功能安全暨資通安全服務中心

Functional Safety and Cybersecurity Service Center

Advancing Zero-Defect Through Process-Oriented Reliability and Soft Error Risk Integration

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OUTLINE

- Introduction & Objective
- Frameworks and Standards Landscape
- Proactive Reliability through FMEA
- Expanding Reliability Scope: Soft Error Risk (SER)
- Building a Zero-Defect Ecosystem

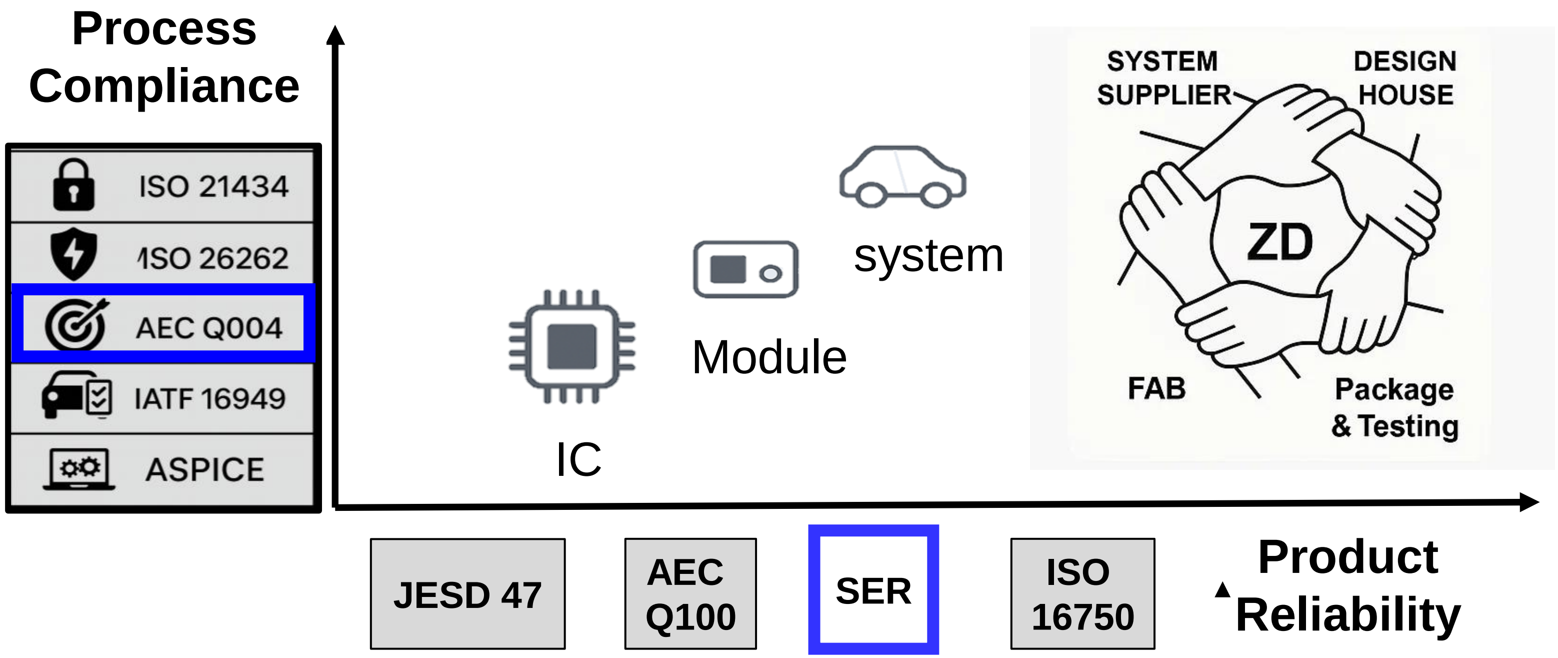
AEC-Q004 Drives Zero Defect

- Zero Defect Approach:
  - Any condition (hard/soft) that threatens zero-defect assurance in automotive electronics
- Supply Chain Collaboration:
  - Integrated with safety and reliability frameworks

