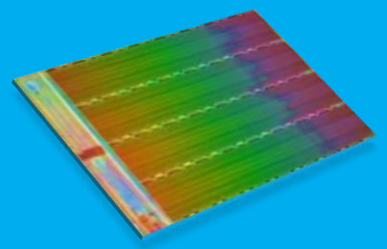
INTEL® SSD DATA CENTER EVOLUTION

March 2018

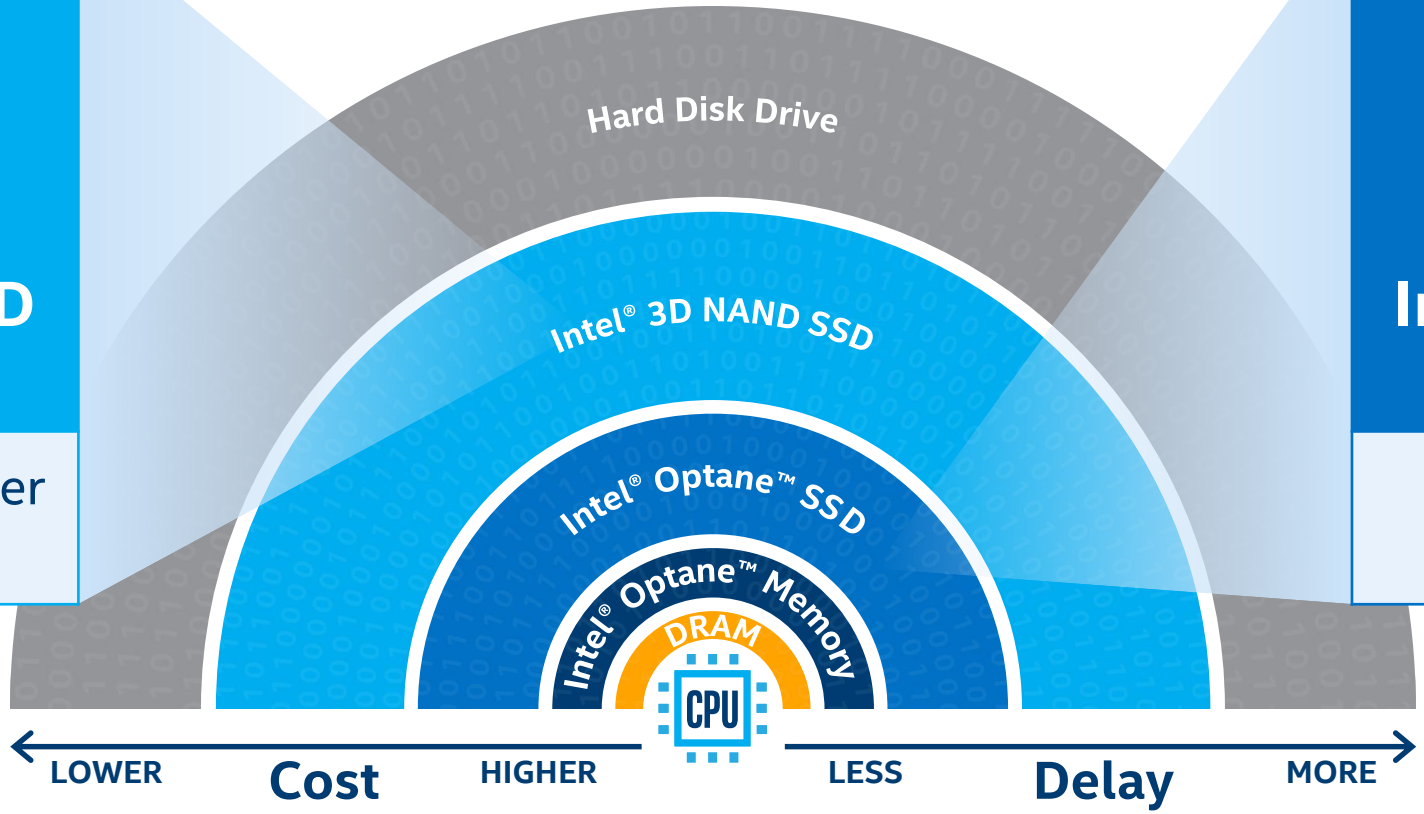
Intel Technology Innovations Fill the Memory and S

