NASA Standard for Screening and Lot Acceptance Testing Based on Mission Classification

Chris Green, Christopher.m.green-1@nasa.gov
Noman Siddiqi, Jacobs Engineering Group Inc, noman.a.siddiqi@nasa.gov
NASA Goddard Space Flight Center
Electrical Engineering Division, Code 560

Acronyms

AEC	Automotive Electronics Council	LAT	Lot Acceptance Testing
ARC	Ames Research Center	MAR	Mission Assurance Requirements
BME	Base Metal Electrode	MIL	Military
COTS	Commercial Off The Shelf	MSFC	Marshall Space Flight Center
DPA	Destructive Physical Analysis	MSL	Moisture Sensitivity Level
EEE	Electrical, Electronic, and Electromechanical	PCB	Parts Control Board
EEEE	Electrical, Electronic, Electromechanical, and Electro-Optical	PDA	Percent Defect Allowable
GRC	Glenn Research Center	PEM	Plastic Encapsulated Microcircuit
GSFC	Goddard Space Flight Center	PIND	Particle Impact Noise Detection
HAST	Highly Accelerated Temperature and Humidity Stress Test	QML	Qualified Manufacturers List
HTOL	High Temperature Operating Life	RF	Radio Frequency
ISO	International Organization for Standardization	RTD	Resistance Temperature Detector
JEDEC	Joint Electron Device Engineering Council	SCD	Source Control Drawing
JPL	Jet Propulsion Laboratory	SMA	Safety and Mission Assurance
JSC	Johnson Space Center	SPEC	Specification
KSC	Kennedy Space Center	STD	Standard
LARC	Langley Research Center	VICD	Vendor Item Control Drawing

Applicable Documents

- **NPD 8730.2:** NASA Parts Policy
- **NPR 7120.5**: NASA Space Flight Program and Project Management Requirements
  - Covers Class A, B, C, and D missions
- **NPR 7120.8**: NASA Research and Technology Program and Project Management Requirements
  - Tech Demo, Do no harm, etc.
- **NASA-STD-8739.10**: Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard
- **NPR 8705.4A**: Risk Classification for NASA Payloads
  - https://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_8705_004A_&page_name=main
  - Rev A, Effective Date April 29, 2021
  - https://sma.nasa.gov/news/articles/newsitem/2021/05/06/osma-releases-significant-npr-8705-4a-updates
- **GPR 8705.4**: Risk Classification Guidelines and Risk-Based SMA Practices for GSFC Payloads and Systems
- **EEE-INST-002**: Instructions for EEE Parts Selection, Screening, Qualification, and Derating
  - Defines 3 “Levels” or “Quality Levels”, 1-3
- **NASA-STD-8739.11:** Electrical, Electronic, Electromechanical, and Electro-Optical (EEEE) Parts Selection, Testing, and Derating Standard
  - To supersede EEE-INST-002
  - Defines 4 “Assurance Levels”, 1-4
  - Quad ”EEEE” to include guidance on electro-optic parts

Converting Mission Class to Part Level

- Mission Classification (A-D) typically determined during Announcement of Opportunity or proposal stage.
  - NPR 8705.4A provides guidance
- Confirmed, stated, flowed down in Mission Assurance Requirements (MAR) document (or similar).
- MAR also defines the part "Assurance Level" requirements
  - GPR 8705.4 is one of the initial drivers
  - Does not necessarily have to be Class A = Level 1, etc.
  - Enables different Part Level requirements per system

NPR 8705.4A Risk Classification for NASA Payloads

P.1 Purpose: This directive defines (1) the criteria for Mission Directorates to define the risk tolerance classes for NASA missions and instruments, and (2) the corresponding Agency-level assurance expectations that drive design and analysis, test philosophy, and common assurance practices.

