

pSLC Cache Design for Enhanced Performance and Lifetime

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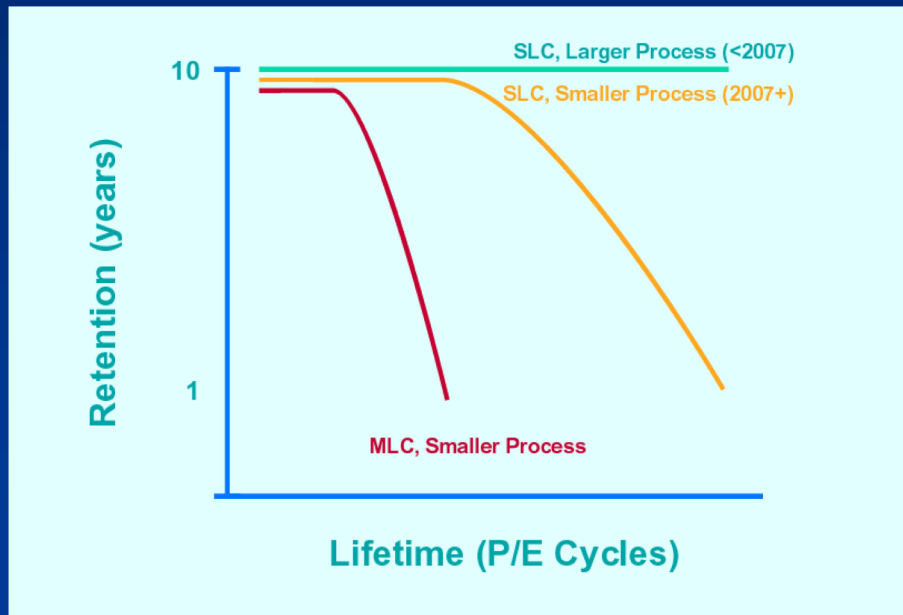
Background - Embedded Systems

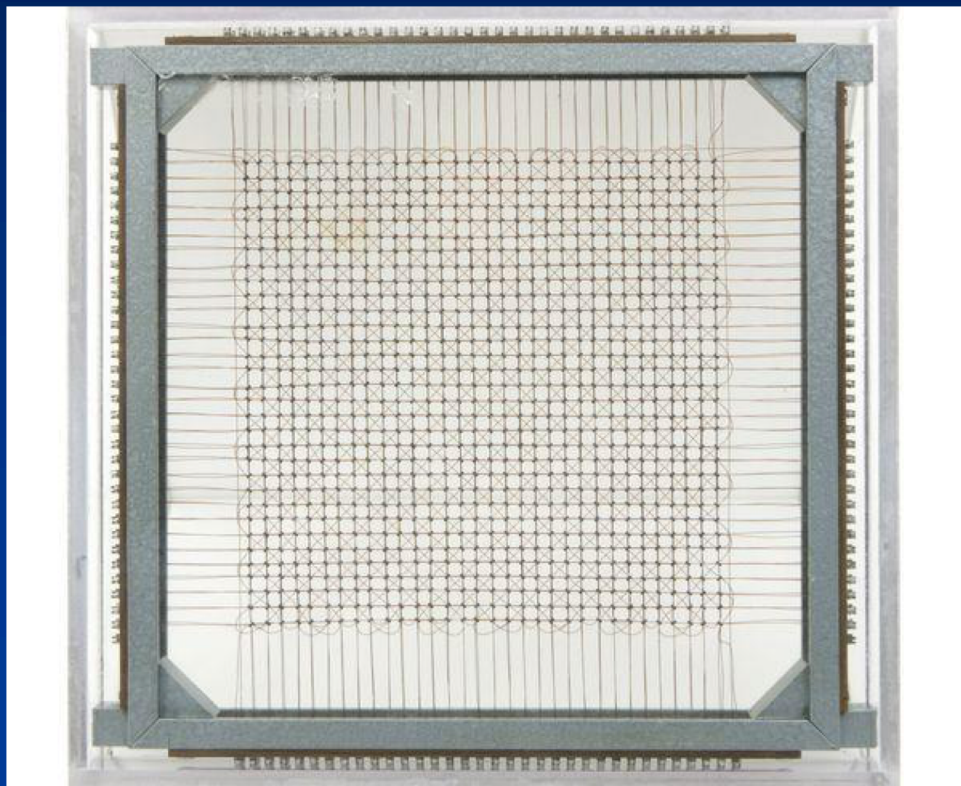
- “Fixed function system”
 - Telecom, automotive, industrial control systems, medical equipment ...
- Commonality: Flash Storage
 - Code & data



