Joint SAE/JEDEC GaN and SiC Working Group

- Topics
  - Market trend of GaN and SiC devices
  - Qualification of GaN devices for Aerospace applications
  - Challenges and approach
  - Proposal/Charter
  - Gan Power device working group activities
  - Revision to MIL-PRF-19500 progress

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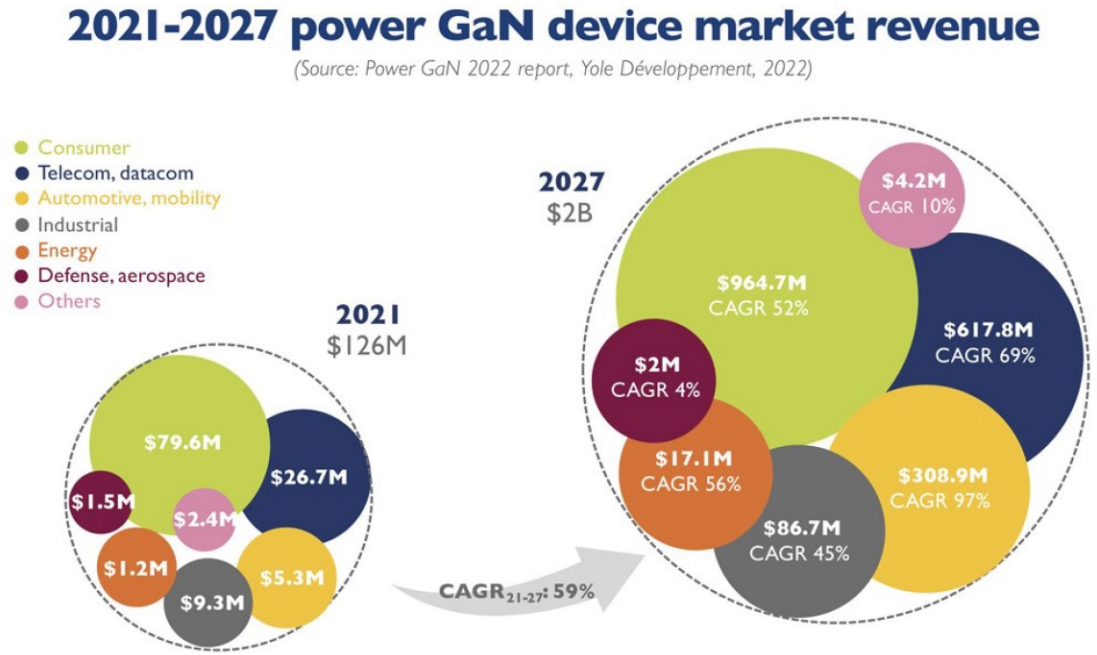
April 2024 CMSE Conference