Mission and Instrument Risk Classification Considerations

Priority (Relevance to Agency Strategic Plan, National Significance, Significance to the Agency and Strategic Partners)	Very High:	Class A
	High:	Class B
	Medium:	Class C
	Low:	Class D
Primary Mission Lifetime	Long, > 5 Years:	Class A
	Medium, 5 Years > – > 3 Years:	Class B
	Short, 3 Years > – > 1Years:	Class C
	Brief, < 1 Year:	Class D
Complexity and Challenges (Interfaces, International Partnerships, Uniqueness of Instruments, Mission Profile, Technologies, Ability to Reservice, Sensitivity to Process Variations)	Very High:	Class A
	High:	Class B
	Medium:	Class C
	Medium to Low:	Class D
Life-Cycle Cost	High :	Class A
	Medium to High	Class B
	Medium :	Class C
	Medium to Low	Class D

NPR 8705.4A, Appendix C: Risk Classification Considerations for Class A – Class D NASA Missions and Instruments

C.1 This appendix provides considerations for designating a mission or instrument risk tolerance class. These considerations constitute a structured approach for identifying a hierarchy of risk tolerances commensurate with the four risk tolerance classes defined in Chapter 3.

C.2 The considerations provided are to be treated holistically with each taken into account in order to most appropriately designate a mission or instrument risk tolerance class based on the applicable mission criteria. The considerations provided in the table below are not definitive, nor is any specific mission criterion alone intended to be the ultimate driver to designating a mission or instrument risk tolerance class. Ultimately, the mission or instrument risk tolerance class is designated by the Mission Directorate in accordance with paragraph 3.1.4.

C.3 Other considerations for designating a mission or instrument risk tolerance class may exist that are not explicitly expressed in this appendix (e.g., alternate research or reflight opportunities, launch constraints).

C.4 Appendix D provides program and project SMA objectives that vary according to risk tolerance class over a continuum of design and management controls, systems engineering processes, mission assurance requirements, and risk management processes to be satisfied in project-specific mission assurance implementation.

C.5 The expectation is that individual projects may mix and match components from different mission or instrument risk tolerance classes to meet the intent of the mission’s overall classification and avoid being more or less conservative than the overall risk tolerance class and mission requirements dictate.

NPR 8705.4A: EEEE Parts Level Guidance

SMA Area	Class A	Class B	Class C	Class D
Electronics, Electrical, and Electromechanical (EEE) Parts	Select EEE parts at an appropriate level for functions tied directly to mission success commensurate with safety, performance and environmental requirements. Perform additional screening and qualification tests, as necessary, to reduce mission risk. For secondary functions not tied directly to mission success, lower level parts are acceptable in accordance with project-level documentation Accepted Standard: NASA-STD-8739.10, Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard.			
	Level 1 parts, equivalent Source Control Drawings (SCD) or requirements per Center Parts Management Plan.	Class A criteria or Level 2 parts, equivalent SCD or requirements per Center Parts Management Plan.	Class B criteria or Level 3 parts, equivalent SCD or requirements per Center Parts Management Plan.	Class C criteria or Level 4 parts, equivalent SCD or requirements per Center Parts Management Plan.

GPR 8705.4: EEEE Parts Level Guidance

Technical Categories	Class A	Class B	Class C	Class D	Ground System (GS)	7120.8 Class	Do No Harm (DNH)	Hosted Payload Class (host requirements)
EEE Parts	Level 1 parts per EEE-INST-002; DPA performed per S-311-M-70; Counterfeit Avoidance requirements per 500-PG-4520. 2.1;	Level 2 parts per EEE-INST-002 ~~except Level 1 parts for single point failures and hybrids containing active components~~; DPA performed per S-311-M-70; Counterfeit Avoidance	Level ~~2~~ 3 parts per EEE-INST-002 ~~for missions greater than 2 years except Level 1 parts for hybrids containing active components and Level 3 parts may be used for fault tolerant, non-critical~~	Level ~~3~~ 4 parts ~~per EEE-INST-002 except Level 2 parts for hybrids containing active components; DPA performed per S-311-M-70; Counterfeit Avoidance requirements~~	For custom designed modules, ~~quality level of parts selected needs to be consistent with the criticality of the module.~~ best practices for COTS parts selection and usage should be applied.	Best commer-cial practices, advise on part selection & derating. ISO certified facilities preferred.	Best commer-cial practices, ISO certified facilities preferred.	Host practices. Advise on part selection & derating.
EEE Parts (cont.)	For short life time missions, Level 2 parts may be used for fault-tolerant applications of low-risk part types.	requirements per 500-PG-4520. 2.1; Use as-is of Class V, S, Q or B microcircuits and JANS and JANTXV semiconductors	~~application;~~ - ~~Level 3 parts per EEE-INST-002 for missions less than 2 years except Level 2 parts for hybrids containing active components; DPA performed per S-311-M-70;~~ Counterfeit Avoidance requirements per 500-PG-4520. 2.1; Use as-is of Class V, S, Q, B, M, or 883-Compliant microcircuits and JANS, JANTXV, and JANTX semiconductors	~~per 500-PG-4520. 2.1;~~ - ~~Use as-is of Class V, S, Q, B, M, or 883-Compliant microcircuits and JANS, JANTXV, and JANTX semiconductors~~		Parts selection and screening should be based on mission duration and environ-ment.		