Motivation

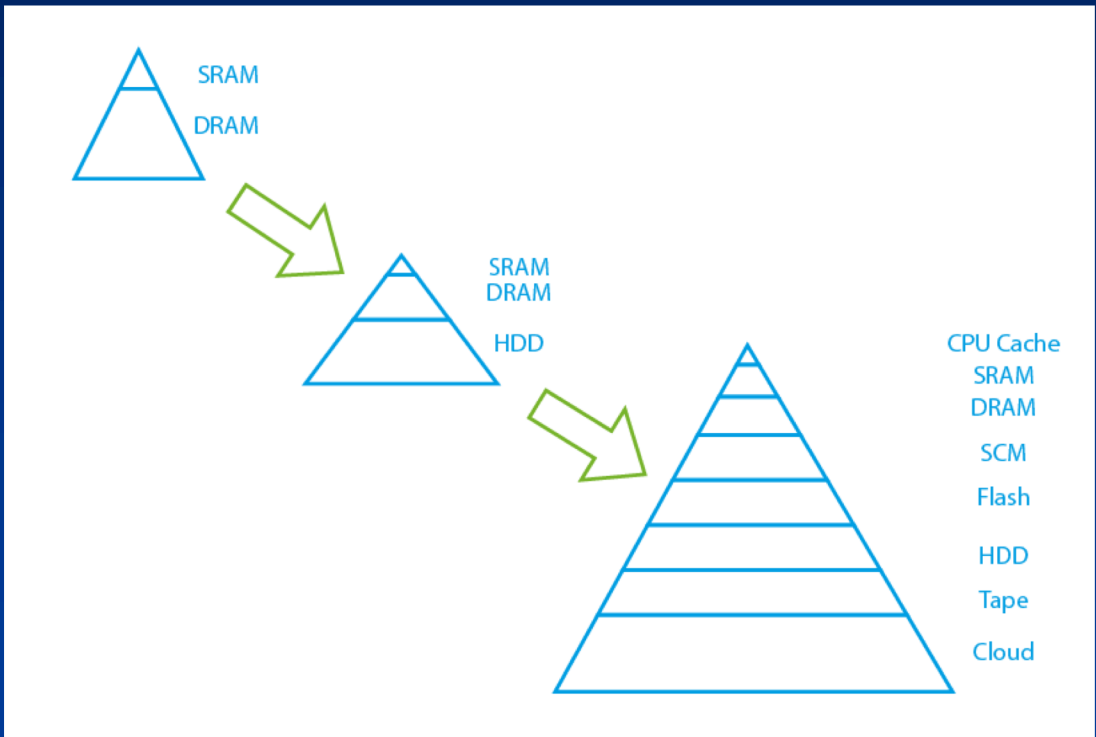
- Smaller process, more bits per cells
 - Endurance & ECC
 - Retention
- Challenge: Maintain acceptable service-life for embedded systems





[Mark Richards, Computer History Museum]

