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MIL-HDBK-179(ER)
25 October 1993

MILITARY HANDBOOK

MICROCIRCUIT APPLICATION HANDBOOK

AMSC N/A

FSC 5962

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FOREWORD

1. This military handbook is approved for use by the US Army Research Laboratory, Electronics and Power Sources Directorate, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, US Army Research Laboratory, Electronics and Power Sources Directorate, ATTN: AMSRL-EP-RD, Fort Monmouth, New Jersey 07703-5601, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. Commercial/industrial and commercial (consumer) microelectronic devices, often having advantages in cost, size, weight, performance and availability, have attracted widespread attention for government and military applications. This handbook takes a major deviation from traditional procurement guidelines by assisting military departments and associated contractors in the selection of commercial/industrial, commercial (consumer), and traditional military microcircuits for military equipments. The document gives greater flexibility and responsibility in selecting devices based on cost-effective performance, designed-in reliability, and high quality for a given application.

4. The handbook introduces two non-military quality systems, commercial/industrial quality and commercial (consumer) quality. Although there are many combinations of component quality systems and operating temperature ranges in actual use, these two "systems," as defined in the handbook, represent two very common application situations. Commercial/industrial quality components are normally purchased to an industry (e.g., user) specification and will normally be specified for operation over an extended temperature range such as -40° to 125°C. Commercial/industrial quality components are currently used in many industrial computer, automotive, telecommunication, avionics and instrumentation applications. Commercial (consumer) quality components are normally purchased to a vendor specification and will be specified over a more limited temperature range such as 0° to 70°C. Commercial (consumer) quality components are used in low-cost driven markets such as video games, VCRs, etc. For military applications, where commercial/industrial quality or commercial (consumer) quality devices meet quality, reliability and operating temperature requirements, a substantial cost savings may be realized by procuring to these quality systems.

5. The handbook uses the term "BEST COMMERCIAL PRACTICES" (BCPs) extensively. The use of this term in connection with microcircuit technology has the potential for creating some confusion. The casual reader might tend to identify BCP with commercial (consumer) quality components described in paragraph 4 above. However, the authors of this handbook believe the term "Best Commercial Practices," as used by the Defense Science Board and others, better fits the commercial/industrial quality system discussed above. Therefore, this handbook uses BCP in association with those components designed, processed, assembled, screened, tested and packaged on high volume lines for industrial customers with requirements for high quality, high reliability and low cost. Although BCP will primarily be associated with commercial/industrial quality parts in the handbook, it should be noted that the military's Qualified Manufacturers' List (QML) program was developed to accommodate BCP to reduce cost and accelerate insertion of new technology.

6. Assurance of highest generic quality and reliability of military, commercial/industrial and commercial (consumer) microcircuits is obtained through the application of BCP systems. The commercial/industrial quality devices are available from mature process lines, which have been qualified by a high volume user and have demonstrated high quality and reliability. Economy-of-scale is realizable because validation cost is amortized over the large number of parts procured. Commercial/industrial BCP parts are predominately plastic encapsulated and produced in high volume. Although the high volume users of industrial BCP parts require a small variety of part types, the application of "structural similarity" may significantly increase the number of qualified part types regardless of the quality system employed (e.g. commercial/industrial or Qualified Manufacturers' List). The military application of dual use technology is becoming a reality, and plastic encapsulated microcircuits (PEMs) will be part of that trend.

7. Development of this Microcircuit Application Handbook was recommended to the Office of the Under Secretary of Defense by the Department of Defense (DoD) Defense Science Board (DSB). The DSB made recommendations for a significant change in procurement directed towards increasing DoD's usage of the device manufacturers' best commercial components and practices. Following the DSB recommendations, the Office of the Assistant Secretary of Defense for Production Resources, Standardization Program Division (OASD-MMD/SPD), requested that the US Army Research Laboratory prepare this handbook as an aid in the selection of commercial/military microcircuit components for military equipments. To accomplish the task a military and industry working group, consisting of the three military departments, the Defense Logistics Agency (DLA), system integrators and device manufacturers, was formed. The following organizations played a significant role in the development of this document:

Department of Defense:	US Army Research Laboratory/EPSD
	US Air Force Rome Laboratory (RL)
	US Naval Weapons Support Center Crane
	Defense Electronics Supply Center
Industry:	Texas Instruments
	National Semiconductor
	GTE Government Systems

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1. INTRODUCTION

1.1 Purpose. This handbook has been prepared as a guide to assist the various military departments and associated contractors in the selection of microcircuits for military equipments. It provides guidance on how the DoD and its contractors can cooperatively select devices which will result in the lowest total cost of ownership for the DoD. Device selection is to be based on cost-effective performance, designed-in high quality, and reliability for a given application.

1.2 Scope and application. This handbook is intended for guidance, reference, and training for all parties involved in military microcircuit device selection. This includes those involved in the application, selection, and handling of microcircuit devices. The handbook will assist the government and associated contractors in identifying and communicating specific application requirements. The handbook is structured for use by the System Program Office (SPO), system integrator and device manufacturer. It is intended to be applied on a contract-by-contract basis. The maximum benefit of this handbook can be achieved if it is used early in contract development and allowed to impact system specifications, statements of work (SOWs), and system design considerations.

1.3 Handbook overview.

a. Chapter 1 - Introduction. This chapter describes the basic purpose of the handbook, explains how to use the handbook, and provides an overview of the handbook on a chapter-by-chapter basis.

b. Chapter 2 - Applicable documents. This chapter contains the applicable documents referenced in the handbook and where they can be obtained.

c. Chapter 3 - Definitions. This chapter contains definitions of acronyms and terms used in the handbook.

d. Chapter 4 - Quality systems. This chapter contains information on the quality systems that are available, under which military microcircuits are procured. The chapter also describes the various attributes of each system and its selection criteria.

e. Chapter 5 - Selection guidance. This chapter contains a selection matrix that provides the information required in each contract category. The matrix identifies acceptable end-use applications for devices from the various quality systems. Also, included is a selection criteria spread sheet that requires approval for commercial (consumer) quality and some commercial/industrial quality devices.

f. Chapter 6 - DoD procurement procedures. This chapter describes DoD procurement practices and the basic traditional flow-down of selection requirements.

g. Chapter 7 - Application practices. This chapter contains information that is intended to raise an awareness of potential problems associated with device application by system integrators and device manufacturers to prevent the misapplication of integrated circuits.

h. Chapter 8 - Selection process as an element of design. This chapter contains selection criteria for the System Program Office (SPO)/Program Manager (PM), system integrator and component manufacturer. The criteria is used to determine the device level requirements of the application as related to the system design, assembly method(s), end use and maintenance requirements. Component manufacturers should make available device capability/limitation data for each selection criteria. The SPO/PM should consider the part costs, total system life cycle cost, performance, and reliability tradeoffs associated with using devices from the different systems.

i. Chapter 9 - System guidance. This chapter provides a general listing and brief explanation of some potential reliability problems that should be addressed early in the development of all electronic hardware. The SPO/PM and system integrator should discuss these issues to insure they are adequately addressed in the initial system design and device selection stage. This information should serve as a valuable reference tool for the system integrator.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

MILITARY

MIL-STD-100	-	Engineering Drawing Practices.
MIL-STD-454	-	Standard General Requirements for Electronic Equipment.
MIL-STD-883	-	Test Methods and Procedures for Microelectronics.
MIL-STD-965	-	Parts Control Program.
MIL-STD-1562	-	Lists of Standard Microcircuits.
MIL-STD-1835	-	Microcircuit Case Outlines.
MIL-STD-2036	-	General Requirements for Electronic Equipment Specifications.

SPECIFICATIONS

MILITARY

MIL-E-5400	-	Electronic Equipment, Aerospace, General Specification for.
MIL-Q-9858	-	Quality Program Requirements.
MIL-P-11268	-	Parts, Materials and Processes Used in Electronic Equipment.
MIL-M-38510	-	Microcircuits, General Specification for.
MIL-H-38534	-	Hybrid (Custom) Microcircuits, General Specification for.
MIL-I-38535	-	Integrated Circuits (Microcircuits) Manufacturing, General Specification for.
MIL-I-45208	-	Inspection System Requirements.

HANDBOOKS

MILITARY

MIL-HDBK-402	-	Guidelines for the Implementation of the DoD Parts Control Program.
MIL-HDBK-217	-	Reliability Prediction of Electronic Equipment.

BULLETIN

MILITARY

MIL-BUL-103 - List of Standardized Military Drawings.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Defense Printing Service Detachment Office, Standardization Documents Order Desk, 700 Robbins Avenue, Building 4D (DODSSP), Philadelphia, PA 19111-5094).

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DODISS - Department of Defense Index of Specifications and Standards.

(Copies of the DODISS are available on a yearly subscription basis either from the Government Printing Office for hard copy, or microfiche copies are available from the Defense Printing Service Detachment Office, Standardization Documents Order Desk, 700 Robbins Avenue, Building 4D (DODSSP), Philadelphia, PA 19111-5094).

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO-9000 - Guidelines for Selection and Use - Quality Management and Quality Assurance Standards.

ELECTRONIC INDUSTRIES ASSOCIATION

EIA JESD 22-A101 - Temperature Humidity Bias (THB) Test Method

EIA JESD 22-A110 - Highly Accelerated Stress Test (HAST) Test Method.

