

# A Comprehensive Approach to Flash-SSD Quality Management for Enterprise Storage

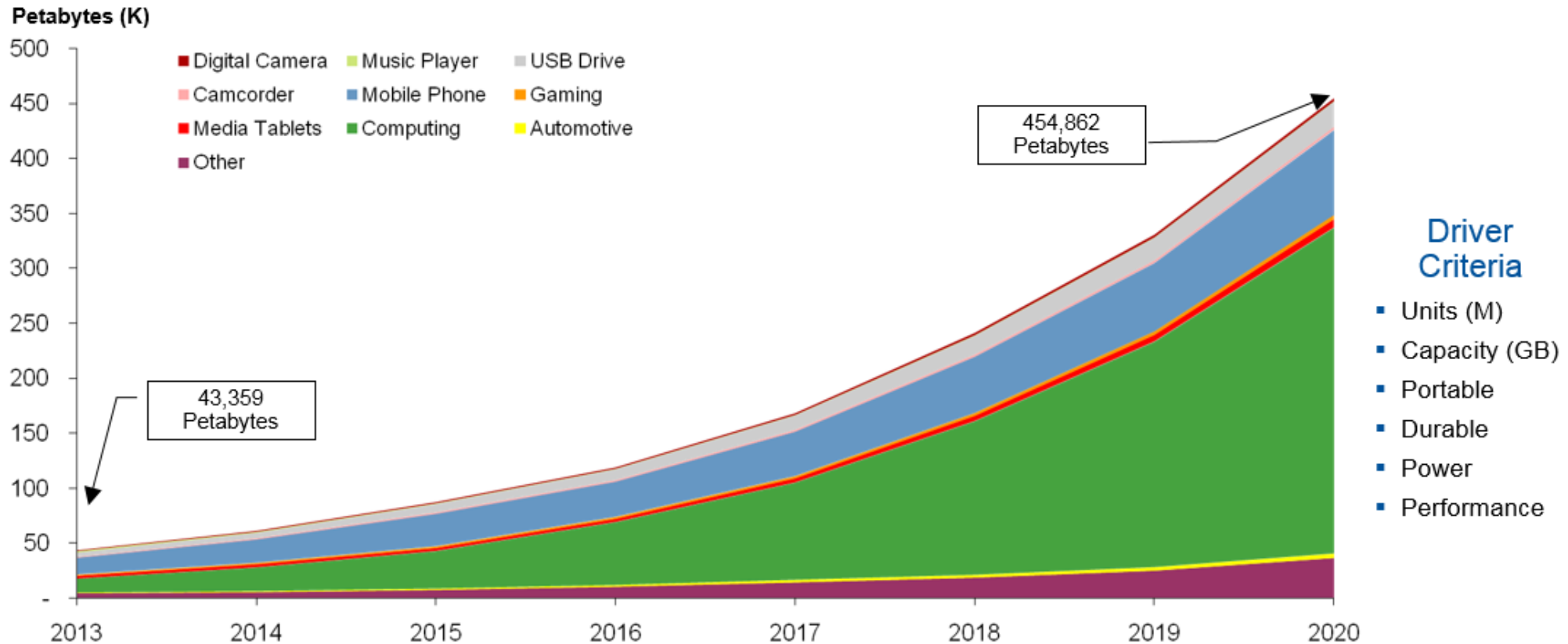
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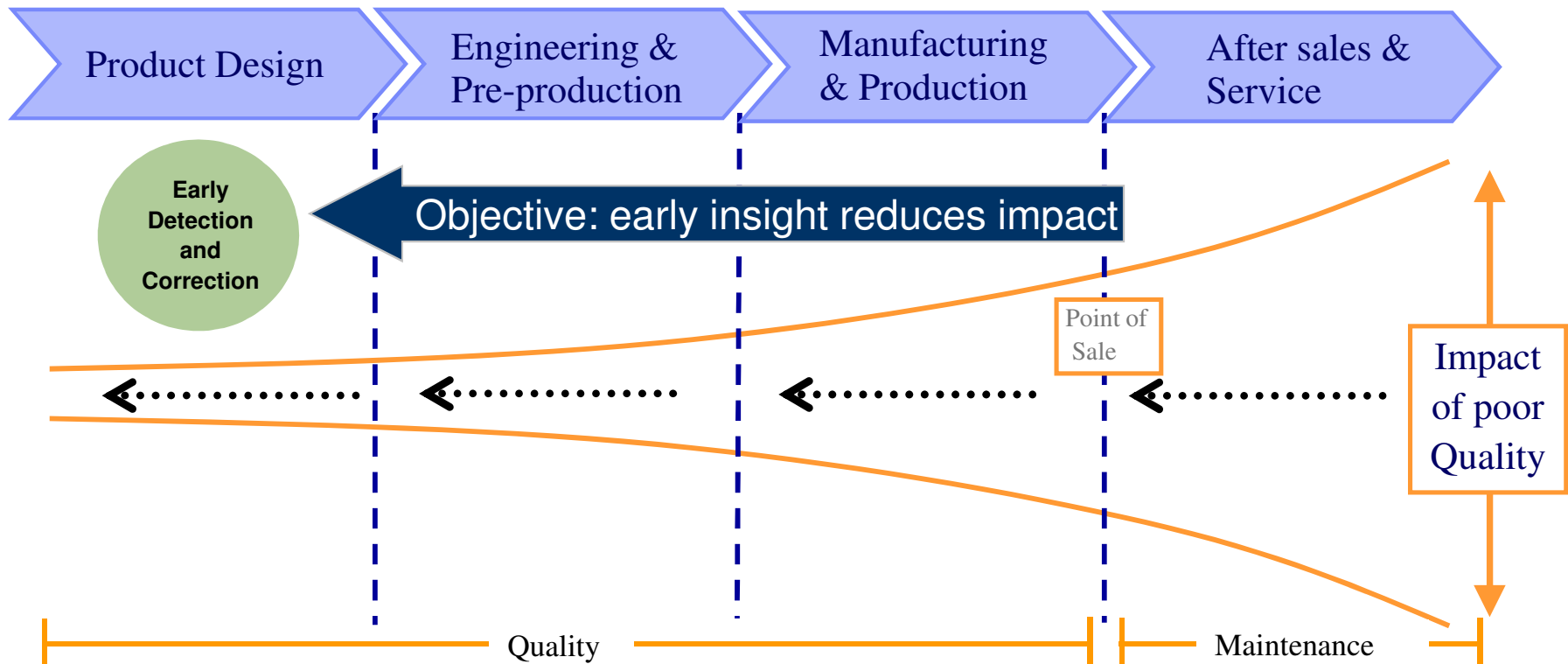
# Outline