Market trend of GaN devices

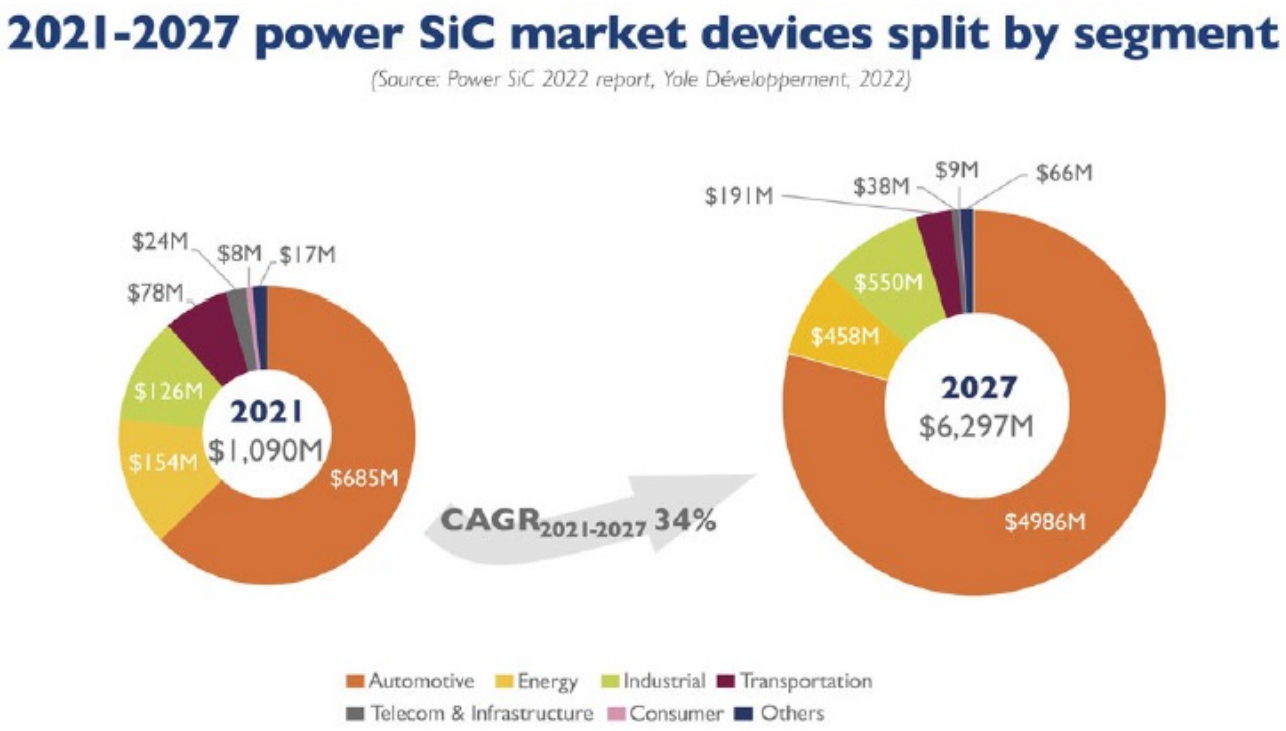
- Trend
  - June 2022 Semiconductor today news published the market trend for **Power Gallium Nitride** (GaN) devices.
    https://www.semiconductor-today.com/news_items/2022/jun/yole-130622.shtml



The power Gallium Nitride (GaN) device market is growing at a compound annual growth rate **(CAGR) of 59%** from just $126m in 2021 to $2bn in 2027, estimates market research and strategy consulting company Yole Dévelopement in the latest edition of its annual report 'Power GaN 2022'.

Market trend of SiC devices

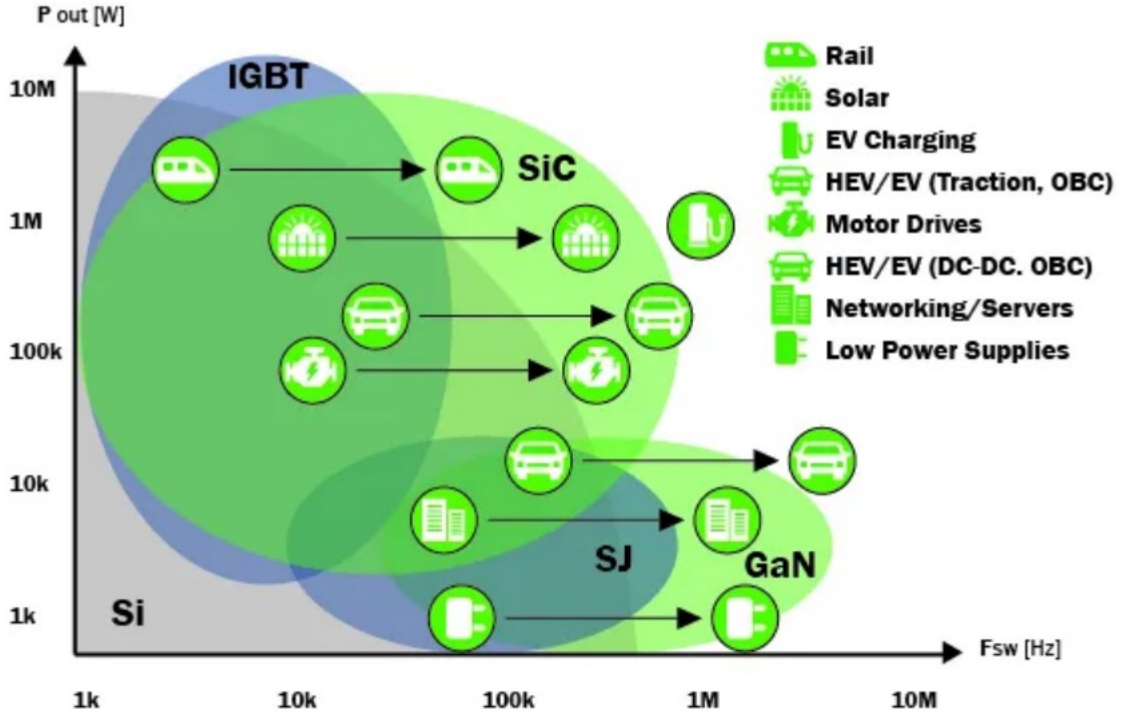
- Trend
  - April 2022 Semiconductor today news published the market trend for **Silicon Carbide** (SiC) devices.
    https://www.semiconductor-today.com/news_items/2022/apr/yole-040422.shtml



