					1-10[c]
-H16/H26	0.006-0.162	L19						1-4[c]
-H18/H28	0.006-0.128	L22						1-4[c]
-H112	0.250-0.499	L13	7					9
	0.500-2.000	L12	5					14
	2.001-3.000	L11.5	4.5					20
-F	0.250-6.000	No requirements						

L = longitudinal
[a] QQ-A-250/1c

[b] No requirement for thicknesses 0.050 in. and under.
[c] Range of minimum elongation which generally increases with thickness.

OTHER DATA

See Wrought Non Heat-Treatable Aluminum Alloys General Technical Information data 5.1.1

ENGINEERING NOMENCLATURE

ENGINEERING MATERIAL CODE	MATERIAL SPECIFICATION		ABBREVIATED DESCRIPTION
1100A	QQ-A-250/1	1100-O	SH AL
1100P	QQ-A-250/1	1100-H14	SH AL
1100B	QQ-A-250/1	1100-F	PL AL
	QQ-A-250/1	H1100-H112	PL AL

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Exhibit A-2. Sample page from a preliminary materials list.

(5) Quality history available from usage[3]
(6) Availability, delivery, and cost of the desired parts

These criteria are pertinent in every phase of project life. They simply become more precise and more complete as the design progresses from concept to hardware.

Initial selections should be made directly from the preliminary parts and materials lists, although this restriction may require early trade-off in such matters as whether a promising design concept should be used which will involve the risk of using parts of less known capability. These choices may be refined in progressing from concept to breadboard design. Later, when the functional design breadboard is complete, a final choice of parts and materials will be necessary.

Detail Design

In the final stage, the selection of parts for each component should be a coordinated effort of the parts and materials specialist, the designer, and the affected packaging group. This requires close continuous communication and an effective working relationship. Broadly speaking, the end result of this process for all components, in total, will be the development of the approved parts list (APL) and the approved materials list (AML), which then become the basis for control of parts and materials usages on the project. During the same period the following processes should take place:

(1) Qualification data on parts and materials should be evaluated
(2) Competing products should be compared for design features and life expectancy
(3) Failure reports should be analyzed in order to determine their impact on continued usage and controls
(4) Cost, multiple sourcing, and availability should be considered

It is also here that minimization of parts and materials types must be achieved because it cannot be effectively implemented later. This task is best served by close adherence to the APL and AML and disciplined justification for all deviations from these lists.

Selections by Subcontractors

Particular attention is needed in parts and materials selection and application, not only by the prime contractor but also by second (and lower) tier subcontractors and vendors. Ideally, the same disciplines exercised by the prime contractor should be imposed upon subcontractors, and lower tier subcontractors should exercise these same disciplines over vendors. Practically, the prime contractor may have to be satisfied by an evaluation which indicates that the subcontractor's methods will achieve commensurate results. Selection of "shelf items" to enhance reliability also poses a dilemma in that the historical data which dictated selection are valid only if the shelf-item vendor initially exercised and maintains an adequate parts program complete enough to repeat past performance with a high degree of certainty and is maintaining his standards.

SOURCE SELECTION AND CONTROL

A corollary function of part and material selection is the selection of the manufacturer and source for the item and control of their approval status. The fundamental basis for selection or approval of each manufacturer is qualification of that manufacturer's part to a procurement

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[3]Information may be obtained from the contracting NASA installation and from interagency data exchange programs such as IDEP and FARADA.

specification adequate to the project's needs. A quality history for each manufacturer is used to observe evidence of continuous control or reasons for deletions from the APL or AML.

Identification of Manufacturer

The designation of a part should include designation of the manufacturer(s) meeting specification (or project) requirements for that part. As the preliminary parts list evolves into an APL, manufacturer designation is mandatory. Because of the need for assurance that all parts on the project APL are qualified or proven to project requirements, the list must identify the item not only by its generic designation but also by specification number and manufacturer or manufacturer's identification number

For convenience these source selections should also be documented and controlled through a project approved vendor list, which is normally maintained by the contractor's parts and materials group to ensure that manufacturers and vendors of proven capability for each specific part are employed. In some procurements, time phasing may not permit full source evaluation when early breadboard or prototype hardware is required. However, experience with a manufacturer whose parts have been used during the breadboard or prototype phase and records of his past performance are particularly valuable in subsequent evaluation and selection of entries for the project APL. Generally, it is safer to continue with the source who produced the particular design originally qualified if he has maintained continued control over design and process changes and has maintained his quality level.