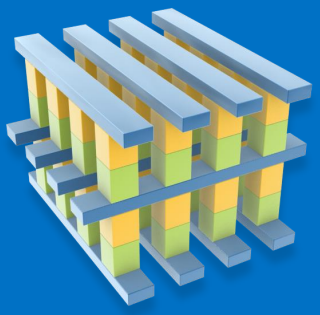
Performance and Capacity for Every Need



Intel 3D NAND Technology

Lower cost & higher density



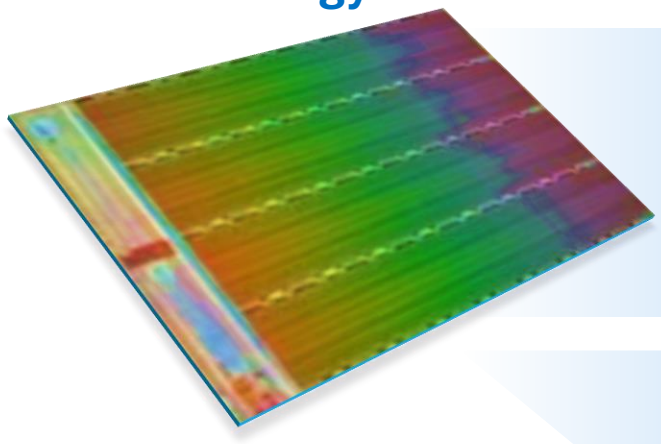


Intel® Optane™ Technology

Higher performance

Intel 3D NAND Leadership

Intel® 3D NAND Technology



Up to 20% Higher Areal Density[1] vs. Competition

Denser memory array Intel floating gate cell has a smaller footprint[1]	**More efficient utilization** Intel CMOS under array

Accelerating Moore's Law into 3 Dimensions

Architected for capacity scaling leadership	**Faster cadence generation to generation**

Why Does This Matter?

The combination of performance, capacity and cost of Intel® 3D NAND SSDs will rapidly accelerate HDD replacement.

[1]Comparing areal density of Intel measured data on 512GB Intel 3D NAND to representative competitors based on 2017 IEEE International Solid-State Circuits Conference papers citing Samsung Electronics and Western Digital/Toshiba die sizes for 64-stacked 3D NAND component.

Intel® 3D NAND SSDs

Transforming the economics of storage with trusted, breakthrough 3D NAND technology

Architected for capacity and cost

- Architected for highest areal density[1]
- Optimized for manufacturing efficiency

Built on a proven process

- Leader in flash cell technology evolution and scaling
- Accelerated development[2]
- First to high volume manufacturing with 64-Layer TLC[3]

Enabling disruptive opportunities

- Growing capacity faster than the market[4]
- Rapid portfolio expansion
- Space and power efficient capacities reduce TCO

1. Comparing areal density of Intel measured data on 512 GB Intel 3D NAND to representative competitors based on 2017 IEEE International Solid-State Circuits Conference papers citing Samsung Electronics and Western Digital/Toshiba die sizes for 64-stacked 3D NAND component.
2. Anand Tech '3D NAND Die Size Comparison' http://www.anandtech.com/show/11377/western-digital-ships-ssds-based-on-512-gb-3d-tlc-nand-chips. Forward Insights 'QLC in the Datacenter', May 2017, http://www.forward-insights.com/reportslist.html
3. Intel® SSD 545s Series available on NewEgg® https://www.newegg.com/SSDs/Category/ID-119 June 27, 2017.
4. Based on Intel internal forecasting 2016-2017. Forecasts are Intel estimates, based upon expectations and available information and are subject to change without notice.

