



Flash Memory Summit

A Proactive approach to SSD quality management

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- Comprehensive approach for SSD Quality Management
 - Drive Flash-SSD supplier capabilities in line with Enterprise requirements and expectations
 - Understand supplier's end-to-end quality management approaches
 - Drive industry best practices and key lessons learned, in line with 'Shift Left' quality emphasis, to identify defects earlier in the SSD development cycle.
 - Suggested Industry learning
- Importance
 - Industry learning key to ensure the same mistakes aren't repeated
 - Firmware is being leveraged more in components, changes from generation to generation make it more prone to issues
- Issues of concern
 - Hardware
 - Firmware



Hardware Issues Observed

- Capacitors

- Supercap: Endurance issues, leaking
- Moved toward electrolytic capacitors

- Controllers (IC)

- Bit flip issues – error recovery algorithm
- Vendor process issues

- Potential Flash Issues

- Wear out/wear leveling issues
- 3D NAND Fab process issues
- Threshold Voltage shifts

Example failure modes

Failure mode	Failure mode pareto
Firmware Related	60%
Could not duplicate	20%
Hardware	10%
Environment related	5%
Mishandling	5%
No Trouble found	Less than 5%



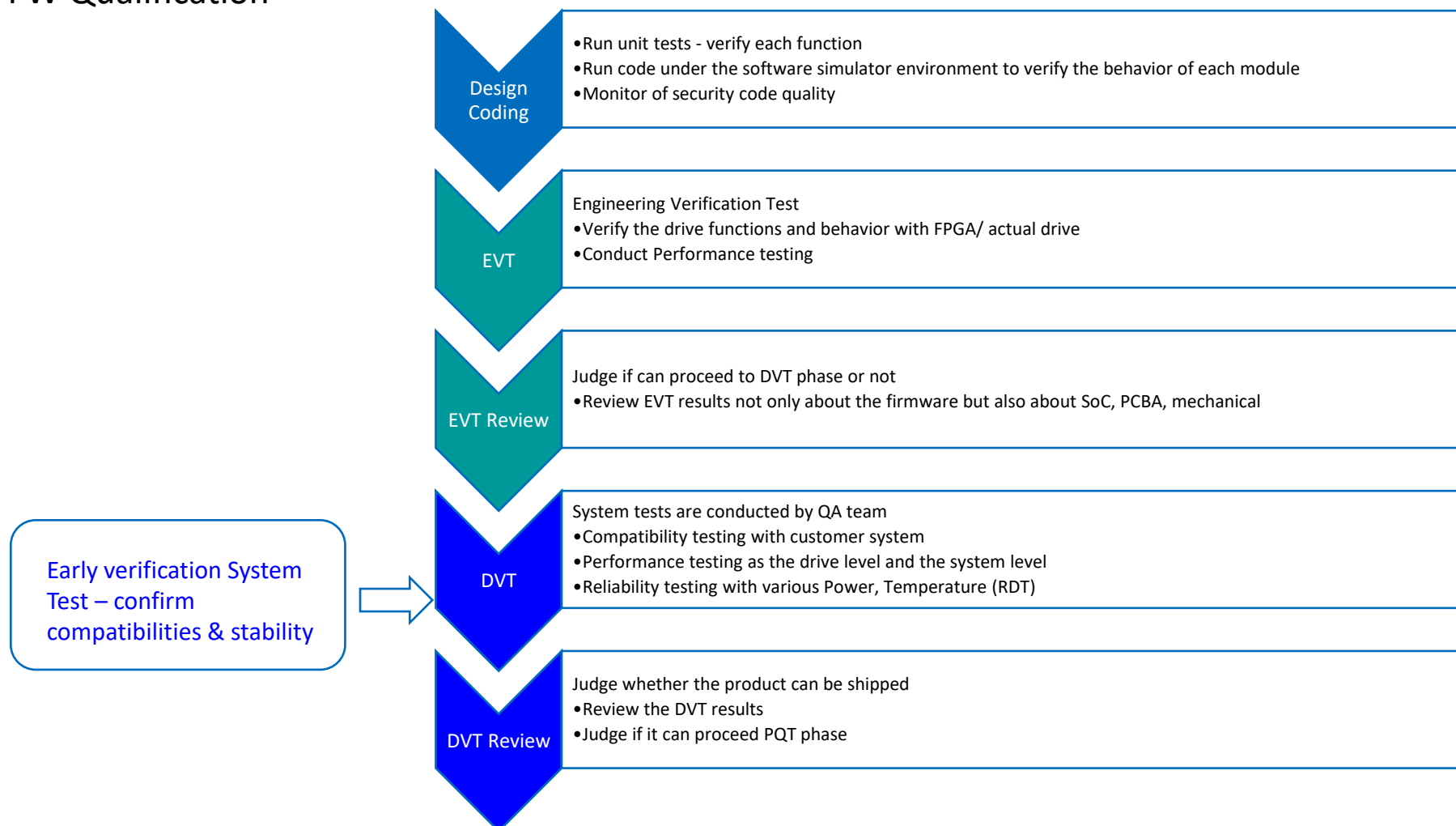
Firmware Issues Observed

Firmware issues



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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