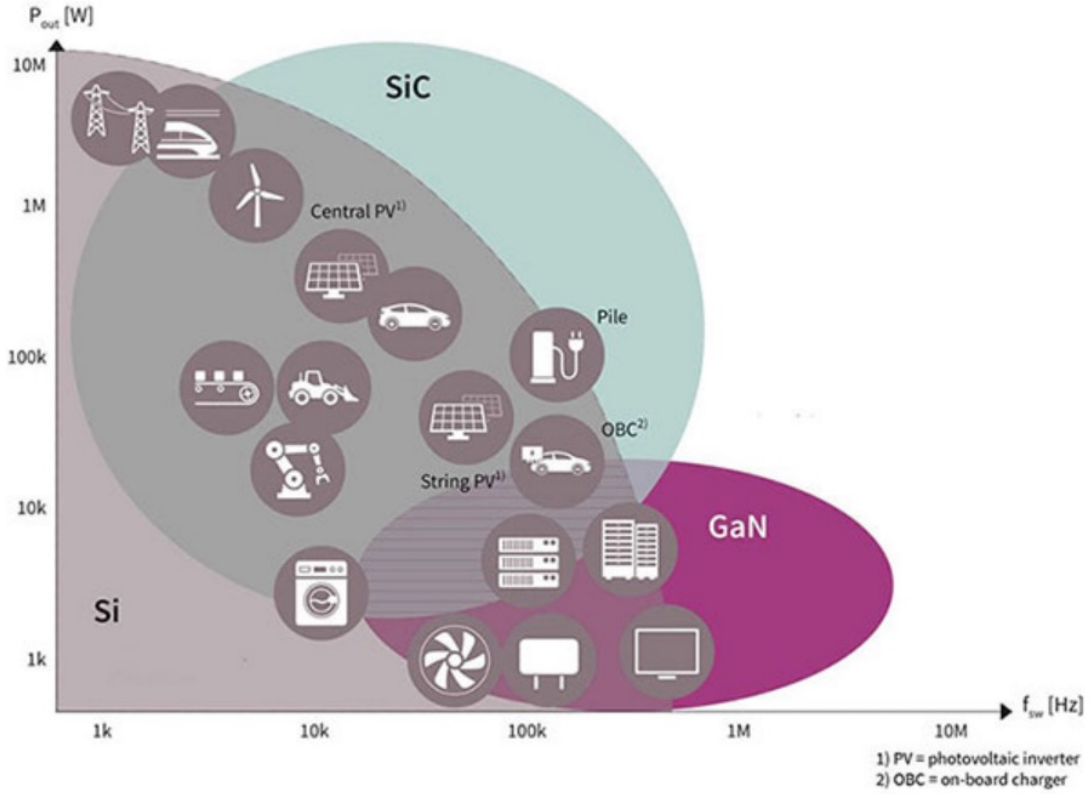
The Silicon Carbide (SiC) device market is growing at a compound annual growth rate **(CAGR) of 34%** from just $1.09bn in 2021 to $6.3bn in 2027, estimates market research and strategy consulting firm Yole Development in its latest annual report 'Power SiC 2022'.