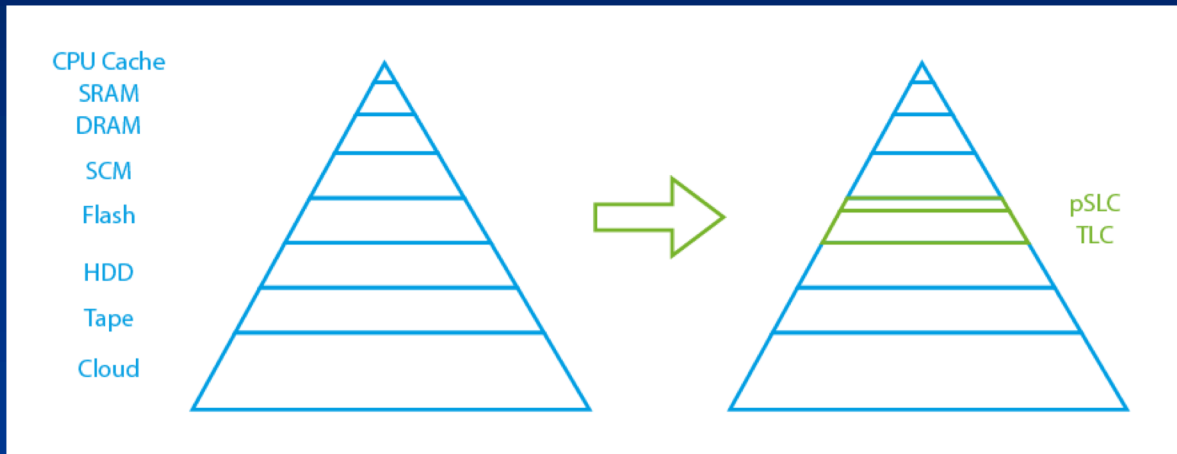
Hierarchy



Cache

- Still a flat memory space (mostly)
- Each layer is a cache
- Cache design is critical
 - Performance issues for misses

Hierarchy (pSLC/TLC)



pSLC vs TLC Specs

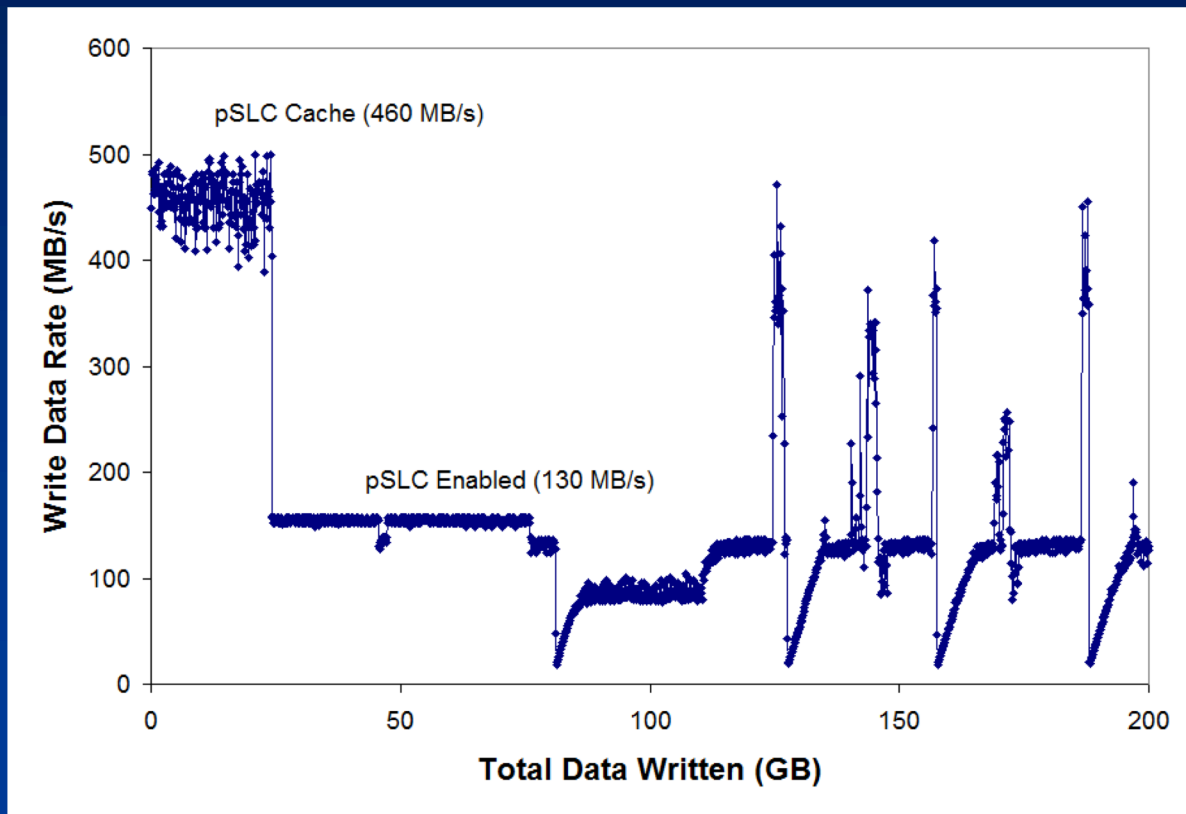
	pSLC	TLC
Speed	+3x	1x
Cost	-3x	1x
Endurance	20K (~7x)	3K