(Application for copies should be addressed to Global Engineering Documents, 1990 M Street NW, Suite 400, Washington, DC 20036 or telephone 1-800-854-7179.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other information services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 <u>Acronyms</u>. The acronyms used in this handbook are defined as follows:

a. ASIC - application specific integrated circuit
b. ASTM - American Society for Testing and Materials
c. BCP - Best Commercial Practice
d. CAD - Computer-Aided-Design
e. CADMP - Computer-Aided-Design for Microelectronic Packaging
f. CDL - correlated device list
g. CID - Commercial Item Description
h. CpK - capability index
i. CTE - coefficient of thermal expansion
j. DESC - Defense Electronics Supply Center
k. DLA - Defense Logistics Agency
l. DMPG - Department of Defense Microcircuit Planning Group
m. DMSMS - Diminishing Manufacturing Sources and Material Shortages
n. DoD - Department of Defense
o. DoDI - Department of Defense Instruction
p. DoDD - Department of Defense Directive
q. DODISS - Department of Defense Index of Specifications and Standards
r. DSB - Defense Science Board
s. EIA - Electronic Industries Association
t. EP/TAB - Environmentally Protected Tab Automated Bonding
u. ER - Established Reliability
v. ESD - Electrostatic Discharge
w. ESS - Environmental Stress Screening
x. GFB - Government Furnished Baseline
y. GIDEP - Government-Industry Data Exchange Program
z. GM - General Motors
aa. HAST - Highly Accelerated Stress Testing
ab. IC - integrated circuit
ac. IES-ESSEH - Institute of Environmental Sciences-Environmental Stress Screening of Electronic Hardware
ad. ISO - International Organization for Standardization
ae. JAN - Joint Army-Navy
af. JEDEC - Joint Electronic Device Engineering Council
ag. JIT - just-in-time
ah. JQA - Joint Qualification Alliance
ai. LTPD - lot tolerance percent defective
aj. MPCAG - Military Parts Control Advisory Group
ak. NDI - non-developmental item
al. NGS - non-government standard
am. OEM - Original Equipment Manufacturer
an. PCM - process control monitor
ao. PEM - plastic encapsulated microcircuit
ap. PIN - Part or Identifying Number
aq. PIND - Particle Impact Noise Detection
ar. PM - Program Manager
as. PPSL - Program Parts Selection List
at. PPM - Parts per million

au. PWB - printed wiring board
av. QCI - Quality Conformance Inspection
aw. QFD - Quality Function Deployment
ax. QIT - quality improvement team
ay. QML - Qualified Manufacturers List
az. QPL - Qualified Products List
ba. RH - relative humidity
bb. RHA - radiation hardness assurance
bc. SCD - Source Control Drawing
bd. SEC - standard evaluation circuit
be. SID - Selected Item Drawing
bf. SMD - Standard Military Drawing
bg. SMT - surface mount technology
bh. SOG - Spun-on glass
bi. SOI - Silicon on Insulator
bj. SOS - Silicon on Sapphire
bk. SOW - Statement of Work
bl. SPC - Statistical Process Control
bm. SPO - System Program Office
bn. SCD - Source Control Drawing
bo. THB - temperature humidity bias
bp. TRB - Technical Review Board
bq. TSMD - Time Stress Measurement Device
br. VHDL - VHSIC Hardware Description Language
bs. VHSIC - Very High Speed Integrated Circuit

3.2 Definition of terms. The terms used in this handbook are defined as follows:

a. Acquisition. The act of acquiring military equipment, systems, subsystems, or parts by Government components.

b. Best commercial practices. This term will be used to address all the design and manufacturing techniques used during the wafer fabrication and assembly processes, the quality assurance provisions used throughout the processing flow, and the end item testing methodologies employed by component manufacturers regardless of the product category or grade. In other words, "commercial practices" refers to the best manufacturing and quality assurance provisions that are employed by a manufacturer regardless of the category of products (e.g., consumer, commercial/industrial or military) they are producing.

c. Commercial (consumer) products. Products that are not exclusively developed for large volume commercial customers or military applications and are being produced and sold to the open market and/or general public. These products are typically designed and verified for operations over the specific electrical envelope in room temperature applications. These products are discontinued very quickly and the next generation of consumer hardware is introduced. These products are almost exclusively offered in plastic packaging technology.

d. Commercial/industrial products. Products that are exclusively developed for a few high volume users. These products typically are used in applications that require temperature application environments of -40°C to 125°C, long-term quality/reliability considerations, and a need for long term availability. These products mostly use plastic packaging technology.

e. Contract categories. Specific phases of the acquisition process.

f. Established reliability. A quantitative maximum failure rate demonstrated under controlled test conditions specified in a military specification and usually expressed as percent failure per thousand hours of test.

g. Established reliability parts. Parts that are identified and/or described in military specifications that have met established reliability requirements.

h. Military Parts Control Advisory Group. A Department of Defense organization which provides advice to the military departments and military contractors on the selection of parts in assigned commodity classes and collects data on nonstandard parts for developing or updating military specifications and standards.

i. Military products. These products are typically available from the open market and are sold primarily to military customers. These products have electrical performance characteristics specified and verified for operations in harsh environmental applications (i.e., -55°C to +125°C). These products are verified for long-term operations and have been offered primarily in hermetic packages.

j. Physics of Failure. A methodology which includes: an analysis of defects and failures; determination of root cause of problem; and based on these analyses correct design, process, assembly, etc. to eliminate defect or failure.

k. Qualification. A process in advance of, and independent of, an acquisition by which a manufacturer's or distributor's products are examined, tested, and approved to determine conformance with requirements of a specification.

l. Qualified Manufacturers' List. A list of manufacturers' facilities that have been evaluated and determined to be acceptable based on the testing and approval of a sample specimen and conformance to the applicable specification. The QML includes appropriate products, processes, or technology identification, and test reference with the name and address of the manufacturer's plant.

m. Qualified Products List. A list of products that have met the qualification requirements stated in the applicable specification including appropriate product identification and tests or qualification references with the name and plant address of the manufacturer and distributor, as applicable.

4. QUALITY SYSTEMS

4.1 Quality systems. The quality systems listed herein are candidate systems for DoD parts procurement. Table I is provided for system comparisons.

4.1.1 QML (Qualified Manufacturers' Listing) MIL-I-38535. This system was developed in the late 1980s in response to the increasing complexity of digital integrated circuits and the availability of application specific integrated circuits (ASICs) in standard cell, gate array or custom variations. The Qualified Parts List (QPL), formally DoD's primary microcircuit procurement document (see 4.2.1), was then merged in to the QML system. The merger allowed the production of qualified parts to the QML, expanding the volume and type of products covered by the QML system. The merging of requirements into one document and the allowance of offshore assembly/test reduces the number of process flows that must be used by the manufacturer. The QML program was selected as the consolidation point for the qualification programs because it allows for and encourages the adoption and implementation of Best Commercial Practices. The US Air Force Rome Laboratory (RL) is the preparing and validating activity for the document, and the Defense Electronic Supply Center (DESC) is their agent. DESC is also responsible for organizing a team of experts who perform a QML validation of the manufacturer's processing flows. The term "audit" is no longer used in this quality system. The flow consists of six main activities:

Design	Testing
Fabrication	Customer Service
Assembly	Management

The following features are included in the QML:

Technical Review Board (TRB) System	Statistical Process Control
Conversion of Customer Requirements	Marketing
Quality Management	Continuous Improvement
Design Control	

The qualifying activity or its agent validates the manufacturers' process flows. Once validated, the manufacturer may produce all products on that flow as specified on one part standard military drawings (SMDs), MIL-M-38510 detail specifications, M-level SMDs, DESC drawings, and selected MIL-STD-883 compliant data book parts (see 4.1.2) (released prior to 1 Jun 93) as MIL-I-38535 compliant parts. Any new QML devices (released after 1 Jun 93) to be supplied by a QML manufacturer will be released as a one part-one part number SMD. QML also allows for plastic encapsulated and Environmentally Protected Tape Automated Bonding (EP/TAB) parts. Since the process is considered qualified, individual products do not have to be specifically and individually qualified to a standard set of tests. Where standard tests are used by the manufacturer to qualify the process, the use of ASTM, ANSI, EIA, MIL-STD-883 or JEDEC specifications is recommended. The manufacturer may also document and use new tests developed to improve quality and reliability. Formal military coordination was accomplished with the Army, Air Force, Navy and NASA by the preparing activity. Revision B of the document dated 1 Jun 93 contains the QPL/QML merger requirements.

Device performance requirements (electrical, thermal, and mechanical) are detailed in the device procurement document (e.g. SMD). This document, prepared by the system design house or the device manufacturer, is reviewed, controlled, and coordinated with registered users by DESC. It is the responsibility of DESC to assign a 5962 part number and insure that only one part number is used for the same function. Manufacturers are required to identify a Technical Review Board (TRB) system within their company. The TRB evaluates and approves all major changes in the process and product and reports to DESC on a periodic basis. Changes in the process and products are reviewed annually by a team of users, the qualifying activity, and the preparing activity. Progress in meeting company established yield, SPC, and reliability goals are reported at this meeting. The manufacturer is also evaluated periodically on meeting Total Quality Management goals using the Malcolm Baldridge criteria or some other similar criteria.

4.1.1.1 System advantages. Some advantages of the QML system are:

a. program focus is on designing and building in quality and reliability and continual improvement, as opposed to reliance on end-of-line testing;

b. manufacturer is responsible for process changes, allowing for timely improvements to the process which should result in continual improvement of quality;

c. emphasis on the acceptability of product design for military application allows new military and commercial product to be introduced at the same time; this can be done without additional end-of-line testing or special reliability testing unique to the military;

d. encourages one system for producing both commercial and military product.

4.1.1.2 System disadvantages. Some disadvantages of the QML system are:

a. the customer must relinquish direct control of day-to-day process changes;

b. although visibility is maintained by the qualifying activity, there is less direct visibility by the customer;

c. since an infrastructure is required to support a military program, the price of the QML part could be greater than that of a high volume commercial/industrial or commercial (consumer) quality part.

4.1.1.3 Cost savings.

a. small volume purchases may be delivered without added cost;

b. should allow ship-to-stock (no user testing required);

c. adoption of BCP under QML can result in product cost savings to the user;

d. QML process and material qualification reduces the time to market on individual devices, when using existing qualified processes;

e. the use of SMDs reduces parts proliferation. The one part-one part number significantly decreases logistics costs.

4.1.1.4 Usage. A variety of parts (e.g., ceramic, plastic, EP/TAB) will be available from various QML manufacturers depending upon which processes are qualified. The user should evaluate the application and type of part required.

4.1.1.5 Manufacturer location. QML parts have wafer fabrication performed in the United States, except as allowed by international standardization agreement. QML assembly and test may be performed in any country. The QML document also has provisions for the use of third party arrangements for any portion of the process flow (e.g. assembly, test, packaging, design, etc).

4.1.2 Class M and MIL-STD-883 compliant devices. This system evolved from various manufacturers' in-house versions of MIL-STD-883 test methods 5004 (Screening Procedures) and 5005 (Qualification and Quality Conformance Procedures). It was an informal and inconsistent system in the late 70s and early 80s known as MIL equivalent or look-alikes. Manufacturers advertised these parts as equivalent to JAN parts. However, some critical JAN requirements (e.g. audits, qualification, QCI tests) were not followed. The Government incorporated a truth-in-advertising paragraph in MIL-STD-883 which requires the manufacturer claiming to meet MIL-STD-883 1.2.1 requirements to self-certify that MIL-STD-883 requirements were met. The primary difference between an SMD product and a MIL-STD-883 compliant product is that DESC manages the procurement document (SMD) for the Class M and approves the sources by accepting their certificate of conformance to the 1.2.1 requirements. A MIL-STD-883 compliant product is produced to vendor controlled data books, and the government has no control over who claims compliancy, nor is it aware of all manufacturers claiming compliancy. Recently, DESC started conducting limited audits on a random basis of self-compliance of manufacturers of MIL-STD-883/SMD 1.2.1 compliant product.

