Testing Methodologies

Achieving Fewer Returns, Satisfied Customers and Richer Markets

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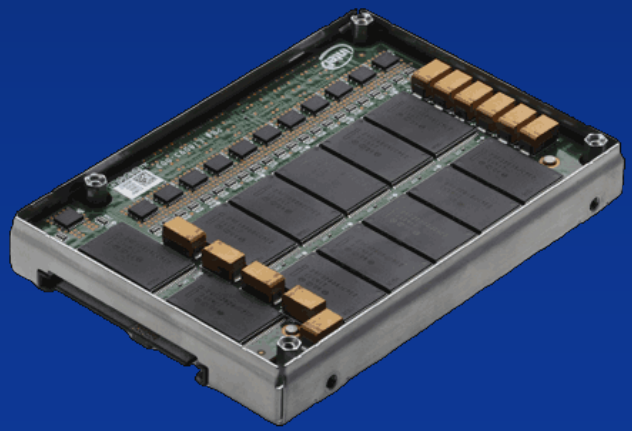
SSD Mortality Survey

The following is an excerpt from an article by Robin Harris for ZDNet*, based on a survey about SSD mortality:

> “Based on what little statistical information is released publicly about SSD mortality, I expected the actual number of consumers experiencing SSD failure would be around 5%. But the results were much higher: 17% of over 600 respondents reported infant mortality.”

*ZDNet, SSD Infant Mortality II, 9/10/12



Threat vs. Opportunity

SSD Manufacturers are faced with a simultaneous threat and opportunity

- Threat – the potential of losing customers due to field failure, and the high costs incurred.
- Opportunity – the ability to differentiate and compete more effectively in an extremely competitive marketplace by providing customers and OEMs with products of the highest quality and reliability.

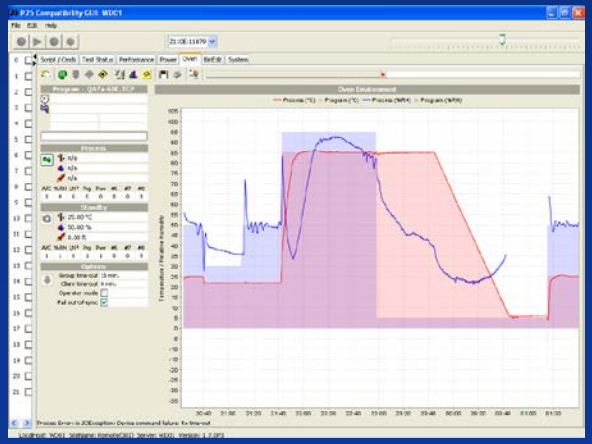
Potential Causes of Failure

The following are factors that cause SSDs to fail or perform at substandard levels:

- Heat
- Adjacent Cell Disturbance
- Smaller Geometries
- Power Failures
- Wear Leveling
- Varying Voltage Conditions
- Mechanical Shock*
- Humidity
- Inaccurate Command Queuing
- Slow Spin Up / Power Off
- Unexpected Power Draw
- Inconsistent Transfer and IOPs Rate
- NAND Defects
- Mechanical Vibration*