Market trend of GaN and SiC devices

- Trend
  - Graphical illustration of application and advantages of GaN and SiC device technology
    - Sources from World Wide Web publications links below



https://www.powerelectronicsnews.com/the-difference-between-gan-and-sic-transistors/



https://nl.farnell.com/wide-bandgap-semiconductor-the-future-of-sic-and-gan-technology

Qualification of GaN Power devices for Aerospace applications

- Motivation
  - Extended mission life in space (could exceed 20 years)
    - Without possibility of repair or replacement specially on Satellite applications
  - Harsh environment
    - Temperature, humidity, mechanical stress, radiation in space (TID, SEE, SEB) and in aircraft altitudes (Neutron, Proton)
  - Safety requirements
    - Military Aircraft/Manned Spacecraft safety
  - MIL-STD requirements are beyond commercial & automotive requirements
    - More stringent requirements
  - Size, Weight and Power, Cost (SWaP-C)
    - Design consideration in optimizing **S**ize (smaller), **W**eight (lighter) **a**nd **P**ower (minimal lost of efficiency) which could offer lowered **C**ost in a system.

Challenges and approach

- Challenges
  - Wideband Gap (WBG) devices, particularly Power GaNFETs, are relatively new, with active academia research into their reliability issues.
  - Insertion of Power GaNFETs require new JEDEC standards, and new qualification procedures for use in aerospace applications.
- Qualification approaches
  - Most commercial manufacturers of non-hermetic or plastic packaged devices adopts the JESD94, JESD47, series of JESD22 documents, and/or customized/modified excerpts of AEC-Q100 or AEC-Q101 from Automotive industry
  - While hermetic packaging for military and space application were adopting MIL-PRF-19500 or MIL-PRF-38535, with customization/modifications.
- Screening approaches
  - Screening is a method to remove infant mortality (marginal or weak parts) through 100% testing, seldom practiced in the commercial industry, some could be in EP product lines.

Aerospace application currently needed significant customization to screen & qualify GaN power devices

The Proposal

Develop an Aerospace standard with priority on GaN power devices, which has dominant market share in the Aerospace applications.
The approach will focus on discrete GaN Power device technology using **MIL-PRF-19500** as baseline.

Characterization and Reliability	• Failure mechanisms • Parametric, i.e. dynamic Rdson, switching • Radiation
Qualification	• Electrical ➢Robustness, i.e. SOA, Transient, Temperature ➢Reliability, i.e. HTRB, HTGB, HTOL, Switching-ALT • Mechanical ➢MSL, HAST, bondpull, die shear • Radiation • Wafer lot acceptance
Screening	• Burn-in (Early failures) • Test methods