4.1.2.1 System advantages. A few system advantages are:

a. the MIL-STD-883/SMD Class M parts are generally readily available because DESC certification and qualification is not required, and most products of these manufacturers have all or portions manufactured offshore;

b. these parts generally cost less since more are produced offshore.

4.1.2.2 System disadvantages. A few system disadvantages are:

a. Government does not evaluate the quality systems used to manufacture the parts, as in the QML program;

b. Government auditors spot check only a few MIL-STD-883/SMD manufacturers; therefore, there is an increased risk that not all testing has been adequately accomplished or correctly interpreted by the manufacturer.

4.1.2.3 Cost savings. The cost savings realized when using these parts must be balanced against the added risk of purchasing devices that may not be adequately characterized or meet the defined requirements.

4.1.2.4 Manufacturer location. Class M and MIL-STD-883 compliant parts can be fabricated, assembled, and/or tested anywhere in the world, and no operation has to be owned by the company selling the parts.

4.1.3 Joint Qualification Alliance (JQA). JQA is the alliance of AT&T, Ford Motor Company, and Hewlett-Packard to develop a qualification system standard which all three companies could accept. Both plastic and hermetic packages would be covered by this standard with a single audit of the JQA device suppliers. The cost of JQA qualification is reduced since it is amortized over many devices. JEDEC Committee JC14.3, consisting of commercial vendors and users, is proposing to make the JQA standard an industry qualification system standard to which all users could procure, and to which all vendors could be qualified. At the time of this handbook issuance, the JQA standard is not completed. The devices covered by this system will be required to operate over the temperature range of -40° to 125°C. MIL-STD-883 test methods are required. Since the standard does not include accelerated humidity testing (e.g. autoclave, biased humidity 85°C/85%RH, and HAST), EIA JESD 22 test methods will be required. It is anticipated that this document will become an industry standard in 1994. Microcircuits procured to this standard may have unlimited application. For an application considered critical and requiring additional data, the Microelectronic Selection Criteria Spread Sheet (see figure I) should be used.

SMDs will be used to procure devices to this Commercial/Industrial Quality System. The SMD will specify device attributes and will reference applicable industry specifications and standards.

4.1.3.1 System advantages. A few system advantages are:

a. provides a qualification system supported by large customers from automotive, communication and test equipment markets;

b. this system has the capability of becoming an industry wide standard with extensive application;

c. all dominant failure mechanisms are addressed using qualification testing which include MIL-STD-883 and JEDEC test methods;

d. both hermetic and plastic encapsulated parts are included.

4.1.3.2 System disadvantages. Some system disadvantages are:

a. the number of part types could be limited;

b. screens or lot sample tests are not included.

4.1.3.3 Cost savings.

a. qualification costs will be low as a result of amortization over a large volume of parts procured by industrial users;

b. high volume results in lower cost per part;

c. cost savings include savings generated at the next level of assembly (surface mountability, subassembly manufacturability, size and weight).

4.1.3.4 Usage. May have unlimited application.

4.1.3.5 Manufacturer location. Anywhere in the world covered by the audit system.

4.1.4 Commercial/industrial quality systems. These products, hermetic or plastic packaged, are normally produced to meet a particular industry specification. These industrial specifications are restricted to a minimal supplier base, limiting business to those suppliers with the best quality track record. Although these industrial specifications are controlled by individual customers, it is possible to buy these parts for military use. For instance, the General Motors (GM) Delco 2000 specification is used by GM to procure electronic components for automotive applications. It uses many MIL-STD-883 tests (although renumbered to fit the GM document control system). Because of the special application environments, the requirements are, in some cases, more severe than some of the military application requirements. In the case of Ford, the manufacturer must pass a Ford Q1 audit before delivering any product to Ford.

SMDs will be used to procure commercial/industrial quality devices. The SMD will specify device attributes and will reference applicable industry specifications and standards.

4.1.4.1 System advantages. A few system advantages are:

a. the primary customer (usually large volume, i.e. millions/day) can tailor specification to meet specific application requirements;

b. it provides the most extensive quality and reliability data base.

4.1.4.2 System disadvantages. A few system disadvantages are:

a. the availability of part types is driven by high volume customers;

b. the Government cannot use similar restrictive buying methods due to procurement regulations;

c. Government customers have limited ability to tailor specifications because of limited quantity buys.

4.1.4.3 Cost savings.

a. large volumes mean lower unit cost;

b. cost savings include savings generated by part type selection, availability, surface mountability, subassembly manufacturability, size and weight.

4.1.4.4 Usage. May have unlimited application.

4.1.4.5 Manufacturer location. Anywhere in the world. Prime customer selects manufacturer.

4.1.5 Commercial (consumer) quality systems. Each supplier has a set of commercial specifications which they use for manufacturing product for general sale. Usually the product specifications are included on a data sheet which is included into a catalog of products for wholesale use. A wide spectrum of performance, quality and reliability can be expected depending on the quality standards applied by the company. The temperature range for these parts is typically specified 0° to 70°C. Commercial Item Descriptions (CIDs) will be used to procure commercial (consumer) devices (see 6.4.2).

4.1.5.1 System advantages. Some system advantages are:

a. initial unit cost of product is lowest available;

b. product availability is good;

c. extensive self-audit test data and customer required test results are typically available.

4.1.5.2 System disadvantages. Some system disadvantages are:

a. additional testing may be required to verify performance, quality, and reliability;

b. part device types may be changed or discontinued without notification, and specifications may be changed without notification;

c. self-auditing may not be equally rigorous across the commercial suppliers;

d. parts may not be interchangeable because of incomplete data sheets;

e. without an industry accepted quality system certification, duplicate user audits and qualifications may be required for individual customers;

f. device types may have short life cycles.

4.1.5.3 Cost savings.

a. part cost should be the lowest of the candidate quality systems;

b. these devices should be available from the largest number of sources.

NOTE: The use of commercial electronic parts in military systems must be done with care. Apparent cost savings in initial procurement cost must be weighed against possible additional testing, auditing and reliability testing required to meet the application requirements.

4.1.5.4 Manufacturer location. Anywhere in the world.

4.2. Unacceptable/obsolete quality systems for DoD microcircuit procurements. The quality systems listed herein are not to be used for parts procurement.

4.2.1 JAN (Joint Army-Navy) MIL-M-38510 Qualified Parts List (QPL) Class B and S. This quality system was developed by the military during the 1960s and came into widespread usage during the late 1970s. The system used a part by part qualification approach. As of 1 June 1993 this quality system was superseded by the QML quality system (see 4.1.1) by merging MIL-M-38510 (QPL) into MIL-I-38535 (QML). The merger allows manufacturers to adapt their system to the QML approach with minimal interruption in supply. As part of this transition from QPL to the QML there is part number overlap. The QPL part number format (M38510/XXXXXBXX) is maintained for all MIL-M-38510 associated detail specifications. For purposes of this handbook and microcircuit selection, the user need only understand that all part numbers that were available under the QPL system are still available under the QML system. The actual quality system used in the manufacture of these parts has changed, but form, fit, and function are identical. Some QPL manufacturers may not transition to QML or may take time to transition to QML. These manufacturers will continue to meet QPL requirements as outlined in Appendix A of MIL-I-38535. The administration of these QPL requirements will be handled by the Defense Electronics Supply Center (DESC). The listing for sources of these parts will be section II of QML-38535. The transition is intended to make better use of Best Commercial Practices in the manufacture of military quality microcircuits.

4.2.2 International quality systems. The ISO-9000 series documents are gaining acceptance as international quality system assurance criteria. The ISO-9000 quality system assurance criteria are applicable to any type of organization. Consequently, these documents are very general and must be interpreted by the applicable assessment body which is typically a third party organization. These third party assessment organizations typically charge fees for their initial and periodic registration services. Numerous organizations will audit and issue ISO-9000 registration to U.S. manufacturers. Several U.S. industry trade associations are studying establishing accreditation schemes for third party auditing organizations as well as determining a mechanism for proper application of these standards within the U.S. community. Direct reciprocity between countries using ISO-9000 documents has not yet been established. This system is not considered adequate for DoD microcircuit procurements, but may be provided as an element of data in the selection spread sheet (figure 1).

4.2.2.1 System advantages. Some system advantages are:

a. this system is internationally recognized;

b. it provides a basic quality system which can become the building block for future enhancements;

c. independent third party auditors can periodically evaluate the system.

4.2.2.2 System disadvantages. Some system disadvantages are:

a. it is a generic quality system designed for any industry, therefore, it may not be specific enough for complex technologies;

b. inconsistent applications and audits are possible due to the generic nature of the document (e.g. not specific to microcircuits).

c. third party auditing costs may make this system expensive;

d. this generic quality system may not directly influence outgoing product quality.

4.2.2.3 Cost savings. Potential savings are possible as international acceptance grows because only one audit system may be needed to verify compliance.

TABLE I. Quality systems.