- Flash-SSD E2E Quality Management Approach & Concept
- Flash Quality
- Firmware Quality
- SSD Qualification Process
- SSD Quality Process
- Summary



Source – Gartner, March 2016

- 3D NAND driven scaling enabling aggressive \$/GB reduction thru 2020
- 3D TLC endurance gains enabling significant Enterprise & Hyperscale SSD market growth
- Enterprise storage customers require robust Storage System Quality performance driving continuous focus on Flash-SSD E2E quality



It's vital to detect quality problems as quickly as possible:

- loss of customer satisfaction and loyalty
- delayed product shipments
- recall of defective product
- higher costs in warranty claims

Comprehensive approach towards the management of Flash-SSD supplier quality for enterprise storage applications <= 'Shift Left' Quality driver

## 2. Firmware Quality

- 1) FW qualification/quality management
- 2) Error detection & recovery
- 3) Key features – Wear Leveling, WA
- 4) 1<sup>st</sup> time data capture

## 3. SSD Qualification Process

- 1) SSD Qualification methodology
- 2) Characterization & reliability modeling
- 3) EMI/thermal modeling & simulation
- 4) Power Hold-up architecture

## SSD E2E Quality

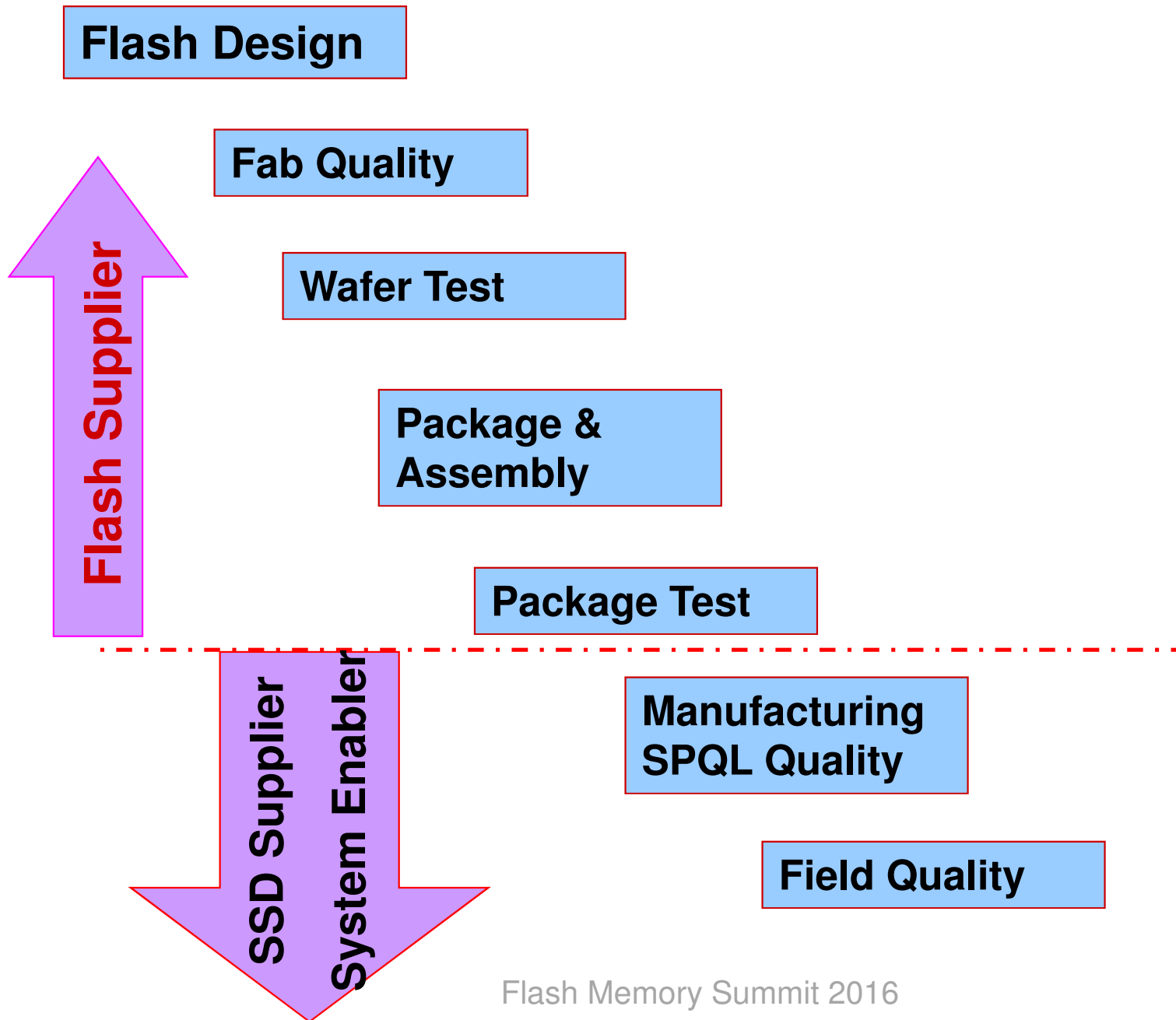
## 1. Flash Quality

- 1) Flash component reliability
- 2) Flash Management
- 3) Reliability Monitoring
- 4) Fab quality, wafer/die sort, trims
- 5) Stacked package quality