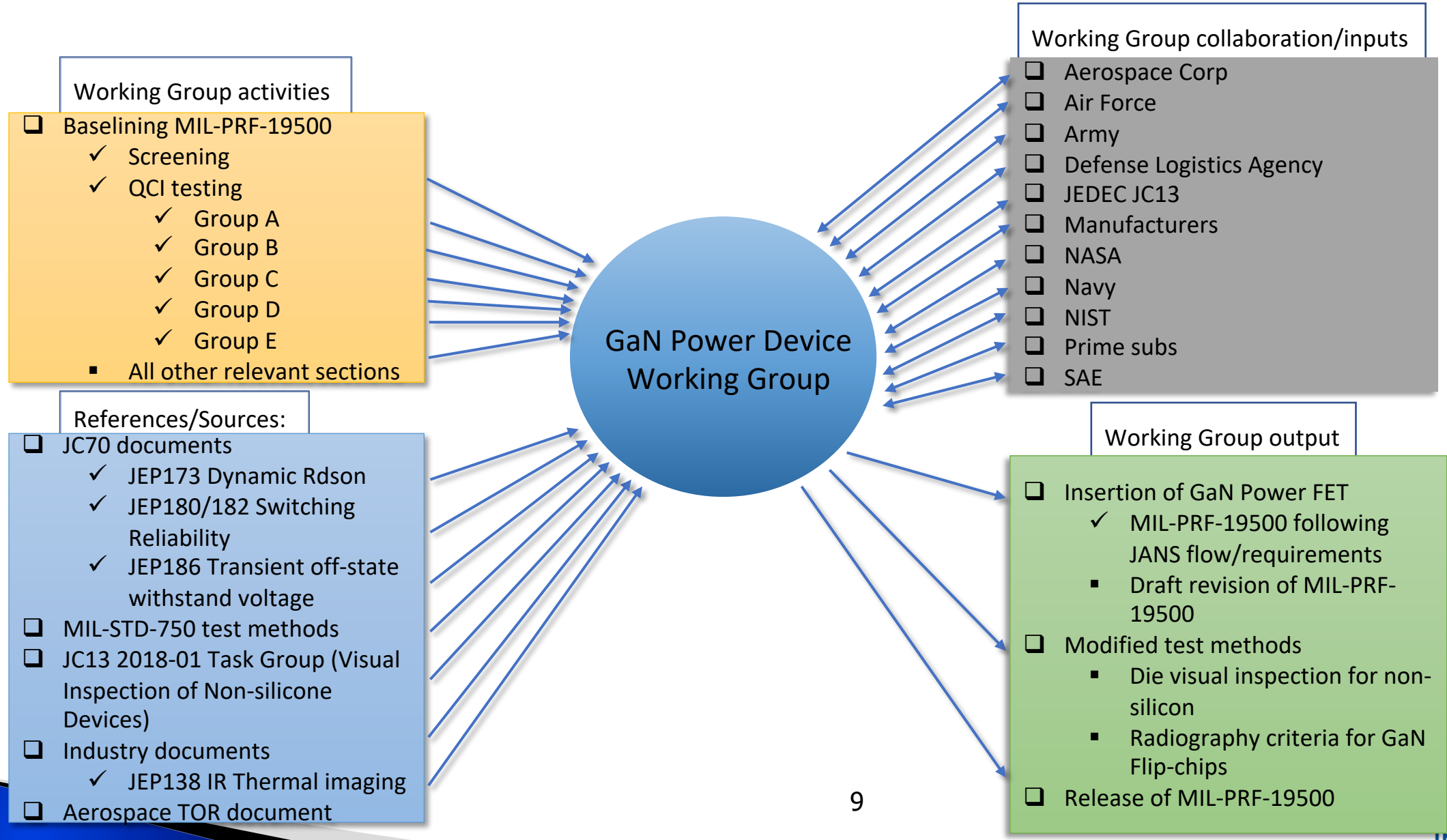
MIL-PRF-19500 – as baseline
- New technology insertion
- Gap Analysis
- Hermetic package only(?)

Applicability:
- MIL-STD-750 TM
- JC70 released Guidance doc
- Aerospace TOR
- JESD47
- JESD94