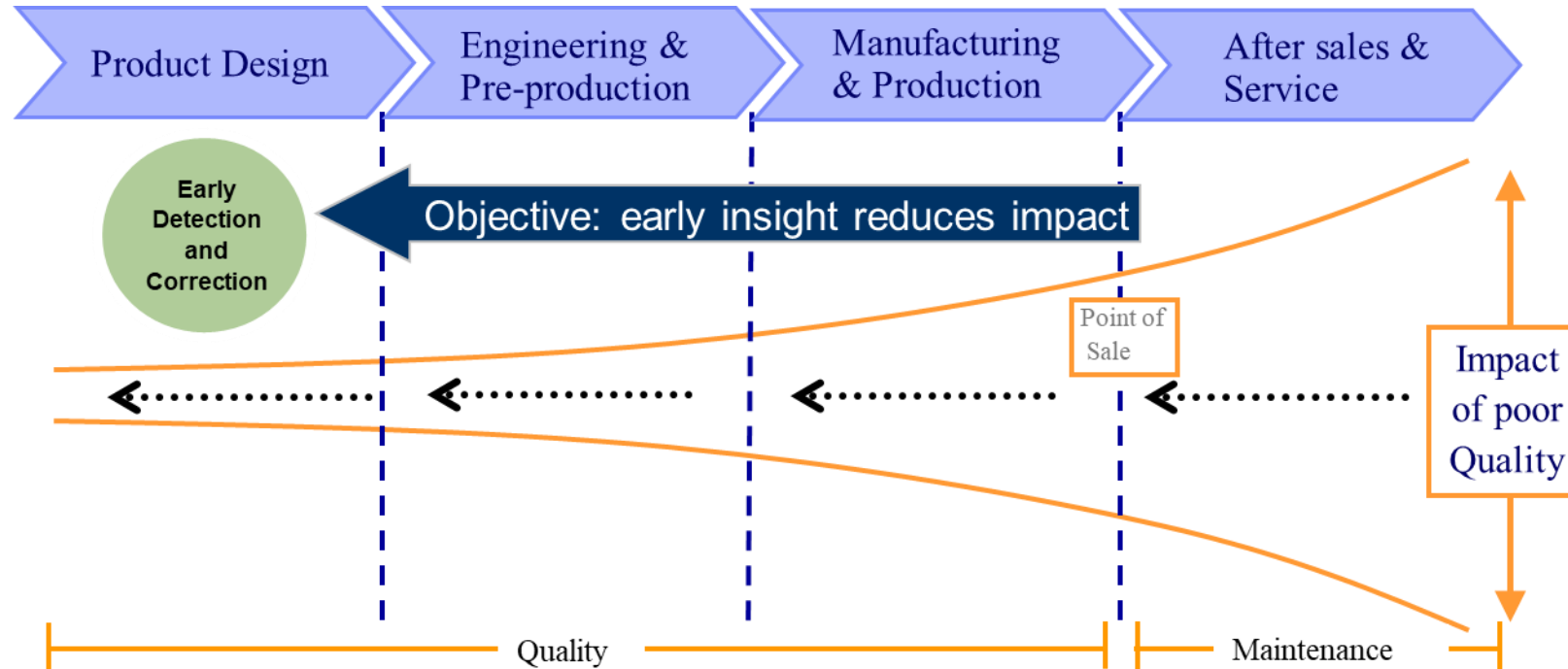
Firmware issues

- **Workload not tested well or difficult to test**
 - Background ops (typically latent)
 - Bugs in counter algorithms, timing algorithm
 - Memory not allocated properly or released properly
 - Performance issues over time
 - Predictive failure based on wrong thresholds
 - Drive life, early drive wear
 - High idle, possibly followed by high workload
 - Part variance issues
- **Firmware management issues**
 - Late changes or changes after GA cause new issues
 - Firmware changes due to unpredicted conditions
- **Proactively adapting to HW issues**
 - Close collaboration with Flash Technology Reliability team needed
- **Data issues**
 - Bugs triggered by corner cases