	Monolithic				
Requirements	QML (with merged QPL)	883 compliant	JQA	Industrial 4/ 5/	Commercial 6/
	Compliant with MIL-I-38535 (class Q/V)	Compliant to MIL-STD-883	Compliant to JQA spec	Compliant to customer specification	Variable per customer
Audit/qual agency	DESC	Self-cert/DESC spot checks SMD suppliers	To be determined	Customer dependent	None/customer dependent
Procurement vehicle	SMD (one part-one part number)	SMD/SCD for 883	SMD/SCD	SMD/SCD	CID/SCD
Ambient operating temp range	Typ -55° - +125°C technology dependent	Typ -55° - +125°C technology dependent	-40° to +125°C technology dependent	-40° to +125°C technology dependent	Typ 0° to 70°C
Reliability required 1/	MIL-I-38535	MIL-STD-883	JEDEC 22	MIL-STD-883/ JEDEC 22	Based on system
Defect rates	Expecting 100 ppm based on mil electricals	SMD based on mil elect; variable for 883	Expecting 100 ppm based on vendor elect	Expecting 100 ppm based on vendor elect	Variable based on CID or SCD electricals
Volume	Expected medium	Medium	High	High	High
Packaging	Hermetic, plastic encapsulated	Hermetic	Hermetic, plastic encapsulated	Hermetic, plastic encapsulated	Per appl; majority plastic encapsulated
SPC	Required and effectiveness evaluated	Not required; not evaluated	Not required; but expected	Not required; but expected	Not required; typically used by industry
Testing	Based on amount in process control	Per MIL-STD-883 para. 1.2.1 control, not evaluated	Per JQA specification	Per specification	Per customer or data sheet
Manufacture location	USA - wafer only Wrldwide -assem/pkg	Worldwide	Worldwide	Worldwide	Worldwide
End use	Any system/product	Any system/product	Any system/product	Commercial aerospace; limited military	Entertainment/ test equipment/ limited military
Traceability distributed	Controlled	Controlled	Customer dependent	Customer dependent	Customer dependent
Cost/system risk 2/	Med/expected lowest	Med/med	Low/low	Low/medium	Low/customer dependent
Delivery time 3/	Short if offshelf; medium otherwise	Short if offshelf; medium otherwise	Expected to be short	Expected to be short	Short if high volume; med otherwise

1/ Reliability assessment based on dominant failure mechanism.
2/ Based on probability of early failure in military systems. High baselined to minimally tested part.
3/ Delivery time: Medium - 1 month; long - 6 months.
4/ Only proposed system at this time
5/ Applications considered critical and requiring additional data will require the Microelectronic Selection Criteria Spread Sheet (see 5.2) in the solicitation.
6/ Application of commercial/industrial and commercial (consumer) quality parts will require the Microelectronic Selection Criteria Spread Sheet (see 5.2) in the solicitation.

5. SELECTION GUIDANCE

5.1 Selection guidance. Devices should be selected according to the guidance provided in table III and applicable guidance provided herein.

5.2 Selection criteria for commercial (consumer) and commercial/industrial quality product (figure 1). Figure 1 and its companion guide, the Selection Criteria Guide (see 5.2.1), is to be used in equipment procurement solicitations. Use of commercial (consumer) devices or commercial/industrial devices requires completion, submission and approval of the spread sheet depicted in figure 1. The spread sheet is to be used to assess the acceptability of proposed microcircuits for system application and to rate equipment manufacturer on their knowledge of the technology proposed. It is the equipment manufacturer's statement of assurance of microcircuit reliability in the proposed system application.

5.2.1 Selection criteria spread sheet guide. The information required in each data item of the spread sheet is explained in a. through j. The descriptions are typical inputs which could meet the data item requirements. Additional inputs which will meet the intent of the data item should be included.

a. Part type and number: Description of device: microprocessor, memory; controller, amplifier, etc. Identification of part through catalog number, Standard Military Drawing (SMD), Source Control Drawing (SCD), etc, with accompanying drawing containing package outline, temperature range, power capability, etc.

b. End item applications: What equipment has this device (part number) been used in, preferably equipment manufactured by the equipment manufacturer? If this is not available, then verifiable data from other government or commercial equipment applications. Applicable information would include number of parts used and use history in these systems.

c. Volume sold per year: An approximate number per year sold by the supplier over the past five years. This will provide an indication of the maturity of the device.

d. Experience factor: This would support category b. above if the equipment manufacturer had used this device in another application. Data could include types of devices used (SMT, DIP, etc), experience at board assembly, and field reliability.

e. Reject rate: If this part has been used before, what has been the incoming or assembly first test experience? Has cause of reject been determined and is it device design or process related? Vendor outgoing final test data will be acceptable.

f. Reliability assurance: How will the equipment manufacturer assure the microcircuit will meet the end item use (reliability) requirement? An approach which implements diagnostics of stress tested parts and field failure returns with feedback to correct problems in design or processing is a technique to assure product reliability. Correct device selection for the circuit design implemented is mandatory. A QML methodology at each assembly operation will assure the greatest quality, highest yield and lowest defect rate. Assessment could be based on possible failure mechanisms and how the supplier and user will assure any impact is eliminated. PCMs (process control monitors) and SECs (standard evaluation circuits) are test devices used as process control monitors and process validation circuits respectively. CADMP (computer aided design of microelectronic packages) is a software program to assure reliability of a packaged assembly at initial design.

g. Use environment: What is the specific end item this device will be used in? What will be the environmental extremes the device will be subjected to and the frequency of these stresses (cycles per year) if applicable. How have these conditions been addressed in category f. above?

h. Derating: Has the equipment manufacturer's circuit designer provided adequate margin (safety factor) between worst case circuit design and device specification performance limits? Provide comparison of design factors and specification limits.

i. Purchased to which qualification system: Provide the qualification system identification to which the microcircuit will be procured. If an accepted military or industry standard, indication of system is the only requirement. If not standard or changes to a standard proposed then detail documentation is required.

j. Proposed additional assurance: This category will be for the identification of added value screening or sampled testing required to assure meeting system requirements. Further assurances from the supplier such as certificate of compliance and warranty.

5.3 Plastic encapsulated microcircuit (PEM) requirements. PEMs selected for use in military systems should, at a minimum, be capable of passing electricals following testing identified in table II. Additionally, issues discussed in paragraph 7.4 should be considered when using PEMs in military equipment. The LTPD (lot tolerance percent defective) with zero acceptance number will be 3 for industrial and 5 for commercial.

Table II. Minimum acceptance tests for industrial/commercial quality systems 1/

Quality System	THB 2/	HAST 3/	TEMP CYCLE 4/
Commercial/Industrial Quality	1000 hrs	250 hrs	500 cycles
Commercial (Consumer) Quality	250 hrs	96 hrs	100 cycles

1/The test data supplied will be data generated from in-house qualification or customer required testing. These are typical number of hours and cycles.
2/Temperature Humidity Bias (THB) Test Method EIA JESD 22-A101.
3/Highly Accelerated Stress Test (HAST) Test Method EIA JESD 22-A110, Condition C.
4/MIL-STD-883, Test Method 1010, Condition B.

FIGURE I. Microelectronic selection criteria spread sheet per vendor 1/

Part Type and Number	End Item Applications	Volume Sold Per Year	Experience Factor	Reject Rate
Microprocessor SNJ XXYY	IBM PC Ford Radio AN/PRC-70, etc			o Past experience o Vendor assurance o at incoming or PCB level
Reliability Assurance	**Use Environment**	**Derating**	**Purchased to Qual System**	**Proposed Additional Assurance**
o PCM o SEC o Life test-need test conditions o Failure rate calculation o CADMP o Failure mechanism o Field data	o Aircraft, tank, etc o Temperature, RH, temperature cycle, vibration, shock, etc for each environment	o Worst care operating electrical conditions (1% of spec limits)	o Vendor self-audit o ISO-9000 o QML o Delco o Details required	o Screens o QCI o Certificate of compliance o Warranty o Rad-hard

1/ used with the Microelectronic Selection Criteria Guide (see 5.2.1)

TABLE III. Multiple entry matrix. [1]

Environment	Category 1 Protected	Category 2 Normal	Category 3 Normal	Category 4 Harsh	Category 5 Hostile	Category S Space
Special issues	Readily accessible to maintenance	High volume Readily repairable	Inhabited A/C area Ground mobile	Uninhabited A/C Extreme temperatures	High shock Extreme temperatures	
Typical systems	Off-the-shelf NDI	Air traffic control Ground radar Communication facilities Ground fire control	Cockpit NAV/COM Ground mobile Most shipboard	Most avionics High G/not shock Some shipboard	Tactical missiles, munitions	Space, strategic missiles
Critical trade-off concerns	Controlled environment, air conditioned	Uncontrolled temperature, moderate vibration	Extreme pressure, vibration, temperature and moisture	Extreme pressure, vibration, temperature and moisture	Extreme pressure, vibration, temperature and moisture	
Typical temperature	0°to +70°C	-40°to +85°C	-55°to +125°C	-55°to +125°C	-55°to +125°C	-55°to +125°
Comparable MIL-HDBK-217 environments	Quasi GB	GB, GF	GM, MP, NS, NBS, NH, NU, NUU, AIC, AIT, AIB, AIA, AIF	AUC, AUT, AUB, AUA, AUF, ARW	USL, ML, MFF, MFA	SF
Preferred quality system	QML JQA [2] Industrial [3,4] Commercial [3,4] Class M	QML JQA [2] Industrial [3,4] Class M	QML JQA [2] Industrial [3,4] Class M	QML JQA [2] Class M	QML JQA [2] Class M	QML CLASS V
Preferred procurement document	SMD CID [5]	SMD	SMD	SMD	SMD	SMD
Alternate procurement document	SCD	SCD	SCD	SCD	SCD	SCD

[1] Inclusion of a device, technology, or supplier in a particular standard does not relieve the user of the responsibility for determining application suitability. The devices, technologies, and suppliers included in the standards have met certain reliability and performance requirements deemed suitable, in general, for usage in a military application. The user is cautioned to examine specific technical, life-cycle, and programmatic considerations when selecting from these standards.

[2] This is a proposed commercial/industrial quality system. When published and adopted by the DoD it could be used for indicated system environments.

[3] Use of commercial (consumer) devices or commercial/industrial devices (other than JQA) requires completion, submission and approval of the Microelectronic Selection Criteria Spread Sheet (see 5.2, figure 1). Recommendations for approval or disapproval of devices (based on spread sheet information) will be made by the Military Parts Control Advisory Group. The Program Manager/System Program Office has final approval authority.

[4] Plastic encapsulated devices must meet the minimum requirements specified in 5.3 and table II.

[5] Commercial Item Descriptions (CIDs) are to be used for commercial (consumer) product only.

6. DoD PROCUREMENT PROCEDURES

6.1 Policies governing defense acquisition. DoDD 5000.1 and 5000.2 are the directives used for the acquisition of defense systems. As stated in DoDD 5000.1, the directives are intended to provide for the following:

a. translating operational needs into stable, affordable programs;

b. acquiring quality products;

c. organizing for efficiency and effectiveness.

In the section addressing acquisition of quality products, the directive emphasizes the need for the utilization of a systems engineering approach to achieve a proper balance among all system design requirements including performance, producibility, reliability, and standardization. It also directs that maximum practical use shall be made of commercial items as well as the use of non-Government standards in describing these items.