Assurance Level Philosophies

- Level 1: Level 1 represents the most stringent set of testing requirements and typically favors the highest classes of MIL-SPEC parts. Requirements include Screening, Lot Acceptance Testing, Destructive Physical Analysis (DPA), and use of Source Control Drawings (SCD) for custom testing flows.
- Level 2: Level 2 is a substantial set of testing requirements and typically favors the second highest classes of MIL-SPEC parts. Requirements include Screening, Lot Acceptance Testing, and DPA, but with some reduced tests, sample sizes, and durations from Level 1. Use of Source Control Drawings is encouraged, but not always required.
- Level 3: Level 3 generally allows both MIL-SPEC based designs, as well as infusion of commercial parts based designs with minimally burdensome piece part testing requirements. Level 3 generally includes some Screening, but does not impose Lot Acceptance Testing. Level 3 criteria rely heavily on Destructive Physical Analysis as an inexpensive test to obtain objective insight into manufacturer workmanship and quality.
- Level 4: Use of commercial parts with no additional screening or qualification. At level 4, in applications that have low tolerance for risk and sufficient resources, it is essential to have detailed information about the manufacturer and part prior histories.
- ***Derating is a primary driver for reliable application, and is independent from the assurance levels.***

EEEE Part Assurance Levels

- EEE-INST-002 / NASA-STD-8739.11 Primarily defining different screening and lot acceptance test requirements.
- Can’t test in quality. Testing doesn’t enhance the quality or grade of part- but does improve confidence.
- Really defining different levels of rigor for how much assurance testing is required.
- Some “grades” of parts may meet a desired “assurance level” as-is. (MIL Class V microcircuit meets assurance level 1, for example).
- For purposes of 8739.11 “assurance level” deemed the most accurate terminology.

NASA-STD-8739.11 Section Format

- Each Commodity Section is Formatted as:

  Introduction:
  - Brief description of the commodity.
  - General guidelines and important usage factors for the commodity.

  Tables
  - Table 1 - Overall requirements for each level
  - Table 2 - Screening (100%)
  - Table 3 - Lot Acceptance Testing (LAT), (sample)
  - Table 4 - Derating Criteria

M5, Plastic Encapsulated Microcircuit, Table 1: Requirements

Table 1. PLASTIC ENCAPSULATED MICROCIRCUIT REQUIREMENTS 1/, 2/, 3/

Quality Level	Monolithic Microcircuit Type	Specification	Use as Is	Screening	LAT	DPA
Level 1	SCD **2/**	SCD		X	X	X
Level 2	QML Class N	MIL-PRF-38535				X
	Automotive, Commercial, SCD **2/**	AEC-Q100, VICD, SCD		X	X	X
Level 3	QML Class N	MIL-PRF-38535				X
	Automotive, Commercial, SCD **2/**	AEC-Q100, VICD, SCD		X		X
Level 4	QML Class N	MIL-PRF-38535	X			
	Automotive, Commercial, SCD **2/**	AEC-Q100, VICD, SCD	X			

Notes:

1/ The character "X" designates a requirement. The character "R" designates a recommendation.

2/ SCD shall be generated to the program-specific Parts Procurement Plan that specifies screening and qualification testing. See Tables 2 and 3 for Screening and LAT requirements. DPA shall be performed in accordance with MIL-STD-1580 Requirement 16 for Plastic Encapsulated Microcircuits.