Frameworks and Standards Landscape

Automotive electronics: increasing complexity & safety-critical role

- AEC-Q004 Zero Defect framework
- Position: **Zero Defect = governance hub**

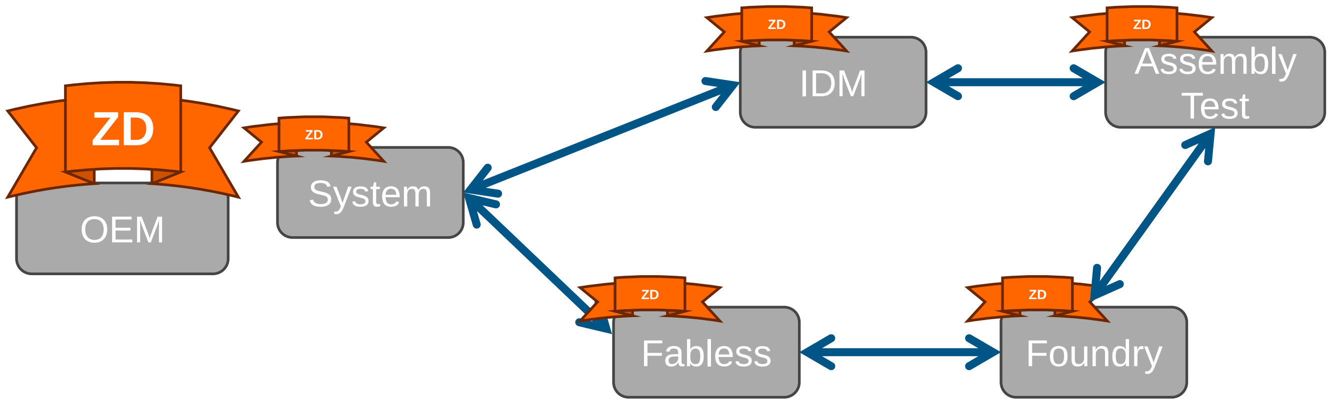


1. ASPICE: **A**utomotive **S**oftware **P**rocess **I**mprovement and **C**apability **De**termination
2. **SER**: **S**oft **E**rror **R**isk

Collaboration Across the Value Chain

- Both upstream and downstream partners should collaborate to achieve Zero Defect across the supply chain
- In response to quality requirements, the upstream partners request ZD compliance, and the downstream partners deliver ZD-compliant parts