## 4. SSD Quality Process

- 1) Quality Organization & major imperatives
- 2) Manufacturing test
- 3) Manufacturing quality process
- 4) Corrosion prevention/mitigation
- 5) Quality Scorecard

Quality summit as key vehicle to drive quality improvements across core SSD suppliers – adopt systematic benchmark/methodologies



## 2D NAND

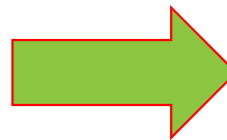
Pre-Read Tuning  
Table based (PE cycles)

ECC  
BCH Centric

Vt Offset retries

RAID/Higher Level Code

Block Retirement



## 3D NAND

Pre-Read Tuning  
Table based (PE cycles)

ECC  
LDPC Centric

Soft Decode methods

Dynamic Trims

Vt Offset retries

Calibrated Reads

RAID/Higher Level Code

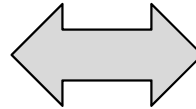
Plane/Die Protection

Block/Page Retirement

# Flash Component Qualification & Endurance RDT Approaches

## Flash Component Centric

- Qual methodology and goals based on JESD47 standard
- One-size fits all methodology
- NAND component qualification/quality centric



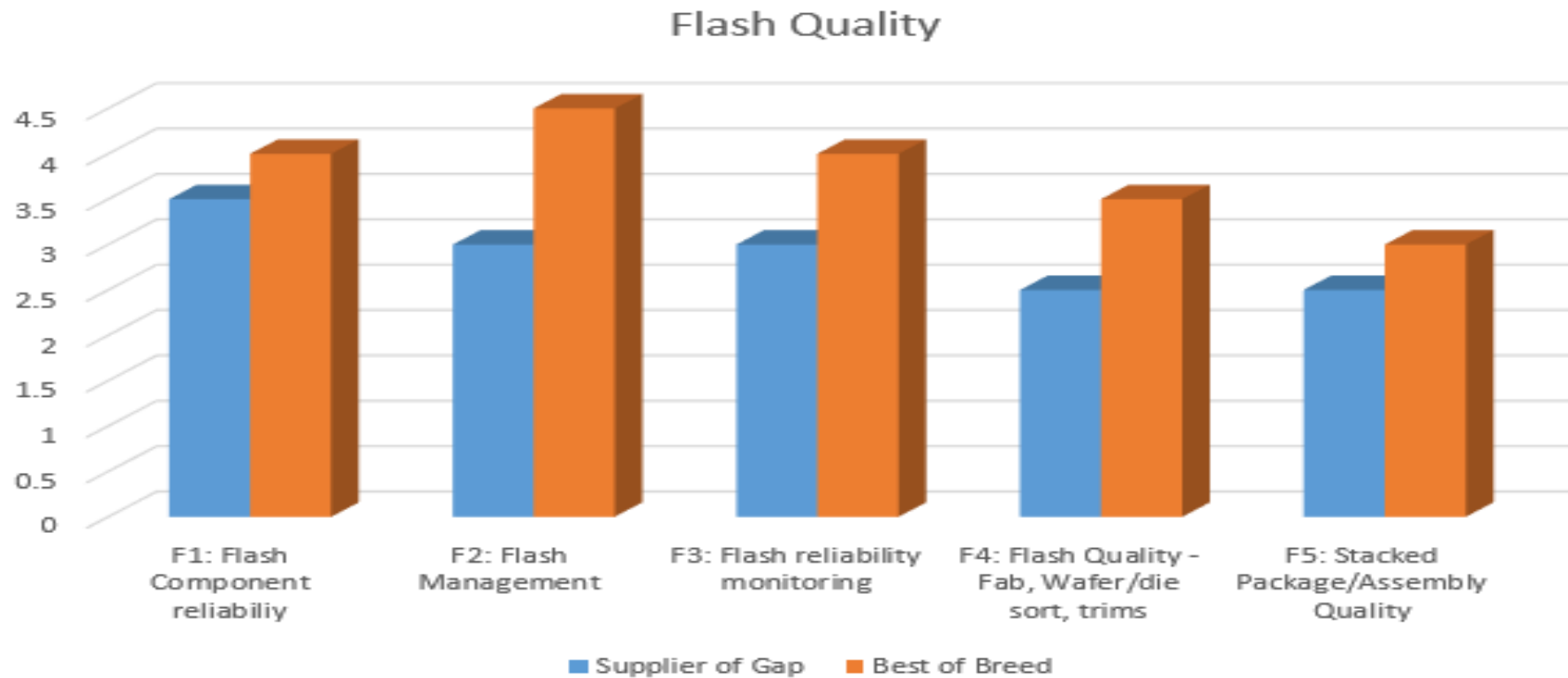
## SSD Use-case based

- Tailor Flash Qualification test conditions & goals to meet intended SSD usage requirements
- Align NAND component qualification to emulate SSD operating conditions
- FW policies emulated at NAND level