M5 Table 2: Screening

Table 2. PLASTIC ENCAPSULATED MICROCIRCUIT SCREENING 1/ 4/

Test	Test Sequence	Test Methods, Conditions, and Requirements	Level 1	Level 2	Level 3
1	Wafer Lot Acceptance	MIL-STD-883, Methods 5010 Appendix II and 5007	X		
2	Nondestructive Bond Pull 5/	MIL-STD-883, Method 2023, 2% PDA	X		
3	Internal Visual	MIL-STD-883, Method 2010	X Cond. A		
4	Temperature Cycling	MIL-STD-883, 1010, Condition B, 10 Cycles min.	X	X	
5	External Visual	MIL-STD-883, 2009 (3 to 10X)	X	R	
6	PIND **2/**	MIL-STD-883, 1010, Condition A	X	X	
7	Serialization		X	R	R
8	Initial Electrical		X	R	R
9	Radiographic	MIL STD 883 Method 2012, Two Views	X		
10	Burn-in **3/**	MIL-STD-883, 1015, Condition D.	X 240 hr. @125°C	X 160 hr. @125°C	R 96 hr. @125°C
11	Final Electrical Measurements at +25°C, Min. and Max. Operating Temp.	Per applicable device procurement specification	X	X	R
12	Calculate Delta		X		
13	Maximum Percent Defective Allowable (PDA)		≤ 5%	≤ 10%	
14	External Visual	MIL-STD-883, 2009 (3 to 10X)	X	X	R X

Notes:

1/ The character "X" designates a requirement. The character "R" designates a recommendation.

2/ PIND required for cavity PEM microcircuits only.

3/ Limit burn-in temperature to below the maximum junction temperature (Tj) as specified by the manufacturer.

4/ Plug cavity microcircuits vent holes before environmental testing.

5/ Nondestructive Bond Pull only possible if performed during production.

M5 Table 3: Lot Acceptance Tests

Table 3. PLASTIC ENCAPSULATED MICROCIRCUIT LOT ACCEPTANCE TESTS 1/

Inspection Test	Test Methods, Conditions, and Requirements	Quantity (Accept Number)	
		Level 1	Level 2
Group 1			
Visual Inspection and Serialization	MIL-STD-883, Method 2009 (3X to 10X)	77	44
Group 2			
Preconditioning Moisture Soak 2/	JESD22- Moisture Sensitivity Level soak shall be in accordance with IPC/JEDEC J-STD-020.	X	X
Reflow		X	
Radiography	MIL-STD-883, Method 2012, Two Views	X	X
Electrical Measurements	Measure and record parameters at 25 °C, min. and max. rated temperatures per device specification.	45 (0)	22 (0)
Life Testing 3/	MIL-STD-883, Method 1005, Test Condition D, HTOL, 125 °C, 1,000 hours minimum Measure and record parameters at 25 °C, min. and max. rated temperatures per device specification.	45 (0)	22 (0)

M5 Table 3: Lot Acceptance Tests (continued)

Inspection Test	Test Methods, Conditions, and Requirements	Quantity (Accept Number)	
		Level 1	Level 2
Group 3			
Baseline C-Mode Acoustic Microscopy	J-STD-035	22 (0)	12 (0)
Temperature Cycling	MIL-STD-883, Method 1010, Condition B; 100 cycles. Measure and record parameters at 25 °C, min. and max. rated temperatures per device specification.	22(0)	12(0)
C-Mode Acoustic Microscopy	J-STD-035	22(0)	12(0)
Group 4			
Biased HAST	JESD22-A110, with continuous bias, 96 hours, +130 °C, 85% RH.	10 (0)	10 (0)
Final Electrical Measurements	Measure and record parameters at 25 °C, min. and max. rated temperatures per device specification.		

Notes:

1/ The character "X" designates a requirement.

2/ Plastic Encapsulated Parts typically have Moisture Sensitivity Levels and require handling and bakeout procedures prior to assembly in accordance with J-STD-033.

3/ Life test: The junction temperature should not exceed the absolute maximum rated junction temperature for the part. If 125 °C ambient causes the maximum rated junction temperature to be exceeded the ambient temperature should be decreased appropriately

Applicable Standards for Test Methods

JEDEC Standards:

JESD22-A113: Preconditioning of non-hermetic surface mount devices prior to reliability testing.
JESD22-A110: Highly accelerated temperature and humidity stress test (HAST).
IPC/JEDEC J-STD-020: Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface mount Devices.

M5 Table 4: Derating

Table 4. PLASTIC ENCAPSULATED MICROCIRCUIT DERATING REQUIREMENTS

Derating of PEM microcircuits is accomplished by multiplying the stress parameter by the appropriate derating factor specified below.

