Guide to Using Automotive-Grade EEEE Parts in Space Applications

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Agenda

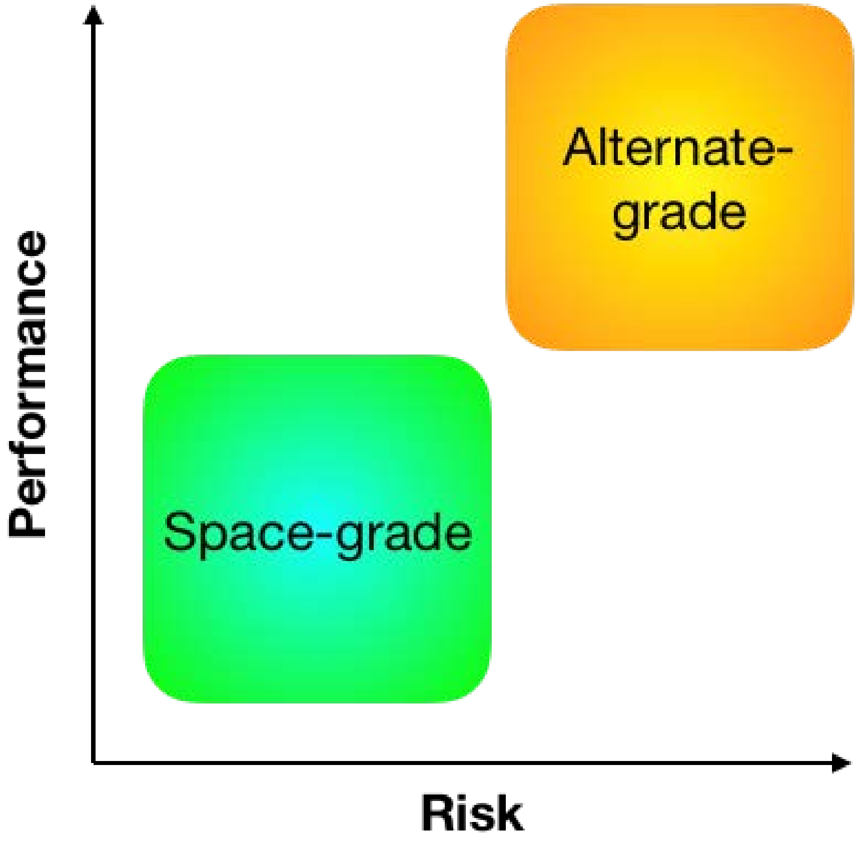
- Introduction/Motivation
- Comparison Table (Pros and Cons)
- Comparison Matrices
  - *MIL-PRF-38535 vs. AEC-Q100*
  - *MIL-PRF-19500 vs. AEC-Q101*
  - *MIL-PRF-123 vs. AEC-Q200 (Capacitors)*
- Key Questions to Ask…
  - *Filling Gaps Between AEC and MIL-Space Requirements*
- Conclusions
- Acknowledgements

Near-Term Technology Working Group

Alternate-Grade Parts for Small-Satellite Applications

Motivation

- Increased use in alternate-grade parts for space applications
- Alternate-grade parts are not designed for space
- AEC-qualified parts are highly reliable in automotive applications (shock, vibe, thermal cycle, high temperatures)
- Space-grade parts may be too expensive (upfront purchase $) – emphasis on lower cost launch vehicles and small satellites
- Technological demands – commercial parts are quicker to adapt
- Space industry no longer able to dictate the EEEE parts market



Key: Risk reduction of Alternate-grade parts

Overall Comparison

Space- vs. Alternate-grade

Space-grade

Pros
High reliability in space
Little/no additional testing needed

Cons
Declining market share
Higher up-front purchase cost
Availability/long lead times
Technology/capability may lag

Alternate-grade

Pros
Greater availability
Lower up-front purchase cost
New technology/capability

Cons
Unknown reliability: may need additional testing/screening and analyses (reliability, FMEA)
Lack of data
No radiation test requirements

Trade space depends on risk posture, mission-specific environments, application-specific constraints, schedule, obsolescence, availability, and cost.

Some launch vehicles and small satellites currently use alternate-grade parts.

Comparison Matrices

User Guide

- Aerospace TOR: Aiming for public release in Q3 2018
- Intended as guidelines
- Qualitative assessments by subject matter experts
- No descriptions of how parts are manufactured
- ”Baseline” reference for incorporating automotive-grade parts in designs
  - *Users should consider risk posture, mission-specific environments, application-specific constraints, schedule, obsolescence, availability, and cost*
  - *Users should look further into referenced MIL-PRF and MIL-STD test methods to verify whether the AEC-qual parts need additional testing.*

Comparison Matrices

User Guide (Cont.)