## Endurance RDT

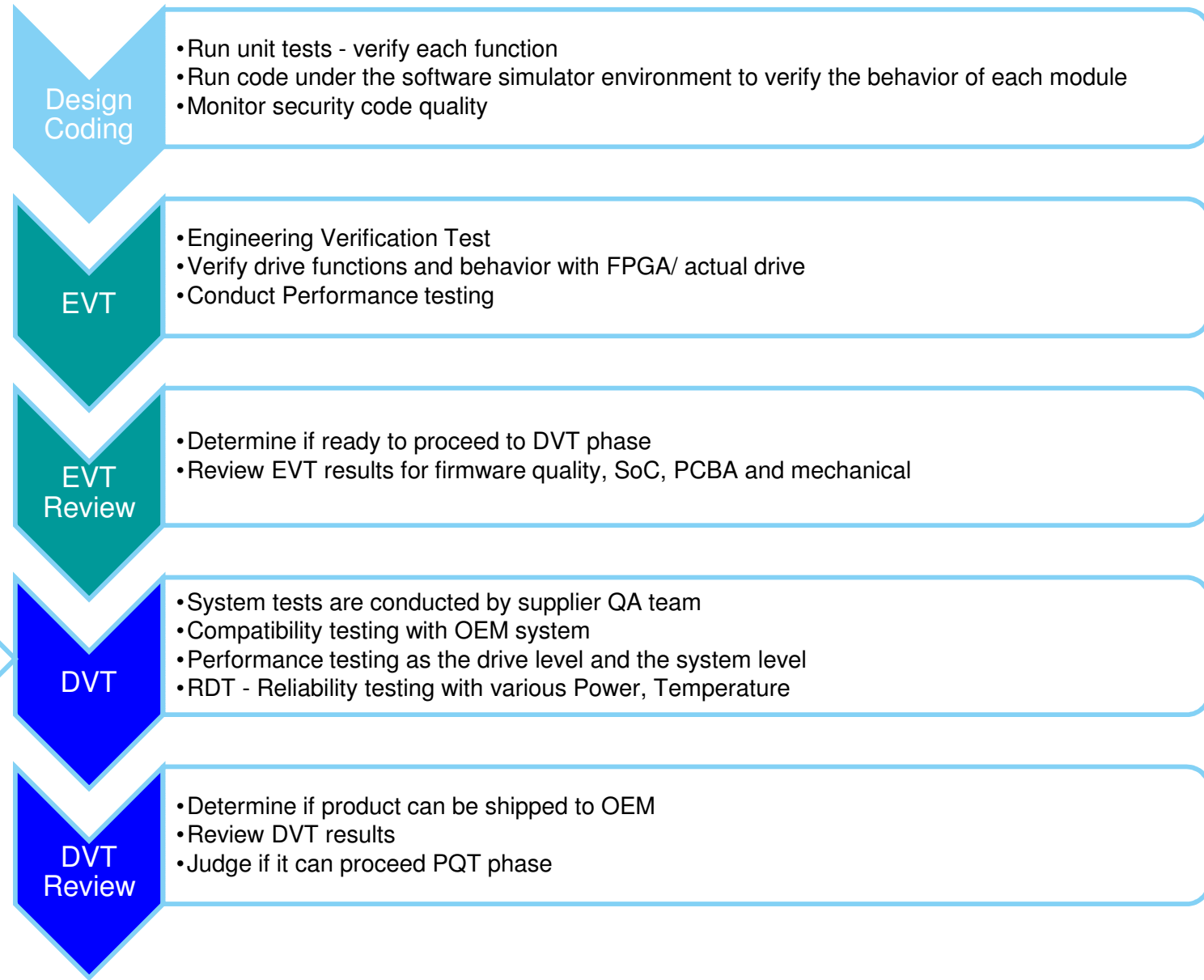
- Flash accelerated Cycling thru EOL – monitor cycling endurance by verifying if process/trims intrinsically meet datasheet. Accelerate defect related failure modes via high voltage stressing
- Endurance RDT – validate flash media's endurance capability thru EOL. Functional fails, NAND Block fails, UBER data errors





\* 'Supplier of Gap' & 'Best of Breed' supplier are based on scoring from each parameter category (not one supplier)

### FW Qualification



\* **EVT** - Engineering Validation Test: Build several units that function as expected, meeting all **functional** requirements

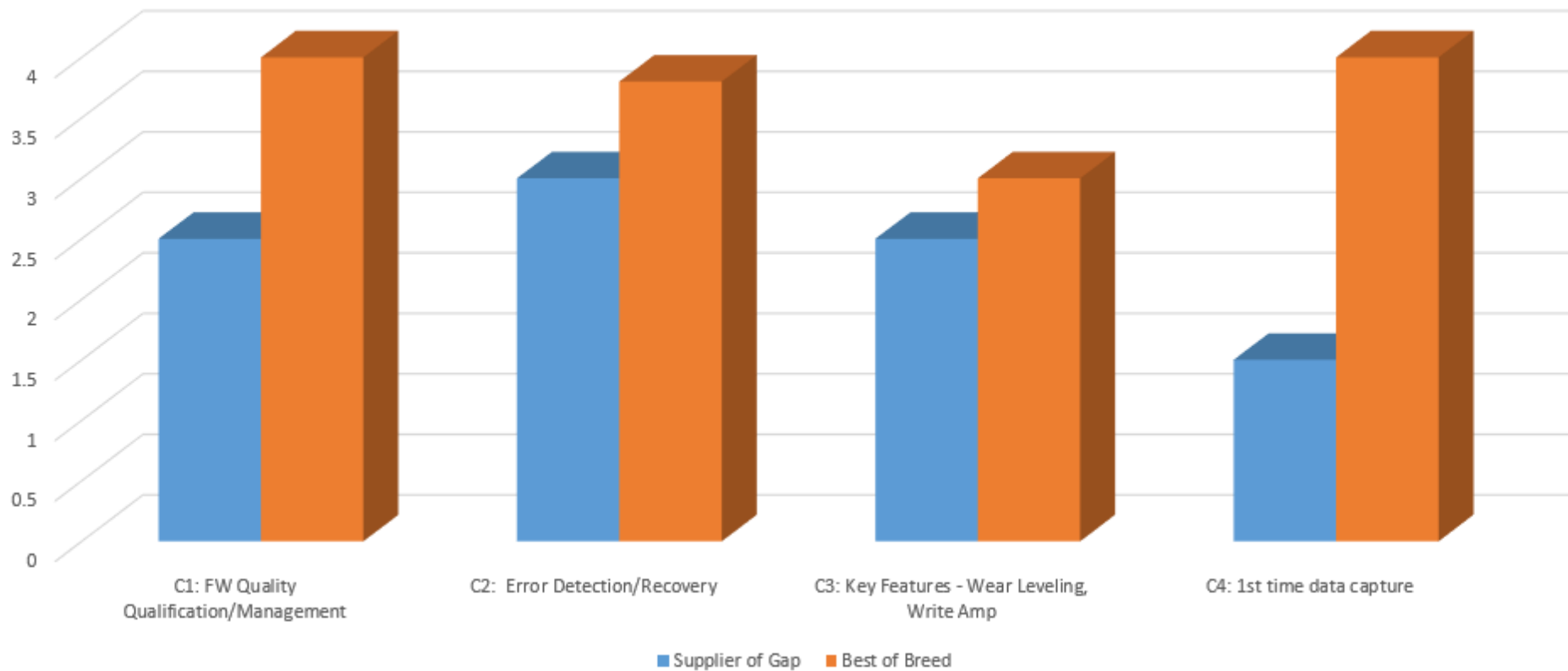
\* **DVT** - Design Validation Test: Build lots of units that function as expected, meeting all **functional** requirement