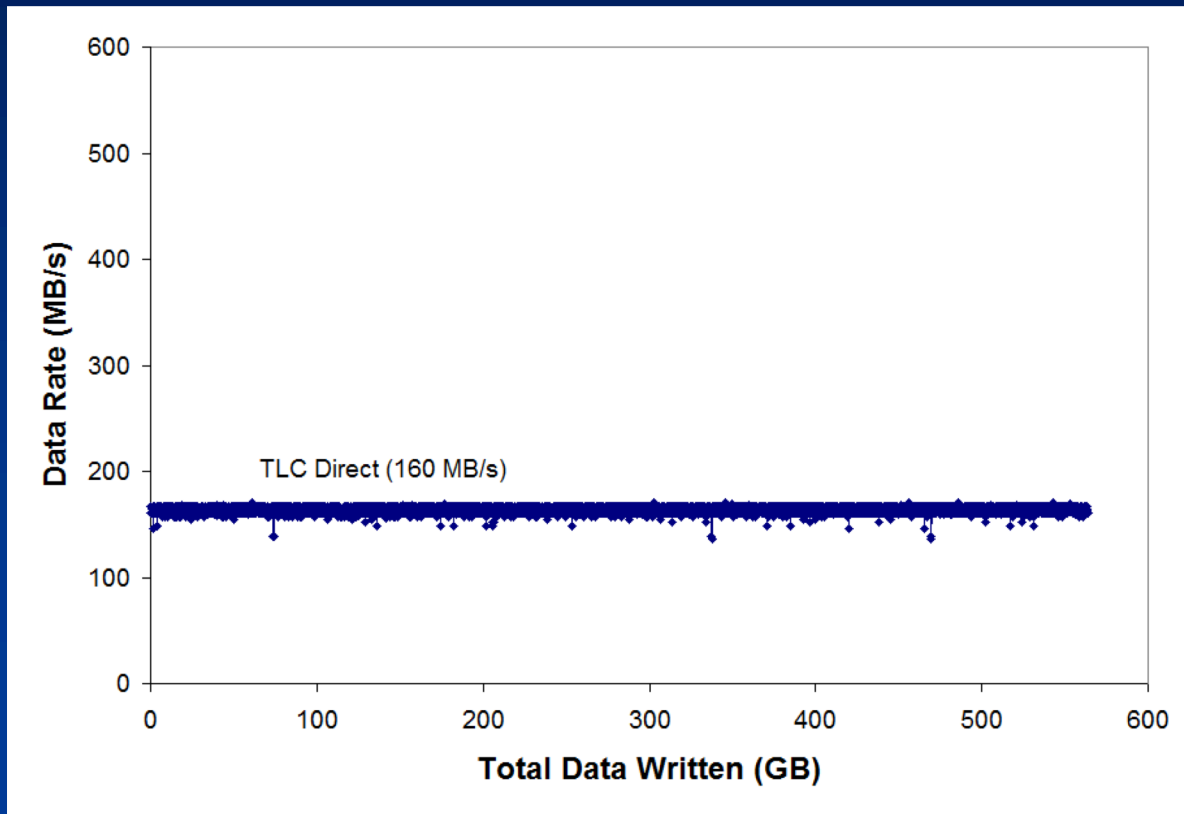
Operating Modes

- pSLC Cache (Fastest) – All pSLC
- pSLC Enabled (?) - Blended
- TLC Enabled (Slowest - ?) – All TLC