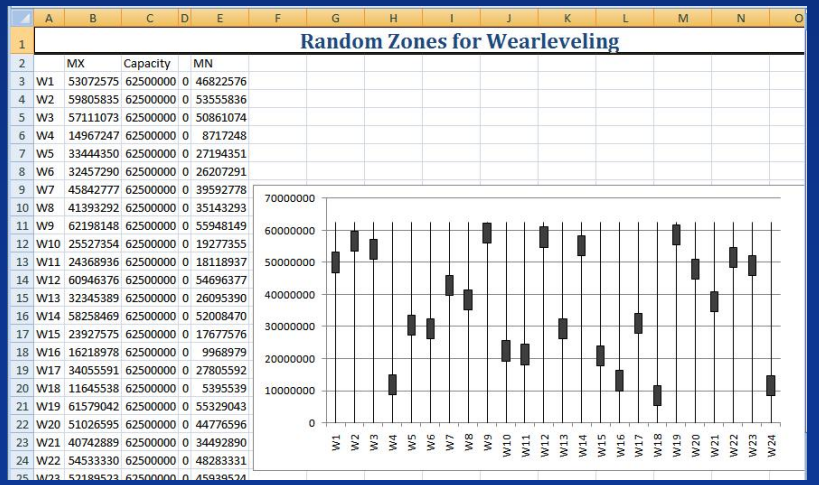
Testing Potential Causes of Failure

Cause	Test
Heat – may cause the break-down of transistor junctions within a device, by 90ºC thermal run-away may occur	WR/RD/Compare during Thermal cycle to ensure proper heat dissipation
Adjacent Cell Disturbance – when a bit is written into a cell it can sometimes cause an adjacent cell to lose its contents	LBA WR/RD/Compare with alternating patterns
Smaller Geometries – may cause a relative increase of field strength in semiconductor devices	LBA WR/RD/ Compare with alternating patterns



Testing Potential Causes of Failure

Cause	Test
Wear Leveling – cells wear out after a number or write cycles. An algorithm moves data from block to block to avoid this. Eventually the algorithm takes longer to calculate where to move data.	Focused write/read operations on specific LBA range, review SMART data / Flash logs for impact.
Smaller Geometries – may cause a relative increase of field strength in semiconductor devices	LBA WR/RD/ Compare with alternating patterns



Random Zones for Wearleveling

	MX	Capacity	MN
W1	53072575	62500000	0 46822576
W2	59805835	62500000	0 53555836
W3	57111073	62500000	0 50861074
W4	14967247	62500000	0 8717248
W5	33444350	62500000	0 27194351
W6	32457290	62500000	0 26207291
W7	45842777	62500000	0 39592778
W8	41393292	62500000	0 35143293
W9	62198148	62500000	0 55948149
W10	25527354	62500000	0 19277355
W11	24368936	62500000	0 18118937
W12	60946376	62500000	0 54696377
W13	32345389	62500000	0 26095390
W14	58258469	62500000	0 52008470
W15	23927575	62500000	0 17677576
W16	16218978	62500000	0 9968979
W17	34055591	62500000	0 27805592
W18	11645538	62500000	0 5395539
W19	61579042	62500000	0 55329043
W20	51026595	62500000	0 44776596
W21	40742889	62500000	0 34492890
W22	54533330	62500000	0 48283331

Potential Causes of Failure / Test

Cause	Test
Voltage Margining – SSDs can be sensitive to varying voltage conditions such as power surges, under voltage.	Voltage Margining tests for this weakness
Surface Inspection – Identifies NAND data errors by writing and reading an entire device. FTL should mask this by relocating data but at a performance hit.	Perform multiple write /read cycles – inspect SMART data after test
Humidity – When the seal around a lead is poorly attached, humidity will enter the device causing an eventual failure	Perform high humidity testing for extended durations

Power Failures in the Data Center

As Big Data continues to grow, the impact of power failures on data centers is often catastrophic. These recent headlines illustrate that power outages, a leading cause of SSD failure, are not at all uncommon:

- Power Outage Knocks DreamHost Customers Offline
  Data Center Knowledge, 3/20/13
- The Price of Failure: Datacenter Power Outage cost Sears $2.2M in profit
  Crain's Chicago Business, 7/24/13
- "Amazon Web Services suffered a power outage in Northern Virginia Data Center
  InformationWeek, 6/15/12

Power Failures in the Data Center

The most devastating occurrence for any IT infrastructure is a complete power failure. In a recent study by Ohio State University / HP Labs* they used specially designed hardware to inject power faults directly into devices. The following is part of their findings:

- "Thirteen out of 15 devices, including the supposedly 'enterprise-class' devices, exhibit failure behavior contrary to our expectations."
- " We observed five out of six expected failure types, including bit corruption, shorn writes, un-serializable writes, metadata corruption and dead device".