Control of Manufacturing Source

In later stages, the contractor should control his procurement operations in order to retain the reliability achieved through his part manufacturer and source evaluation. The quality and procurement organizations should provide such surveillance, but the parts and materials program will contribute to quality program requirements in such areas as original qualification requirements, periodic requalification, and levels of inspection and test. Careful attention must be given to all drawing discrepancies, omissions, questions, and negotiations that occur when orders are processed, and equal care must be exercised in monitoring of source inspections during production. Each lot procured should be accompanied by documentation identifying the source and giving evidence of compliance with the requirements of the applicable specification.

The prime contractor is also responsible for assuring proper source selections by his subcontractors and their suppliers. In a practical sense, he will satisfy this need through his evaluation of the component subcontractors' or component vendors' capabilities and methods in his initial procurement, not through detailed monitoring at these lower levels. This aspect of a subcontractor's operation should be one of the criteria for including this subcontractor in the prime contractor's approved vendor list.

Storage and assembly conditions must also be controlled in order to avoid degradation of parts and materials. There is greater probability of receiving fresh stocks of the age-critical items from a manufacturer than from a distributor, even though the latter delivers bonded stock certified to a standard specification. However, the contractor may buy with more confidence from a distributor whose lots are identified by date or lot code numbers indicating acceptable ages. In some cases, this approach may result in shorter procurement lead time. In all cases, contractors and subcontractors must avoid bargain purchases of standard items from unauthorized sources who have not been evaluated and are not on the project approved vendor list.

SPECIFICATIONS

Definitive specifications or drawings should be used in the procurement of all parts and materials. For the sake of economy, reliability, and procurability, existing specifications should be employed whenever applicable and adequate. However, when existing specifications do not satisfy the system requirements, "add on" modifications or completely new specifications must be prepared in accordance with project requirements. These specifications define the characteristic capabilities inherent in the part or material as well as the quality controls necessary to insure adherence of the part or material to the specification requirements.

Terminology

Specifications should be written in terminology familiar to the applicable parts discipline; and government or industry standard tests and test sequences should be required, where adequate for the particular application. In this regard, part specifications should be geared to the capability of the part, not to usage requirements, and translated to terms standard to the producing industry. Any interpretation necessary to convert mission requirements to part requirements should be performed by the systems contractor and put in the purchase specification in conventional part capability terms. Similar precautions should also be observed in specifying materials, although material procurement is usually less complex and more conventional than part procurement. Typical examples are as follows:

(1) A manufacturer's part may be qualified in sinusoidal vibration, even though the mission requires resistance to an equivalent random vibration
(2) A material may be qualified by conventional sinusoidal fatigue testing, even though the mission requires random loading

In order to permit part procurement on an economic and orderly basis, it is essential that the part specifications use standard definitions, terminology symbols, and format. It is also important to establish clearly buyer-vendor understanding of the requirements at the time when the procurement is placed. It is the prime contractor's responsibility to verify the translation of mission requirements into parts requirements. This is usually done by later testing to actual mission requirements at a higher level of assembly.

Acceptance Criteria

Specifications not only define performance and environmental capabilities of properly made parts and materials but also prescribe acceptance techniques in order to ensure their conformance. The development and inclusion of acceptance criteria are necessary for defining supplier requirements as well as for receiving inspection. Quality assurance provisions, including selection of tests and establishing levels for parts qualification or evaluation, screening, and lot acceptance, are a major portion of the specification. Where these requirements are special, however, the contractor must be prepared to pay for added control procedures demanded by his new or modified specifications.

Purchase specifications are finalized as soon as acceptance criteria can be identified, since the parts requirements criteria are fixed and represent the capabilities of the selected part. However, the fact that a part has been qualified to meet specified environmental and performance requirements as a part does not of itself qualify that part for use in any specific application. The final approval of use of the part in a particular application must wait until local stress and environmental levels have been established and appropriate derating and safety factors have been applied and confirmed through qualification testing of the component. In effect, this is the "qualification" of the use of a part in a particular application and is the essence of application review described in this document.

TESTING

The performance capability as well as the quality of parts and materials must be supported by sufficient test data. In order to restrain costs and to keep the total test effort within manageable proportions, full use must be made of existing data from established data banks, previous in-house tests, and vendor tests. Of course, when existing data are used, the objectivity of these data and their valid relevance to the intended new application should be judged carefully. If existing data are inadequate, evaluation or qualification tests will be necessary.