These policies set the general tone for the more detailed procedures discussed in DoDD 5000.2 Of particular importance for the selection and application of microcircuit technology components are two sections of the Systems Engineering chapter of the Directive: Reliability and Maintainability and DoD Parts Control Program. The Reliability and Maintainability section requires the development of a Design Reference Mission Profile which defines the performance and environmental envelopes for the system to be acquired. This information is critical for enabling the tailoring of microelectronic component requirements to meet the system requirements. A second requirement which ripples down to the component level is evaluation of system design based on predicted and demonstrated failure rates. These predictions are to be based on the Design Reference Mission Profile and prior reliability data. With the exception of the portions of the system designed using non-developmental items (NDI), this predicted or demonstrated reliability data must be based on component and assembly data. MIL-STD-785 is established as the basic reference for further guidance for defining system reliability requirements.

The DoD Parts Control Program section of DoDD 5000.2 emphasizes that the focus of an effective parts control program should be on reducing the variety of parts and associated documentation used in the system. This is to be accomplished through the application of MIL-STD-965. Thus the principle focus of the parts control program is effective logistics support over the system life cycle.

These top-level policies and procedures describe a continued concern for as-delivered quality, operational reliability and life cycle support of DoD systems. However, they signal a new emphasis on affordable acquisition and a shift toward increased responsibility and freedom given to the industrial community for delivering systems with these desirable characteristics. The intent of this handbook is to provide practical guidelines for implementing these policies in the specific area of acquisition of microelectronic technology.

6.2 Contractual requirements. In order to implement DoD policies and procedures, most contracts for major systems include the following requirements related to microelectronics technology:

a. MIL-E-5400, MIL-STD-2036 (NAVY) or MIL-P-11268 (ARMY) - General Equipment Specifications

b. MIL-STD-785 - Reliability Program for Systems and Equipment

c. MIL-STD-965 - Parts Control Program

d. MIL-STD-454 - Standard General Requirements for Electronic Equipment.

MIL-STD-785 and MIL-STD-965 are appropriately designed to be tailored to the application and requirements of the system being procured. Task 207 (Parts selection/application criteria) of MIL-STD-785 which calls out a parts control program in accordance with MIL-STD-965 and a parts standardization program is selected for most contracts. MIL-STD-965 in turn specifies requirements for the use of the Military Parts Control Advisory Group (MPCAG), the Government Furnished Baseline (GFB) parts list, and the maintenance of the Program Parts Selection List (PPSL), as applicable. Some services also reference MIL-STD-1562, Lists of Standard Microcircuits, contractually.

MIL-STD-454 is typically invoked through the General Equipment Specification. Requirement 64, Microelectronic Devices, establishes the criteria for the selection and application of microelectronic devices. This requirement establishes the order of precedence for the application of microelectronic devices based on their quality system, the requirements for electrostatic discharge (ESD) susceptibility assessment, and the need for device design and test documentation. This order of precedence, in conjunction with MIL-HDBK-402, Guidelines for Implementation of the DoD Parts Control Program, and MIL-STD-965, The Parts Control Program, defines the lowest quality level microcircuits which are recommended for use by the Military Parts Control Advisory Group (MPCAG) (those which comply with the requirements of paragraph 1.2.1 of MIL-STD-883).

In the past, MIL-STD-454, Requirement 64, has been interpreted as a rigid order of precedence which mandated the usage of "military" parts with little regard for the system application or requirements. Although this practice has resulted in the fielding of systems with consistent parts quality and reliability, it has not necessarily resulted in the most cost-effective acquisition or the insertion of the most advanced technology. With the pervasive availability of high quality microelectronic technology in the commercial and industrial marketplace, many feel that the time has come to modify system acquisition procedures to include such high quality parts. The intent of this handbook is to "open the door" to the usage of high quality parts manufactured to "best commercial practices" by replacing the order of precedence in MIL-STD-454, Requirement 64, with a selection matrix which includes both military and best commercial practice parts.

6.3 Quality systems. In order to provide consistent surveillance of suppliers to quality systems requirements specifications, such as MIL-I-45208 and MIL-Q-9858, and to eliminate the need for each OEM to perform audits individually, a third party surveillance team was formed. This team has the sole purpose of consolidating OEM MIL-I-45208 and MIL-Q-9858 audits. This system does not in any way verify compliance to MIL-STD-883, paragraph 1.2.1. The program is under the management of the Electronic Quality Registry which also administers certification of US companies to the ISO-9000 standard.

6.4 Procurement documents. Military microcircuits are purchased using three procurement documents: Standard Military Drawings (SMDs), Commercial Item Descriptions (CIDs), and Source Control Drawings (SCDs).

6.4.1 Standard Military Drawing (SMD) one part-one part number system. The one part-one part number system described below has been developed to allow for transitions between identical generic devices covered by the three major microcircuit requirements documents (MIL-I-38535, MIL-H-38534, and 1.2.1 of MIL-STD-883) without the necessity for the generation of unique Part or Identifying Numbers (PINs). The three military requirements documents represent different class levels. Previously, when a device manufacturer upgraded military product from one class level to another, the benefits of the upgraded product were unavailable to the Original Equipment Manufacturer (OEM), who was contractually locked into the original unique PIN. By establishing a one part number system covering all three documents, the OEM can acquire to the highest class level available for a given generic device to meet system needs without modifying the original contract parts selection criteria.

Military documentation format	Example PIN under new system	Manufacturing source listing	Document
New MIL-I-38535 Standardized Military drawings	5962-XXXXXZZ(Q or V)YY	QML-38535	MIL-BUL-103
New MIL-H-38534 Standardized Military Drawings	5962-XXXXXZZ(H or K)YY	QML-38534	MIL-BUL-103
New 1.2.1 of MIL-STD-883 Standardized Military Drawings	5962-XXXXXZZ(M)YY	MIL-BUL-103	MIL-BUL-103

The one part SMD (and all SMDs) are controlled by DESC and describe the performance characteristics of a specific device (e.g., 1 megabyte memory). For each quality system the SMD represents that quality system's specific requirements. Under the QML system, the QML device is described by the SMD, written and verified by the manufacturer, but controlled by DESC. The QML quality system assures that the SMD is complete, because the process for generating the SMD has been validated during certification. The manufacturer is held responsible for the quality of the SMD. Under the MIL-STD-883, 1.2.1 compliant system, the manufacturer (or OEM) prepares the SMD and DESC is responsible for insuring that the SMD is complete. There is less assurance under the MIL-STD-883 system that the part actually meets the requirements of the specification. It is only recently (1990) that DESC has begun spot check verification audits of the Class M/MIL-STD-883 compliant manufacturers. The SMD system is currently being expanded to cover industrial quality devices. The SMD will specify device attributes and will reference the applicable industry specifications and standards.

6.4.2 Commercial Item Descriptions (CIDs). CIDs are short, simple product descriptions or specifications that describe available commercial products that will meet the Government's needs by salient functional or performance characteristics. If a suitable NGS is not available or could not be revised or developed in time to satisfy an acquisition need for a commercial product, then develop a CID. A useful approach is to use an NGS as the basis for the CID,and then make additions or modifications to the NGS in the CID. In the case of microcircuits, CIDs should be used for documenting those commercial (consumer) devices considered acceptable for military use.

6.4.3 Source Control Drawings (SCDs). SCD is a catch-all name commonly used to refer to any contractor-prepared procurement document. These predominantly occur in three forms: the Source Control Drawing (SCD), the Selected Item Drawing (SID), and the vendor item drawing (formerly Specification Control Drawing (SCD)). Source Control Drawings are used when it is necessary to limit procurement to one or more sources which exclusively meet critical applications. Selected Item Drawings are used when it is necessary to further limit an existing item by selecting for a characteristic not previously identified. Specification Control Drawings are typically used when the vendor's "off-the-shelf" item is suitable for use.

This document is written by the customer and the contract regulations are controlled in accordance with MIL-STD-100. These documents may vary widely as to completeness. A space systems supplier may have a very high quality SCD. A loosely monitored subcontractor may have little or no control over the SCD and be subject to parts performance surprises (i.e., poor reliability, missing test requirements, etc). The use of SCDs should be carefully worked into the total quality system and be replaced by an SMD if possible.

7. APPLICATION PRACTICES

7.1 General. Proper application of microcircuits is crucial to the overall effectiveness, functionality, performance, and availability of the system. This chapter will discuss the issues which need to be addressed to assure optimum system performance.

7.2 Quality and reliability concerns. The overall system performance is highly dependent on the quality and reliability of its components. The required performance objectives and environmental operating conditions should be communicated to the component suppliers at the initial meeting. The establishment of this line of communication between the system designer and the device designer and vendor is crucial to the overall program success as devices get more and more complex. Most standard commercial parts are designed and assembled based on the supplier's internal specifications for a specific environmental window. Customer designed components, such as ASICs and gate arrays, give the system designer the option to optimize device performance and functionality based on the system environmental conditions. Therefore, different approaches need to be taken in each case during the system design and part selection process. The following are some issues which need to be taken into account:

7.2.1 Environmental envelope. Knowing whether the system will experience adverse or extreme conditions in temperature, temperature cycles, vibration, moisture (humidity), radiation, or stress (G-force) has an impact on the features one looks for during the part selection process. However, the process of determining the environmental window is difficult. In most cases, one relies on data from similar systems. Today, there are devices, such as the Time Stress Measurement Device (TSMD), which can be placed in the equipment bay or on the board to give an accurate representation of the operating environment of the system. Table III outlines several environmental conditions and identifies some of the issues that need to be addressed.

7.2.2 Reliability consideration at package design. A software tool has been developed to assure a particular part will provide the reliability necessary to meet application requirements. Computer-Aided-Design for Microelectronic Packaging (CADMP) has been developed at the University of Maryland for this purpose. At package design the software tool has inputs to menus which address materials, form factor, failure mechanisms, use environment, stresses, etc. A reliability assessment is calculated to determine if the proposed design meets the reliability requirements. If not, the parts can be varied, within reason, until the desired reliability is achieved. A system designer can determine if the device supplier has performed such an analysis.

7.2.3 Assembly level reliability goals. As device density grows, so does the silicon chip size. Thus, the choice of packaging style needs to address weight, solderability, heat dissipation, mechanical and thermal integrity, and manufacturability.

7.2.4 Storage. Many systems, such as weapon systems, are placed in storage for long periods of time before they are needed. This is becoming more the norm for many other systems also. Therefore, the conditions under which the system is to be stored in needs to be considered and taken into account before parts are selected for the system. Issues of concern are whether the system is stored in a controlled environment or not.