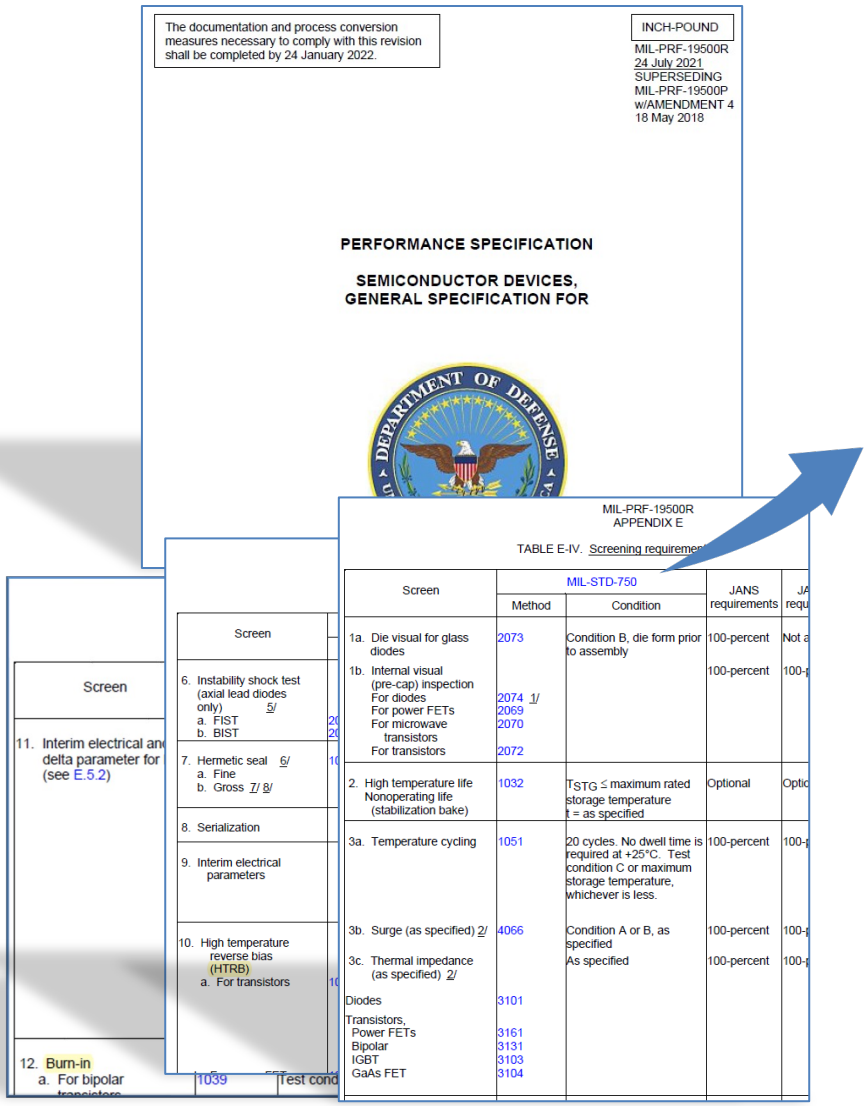
Joint SAE/JEDEC GaN Power device Working Group

- Joint SAE/JEDEC GaN Power device working group
  - CHARTER
    - The task group shall be responsible for the development and establishment of standardized screening, conformance inspection and qualification requirements of Power GaN devices (non-RF) for space application.
    - Shall utilize relevant technical information and other industry guidance or standards as appropriate.
    - Baseline the General Specification for Semiconductor devices MIL-PRF-19500 document and focus on hermetic packaged HEMT (E-Mode) discrete Power Gallium Nitride lateral technology devices only.

Joint SAE/JEDEC GaN Power device Working Group



MIL-PRF-19500 Screening progress update…



Internal visual inspection (TM2069):

- leverage JC-13 TG 2018-02: Visual Inspection for Non-Silicon Devices
- Need updating of TM2069

Surge current (TM4066):

- Not applicable to GaN technology
- Implement JEP186 Transient off-state withstanding voltage

Thermal impedance (TM3161):

- Difficult to measure, require an open part to directly measure the flip-chip
- Implement instead Radiography at screening (effectiveness of bump attachment)
- Perform characterization in Group E using JEP138 IR Thermal imaging

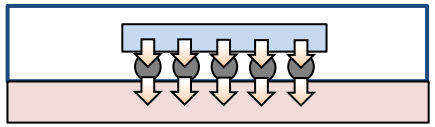
High Temp Reverse Bias (HTRB) & High Temp Gate Bias (HTGB) TM1072:

- Implement JEP173 for Dynamic Rdson

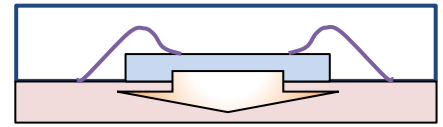
Radiography (TM2076):

- Need updating to include flip chip mount devices, such criteria addresses this type of mounting
  - Resources: Ball Grid Array (BGA) and Land Grid Array (LGA) X-Ray criteria in MIL-STD-883, MIL-PRF-38535 & MIL-PRF-38534

Flip-chip attach



Eutectic attach



100% Screening is an infant mortality tests to remove weak or marginal parts of a production lot

MIL-PRF-19500 Quality Conformance Inspection progress…

Group A
- All subgroups were deemed applicable
- Add Capacitance testing
- Switching parameter to be indirectly measured using Gate charge, Capacitance and Dynamic Rdson

Group C
- Essential elements identified
  - Insert Die shear/Pull TM 2017 for GaN flip-chip
  - Thermal resistance to use Radiography TM2076

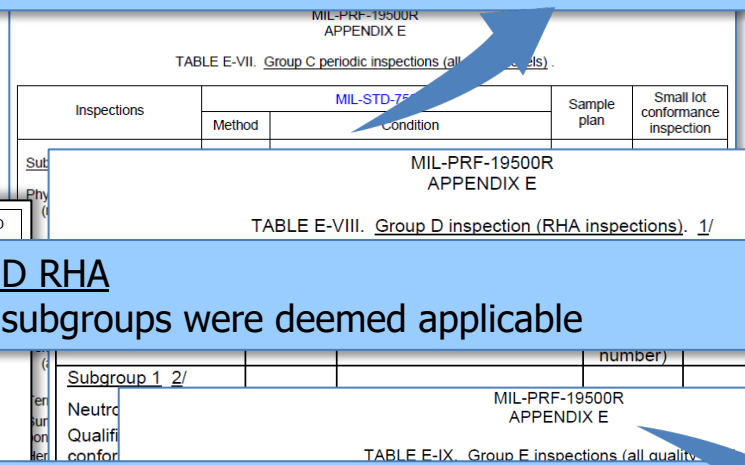

MIL-PRF-19500R
APPENDIX E

TABLE E-VII. Group C periodic inspections (all ...els)

Inspections	MIL-STD-75... Method	Condition	Sample plan	Small lot conformance inspection