- AEC –Q004 Compliance
- Zero defect delivered across ecosystem

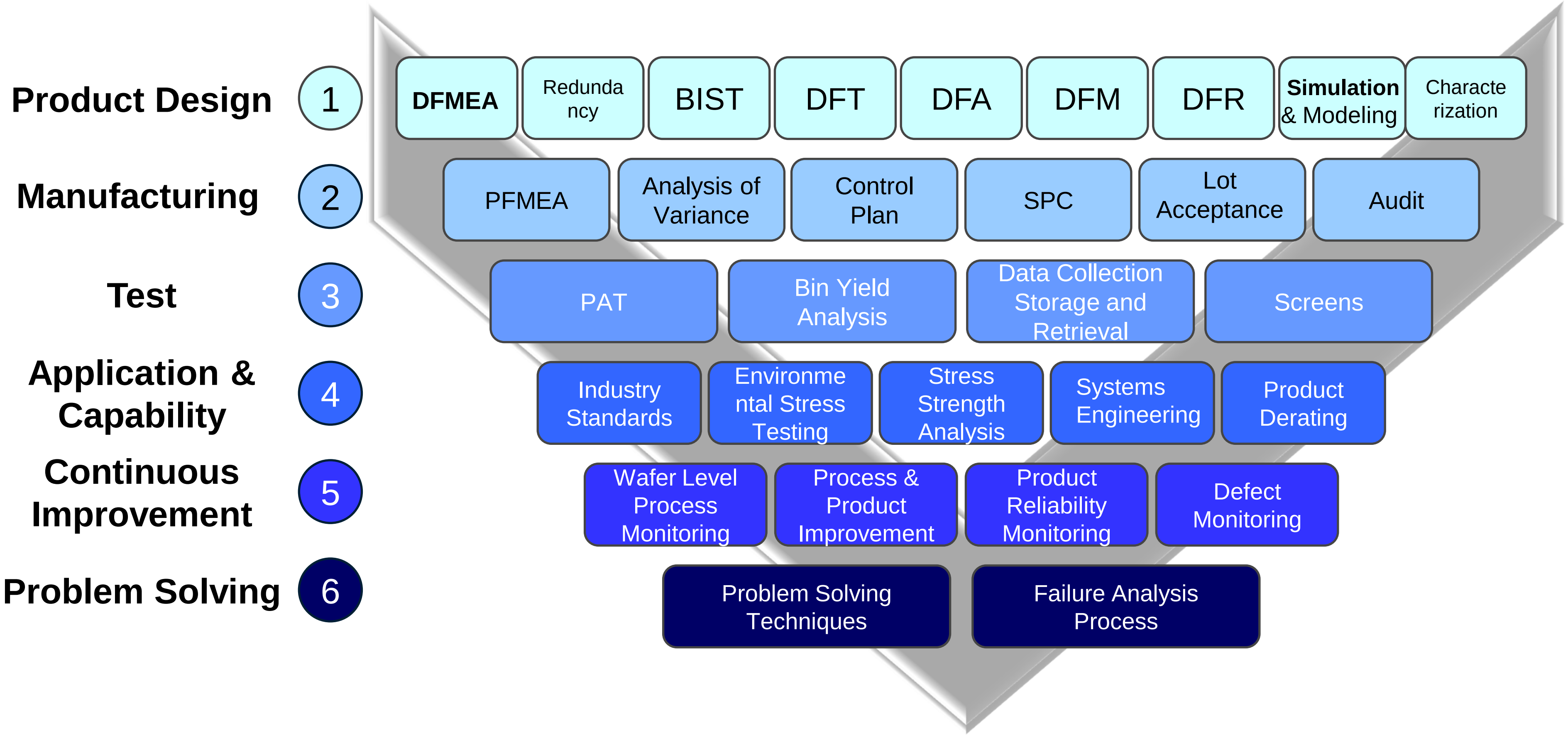


Objective

- Unified Zero-Defect Strategy
- Transparency and OEM Confidence
- Addressing Emerging Reliability Threats
- Process-Oriented Assurance Across the Value Chain

Zero Defect Framework

- The framework shows how applying these methods can enhance Zero-Defect (ZD) performance
- Leveraging systematic tools improves quality and reliability across design, manufacturing, and management



Building Value Through Connection

Connectivity | Reliability | Skill

- Each jewel demands state-of-the-art standards — connectivity, reliability, and skill woven into every strand.

- The Zero-Defect Dilemma in the Semiconductor Industry
  - A Single Company Cannot Achieve True Zero-Defect Alone
  - Checklist Expansion Creates a Resource Trap
  - Why the Ecosystem Fails Without Coordination
  - What's Needed for a Real Zero-Defect Ecosystem

Reference

- Powell, Magnanini, Colledani, Myklebust, *Advancing Zero Defect Manufacturing*, 2022
- Psarommatis, May, Dreyfus, Kiritsis, *Zero-Defect Manufacturing & Sustainability*, 2020
- Kennedy & Alexandrescu, *Automotive Electronics Reliability In-Field Monitoring*, 2024
- AEC Council, *AEC-Q004 Standard*, 2020
- Gandhi & Gandhi, *Advanced Analytics for Yield Improvement*, 2015

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From Failure Analysis to Leading Metrics for Manage Risk

- Systematic analysis: Use FMEA, FTA, and FMEDA to identify
- Quantitative linkage: provide the failure rate (λ) as a leading metric
- Design insight: the logical connection from item/system faults down to individual failures

Absence of
Safety (Reliability) violations

Derived from ISO26262 and
suppress the potential risk

Qualitative → Quantitative

FMEA ↔ FTA ↔ FMEDA

FMEA
- Cause
- Failure mode
- Effect,
- AP

FTA
- Top event
- logic gates
- cut sets
- probability

FMEDA
- λ : Failure
- SPF
- RF,
- MPF,
- Unsafe

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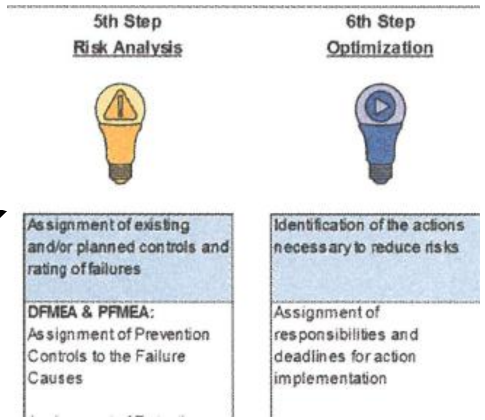
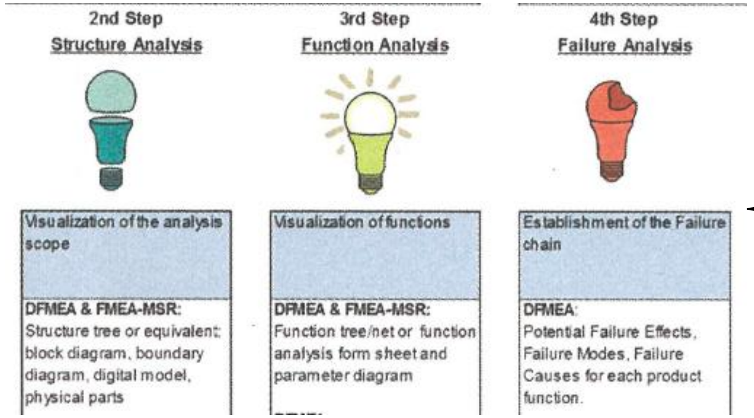
FMEA vs. FMEDA

FMEA



Make sure systematic fault is sufficiently low by preventive and detective control measures



FMEDA
(FMEA-MSR)

SPFM $$1 - \frac{\sum_{\text{Safety related HW elements}} (\lambda_{SPF} + \lambda_{RF})}{\sum_{\text{Safety related HW elements}} \lambda}$$