# Data Integrity: Error Detection and Recovery

Data is protected thru several levels of checks and corrections

- **Data in NAND** is protected by
  - NAND BCH-ECC
  - Read Level Correction
  - Corrective Read
  - RAID across NAND
  - FW background data integrity scans
- **Data between Host and NAND** is protected by Data-path Protection, Parity and Power-loss protection
  - Internal Controller Data-paths & Memories
  - External DRAM/buffers

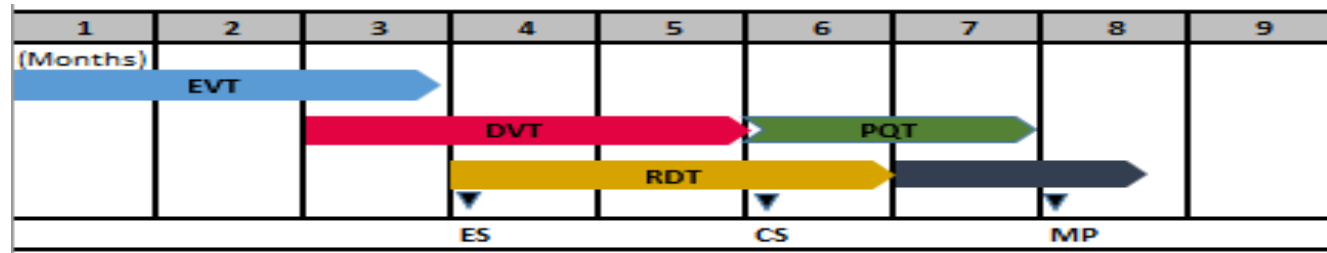
### Firmware Quality



## SSD Qualification Methodology

Phase	Purpose	Typical Confirmation Items
EVT	* Confirm basic functionality for key items	<ul style="list-style-type: none"> <li>* Mechanical (shock &amp; Vib/Temperature distribution)</li> <li>*Electricity (Power/Signal Integrity)</li> <li>*NAND Control function/ Parameter tuning</li> <li>*Firmware Function test</li> <li>*SoC Phy verification</li> <li>*Performance test</li> </ul>
DVT	<ul style="list-style-type: none"> <li>* Confirm drive readiness by prototype</li> <li>* Risk assessment for transition to the mass production</li> </ul>	<ul style="list-style-type: none"> <li>* Verification assurance test (Power/ Transport Jitter/ Weight/ Dimension)</li> <li>*Environment (Temperature/ Humidity/ Shock &amp; Vib/ Packaging/ESD/EMI)</li> <li>*RDT - Reliability test</li> <li>*Firmware Function test</li> <li>* Compatibility test</li> <li>*Performance test</li> <li>*Safety/EMI standard certification</li> <li>* Component parts</li> <li>*PCBA evaluation</li> <li>*Manufacturing Process Test</li> <li>*Productivity confirmation</li> </ul>
PQT	* Product readiness and Productivity confirmation	<ul style="list-style-type: none"> <li>*Equipment/Jig</li> <li>*In-Process Quality/Yield</li> <li>Repair system set up and validation</li> </ul>

**PQT** – Production Qualification Test,  
**RDT** – Reliability Demonstration Test,  
**ORT** - Ongoing Reliability Test



## SSD Qualification E2E Ownership

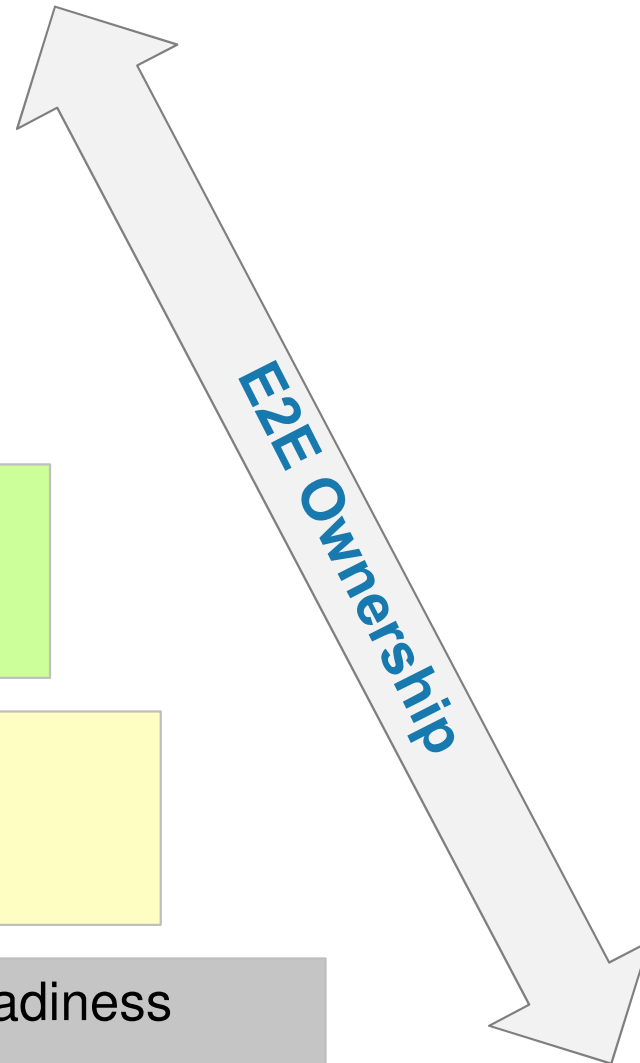
1. Flash Characterization and Verification, Flash Management Development