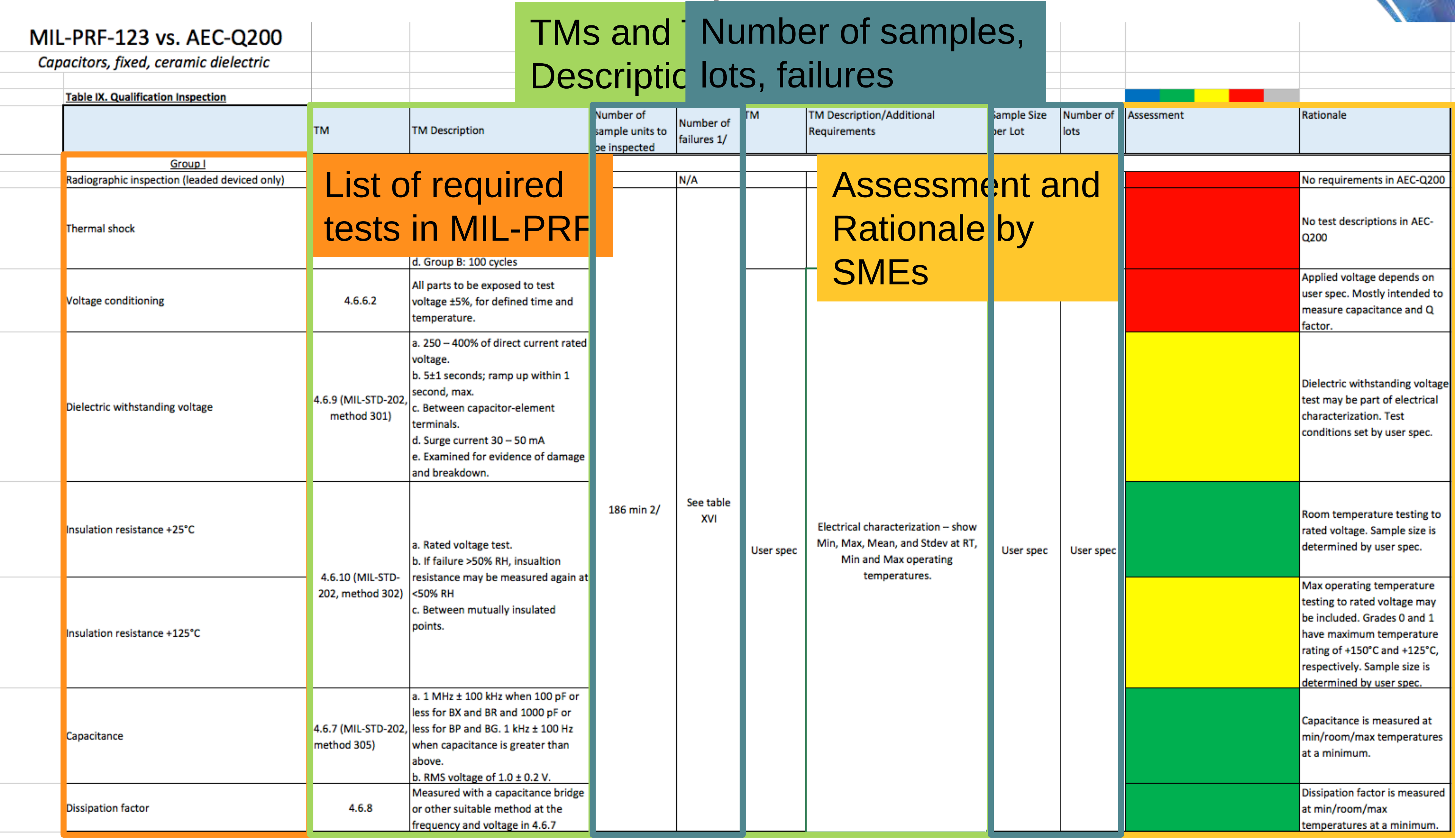
- Assessment Column:

🟦	AEC Requirement fully meets or exceeds that of the MIL-PRF
🟩	Meets intent (e.g., test might be different, but tests for same failure mechanism)
🟨	Partially meets intent
🟥	Fails to meet intent