LFM $$1 - \frac{\sum_{\text{safety related HW elements}} (\lambda_{MPF\ Latent})}{\sum_{\text{safety related HW elements}} (\lambda - \lambda_{SPF} - \lambda_{RF})}$$

Make sure random hardware fault could be controlled by safety mechanisms

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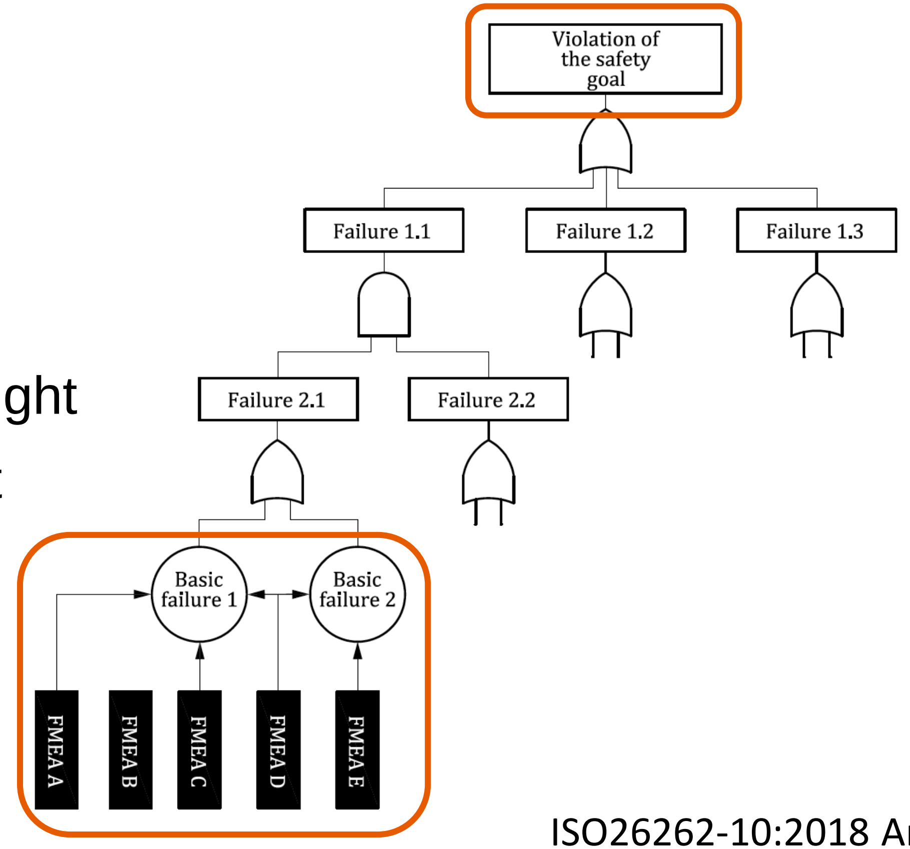
Insight Through Skill: Combining FTA and FMEA

- FTA
  - Top-down logic to trace risks
- FMEA
  - Bottom-up discipline to capture weaknesses.
- Together
  - Reflect engineering skill and insight
  - Connecting system faults to root causes

Top event: safety goal violation



Bottom event: failure of elements

ISO26262-10:2018 Annex A

Visible Failures Anchored in FMEA

- Automotive ECU Example, Brake-by-Wire System

Safety Goal
- Prevent unintended loss of braking torque

Violation
- Brake ECU fails → loss of braking function

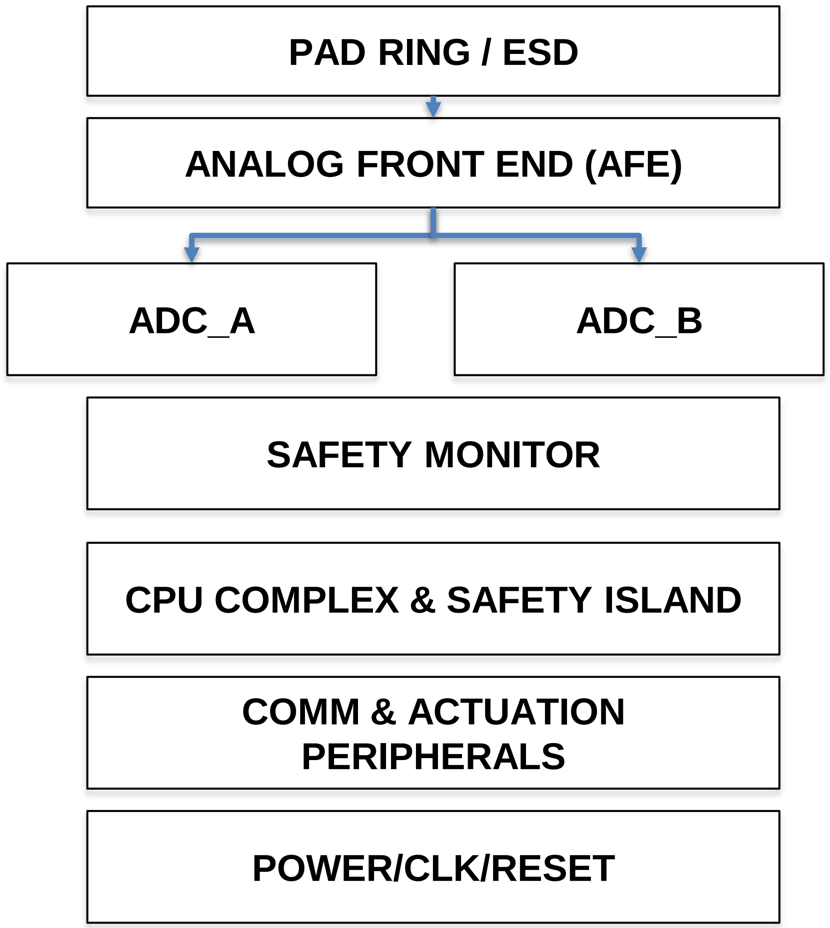
Failure Mode
- MCU stuck-at fault → wrong brake pedal signal