pSLC Cache & pSLC Enabled



TLC Direct

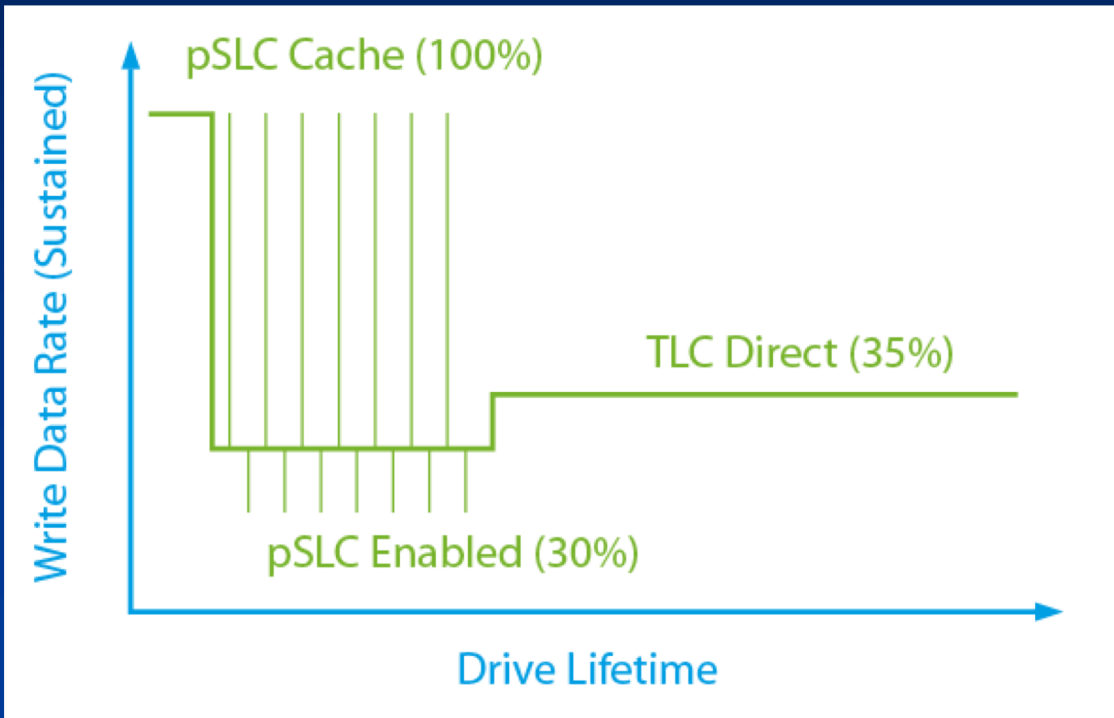




Operating Modes

- pSLC Cache (Fastest) – 100%
- pSLC Enabled (Slowest!) – 30%
 - Widely varying performance (>10x)
- TLC Enabled – 35%