Comprehensive Approach

Shift Left Approach

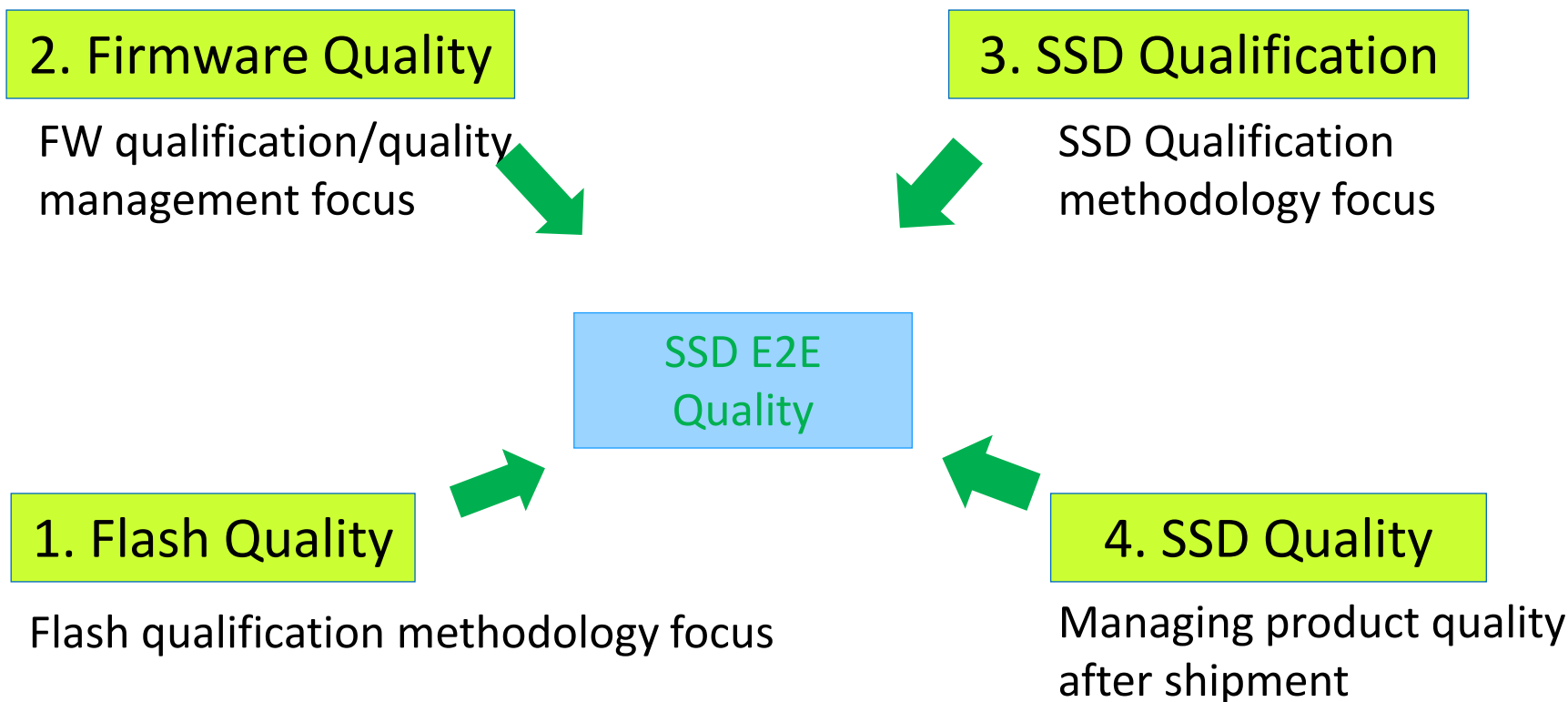


It's vital to detect quality problems as quickly as possible:

- Loss of customer satisfaction and loyalty
- Delayed product shipments
- Recall of defective product
- Higher costs in warranty claims

- Quality Summit process
 - Same categories for all suppliers
 - Systematic scoring by Subject Matter Experts
 - Olympic style scoring
 - Drive supplier capabilities in line with Enterprise requirements
 - Apply industry learning
 - Drive industry best practices in line with 'Shift Left' quality emphasis
 - Feedback with suggested and targeted actions

Comprehensive process



Quality summit as key vehicle to drive quality best practices across SSD supplier – adopt systematic ‘Olympic Benchmark & methodologies’

Improvement suggestions for the Industry

Category	Findings	Lessons learned
FW Quality	<ol style="list-style-type: none"> 1. Defects that require a lot of run-time to hit aren't caught in normal test 2. FW Hangs due to unpredicted condition 3. Late changes or changes after GA cause new issues 4. Data integrity / data loss events 	<ol style="list-style-type: none"> 1. Add special "hooks" for FW testing to accelerate some routines, also check variables 2. Add watchdog timers to controller 3. Expert review of changes ; Designer input into test 4. Add corner cases to accelerate the bugs triggers (resource validation, error recovery)