Root Cause
- Register bit stuck (chip defect)

FMEA
- Special Characteristic = Critical (High severity, low detectability)

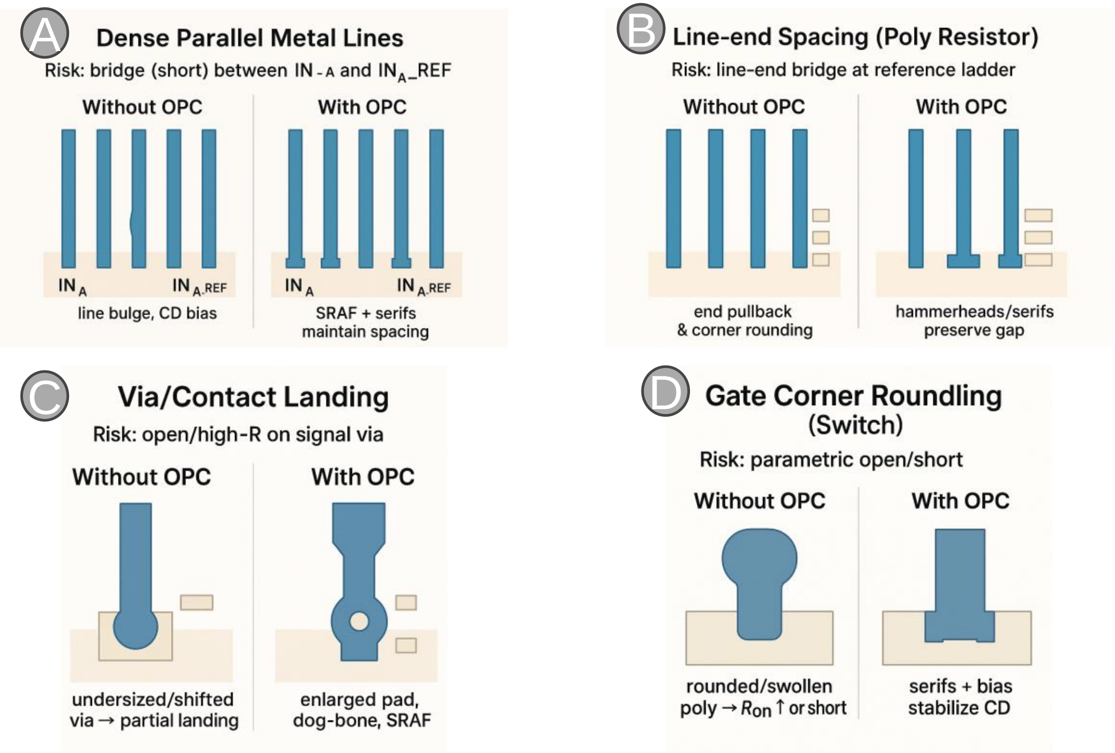
Countermeasure
- Redundancy + plausibility checks + diagnostics → Safe State

- MCU Block Diagram



OPC-Driven Risk Mitigation for Reliability

- Applying OPC reduces critical manufacturing risks—such as shorts, opens, and signal distortions—ensuring that the circuit, marked as a Special Characteristic, remains reliable.
- Linking risks to FMEA ensures proactive quality control, with checks built into the process to safeguard product integrity and yield