2. ASIC Validation  
Electrical Integration  
Thermal & Mechanical Validation

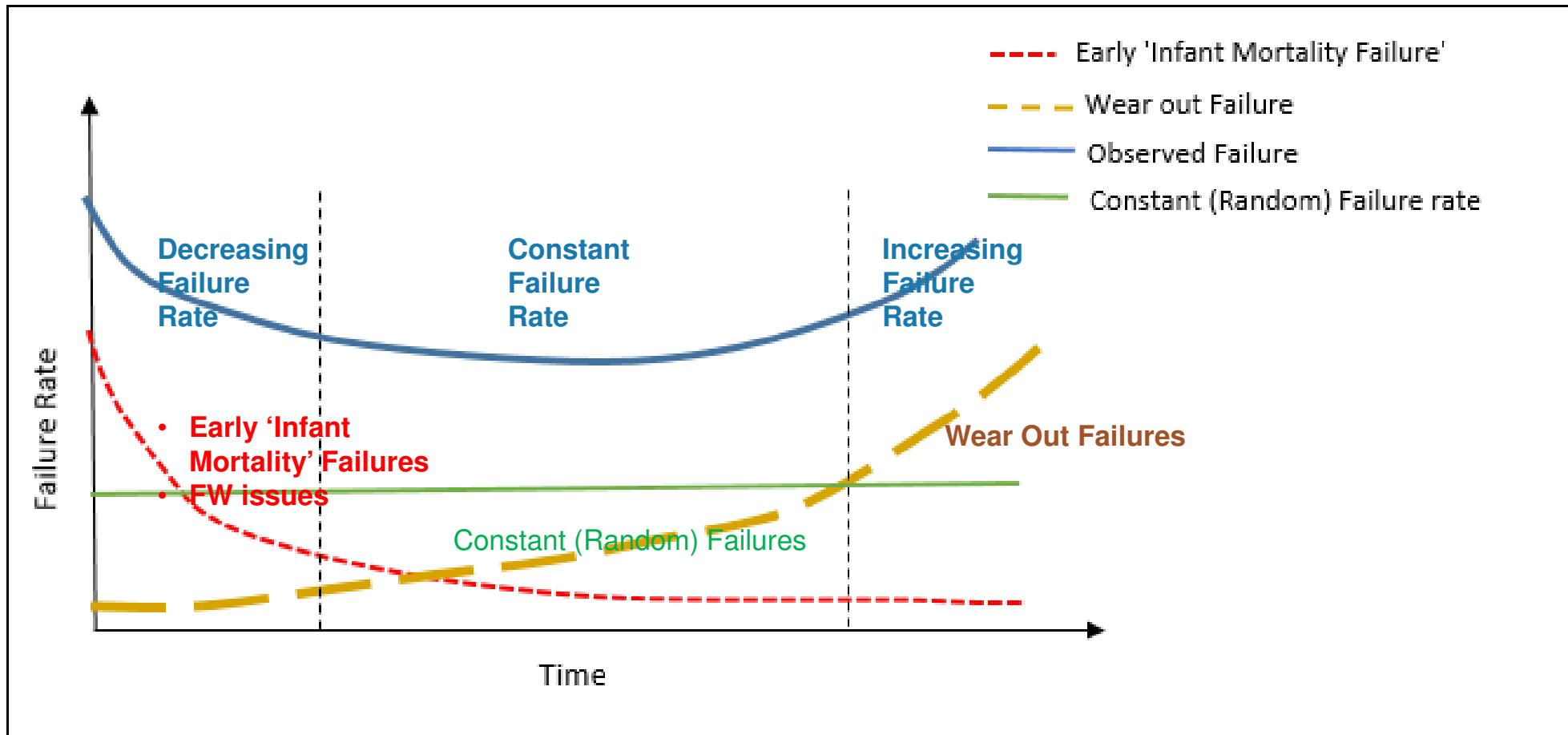
3. FW unit testing  
FW Qualification and Regression  
Customer System Testing