7.3 Design specifics. The most common system, functional and performance related, failures are caused by careless design practices. A required design practice is to identify all critical limits of the system. This is necessary so that these requirements can be translated into applicable part requirements. Once the part requirements have been defined, a designer must carefully review and evaluate the device vendor's data sheet. This data sheet defines the critical operation and reliability parameters of a device. Caution needs to be exercised during this process since not all applicable part data sheets define all critical parameters that one needs to know. Therefore, the device vendor should be kept in the part selection loop. Also, the same device functionality and type manufactured by different vendors are not necessarily the same device. Seemingly insignificant differences between the devices can result in catastrophic system failure. This is particularly critical in the logistic support aspects of the system where part interchangeability needs to be carefully evaluated. The following discussion identifies other design specifics which need to be considered.

7.3.1 Data sheet/performance level. Data sheet limits are measured under specific conditions. System designers should allow for some variations due to absolute temperature tolerances and test setups. In addition, there may be some lifetime speed/parametric degradation which can cause marginal performance compared to the specified limits in the data sheet. One should be cautious and understand what the vendor means by "guaranteed but not tested." Also, one absolute rule which should always be followed is never to design to the maximum rated limits of the part.

7.3.2 Technology selection (speed, power, radiation tolerances, geometry). There is generally a trade-off between speed and power. This choice may limit the technology selection. Slower parts are necessarily replaceable with faster ones. Faster devices tend to have smaller geometries which can impact certain reliability factors while enhancing others. New technologies may have inherent reliability sensitivities which must be determined and evaluated for the field environment prior to part selection. In regard to radiation tolerance, understand the implications of the various tolerance levels and whether or not the actual device has been tested to that level.

7.4 Plastic encapsulated microcircuits (PEMs). A plastic encapsulated package is an enclosure which uses organic material, usually transfer molded for environmental protection. This material is in direct contact with the active element or with an inorganic barrier layer. Since there is no cavity, traditional hermeticity measurements are meaningless. PEMs selected for use in military systems should, at a minimum, be capable of passing electricals following testing identified in table II.

Historically, plastic-encapsulated microcircuits (PEMs) have been primarily used in commercial, industrial, automotive, and telecommunication electronics. Consequently, they have a large manufacturing base (97% of world production). With their major advantages in cost, size, weight, and availability (30% more part functions than hermetic), they have attracted widespread attention for government and military applications. Although this is a major opportunity for PEMs, there have been formidable challenges in adapting plastic packages to the high-reliability demanding environment, cost-conscious government, and military markets. While the major impediment to their application has been the perception of lower reliability as a result of moisture related failure mechanisms, the challenges arise as a result of small procurement/production volumes, a conservative approach by SPOs in the use of these devices, and the defense industry's lack of standards and handbooks for these types of devices.

Some of the first semiconductor devices were encapsulated in plastic. These early encapsulated devices, which employed plastic molding compounds, were plagued by thermal intermittence problems. Because of the coefficient of thermal expansion (CTE) difference between the bond wires and the encapsulant, such devices and circuits produced open circuit failures at elevated temperatures. Returning to a lower temperature, compressive forces restored contact of wire to bond pad. Moisture-induced failures, like corrosion, cracking, fracture and interfacial delamination, were also significant. Early 85°C/85% relative humidity (RH) testing in 1974 produced 25% cumulative failures at 1,000 hours, compared with 0.1% in 1990. Today's nearly exclusive continued use of hermetically sealed microcircuits in military, aerospace, and other high-reliability, highly critical applications is a direct result of the problems associated with early plastic packaging.

The last decade has brought revolutionary changes in electronics technology in general and in plastic packaging in particular. Earlier plastic encapsulation of transistors and diodes was done by dispensing a small amount of material over the die and bond wires (glob topping). Subsequently, various molding techniques were attempted including transfer, injection and potting. Hundreds of molding material variations (epoxies, silicones and phenolics) were evaluated for cost, performance, implementation, shelf life, repeatability, flammability and reliability impact. Included in these evaluations were various additives for heat removal, adhesion, viscosity, mold release, flame retardant, and appearance. Very popular was the protection of the die surface prior to molding by coatings which include silicone elastomers, varnish, and spun-on glass (SOG). To reduce voiding occurring between encapsulant and lead wires, silicone resin was forced, under a vacuum, into these voids using a process known as "backfilling."

The progressive improvement in plastic packaging integrity has been affected by improved materials, increased plastic purity, high-quality device passivation, improved leadframe designs, and device manufacturer's quality programs. In general, the failure rate of plastic packages has decreased from about 100 failures per million device hours in 1978 to about 0.05 per million device hours in 1990. Furthermore, hermetic packaging does not appear to have kept up with these advanced requirements in either performance or cost. It has become clear that performance must not be compromised by packaging: high-volume controlled processes and materials will be required for quality and reliability; most or all devices must be available in reliable cost-effective packaging; and evaluation, screening, qualification, and test procedures must be developed and managed.

Today the most popular molding compound is epoxy novolac. The basic composition contains, by weight, the following: 15-30% epoxy resin and hardeners, 60-80% fillers, 1-7% pigment, mold release, coupling agent and stress absorber, 1-5% flame retardant, and 1-2% catalyst. Major strides have been made on the corrosive effects of aluminum chip metallization. Reduction of chloride and other halides in the basic epoxy composition, stable flame retardants and ion scavengers have essentially eliminated corrosion problems. Some questions remain regarding toxic fumes liberated from packages exposed to excessive temperatures (>200°C) emanating from flame retardant additives. A serious failure mechanism in memory devices, data loss due to alpha particle impact caused by thorium and uranium elements contained in the filler material, has been greatly reduced. Single bit loss and soft errors have been reduced through reduction of those alpha emitting elements and by barrier coating of the integrated circuit (IC) die.

Delamination or "popcorning" associated with thin package leadless chip carriers which are surface mounted using various soldering techniques is understood and can be controlled. Techniques used include baking the finished part and sealing in an airtight plastic bag. Parts removed from this enclosure must be used in a specific time period. At the part level, delamination effects can be reduced by having perforated leadframe die pad, decrease in filler particle size, and stamping of leadframes which eliminate burr formation sites for stress concentration.

Plastic encapsulated microcircuits have been used in many DoD systems, in large quantities. In some applications, military specific materials, processing, and testing was believed necessary. Because of these requirements, cost of parts neared that of hermetically sealed versions. Cost benefits, high quality and reliability, of plastic encapsulated microcircuits can be achieved by realization of the "economies of scale" associated with procurement driven by high volume users.

Plastic product reliability has improved dramatically over the past 15 years. Today they are used in harsh environments, such as automotive under-hood applications and commercial avionics systems. The mechanical ruggedness of plastic packages makes them superior in high shock and vibration applications that can damage ceramic packages. The user must carefully review the manufacturing process, reliability test results, and customer base of each prospective plastic IC supplier. Some items useful in evaluating the integrity of a supplier of plastic parts include but are not limited to:

a. reduced phosphorus levels in passivation;

b. dual layer passivation in critical cases;

c. perforated frames;

d. benign (non-ionic) cleaning of frames after molding;

e. use of copper frames;

f. reduced stress trim and form;

g. corrosion resistant mold compounds;

h. nitride passivation;

i. ionic contamination;

j. comprehensive reliability program.

8.7 Suitability evaluation/qualification. Durability depends upon selection of parts that will perform properly for the service life of the equipment. A formal process for determining technology family suitability should be established and applied to all parts regardless of which quality system parts are purchased to. The highest quality part or technology family can be misapplied due to incompatibility with design tools and methods and become a reoccurring failure and logistic support problem.

Top level initial suitability analysis of technology families can be done with respect to bias levels, external temperature, loading conditions, power cycles, and family specific sensitivities and limitations immediately after an estimate of the intended usage, use environment, and assembly level block diagrams is developed. As a design becomes more defined, the effects of specific component power dissipation, internal and external temperature, specific loading conditions, operating signal frequencies, vibration, input signal conditions, etc at specific assembly locations can be evaluated and suitability reaffirmed. Suitability analysis should be carried out as an iterative part of the design process.

Formal equipment designer/manufacturer procedures for qualifying technology families from particular vendors is highly desirable. Such procedures should establish suitability for each design task (desired end function, performance, and use/stress environment) in light of possible vendor to vendor variabilities. This supports a closed-loop design process and will assure highest probability of designing with parts having the necessary characteristics from the very beginning. In addition, the qualification procedure should evaluate the level of supplier technical support and control over key variabilities available as a result of compliance to the applicable quality system(s).

Each vendor technology family should also be evaluated for compatibility with design tools and methods as a part of suitability qualification. Incompatibilities with computer-aided design (CAD) tools for design, analysis and simulation can lead to the misapplication of high quality parts or technology family.

A final element of technology family qualification is evaluating compatibility with equipment manufacturing processes and procedures. The various stress exposures inherent in each manufacturing process should be evaluated in terms of type and duration against technology family sensitivities to assure excessive degradation will not occur. A component should be capable of lasting the service life of the equipment, AFTER exposure to manufacturing and inspection/test stresses (including rework) and environmental stress screening (when applicable).

8.8 Closed-loop design process. A controlled design process with variability reduction is essential to designing high-complexity systems in a timely economic fashion. Variability reduction, as applied to a design process, would drive toward a design environment capable of producing designs with a high probability of first pass success (fewer re-design iterations). An example of such a process would involve the use of a computer-based design and simulation environment to develop and verify a desired assembly function and performance. The design would then be fabricated and electrically tested under various environmental conditions for proper function and performance. Differences in simulation and electrical test would form the basis for analysis and corrective actions to bring the designed and simulated function and performance into agreement with actual test results. Corrective actions might involve refining CAD tool component models with new and/or more precise parametric limits or central tendency values, or adding CAD routines to accept and utilize data representing such things as parametric drift of specific technology families induced by high or low temperatures.

A disciplined design process would also include a design process suitability verification. The purpose of such a verification is assuring the tools, methods, and procedures used have no inherent limitations or assumptions which will force a less than satisfactory result (assembly design) with respect to short and long term function, performance, and durability for the kind of assembly/function being submitted to the process.

A typical item to be checked in such a verification would be compatibility (e.g., verify that embedded design rules account for transmission line properties and proper impedance matching of components and interconnecting medium (printed wiring board (PWB), coax)) when assemblies operate at very high frequencies. If the design process consists of an engineer drawing schematics by hand while referring to component data manuals, a suitability verification might consist of assuring the designer is well trained in the proper design application of all proposed component technologies in each new/different type of assembly to be designed. Expertise with the type of function and concepts key to proper functionality and performance (such as, transmission line properties of PWBs for high frequency assemblies) is also a possible consideration.