FMEA Linkage with Special Characteristic

A: Input nets integrity (Metal spacing)
OPC/LFD check

B: Reference ladder accuracy (Poly ends)
End-gap OPC check

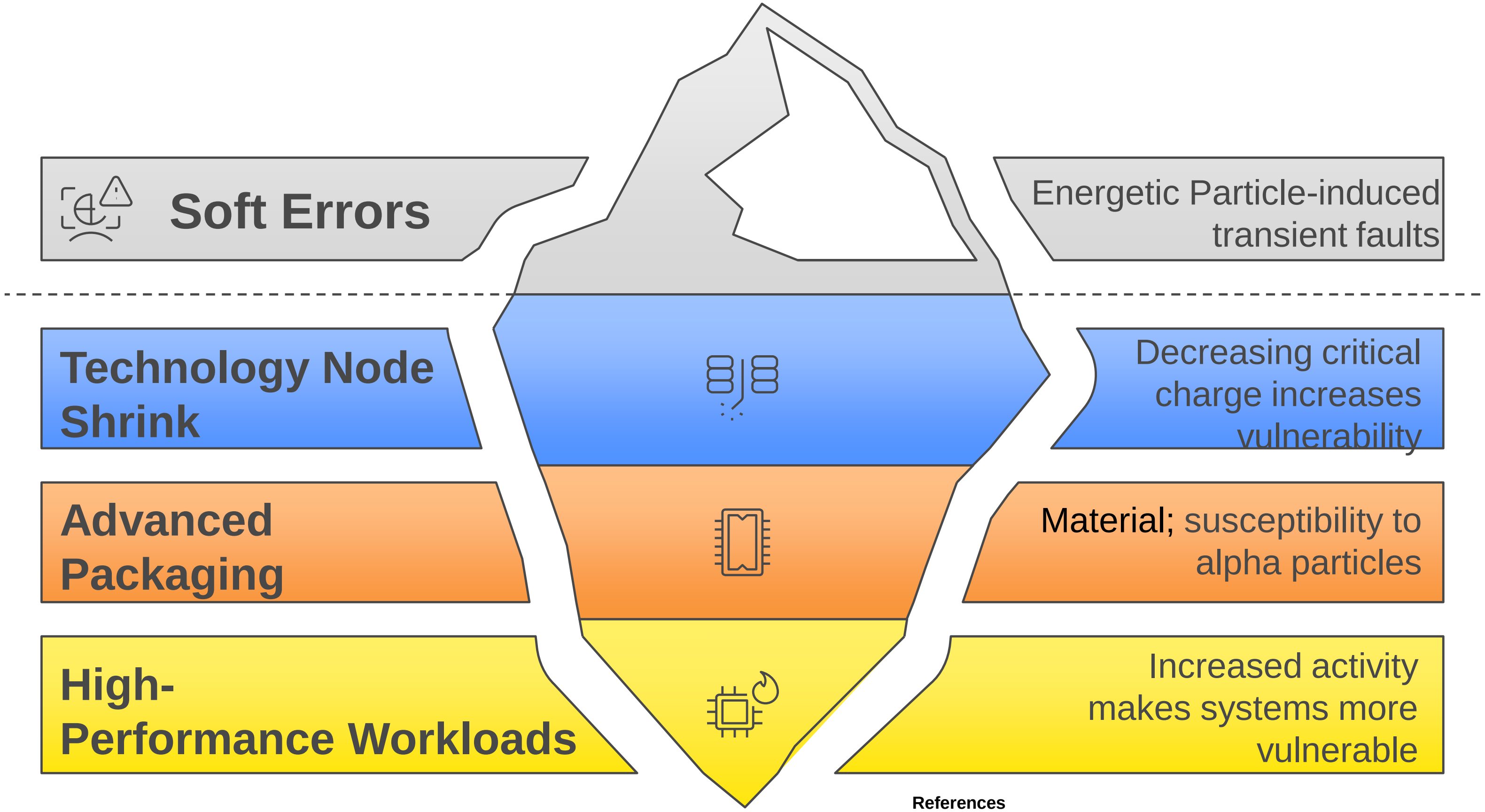
C: Signal continuity (Via stack)
Redundant via, OPC bias

D: Switch linearity (Poly gate)
Gate CD OPC sign-off

OPC : Optical Proximity Correction
LFD : Lithography Friendly Design
SRAF: Sub-Resolution Assist Feature
Serifs: Tiny layout extensions at corners

Soft Errors: A Hidden Threat to System Reliability

- Node shrink, packaging, and workloads drive hidden soft-error risks
- Zero defect needs proactive SER modeling and mitigation