Special Environmental Verification Tests

The basic purposes of these tests at part level are:

(1) To determine suitability of parts and materials for their application
(2) To establish special environmental criteria for acceptance

Initial testing in these categories is required for parts and materials selection and procurement.

During the life of a program, the need for additional parts or materials testing may arise at unpredictable intervals. Examples are:

(1) Component or higher assembly design changes
(2) Part design change (by vendor)
(3) New or alternate vendor evaluation (i.e., change of source for procurement)
(4) Special requirements (unanticipated environment or exposure, particularly an environment not normally covered by existing parts or materials specifications (such as sterilization gases or radiation)
(5) Unexpected failure(s) of specified part or component

Acceptance Testing

Once the capability of the parts and materials has been verified, acceptance testing is required in order to assure that the inherent capability is retained throughout manufacture and delivery. Various screening tests or sampling plans may be used (e.g., the 100 percent screening and burn-in in space projects). The extent and method of testing are dependent upon the prevalent failure mode of the part or material, the quantity being procured, and the acceptable risk or level of reliability required.

In-House Versus Vendor or "Outside" Testing

When such additional testing is required, the advantages and disadvantages of contractor in-house testing must be weighed against the possible economy of testing by part manufacturers, customer, or outside laboratories. Differences in schedules should also be considered in the decision.

The possible advantages of in-house testing are:

(1) Direct communication with design and application personnel
(2) A gain in understanding of part characteristics by project personnel
(3) Assurance in the objectivity of the data, particularly when indirect results must be interpreted

The practical difficulties of in-house testing are:

(1) Possible schedule limitations
(2) The availability of suitable test facilities and experienced personnel

(3) The additional burden of failure analysis and evaluation of test results by parts and materials specialists

Regardless of whether this additional testing is done by the contractor in-house or performed by the vendor or an outside agency, it should be planned to complement the total project testing program and to validate the project parts selection.

SUPPORT

Support activities for the parts and materials program extend beyond design to include:

(1) Participation in failure investigations
(2) Conduct of failure analyses at part level
(3) Determination of failure rates or life experience during the test and use of the hardware

Failure rates and specific failure experience during testing of developmental models and end items supply the basis for reliability predictions for the operational hardware. If this experience is appreciably different from original prediction, the impact upon the program may be great. Therefore, failure data should be monitored closely to yield the earliest indication of reliability trends.

For large systems, the coordination of and participation in subcontractor parts program support activities at subcontractor plants can become a greater task for the prime contractor than in-house support. This is particularly true when high reliability is required and the corrective action for any failure receives great emphasis. Neglecting this participation, however, is a risk which the contractor cannot afford to take.

DOCUMENTATION

A large volume of data pertinent to the parts and materials program must be accumulated and organized during the life of a project. These data are derived from the following three basic sources:

(1) <u>Design groups</u>. Designers, system engineers, and environmental specialists provide data on physical, functional, and environmental requirements which the components and parts must meet
(2) <u>Reliability group</u>. These personnel provide apportioned reliability goals, data for trade-off decisions (cost and weight vs. reliability), failure mode and effects data, and reliability status information.
(3) <u>Parts and materials group</u>. This group provides generic and test data on parts and materials capability. It also develops the preferred and approved parts and materials lists.

Data from the first two groups provide specialized information on parts and materials applications requirements. Some of this information is based on parts capability data[4] supplied by the parts and materials group; other requirements data are generated by them directly. All this information must be incorporated in the total project parts and materials documentation. Such documentation is essential to application reviews and design reviews. It is also vital to the

[4]Where existing parts and materials cannot withstand the component's environmental requirements, the component must be designed to provide necessary environmental protection; e.g., thermal control or shock cushioning.

initial selection of parts and materials, to the subsequent verification of parts and materials application in the system, and, later, to the evaluation of these or similar parts and materials for new applications.

Efficiency in Documentation

The data required for a parts and materials application review are not new or additional. They are necessarily generated in a thorough design task to make parts and materials selections on a sound basis. The only effort necessary in order to avoid additional cost in this area is to devise at the beginning of the project a single data-recording format which presents the data in a manner that serves the purposes of both the part (or material) selection worksheet and the part (or material) application review data sheet.

Selection worksheets may vary in form among projects and organizations. However, the principal items of this documentation are capability data, design parameter limits, stress and dissipation levels, environmental limits, and reliability estimates for each part or component as a basis for selection. Any format which provides this is acceptable. The typical forms shown in exhibit 1 are representative of worksheets for part selection which can later be used for application reviews.[5] The use of such forms is extremely valuable even on programs where formal application reviews are not a requirement, since they enable the designer himself to perform a better job of parts and materials selection.