Write / Splice Test
Power cycle during read / write operations, check for data consistency

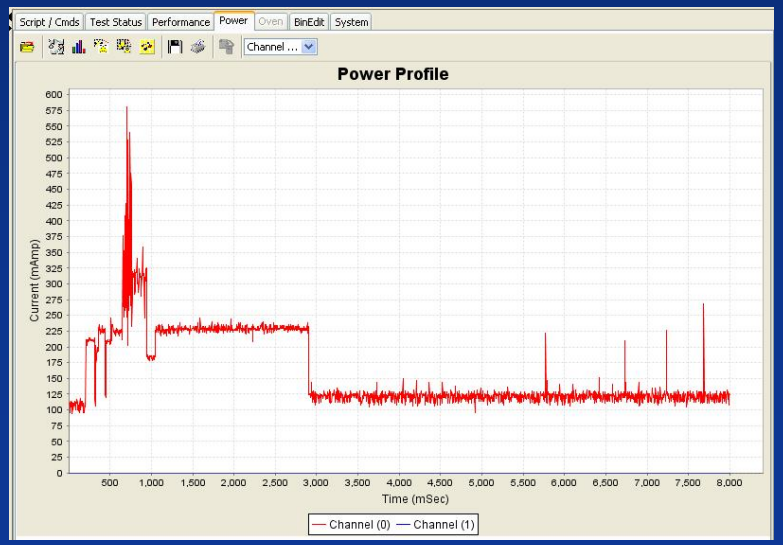
* USENIX Association, (FAST '13)

Testing for Optimum Performance

While the following tests don't identify hard failures, they do show where a device's reliability and performance isn't at an optimum level:

- Command Queuing – SSDs should optimize the order in which read and write commands are executed. Testing identifies when a device isn't handling queued commands properly.

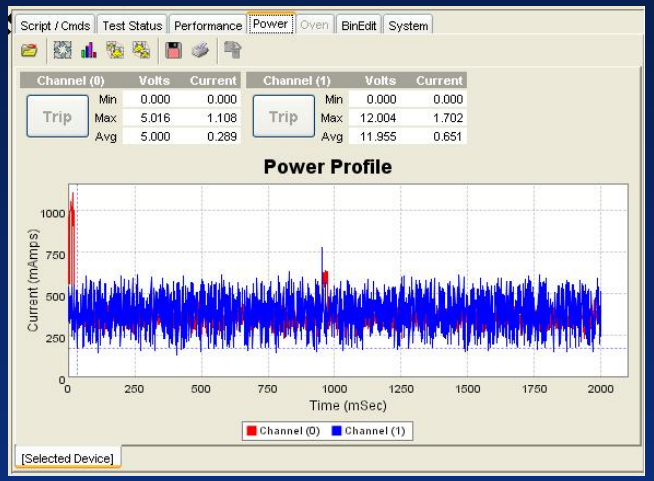
- Spin-Up / Power Off – measures the amount of time needed to power-on and self-test before the device can respond to a command.

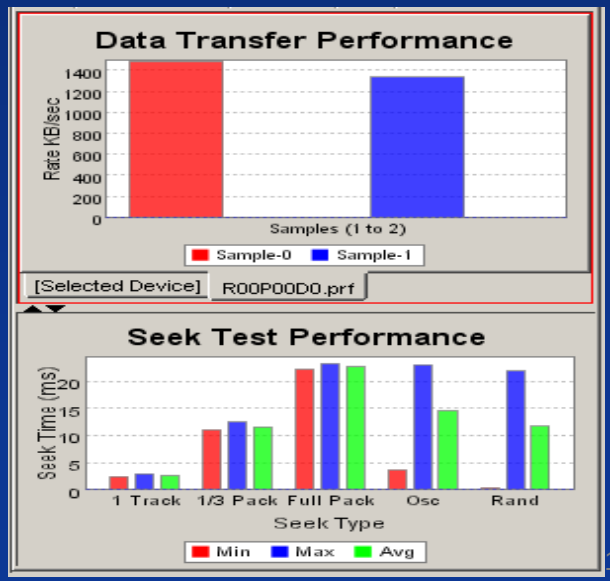


Testing for Optimum Performance

- Power Management Profiling – Shows how a device's power draw reacts to standard power commands such as idle, Idle Immediate, Sleep, Standby immediate and Wake.

- IOPs Test – Identifies the optimum transfer and IOPs rate based on block size.





S.M.A.R.T.