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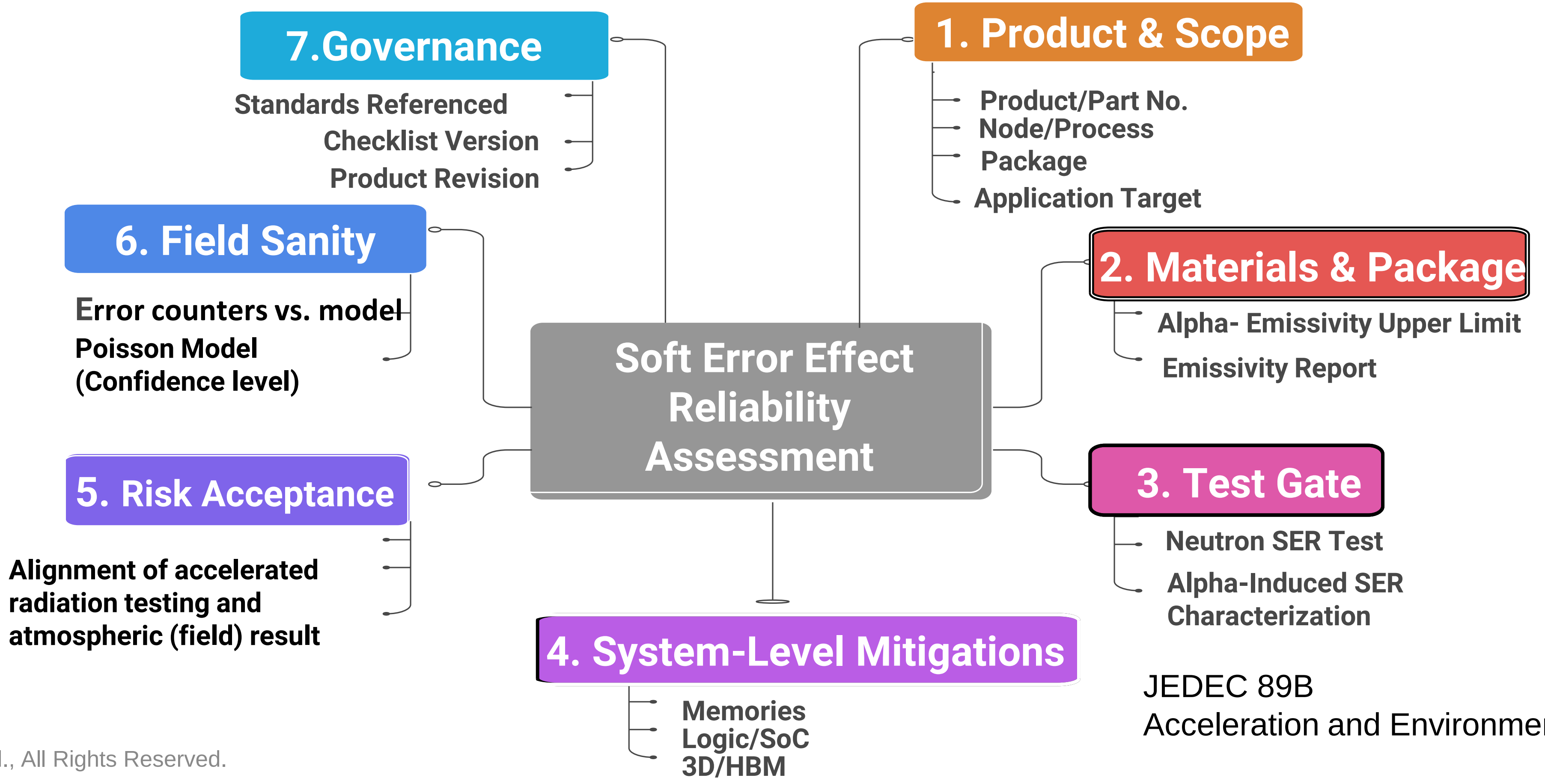
- Zebrev, Samotaev, Useinov, Proton/Neutron SEU Cross-Section Modeling, arXiv, 2024
- MacDermid Alpha, Mitigating Soft Errors in Advanced Packaging, 2025.
- 3D InCites, New Ultra-Low Alpha Tin Plating Solutions for Reliability, 2025

Semiconductor Reliability Assessment Process

- SER assessment connects design, package, test, and system
- Zero defect needs proof at every gate



JEDEC 89B
Acceleration and Environment Test

Failure Classification and Management Strategies

- Hard and soft failures demand dual metrics: lagging (PPM) & leading (FIT)

•Hard Failures (PPM focus)