- MIL-PRF-38535 vs. AEC-Q100: Integrated Circuits (Microcircuits)
  - *Table 1A. Screening Procedure for Hermetic Classes Q, V, and Non-Hermetic Class Y*
  - *Table 1B. Tests/Monitors for Plastic Packages*
  - *Table II. Group B Tests (Mechanical and Environmental)*
  - *Table III. Group A (Electrical)*
  - *Table IV. Group C Life Tests*
  - *Table V. Group D Tests (Package Related)*
- MIL-PRF-19500 vs. AEC-Q101: Semiconductor devices
  - *Table E-IV. Screening Requirement*
  - *Table E-IVA. Group B*
  - *Table E-IVB. Group B Inspection*
  - *Table E-V. Group A Inspection*
  - *Table E-VII. Group C Periodic Inspection*
- MIL-PRF-123 vs. AEC-Q200: Capacitors, fixed, ceramic dielectric
  - *Table IX. Qualification Inspection*

Comparison Matrices Example

Additional information found in AEC-Qxxx and PPAP documents



TMs and T
Descriptic

Number of samples, lots, failures

List of required tests in MIL-PRF

Assessment and Rationale by SMEs

MIL-PRF-123 vs. AEC-Q200

Capacitors, fixed, ceramic dielectric

Table IX. Qualification Inspection

🟦 🟩 🟨 🟥 ⬜

	TM	TM Description	Number of sample units to be inspected	Number of failures 1/	TM	TM Description/Additional Requirements	Sample Size per Lot	Number of lots	Assessment	Rationale
Group I										
Radiographic inspection (leaded deviced only)				N/A					🟥	No requirements in AEC-Q200
Thermal shock		d. Group B: 100 cycles	186 min 2/	See table XVI					🟥	No test descriptions in AEC-Q200
Voltage conditioning	4.6.6.2	All parts to be exposed to test voltage ±5%, for defined time and temperature.			User spec	Electrical characterization – show Min, Max, Mean, and Stdev at RT, Min and Max operating temperatures.	User spec	User spec	🟥	Applied voltage depends on user spec. Mostly intended to measure capacitance and Q factor.
Dielectric withstanding voltage	4.6.9 (MIL-STD-202, method 301)	a. 250 – 400% of direct current rated voltage. b. 5±1 seconds; ramp up within 1 second, max. c. Between capacitor-element terminals. d. Surge current 30 – 50 mA e. Examined for evidence of damage and breakdown.							🟨	Dielectric withstanding voltage test may be part of electrical characterization. Test conditions set by user spec.
Insulation resistance +25°C	4.6.10 (MIL-STD-202, method 302)	a. Rated voltage test. b. If failure >50% RH, insualtion resistance may be measured again at <50% RH c. Between mutually insulated points.							🟩	Room temperature testing to rated voltage. Sample size is determined by user spec.
Insulation resistance +125°C									🟨	Max operating temperature testing to rated voltage may be included. Grades 0 and 1 have maximum temperature rating of +150°C and +125°C, respectively. Sample size is determined by user spec.
Capacitance	4.6.7 (MIL-STD-202, method 305)	a. 1 MHz ± 100 kHz when 100 pF or less for BX and BR and 1000 pF or less for BP and BG. 1 kHz ± 100 Hz when capacitance is greater than above. b. RMS voltage of 1.0 ± 0.2 V.							🟩	Capacitance is measured at min/room/max temperatures at a minimum.
Dissipation factor	4.6.8	Measured with a capacitance bridge or other suitable method at the frequency and voltage in 4.6.7							🟩	Dissipation factor is measured at min/room/max temperatures at a minimum.

Organization and Features

MIL-PRF-38535 vs. AEC-Q100: ICs (Microcircuits)

Key Tests Missing in AEC-Q100

Wafer Lot Acceptance Test

Quality of wafer manufacturing process

MIL-STD-883, TM 5007

- Wafer, metallization, glassivation, Au backing thicknesses
- Thermal stability
- SEM

Radiation Test

Dose rate induced latchup test

MIL-STD-883, TM 1020

- AEC-Q100-004 Latch Up test requirements are not as stringent

Electrical Tests

AEC does not require 100% screening

Burn-in, reverse bias burn-in tests

- Mostly a concern with lack of screening

MIL-PRF-38535 vs. AEC-Q100: ICs (Microcircuits)

Key Tests Missing in AEC-Q100

Steady-State Life Test

Quality/reliability over extended time

MIL-STD-883, TM 1005

- 1000 h minimum at 125°C

DPA, internal visual

Internal materials, construction, workmanship

MIL-STD-883, TM 2013

- Low- and high-magnification inspections

Mechanical Tests

Die shear, substrate attach strength, stud pull, flip-chip pull off

MIL-STD-883, TM 2014, 2004, 2038

- No AEC requirements for DPA or mechanical testing of internal bonds

MIL-PRF-19500 vs. AEC-Q101 (Semiconductors)