In both cases, a capabilities demonstration (designing a small assembly requiring the same kind of component technology and same level of operational performance) is an excellent verification tool and provides information about process capabilities and need for corrective actions. Small scale capability demonstration results provide a way of rating potential contractors with respect to a proposed design and development effort providing a criteria appropriate to the desired item of supply. This approach provides more insight into current capabilities as opposed to results of previous design efforts with lower equipment performance levels and different component technologies.

8.9 Characteristics variability. Another consideration in proper design application of a component technology family is an evaluation of the allowed variabilities to determine if any of them will affect proper component function, performance, or durability in a specific circuit insertion. An example of this is the lead dimension limits found in MIL-STD-1835. Mechanical analysis of these dimensions with respect to typical vibration induced bending stresses indicates that life expectations of leads with dimensions at the extremes can vary by as much as 70,000 to 1. With this in mind, the designer must consider the effect on the assembly of worst case lead dimensions.

If analysis shows, for example, that the expected vibration environment is likely to stimulate an early lead failure, design adjustments, such as repositioning the part or adding board stiffeners, can be used to make the design tolerant to lead dimension variations. If service life requirements cannot be met through adjustments, source or specification control may be necessary to assure that installed components have robust leads.

8.10 Specifications and quality system. Variabilities affecting long term function, performance, and reliability are present in every quality system and each technology family. Each application has a unique set of stresses which can turn a particular variability into a source of early failure in the deployed equipment. The specification and quality systems control only a subset of device characteristics. In a specific application, one or more uncontrolled characteristics may be critical to satisfactory component function, performance, or durability. By their nature, these uncontrolled characteristics are likely to vary from vendor to vendor. Identifying these characteristics is not a trivial task and the contractor should have a disciplined "variability affects assessment" procedure to pinpoint them.

Again, the equipment designer should strive to make adjustments so the assembly is tolerant of these characteristics. If this is not possible/ practical then specification, source, or item control, or even use of an application specific device may be necessary when safety or mission readiness demand it. It must be recognized that, since these characteristics are uncontrolled by the specification or quality system, it is necessary to document both the characteristics and acceptable limits for each application of the part as identified in the design process. This enables the disciplined procurement of acceptable parts for production and meeting deliverable data item requirements.

The design process must be iterative to assure that, as parameters/properties of the end item become more defined, changes which might render a previously acceptable part less than suitable are identified and addressed. The objective is to have a high probability of first pass success as a design transitions from development to qualification and then to production and deployment. A controlled, closed-loop, iterative design process will minimize the failure events in qualification testing reducing time and cost impacts of design modifications made after assemblies are in production.

8.11 Application specific integrated circuits (ASICs). The primary purpose of application specific devices in equipment design is to achieve a unique function or set of functions at a necessary level of performance in a single device or set of devices. The influences which typically drive use of ASIC devices are unique functionality, space and power constraints, expansion of practical performance limits, and improving reliability. This last point warrants additional consideration. Typically, discussions of improving reliability through the application of ASIC devices revolve around reducing the statistical probability of a component level failure by replacing several components with a single ASIC. This same consideration applies to a reduction in the number of device/PWB interconnections. The fewer devices or solder joints present in an assembly, the fewer possible failures per unit time. This is a valid method of improving reliability assuming the ASIC is robust enough to withstand the use environment stresses.

Application specific devices should be designed for function, performance, and long-term reliability under end item use environment conditions. Reliability physics-based analysis of proposed ASIC designs should be used to evaluate suitability during the equipment service life. Verification of suitability should be done via testing which imposes amounts and types of stress equivalent to the actual use environment and service life.

Another potential avenue of assembly level reliability improvement is the use of an ASIC device designed to provide service life durability (minimize probability of both open/short and parametric degradation). If durability analysis indicates no existing device having the desired function and performance can meet reliability requirements, a durability enhanced ASIC may be necessary to assure safety of flight or mission criticality criteria are met. The use of reliability physics-based design, suitability analysis and verification testing is essential to be successful with this kind of ASIC development. The QML quality system is particularly well suited to meeting equipment designer needs for this type of device. The conversion of customer requirements process must include the use environment in great detail. In selecting a supplier of an ASIC device, consideration should be given to whether or not the device manufacturer is using VHSIC Hardware Description Language (VHDL) tools up front in behavioral level device design VHDL descriptions of the device interactions at the system level. This provides a system designer with the opportunity to redesign or reselect a device based on the interactions before the design is committed to fabrication and/or system insertion. Failure to use these standard design tools can result in high cost, sole source situations both in first time buys and during the remainder of the system life cycle.

8.12 Summary. The design and part selection procedures suggested here are inseparable and much more rigorous than might otherwise be necessary when following traditional methods described in military/industrial/commercial specifications and standards. They are aimed at making the design process (including selection of appropriate components) responsive on a real time basis to the very rapid changes in design tools and component technology. Being rooted in reliability physics, these methods are deterministic and quantitative. From this a more realistic design solution can be reached than with methods applied across the entire vendor base without regard to differences in component reliability, sources and types of variability, and limitations and sensitivities of technology families from different vendors. The quality systems discussed in Chapter 2 are established to allow a designer to select a manufacturer with a defined set of quality standards and practices which should minimize variability of the various technology families produced/shipped, thus minimizing the risk of using their devices in the respective system application. Furthermore, the process discussed in this section requires military equipment designers to consider all aspects of component selection that impact the DoD mission needs, moving beyond questions of compliance to specifications and standards into questions about reliability in specific applications. The reliability physics used in the design of components can be brought to bear on the application of those components. The design rules, tradeoffs, and application assumptions made/used by the device designer can be used to establish design rules for the equipment designer and contribute to reducing misapplications which can severely reduce the useful life of even the highest quality component. The objective of this effort is military equipment that meets all specification requirements and has a very low cost of ownership.

9. SYSTEM GUIDANCE

9.1 Introduction. The competitive nature of today's electronic industry has created an environment suitable to promote, demand, and apply the best manufacturing practices. A manufacturing system capable of producing high quality products must comprehend the basic elements of design, manufacturing, marketing and customer services. The success of this system is based on communication of customer needs and requirements to suppliers. The customer-supplier communication is the key to manufacturing and marketing high quality products.

9.2 Manufacturing and cycle time. The term manufacturability is used to define manufacturers' ability to produce products with an acceptable quality/cost and it is a function of product maturity for both the supplier and the customer. For new products utilizing new technologies, a yield of 20% may be acceptable in order to supply products ahead of competition. Time-to-market or manufacturing cycle time for introducing new products has become the driving force of many manufacturers. This concept has forced manufacturers to study their cycle time for each operation. In some cases production flows have been streamlined to implement Just-In-Time (JIT). Contracts should require a comprehensive yield improvement program for the new technologies as well as cycle time analysis to reduce cost and obtain continuous improvement.

9.3 Statistical Process Control (SPC). High yield and high quality consistently at the lowest cost is any manufacturers' goal. Statistical process control techniques are tools to achieve this goal. The publication, JEDEC-19, outlines requirements for an SPC program. This specification requires study of all process nodes, selection of critical nodes, proper use of SPC data, corrective actions based on SPC data, piece parts SPC program, etc. SPC and low yield are not necessarily mutually exclusive. For example, a tester may be under SPC and produce low yield. The low yield is due to incoming material characteristics, not the tester. Contracts should require use of SPC; however, they should avoid selection of critical nodes, CpK, etc. Contracts requiring SPC should provide for some type of detailed review by SPC trained personnel to ensure adequate and effective use of SPC. Under the QML and QPL quality systems SPC is required and is evaluated periodically by the Government for its effectiveness.

9.4 Screening. Recent published data by the Institute of Environmental Sciences-Environmental Stress Screening of Electronic Hardware (IES-ESSEH) in 1988 and 1990 has shown that the majority of military grade components are defect free. Industrial systems manufacturers have helped drive the increase in quality and reliability by demanding quality levels similar to those imposed by the military. These commercial users consume the largest quantity of IC products and thus have significant impact on the rate of quality improvement. Defects found are typically due to miscorrelation of test hardware/software or ambiguity of specifications. In addition, the above publications show that an active customer-supplier quality improvement team (QIT) can systematically eliminate all defects. A proposed correlated device list (CDL) for the industry to be hosted by the Government-Industry Data Exchange Program (GIDEP) will list components that have reached defect free status based on the correlation effort among specific supplier-user teams. Contracts should reference the above proposed CDL. Mandatory 100% rescreening of components must be avoided. Rescreening may be allowed for a short period of time to give time for quality improvement programs to work or to locate another source. Each program should have as one of its major goals the task of reducing or eliminating costly ESS screening.

9.5 Interchangeability/substitution. One of the most frustrating problems in the field is interchangeability of components. In many cases, a standard component from another manufacturer cannot be used to replace a failed component. This problem has also been found in the list of allowed substitutions. In both cases, designers and the original equipment manufacturers have not fully defined all critical parameters in their application. Contracts should require proper documentation of critical parameters. It is also recommended that OEMs verify the validity of the substitution list.

9.6 Radiation hardness assurance (RHA). RHA is a series of radiation simulations which assists the system builder in determining the amount of radiation a device will withstand during a nuclear event or during normal operation within a natural generated radiation field (i.e., solar flair, radiation belts, and atmospheric anomalies). The general specifications and detailed device specifications such as MIL-I-38535 and the SMDs have been developed and structured to provide the user with as much information about device capability as possible.

All RHA SMDs require devices to be characterized to the device capability (not to system survivability) using the following MIL-STD-883 and ASTM test methods:

Method 1017 - Neutron irradiation.

Method 1019 - Total ionizing dose (gamma).

Method 1020 - Radiation induced latchup (X-ray).

Method 1021 - Dose rate upset.

ASTM method 1192 - Single event phenomena (heavy ions).

Because all devices ar inherently hard to some level of gamma radiation (method 1019), four RHA designators were developed to allow for the categorization of all the different capability levels observed, as follows:

M = 3×10^3 rads(Si)

D = 1×10^4 rads(Si)

R = 1×10^6 rads(Si)

H = 1×10^5 rads(Si)

For example, if a part is characterized to 5×10^4 rads(Si) the part would be listed as a D level part, but is that same part from a different manufacturer shows a capability to 5×10^5 rads(Si) the part would be listed as a R level on the same SMD.

The other test methods are handled within the Group E paragraphs in each detailed specification as required by design or by the purchase order. By putting these methods into paragraphs, RHA hardened devices such as Silicon on Sapphire (SOS) and Silicon on Insulator (SOI) may not need to be tested for a particular effect and can so be stated without changing the requirements.