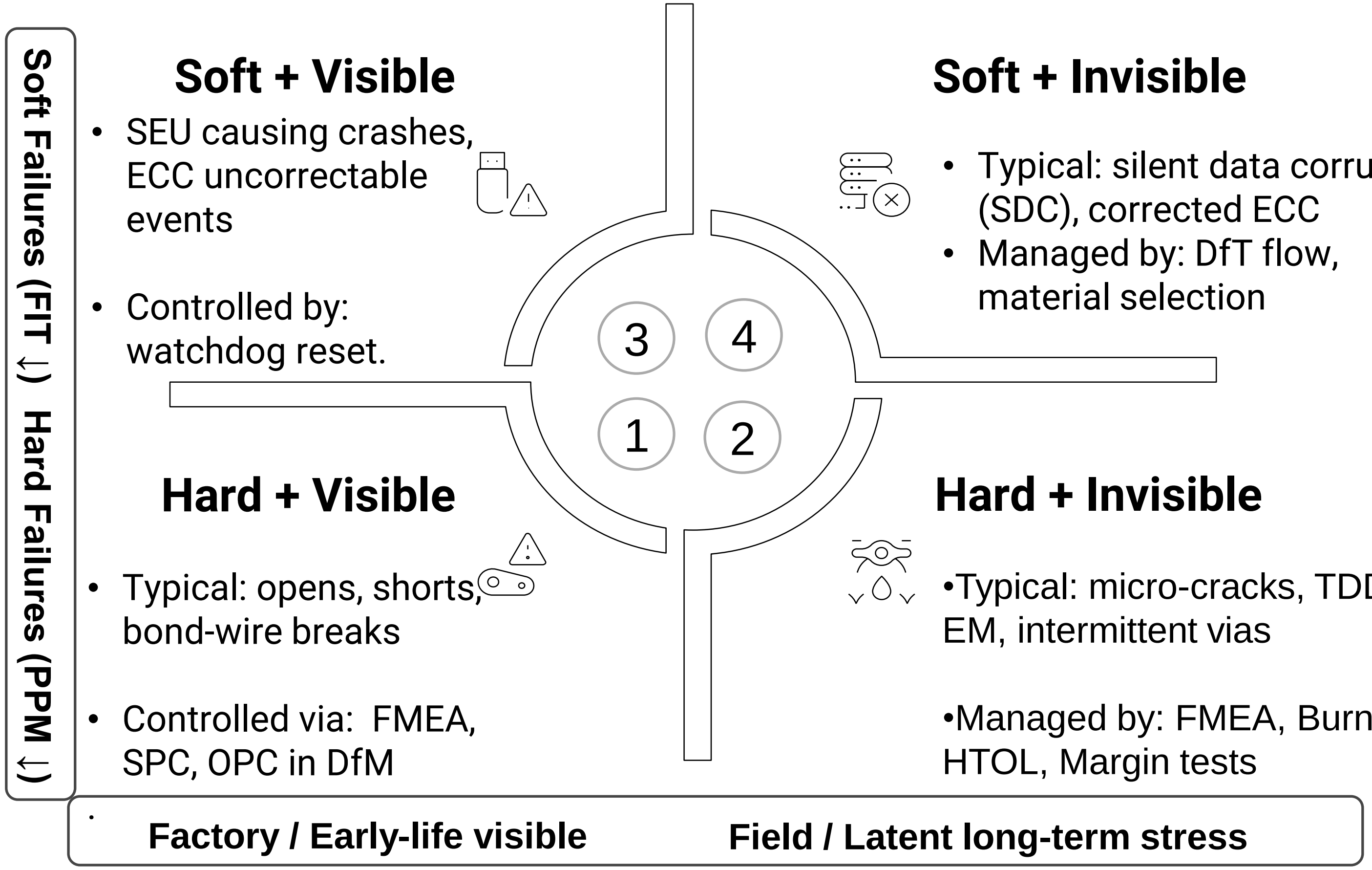
•*Factory*: visible at ATE/outgoing tests.
•*Field*: latent, invisible w/o stress tests.

•Traceability via DfM (e.g., OPC).

•Soft Failures (FIT focus)

•*Field errors*: visible if reported (ECC/system), invisible if silent (SDC)

•AEC-Q004 DfT + verification flows build systematic detection & ecosystem.



AEC-Q004 as the Linkage between IATF 16949 & ISO 26262

- Bridges quality and safety through FMEA, gating logic, and dual metrics (PPM & FIT)
- Drives continuous improvement, evolving from defect reduction to functional safety assurance

Characteristic	IATF 16949	AEC-Q004	ISO 26262
Focus	Quality Management System & PPM Reduction	Core framework bridging quality and safety	Functional Safety (ASIL, SGV, PMHF)
Hard Failure Handling	Handled via FMEA/PFMEA	DfM flow ensures OPC correction traced from FMEA	May cause Safety Goal Violation if not mitigated
Soft Failure Handling	Latent defects managed via audits, SPC, PAT	DfT + Verification flow for Soft Failures (SER, transient)	Addressed by safety mechanisms (ECC, lockstep, diagnostics)
Metrics	PPM, Cp/Cpk, audit scores	Dual governance: Quality (DPPM) × Safety (FIT/DC)	SPFM, LFM, PMHF, DC
Improvement Driver	Customer requirements and audits	Extendable ecosystem: quality↔ safety, unified under ZD	Ensures end-to-end safety compliance

Thank you!

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