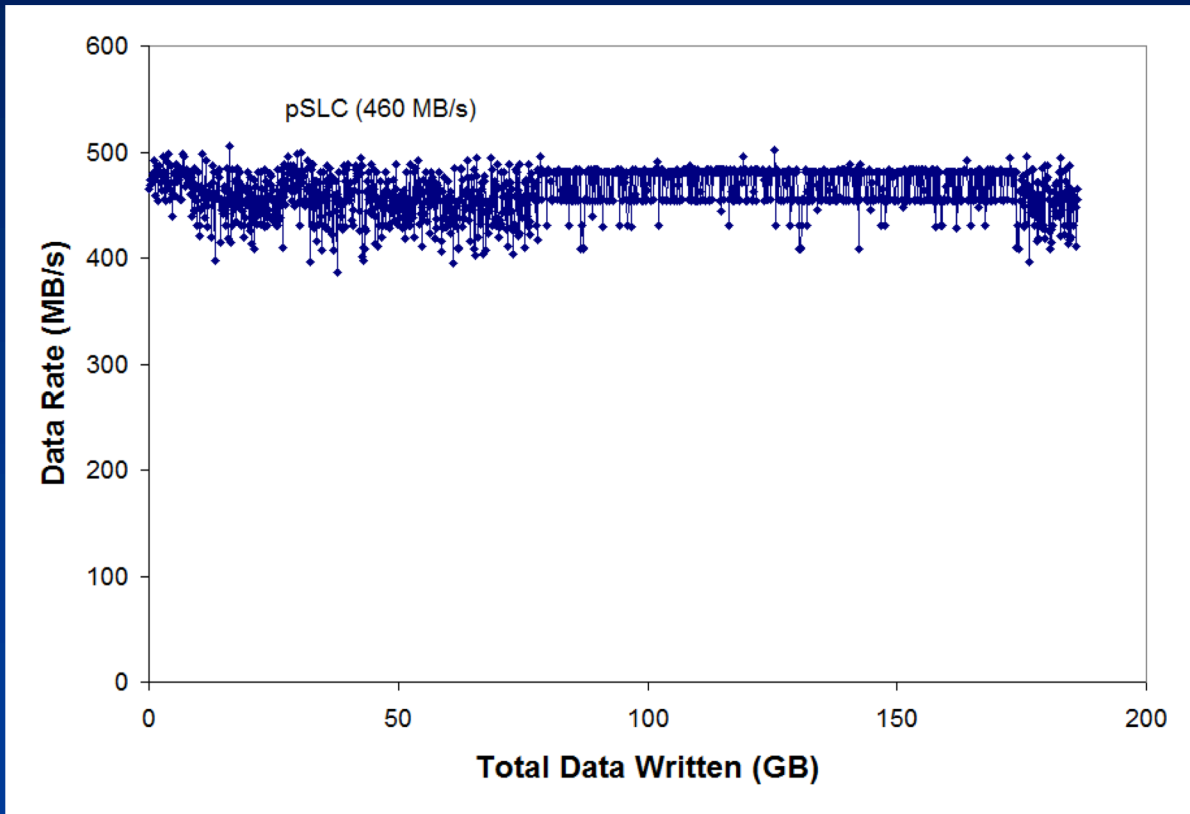
Model



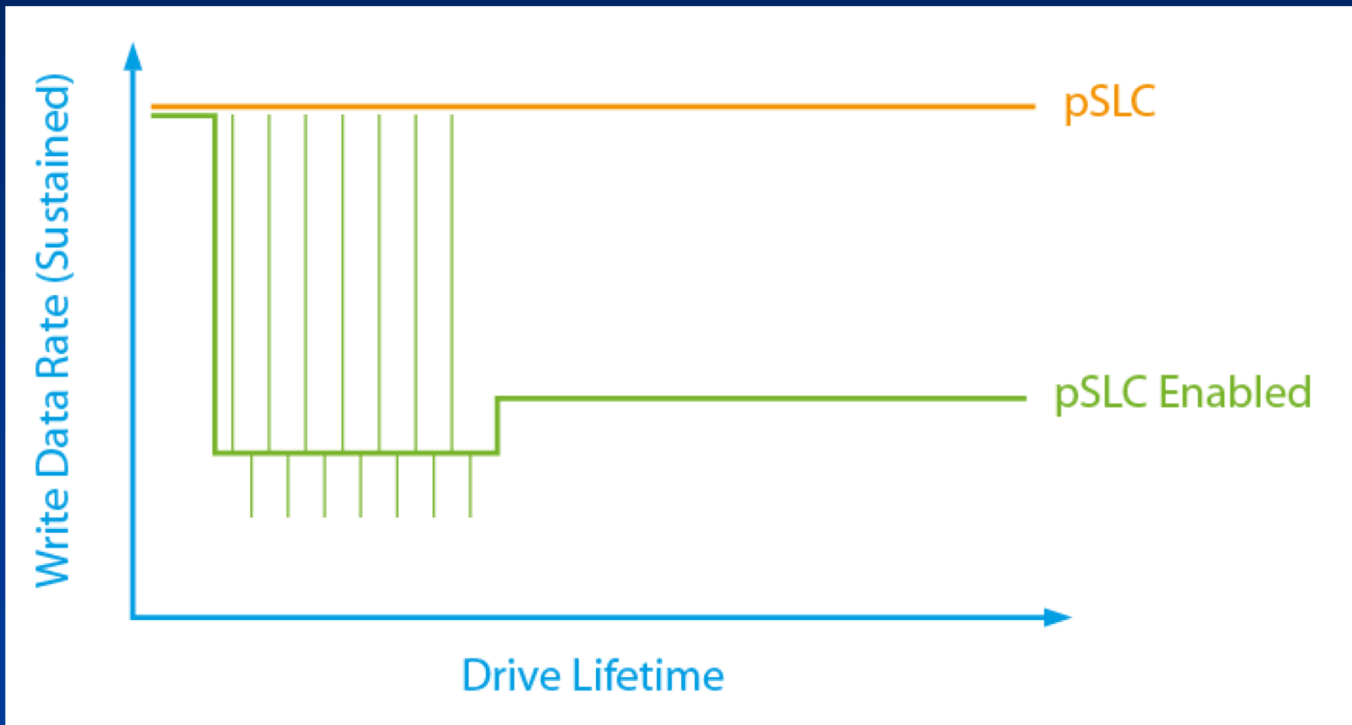
Summary (pSLC Cache)

- pSLC Cache
 - Improved burst performance (up to 100% pSLC)
 - Reduced sustained performance (lower than TLC)
 - Workload dependant

pSLC (100%)



Model - pSLC (100%)