At later stages of development, failure and failure analysis data, reports of parts and materials application problems, and test program outputs which yield information at the part level must be added to the documentation in order to reflect actual performance. Normally this is accomplished by way of the contractor's failure reporting and corrective action system, and its status may be indicated (by a "test status" coding) on the project APL and AML. Similar trouble and failure documentation requirements should be imposed on first-tier subcontractors and on lower tiers which produce critical components. Manufacturers' test results should also be filed and, where practicable, vendor data should be consolidated with in-house data. Further, data analysis requirements should be established in order to detect trends, and the analysis should be kept current as test results accumulate in order to permit effective use in future applications. Failure data are useful in parts selection and control activities. The parts documentation activity should continue through design into production and operation in order to provide a complete and accurate source of parts and materials data which will serve as a basis for the advancement of starting points of parts program activity on future projects.

Project Approved Parts and Materials Lists

Control of parts lists. As used here, the term "project-approved parts list" (or APL) denotes a composite project listing which incorporates all electronic and electromechanical (also many purely mechanical) parts called out on all the various component and higher assembly

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[5]These forms can either be used directly or be transformed into data summaries, the choice depending on the depth of application review needed for the component in question. The "Documentation" subsection of chapter 3, "Functions of Application Review," describes these requirements in more detail and contains representative formats for summary sheets to be used in the application review. The same kind of information also appears in the preferred and approved parts lists, with increasing completeness. Preparation of these lists is also a documentation requirement which can be supported effectively through the worksheet format.

drawings for the project.[6] On the APL, the parts are listed in order of part type rather than by the assembly where used. Entries are made on the APL from each component drawing as the component drawing is "released" for fabrication. Since all component drawings are not released at the same time, the APL grows over a period of time. Typically, the parts and materials group, when consulting on unfinished component designs during this period, will recommend parts already on the APL for as many new applications as practical.

Significance of listing. Entering an item on the project APL or AML certifies that:

(1) The item meets all engineering requirements of the applications for which it has been approved
(2) Qualification tests, failure rate investigations, and vendor determinations are either completed or their status (and risk therefrom) is known and accepted
(3) Drawings and specifications for the part or material are complete and satisfactory

Exhibit 2 shows a typical format for a project APL. An AML format, though differing in detail, would be designed to provide materials information analogous to the parts information provided by the APL.

The project APL and AML can serve as basic controls over accepting changes in specifications and part drawings; they also illustrate the success of the standardization effort and reveal areas where further standardization is desirable.

From a project standpoint, it is highly desirable to place the APL under drawing change control and require that it indicate the revision symbols for the drawing and specification on the APL which describes each part as it was approved in its application. This is important in helping to avoid purchasing or using an "updated design" of an approved part without insuring that the updating "improvements" are satisfactory.

It is also highly desirable that the APL include some means of identifying the specific applications of each part.[7] This will provide rapid traceability for assessing effects on all project hardware in the event that changes are made in design of a part or that problems are encountered in any use of a particular part. However, the identification on the APL of each and every application of each part presents serious practical problems, since certain parts are used in a very large number of applications. The decision on specifically how to implement this cross-referencing concept involves a trade-off, in which both the needs of the project hardware and the documentation load imposed by the chosen approach are considered. In general, the APL should attempt to identify the lowest level of assembly (i.e., subsystem) which includes all uses of the part or, for a less frequently used part, should list drawing number of each component which employs it.

The importance of the APL to project design activities justifies its inclusion under the broad disciplines of configuration and data management. This step will simplify configuration control at part and material levels and improve the traceability of system hardware.

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[6]In some situations, the term "approved parts list" is used to designate a list of "approved" parts furnished early in project life for use by designers in selecting parts. In this document, lists of that type are described either as "customer preferred" or "project preliminary," since such lists do not take into account the proper use of the parts in specific project applications.

[7]This may prove less practical for the AML.

EFFECTS OF APPLICATION REVIEW

As a source of a basic design review input, the primary role of application review is design assurance. However, in measuring the adequacy of parts and materials selections for each component, the application review function also gives a measure of the success of the parts and materials program in meeting its own goals. As an additional effect, the mere existence of a requirement for application review exerts an indirect disciplinary (technical) influence on the parts and materials function as well as other interrelated project functions throughout the project life cycle. Thus, application review not only serves to support the design review activity but is also an important element in a closed-loop parts and materials program.

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