The electrical test limits after irradiation can be found in table I of the SMD for the level specified by the RHA designator. These limits are derived from the characterization data with a mean plus 3 sigma applied to that data.

By providing a fully characterized detailed device specification the user knows the device capability and can make a better judgement on which part best suits his particular application.

9.7 Obsolescence. Obsolescence or non-availability of items required to support DoD systems has become an increasingly prevalent problem in recent years. This situation may occur among all classes of items and materials, but most commonly affects solid state microelectronics. Various DoD and industry-driven factors may combine to make continued manufacture of selected components uneconomical or otherwise unattractive. Reasons manufacturers cite for ceasing production include rapid technological advances, foreign source competition, federal environmental and safety regulations, and limited availability of items and raw materials. Department of Defense procurement practices further compound the problem. Long design-to-acquisition lead times, uneconomical production requirements, and service life extension programs may all impact profitability and/or availability of specific product lines and thus decrease manufacturers' desire or ability to provide life cycle support for obsolete parts and components. Diminishing Manufacturing Sources and Material Shortages (DMSMS) are defined as the loss or impending loss of manufacturers or suppliers of items or shortages of raw materials. DMSMS cases may occur at any time during the acquisition cycle, from design and development through post production, and have the potential to adversely impact the military's ability to outfit and support critical equipment, components, and parts.

9.8 Testability.[1] Integrated circuit designers continue to design circuits that can be made smaller and faster, sometimes using design practices that produce untestable circuits. For the systems of the past this probably was a cost-effective way of bringing systems to the field. However, with continuing decrease in the hardware costs and increase in the field engineering costs, this practice is far from being cost-effective in today's very competitive industry. Today it is necessary to detect, diagnose, and correct problems quickly, accurately, and economically in a mass production environment.

The notion of design and test as two separate activities cannot continue in the future because it will adversely affect the overall cost of integrated circuits and systems. This has been realized by system manufacturers who introduced design for testability techniques in order to essentially minimize the cost for test pattern generation, test pattern validation, and test application. Self-testing techniques are also increasingly being used for functional verification of high performance

[1] Hakim, Edward B., Microelectronic Reliability, Volume I Reliability, Test and Diagnostics (Norwood, MA: Artech House, 1989), Chapter 3 - Testability for Functional Verification and Diagnostics and Chapter 4 - Automatic Testing.

circuits capitalizing on their advantage of at-speed testing. Finally, when design and test are considered as an integral activity at the component level, system testing can be greatly affected by adopting a system design methodology that takes advantage of "testable" components to create system BIT structures at all levels of design hierarchy so that systems are easily testable.

An important consideration in testing digital microcircuits is the definition of some kind of measure of test "quality." Traditionally, this measure was called fault coverage and is the fraction of detectable faults that are detected using a given test set.

The number of faults detected is relatively easy to determine. A fault simulator is able to count them. The problem is with determining the number of all possible faults. With a structural model, we can define it as the number of interconnections doubled (assuming that we do not allow for bridging faults). At the functional level this measure is relative. The same functional unit can be built in many different ways, each using a different number of gates and, thus, having a different number of interconnections. This means, if we try to use the definition above, we can actually "manipulate" the result, and by adding logically transparent components, such as a noninverter to our functional primitives, we can report a higher percentage of fault coverage without improving the comprehensiveness of the test. An example of cost reduction through the use of increased fault coverage testing is given below:

Example:

Assume that the fault coverage of untested ICs is 98%. Assume further that through testing we can improve the fault coverage of the lot to 99.8%. In the intended operation, 50 ICs are used in accordance with PWB, and 10 PWBs are needed to construct a system. The workload is uniform at 1000 systems per month. The company has found that eliminating a fault at the IC level costs \$0.75; \$7.50 at the PCB level; and \$75.00 at the system level. What is the cost savings by high fault coverage assurance?

Let Q_I = fault coverage of ICs,
n = number of ICs on the PWB,
P_B = probability that the PWB is free of bad ICs,
m = number of PWBs in the system, and
P_s = probability that the system is free of bad ICs.

Then, if we do not test ICs, the probability that a PWB is free of bad ICs is

$$P_B = (Q_I)^n = (.98)^{50} = 36.42\%$$

At the system level, we have an unacceptably low probability that the system is free of bad ICs:

$$P_S = (P_B)^m = (.3642)^{10} = .004\%$$

Now, if through testing we bring the fault coverage of the IC to 99.8%, we will have

$$P_B = (Q_I)^n = (.998)^{50} = 90.47\%, \text{ and}$$
$$P_S = (P_B)^m = 36.75\%$$

The cost differential at the board level (CD_B) can be predicted by subtracting the difference in board fault coverage and multiplying it by the quantity and cost of repairing each PWB:

$$CD_B = \$7.50 * (.9047 - .3642) * 10{,}000$$
$$= \$40{,}537.50$$

Similarly, a cost differential (CD_S) exists at the system level:

$$CD_S = \$75.00 * (.36750 - .00004) * 1{,}000$$
$$= \$27{,}559.50$$

In this example, it was shown that if the fault coverage of the ICs is only 98%, the probability that the system constructed will be free of IC failures is only 0.004%. If, however, we increase the fault coverage of the ICs to 99.8%, a mere 1.8% increase in IC fault coverage, the probability that the system will be free of IC failures increases to 36.75%. This is nearly a 10,000-fold increase in the probability that the system will work.

It is clear that higher-quality ICs will produce higher-quality systems and, from an economic perspective, will also result in lower costs. Ideally, we would like to have ICs with 100% fault coverage, but we must work within both technical and economic limitations. In order to detect all possible failures that could befall an IC, a very comprehensive test program must be produced. The amount of effort needed to produce such a test program grows exponentially as higher percentages of fault coverage are required. Figure 2 shows how time, cost, and test engineering effort grow with respect to percent fault detection or test effectiveness. An additional substantial cost is that of purchasing, operating, and maintaining an automatic test system.

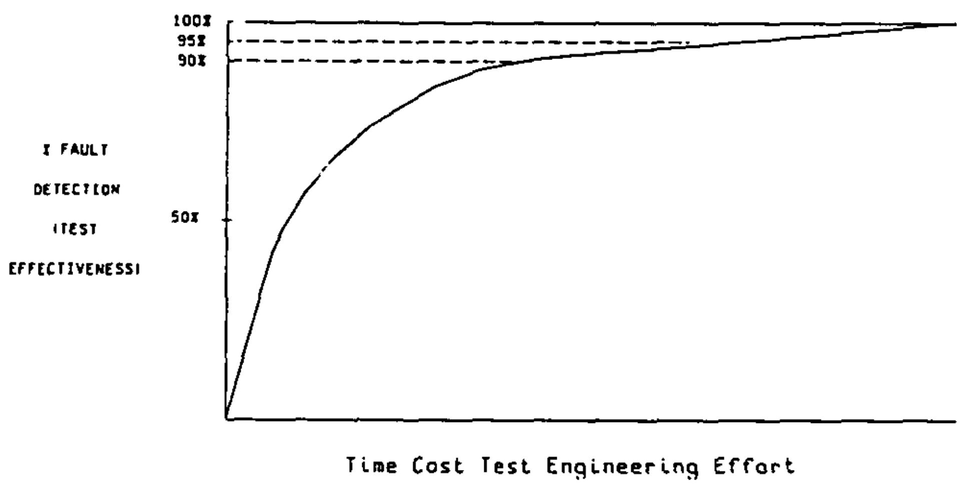

FIGURE 2. Fault coverage as a function of test program development cost.

9.9 _Environmental stress screening (ESS)_. Environmental stress screening (ESS) is a process employed by DoD for discovering defective parts and materials at incoming inspection. Effective application of ESS is designed to reduce in-plant rework costs by disclosing defects due to parts, workmanship, and manufacturing process deficiencies. Furthermore, it is designed to decrease maintenance and support costs attributable to early life failures of fielded systems and improves availability during initial deployment. A closed loop corrective action process, dedicated to determining defect cause and instituting corrective action to prevent recurrence is encouraged as an integral part of ESS to assure maximum benefit of instituting this program.

ESS is used at the component, subassembly and system levels to remove quality related defects. Stress screening required of component suppliers, via the quality systems cited, is usually sufficient enough to remove assembly and packaging and workmanship problems. However, many DoD programs specify 100% ESS at receiving inspection. At the component level the most used ESSs are temperature cycle, burn-in, hermeticity and Particle Impact Noise Detection (PIND). An ESS program at the board or higher assembly level should be designed to eliminate workmanship defects resulting from the board or higher assembly processing (solder, contamination, etc) and not due to component defects. These screens include temperature cycle, shock and vibration.

In order to minimize the cost and possible schedule impact when 100% ESS is required, the implementation of government contractor receiving inspection and test is changing to reflect a process for augmenting the component/board supplier control system which in turn will reduce the level of nonconforming product entering the assembly process. The decision to perform electrical and mechanical verification at receiving is based on several factors. These factors may include, but are not restricted to the following: The lack of component/board characterization data, the criticality and/or relative risk of the component/board in its application, demonstrated performance of the component/board, or application specific testing. Decisions regarding receiving inspection and test of components/boards should be made on a supplier and part/board basis. Through implementation of a well thought out receiving inspection program, ESS would be limited to those products meeting the factors cited above. Also, any ESS program should reflect the end use system requirements.

9.10 _Quality function deployment (QFD)_. QFD is a structured system for designing product or service based on customer demands and involving all members of the producer or supplier organization that assures product characteristics equate to customer requirements. QFD can be used to clarify an identifiable supplier/customer interface. It should be used in any new systems contract to assure that the final system meets or exceeds all the customer expectations.

Briefly, in a matrix format, it lists the customer's "wants" with priority ratings on one side of the matrix and the "how to" across the top of the matrix. In a system design this process is reiterated through a Requirements Matrix, a Design Matrix, a Product Characteristics Matrix, a Manufacturing/Purchasing Matrix, a Control/Verification Matrix, and a Control/Verification of Product Matrix.

In the context of this handbook, QFD should be used by the parts supplier with the systems builder to assure that all the customer application and performance requirements are properly communicated to the parts supplier so that the capability of the part may be matched to the systems environment (electrical, thermal, mechanical). For instance, it would be inappropriate to use plastic parts in an exposed wing tip avionics pod, but unfortunately, it was done on one system at a considerable retrofit/redesign cost. QFD would have established the structured communications link between the supplier and the customer.

CONCLUDING MATERIAL

Custodian:
Army - ER

Preparing activity:
Army - ER

Agent:
DLA - ES

(Project 5962-1338)