Stress Parameter	Derating Factor	
	Digital	Linear
Maximum Supply Voltage 1/	0.9	0.8
Maximum Input Voltage	Do not exceed 100% of derated supply voltage	Do not exceed 100% of derated supply voltage
Power Dissipation	0.8	0.75
Maximum Specified Operating Junction Temperature	Tj = +110 °C or 40 °C below the manufacturer's maximum junction temperature rating, whichever is lower.	
Maximum Output Current	0.8	0.7
Maximum Operating Frequency 2/	0.8	0.7

Notes:

1/ For low-voltage (<= 5 V) devices, use manufacturer's recommended operating conditions as the derated limit.

2/ Unless the part is intended to be used as a communication data bus standard (for example MIL-STD-1553 that operates at 1 MHZ) or another application used for a specific frequency only, in which case frequency will not be derated.

Recommended vs Required Tests

- NASA missions require additional flexibility to successfully infuse new technologies and commercial parts for flight applications.
- Hardware developers are expected to provide data to justify proposed candidate parts.
  - This may include successful previous flight missions, a known or expected radiation performance, significant part experience through prototype designs or engineering model testing, and familiarity with and knowledge of the part manufacturer, product line, process controls, and quality. Information regarding design fault tolerance, benign stress conditions, low criticality applications, and planned board and box level testing campaigns will also help to support this justification.
  - In situations where this data is available and can be presented, it is expected that the Parts Control Board (PCB) will not impose the "recommended" piece part tests.
- When a candidate part represents a relatively new technology, lesser known manufacturer data, challenging construction techniques, manufacturing processes, or stressful or unique application conditions, the PCB may impose the "recommended" piece part tests to achieve the desired assurance.
  - These tests should be imposed sparingly, but ultimately the PCB is responsible to determine if the justification is sufficient, or the additional tests are needed to establish parts assurance.

Alternate Assurance Approaches

- Piece part testing is a brute force method for establishing an assurance level or confidence in the reliability of a part.
  - Tried and true- but expensive on a production basis.
  - MIL spec approaches and manufacturing processes have generally followed this approach.
- Commercial industry has evolved different methods for ensuring production of reliable parts.
  - Favors reliability through high volume production, high levels of automation, statistical process controls, and process parameter trending.
  - Many commercial parts are achieving comparably high reliability, and would be suitable for NASA missions- but how do we tell them apart ***without*** the expensive testing?
  - Out of scope for 8739.11- but there are parallel efforts working towards that goal. 8739.11 hopes to be compatible with these approaches- particularly in level 3 applications, and in place of “recommended” tests.
- *NESC-RP-19-01490: Phase I - Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions*
  - Available on https://ntrs.nasa.gov/citations/20205011579
  - Phase II in progress

NASA-STD-8739.11 Progress, Plan Forward

Part Category	Document Section
General Instructions for All Part Categories	1
Capacitors (including BME*)	C1
Connectors and Contacts	C2
Crystals	C3
Crystal Oscillators	C4
Detectors*	D1
Fiber Optics and Passive Components* (Fiber, Cables, Connectors, and Assemblies)	F1
Filters	F2
Fuses	F3
Heaters	H1
Magnetics	M1
Microcircuits, Hybrid Hermetic	M2
Microcircuits, Monolithic	M3

Part Category	Document Section
Microcircuits, Monolithic Plastic Encapsulated	M5
Microwave and RF Devices*	M6
Microcircuits, Hybrid Non-Hermetic*	M7
Optoelectronic Devices*	O1
Laser Devices*	L1
Printed Circuit Boards*	P1
Relays, Electromagnetic	R1
Resistors	R2
Semiconductor Devices, Discrete	S1
Semiconductor Devices, Plastic Encapsulated*	S2
Switches	S3
Temperature Sensors and RTD	T1
Wire and Cable	W1

- All individual 26 sections completed.
- *9 new sections incorporated
- Compiling sections, final edits, and entering NASA-STD review process.

NASA Centers Review Team

- 8739.11 Section drafts established with help from EEEE Parts experts from across NASA Centers and external reviewers.
- Thank you to all contributors!
- Thank you to the NASA Electronic Parts and Packaging Program!

NASA Centers	
ARC	Ames Research Center
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LARC	Langley Research Center
MSFC	Marshall Space Flight Center