Key Tests Missing in AEC-Q101

High-Temperature Life Test

Quality/reliability over extended time

MIL-STD-750, TM 1032

- ≤ Max storage T, 340 h minimum
- Optional for JANS, JANTXV, JANTX

DPA, internal visual

Internal materials, construction, workmanship

MIL-STD-750

- TM 2074, diodes
- TM 2069, power FETs
- TM 2070, microwave transistors
- TM 2072, transistors

Salt Atmosphere

Accelerated corrosion test

MIL-STD-750, TM 1041

- +35°C salt atm for 24 +2/-0 h

MIL-PRF-19500 vs. AEC-Q101 (Semiconductors)

Key Tests Missing in AEC-Q101

Moisture Resistance

Resistance to high humidity and heat

MIL-STD-750, TM 1021

Internal Gas Analysis

Gas atmosphere inside hermetic devices

MIL-STD-750, TM 1018

- Gases inside hermetically-sealed packages can affect reliability

MIL-PRF-123 vs. AEC-Q200 (Capacitors)

Key Tests Missing in AEC-Q200

Radiographic Inspection

Inspection for defects

MIL-PRF-123, sec 4.6.5

- All leaded devices are inspected

Thermal Shock

Resistance to temperature extremes

MIL-STD-202, TM 107

- Tested at +125°C
- AEC-Q200 does not include test conditions

Voltage Conditioning

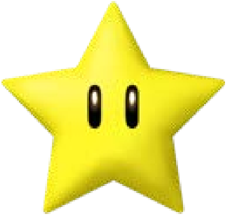
Help eliminate infant mortality

MIL-PRF-123, sec 4.6.6.2

- All parts to be exposed to test voltage ±5% for defined time and temperature
- AEC-Q200: depends on user spec

MIL-PRF-123 vs. AEC-Q200 (Capacitors)

Key Tests Missing in AEC-Q200



Terminal Strength

Determine integrity of terminals

MIL-PRF-123, sec 4.6.5

- All leaded devices are inspected
- AEC-Q200 does not require testing of non-leaded devices

Life Test

Quality/reliability over extended time

MIL-STD-202, TM 108

- Tested at +125°C, 4000 h (qual) and 1000 h (Group B)
- AEC-Q200 does not include test conditions

Key Questions to Ask…

Filling Gaps Between AEC and MIL-Space Requirements

- **Lack of 100% screening**
  - *Demonstrate lot homogeneity and device consistency (e.g., Cpk, Ppk)*
    - Cpk alone does not necessarily demonstrate this – both Cpk and Ppk would be ideal, but may not be always available.
  - *Parts currently available vs. future builds*
  - *Qualification by similarity*
  - *Screening test data*
  - *Verification schedules for AEC qualification*
  - *Origin of design, manufacturing, packaging, and testing*
  - *Perform DPA (third party vendor or in-house)*
- **Tailoring to mission conditions**
  - *Radiation environment*
  - *Mission duration*
  - *Potential single-point failure and mission criticality*

Key Questions to Ask…

Filling Gaps Between AEC and MIL-Space Requirements

- **Insufficient testing (qual or screen) requirements**
  - *Operating temperature range of device*
  - *Stress test results and failure mechanism information*
  - *Supplier’s reliability test criteria*
  - *FIT (failures in time) data*
  - *Test to failure data*
  - *Identification and elimination of potential causes of defects*
  - *FMEA, corrective and preventive actions*
  - *Flight heritage information*
  - *Supplier audits (if possible)*
  - *Level of process and materials changes that trigger advanced notifications*
  - *Priority problem resolution or end-of-life notifications*
  - *Lessons learned or early alert system*
  - *Prevention of counterfeit parts (when purchased through third-party vendors)*
  - *Maintain preferred vendors list*

Conclusions

Holistic Approach to Parts Selection

- High reliability is no accident!
  - *Collect as much information/data available from the supplier*
  - *Assess process repeatability*
  - *Maintain preferred suppliers list*
  - *Perform additional testing as needed*
    - Radiation
    - DPA
- AEC-Qxxx: Qualification requirements, not screening – screening may be performed as part of manufacturer’s own requirements or as an agreement between the manufacturer and its customer (PPAP).
  - *Level of testing/assurance may vary amongst part lots.*
- Tailoring to mission conditions
  - *E.g., Short missions may not require extensive radiation or lifetime testing*
  - *Redundancies – costs of launch services are decreasing*
  - *Single, high-cost mission vs. multiple, lower-cost vehicles in constellation*
  - *Technological needs – do space-grade parts provide sufficient capabilities?*

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