4. SSD Reliability Modeling  
Product Assurance  
SSD Quality & Reliability

5. Mass Production Readiness  
Factory Validation  
Factory Quality Monitoring Process

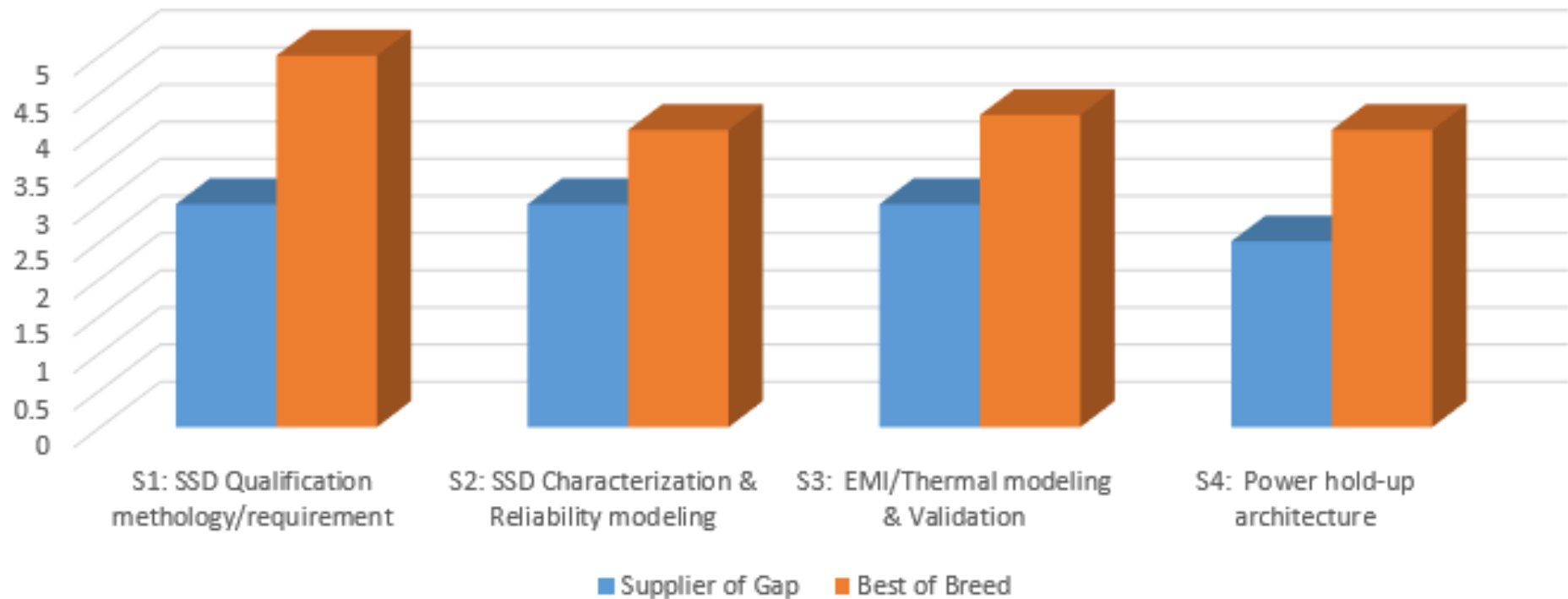


# SSD Reliability Model



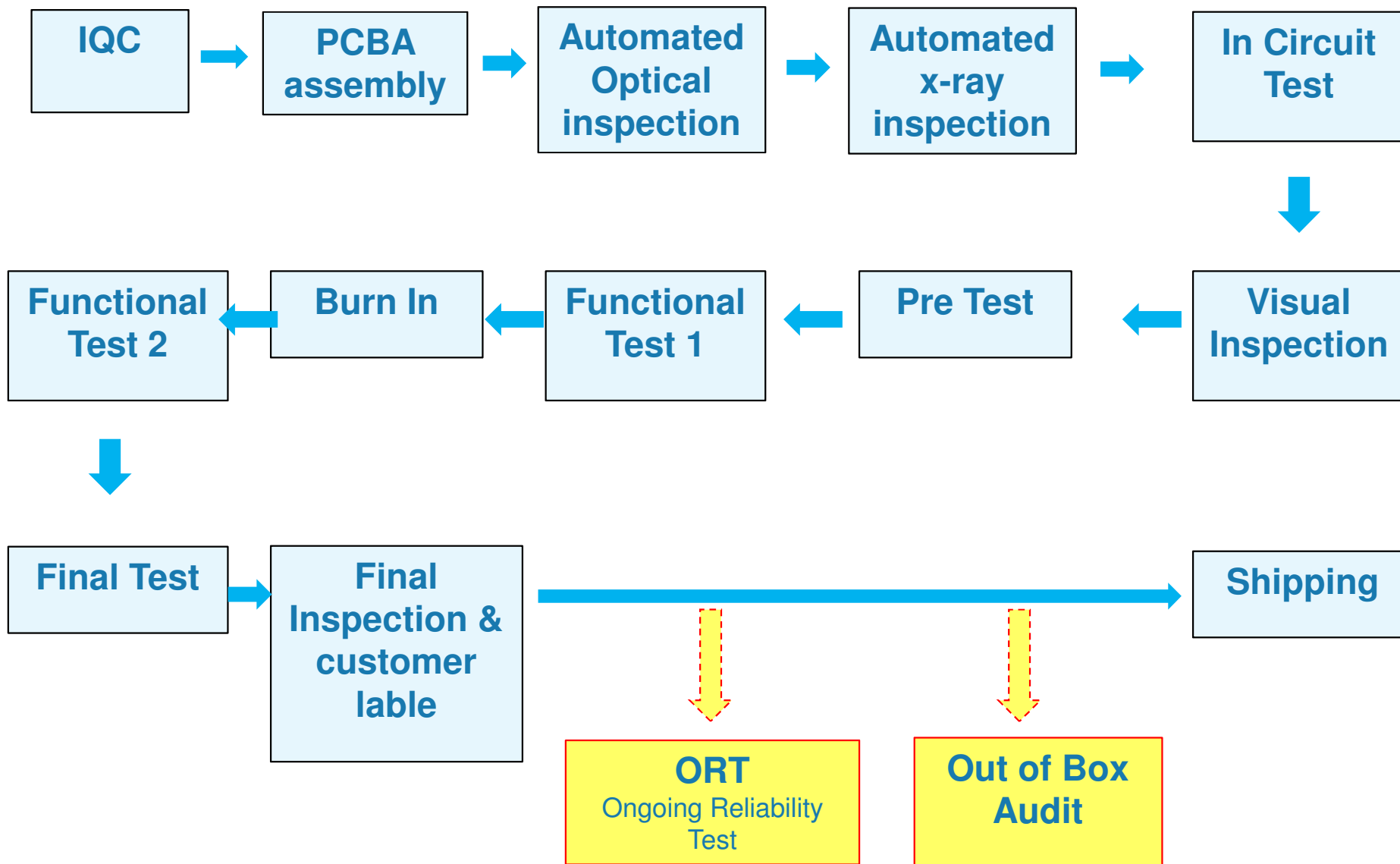
1. Early Life Fails – Flash particle driven defects, Firmware quality
2. Constant Failure rate – Random defect driven
3. Need to focus on Mid Life/End of Life Reliability failure modes – Flash reliability, Components, Sub-tier quality focus