FW Quality + SSD Qualification	<ol style="list-style-type: none"> 1. Customer workload is different than test workload (e.g., long idle time and then stressed) 	<ol style="list-style-type: none"> 1. Include some idle test and Aggressive power cycle testing
FW Quality + SSD Quality	<ol style="list-style-type: none"> 1. Parts variance causes issues 2. FW hang conditions difficult to debug 	<ol style="list-style-type: none"> 1. Purposely include corner components for FW testing from different vendors ; Add simulation test to FW testing 2. Add logging and state dumps, even if can't imagine would be needed
FW Quality + Flash Quality	<ol style="list-style-type: none"> 1. Issues where hardware changes over time 	<ol style="list-style-type: none"> 1. Close collaboration between FW team and Flash Technology Reliability team: (closed-loop device characterization)

- Firmware growing in importance for components; changes from generation to generation make it more prone to issues
 - Firmware can also be leveraged to mitigate hardware issues
 - This learning can be applied to other types of components as firmware is growing importance
- Industry learning is key to improve quality
- A Systematic approach focusing on 4 areas critical to Flash-SSD quality is key to driving industry best practices and “Shift Left” quality imperatives
 - 1) Flash Quality
 - 2) SSD Qualification Methodology,
 - 3) Firmware Quality
 - 4) SSD Quality

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