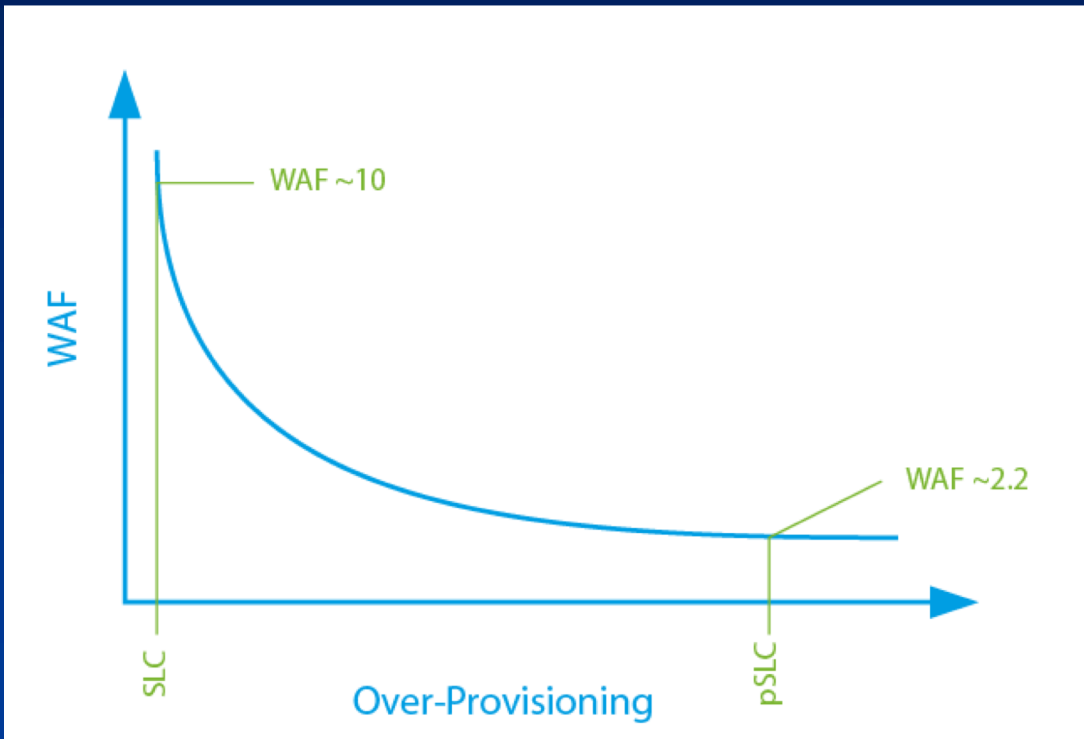


pSLC (100%)

- pSLC is 1/3 storage (512 GB -> 170 GB)
- What about 1/4 storage (512 GB -> 128 GB)?

$$\frac{\text{Lifetime}_{\text{pSLC}}}{\text{Lifetime}_{\text{TLC}}} = \frac{\left(\frac{\text{Endurance} \cdot \text{Physical Drive Size}}{\text{WAF}} \right)_{\text{pSLC}}}{\left(\frac{\text{Endurance} \cdot \text{Physical Drive Size}}{\text{WAF}} \right)_{\text{TLC}}}$$

WAF



Lifetime

$$\frac{\text{Lifetime}_{\text{pSLC}}}{\text{Lifetime}_{\text{TLC}}} = \frac{\left(\frac{\text{Endurance} \cdot \text{Physical Drive Size}}{\text{WAF}} \right)_{\text{pSLC}}}{\left(\frac{\text{Endurance} \cdot \text{Physical Drive Size}}{\text{WAF}} \right)_{\text{TLC}}}$$

$$\frac{\text{Lifetime}_{\text{pSLC}}}{\text{Lifetime}_{\text{TLC}}} = \frac{\left(\frac{20000 \cdot 1/4}{2.2} \right)_{\text{pSLC}}}{\left(\frac{3000 \cdot 1}{10} \right)_{\text{TLC}}}$$

$$\frac{\text{Lifetime}_{\text{pSLC}}}{\text{Lifetime}_{\text{TLC}}} = 7.6x$$



Summary

- pSLC Cache
 - Improved burst performance (up to 100% pSLC)
 - Reduced sustained performance (lower than TLC)
- pSLC (100%)
 - Improved burst and sustained performance
 - 8x drive lifetime
 - True SLC drive size



More Embedded Sessions

- Flash Memory System Embedded Events:
 - Embedded Applications, Part 1 (101-B)
 - Tues 8:30 – 9:35 AM
 - Embedded Applications, Part 2 (102-B)
 - Tues 9:45 – 10:50 AM
 - Beer, Pizza, and Chat with the Experts
 - Tues 7:00 – 8:30 PM
 - Flash and the IoT (302-B)
 - Thurs 3:40 – 5:00 PM



Questions?

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