### SSD Qualification Process





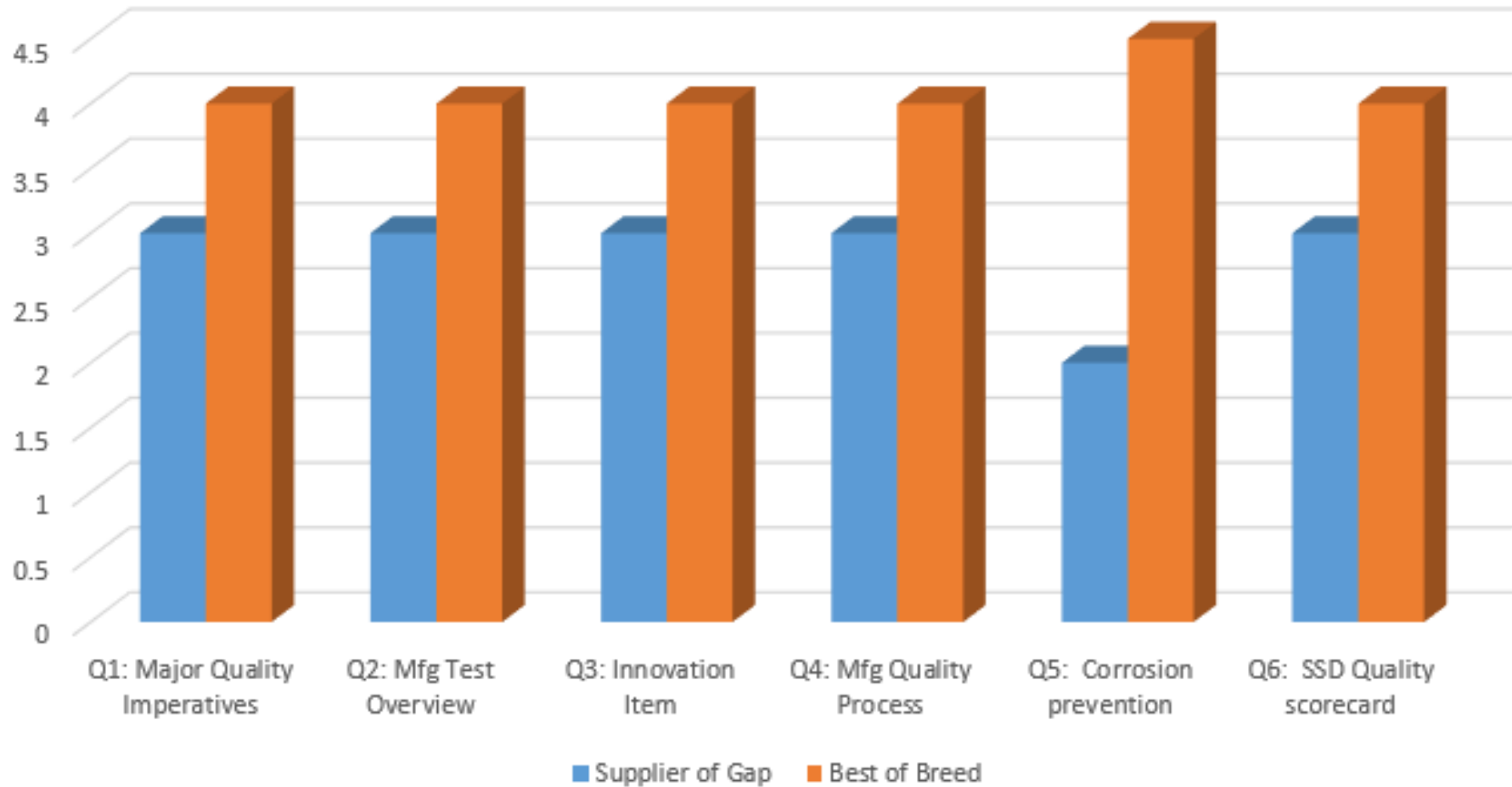
## SSD Manufacturing Test Flow



# Industry Consistency in how to handle EOL

- 1) PFA (Predictive Failure Alert) based on rated PE cycles & Data Retention target
- 2) Continue use of drive upon PFA (read & write).  
Read only mode – determine when to stop use of drive based on spare block %, block retirement based on OP. Need graceful transition into read only mode
- 3) Combination of 1) & 2)

### SSD Quality Process



# Summary

- Enterprise Storage growth driven by 3D NAND density, reliability improvements, and \$/GB reduction in 2016-2020. Enterprise customers continue to require strong Storage System Quality performance enabled by robust Flash-SSD E2E quality
- A comprehensive approach towards the management of Flash-SSD supplier quality for enterprise storage applications is presented
- Systematic approach focusing on 4 areas critical to Flash-SSD quality – 1) Flash Quality, 2) SSD Qualification methodology, 3) Firmware Quality and 4) SSD Quality. We further apply detailed breakdown and benchmark, thus driving industry best practices and ‘Shift Left’ quality imperatives.