Self Monitoring Analysis and Reporting Technology

S.M.A.R.T. is a self monitoring system that detects and reports on various indicators of reliability used to anticipate device failure including:

- Drive Life Protection Status
- Temperature
- SSD Life Left
- Endurance Remaining
- Available Reserved Space
- Power-On Hours
- Media Wear-Out Indicator
- Average and Maximum Erase Count
- Good Block and System Free Block Count
- Transfer Error Rate
- LBAs Written
- LBAs Read
- Read Error Retry

JEDEC and SNIA Certification

JEDEC requirements for Client and Enterprise application classes are based on endurance ratings. The following conditions for SSDs need to be satisfied:

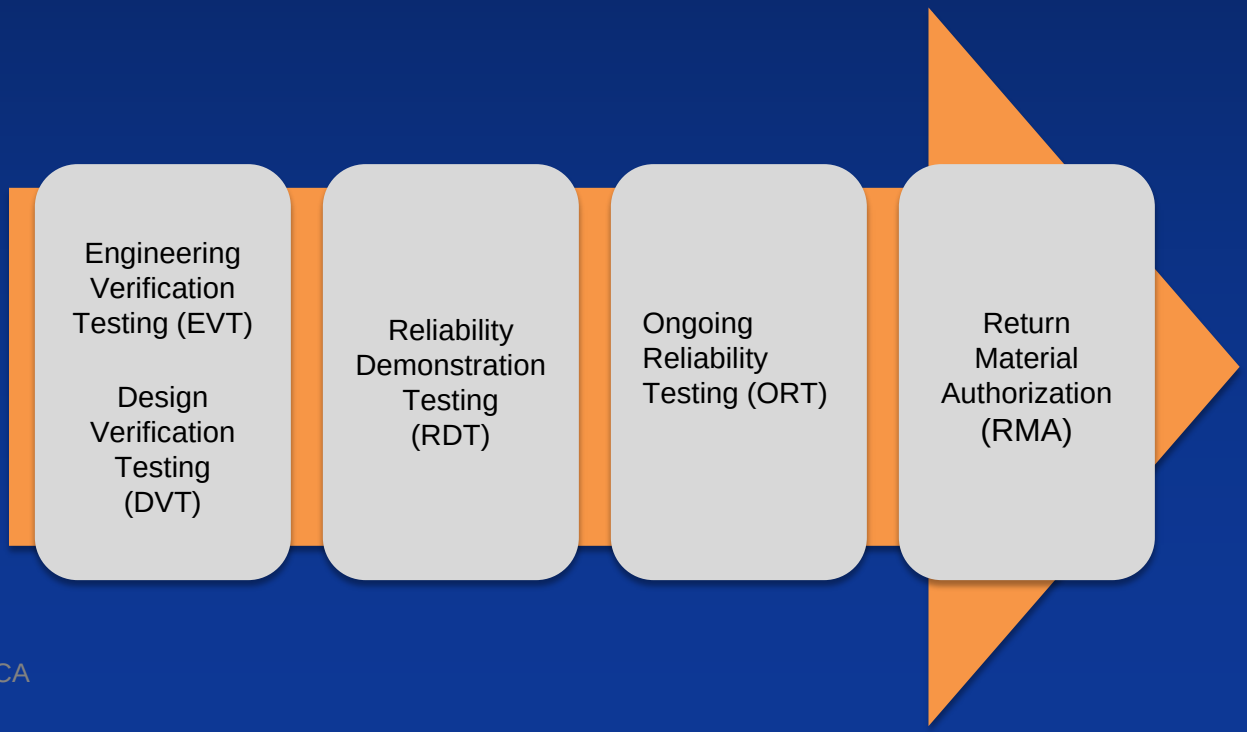
- Maintain capacity
- Meet required Functional Failure Requirement (FFR)
- Maintain required Uncorrectable Bit Error Rate
- Maintain data with unplanned power off

The Storage Networking Industry Association (SNIA) test process is based on testing SSDs using the following procedures:

- IOPs Test
- Throughput Test
- Latency Test

Testing Throughout the Manufacturing Phases

Testing and certification enables manufacturers to arm their products with proven quality and reliability.



Conclusions

- Differentiation of your product within a fiercely competitive field.
- OEMs and Data Centers are willing to pay for quality; without proven results manufacturers cannot penetrate high-end markets and applications.
- Field failures cost far more to remedy than plant failures
- Substandard manufacturers will lose the competitive battle for market share.
- Increasing numbers of Data Centers are using SSDs for caching and performance enhancement. Without valid test data this segment of the market will be lost.

- Questions
- Feedback
- Discussion