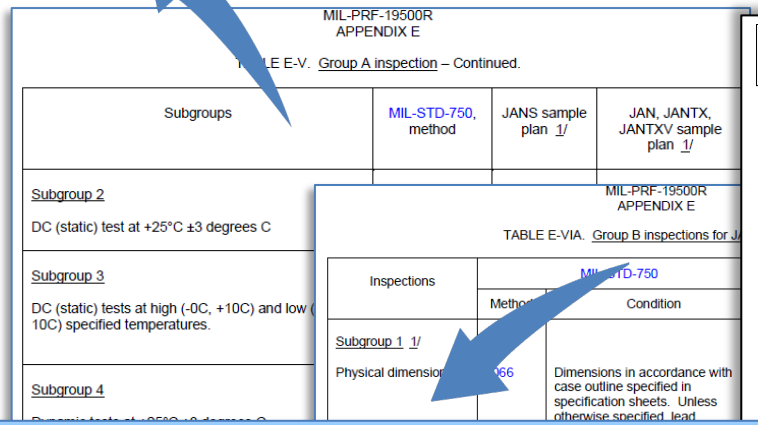

MIL-PRF-19500R
APPENDIX E

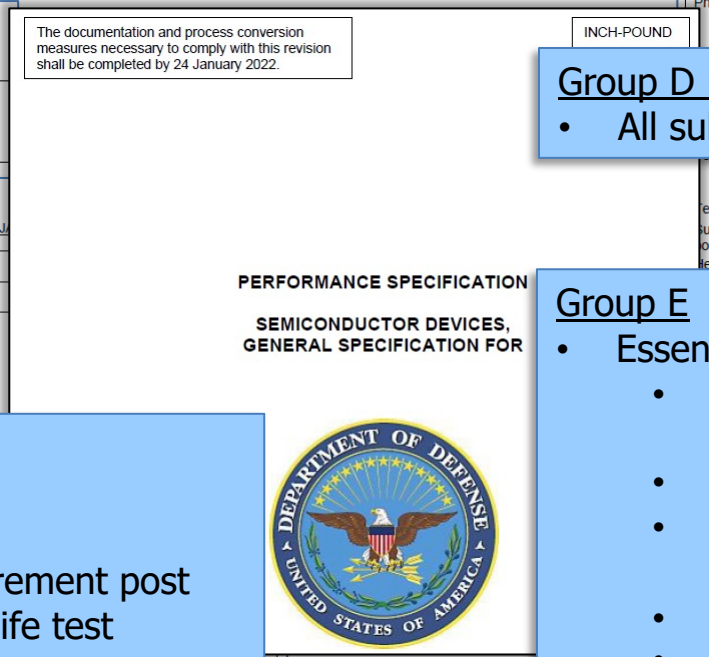
TABLE E-V. Group A inspection – Continued.

Subgroups	MIL-STD-750, method	JANS sample plan 1/	JAN, JANTX, JANTXV sample plan 1/
Subgroup 2 DC (static) test at +25°C ±3 degrees C			
Subgroup 3 DC (static) tests at high (-0C, +10C) and low (10C) specified temperatures.			
Subgroup 4			

MIL-PRF-19500R
APPENDIX E

TABLE E-VIA. Group B inspections for J...

Inspections	MIL-STD-750 Method	Condition
Subgroup 1 1/		
Physical dimensio... 66		Dimensions in accordance with case outline specified in specification sheets. Unless otherwise specified, lead


The documentation and process conversion measures necessary to comply with this revision shall be completed by 24 January 2022.

INCH-POUND

PERFORMANCE SPECIFICATION

SEMICONDUCTOR DEVICES, GENERAL SPECIFICATION FOR

MIL-PRF-19500R
APPENDIX E

TABLE E-VIII. Group D inspection (RHA inspections). 1/

			number)	number)
Subgroup 1 2/				
Neutro...				
Qualifi... confor...				

Group D RHA
- All subgroups were deemed applicable

Group B
- Essential elements identified
  - Surge test replaced by JEP186
  - Add Dynamic Rdson (JEP173) measurement post Accelerated steady-state operational life test
  - Thermal resistance to use Radiography TM2076

MIL-PRF-19500R
APPENDIX E

TABLE E-IX. Group E inspections (all quality ...)

Group E
- Essential elements identified
  - Life test TM 1042 both HTRB & HTGB extend durations to 2,000 hrs @ 80% bias
  - Add Dynamic Rdson (JEP173) measurement post Life test
  - Thermal impedance characterization to use JEP138 IR Thermal imaging
  - Add subgroup 10 for Switching reliability iaw JEP180/182
  - Add subgroup 11 for Single-Event Effect (SEE) TM1080
  - Add subgroup 12 for JEP186 Transient off-state withstanding voltage test

QCI testing is a validation of a specific production lot to be used for flight meets the requirements

Joint SAE/JEDEC GaN and SiC Working Group

- Task group information:
  - Joint SAE/JEDEC GaN and SiC Working group is leading this task activity, chaired by Rod de Leon/Boeing
  - Kick-off meeting started Feb 15th 2023 with bi-monthly meeting that officially started last March 2nd, 2023.
  - Members to date includes the following Organization:
    - Aerospace Corp, Airbus, BAE, Ball Aerospace, Boeing, DLA, DLR(Tesat), EPC Space, ESA, Golden Altos, Infineon, Integra, LMCO, Maxar, Microchip, NASA (MSFC/GSFC/JPL), Navy-CRANE, NIST, Renesas, SAE, Texas Inst, Teledyne, US-Air Force, US-Army