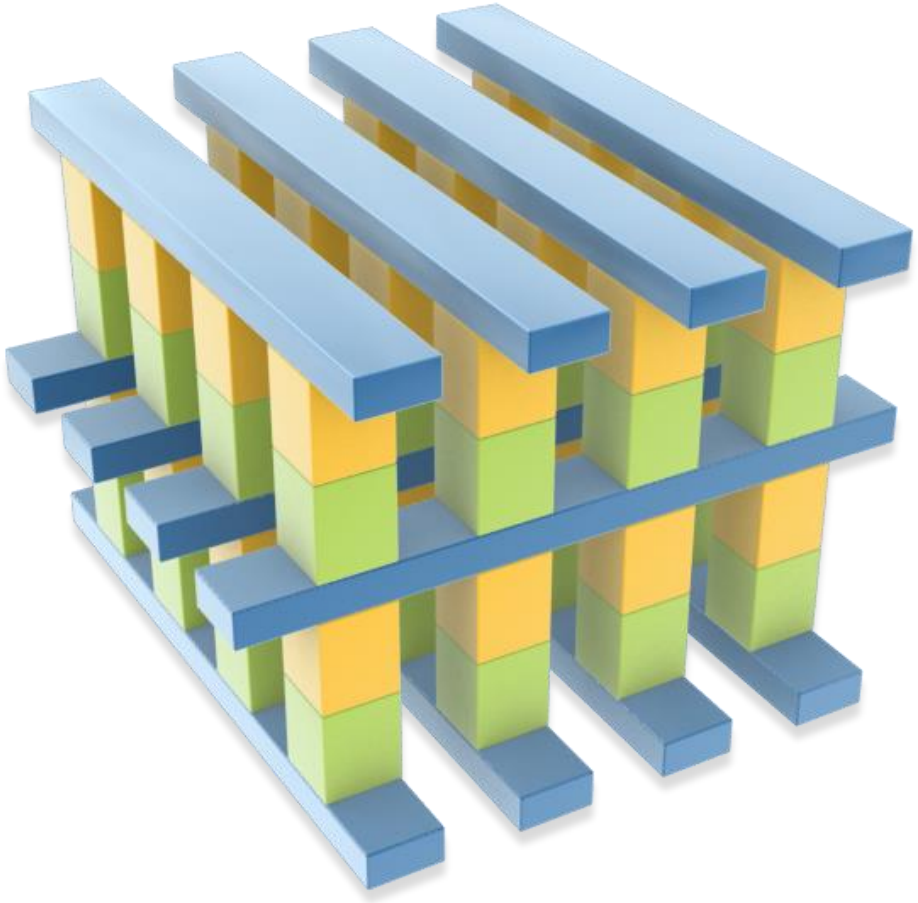
Intel® Optane™ Technology: 3D XPoint™ Memo

Cross Point Structure

Selectors allow dense packing and individual access to bits

Scalability

Memory layers can be stacked in a 3D manner



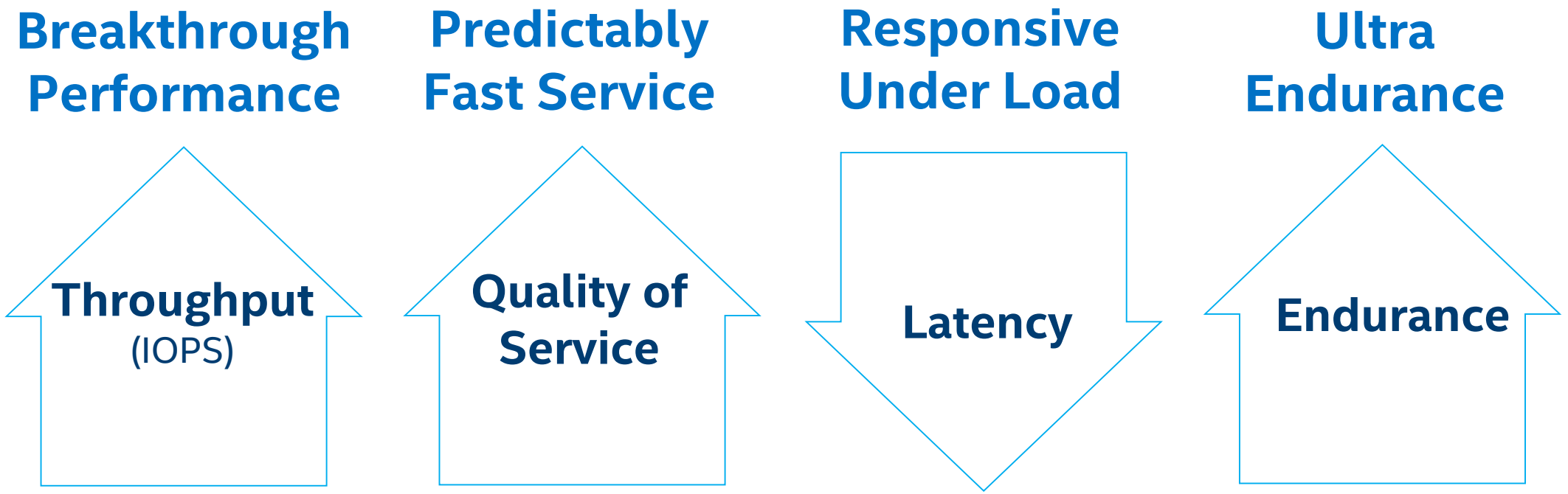
Breakthrough Material Advances

Compatible switch and memory cell materials

High Performance

Cell and array architecture that can switch states much faster than NAND

Intel® Optane™ SSD DC P4800X



Storage Performance Characterization

Latency vs. Load[1]: NAND SSD vs. Intel® Optane™ SSD (Intel® SSD DC P3700 vs. Intel® Optane™ SSD DC P4800X)

10x latency reduction

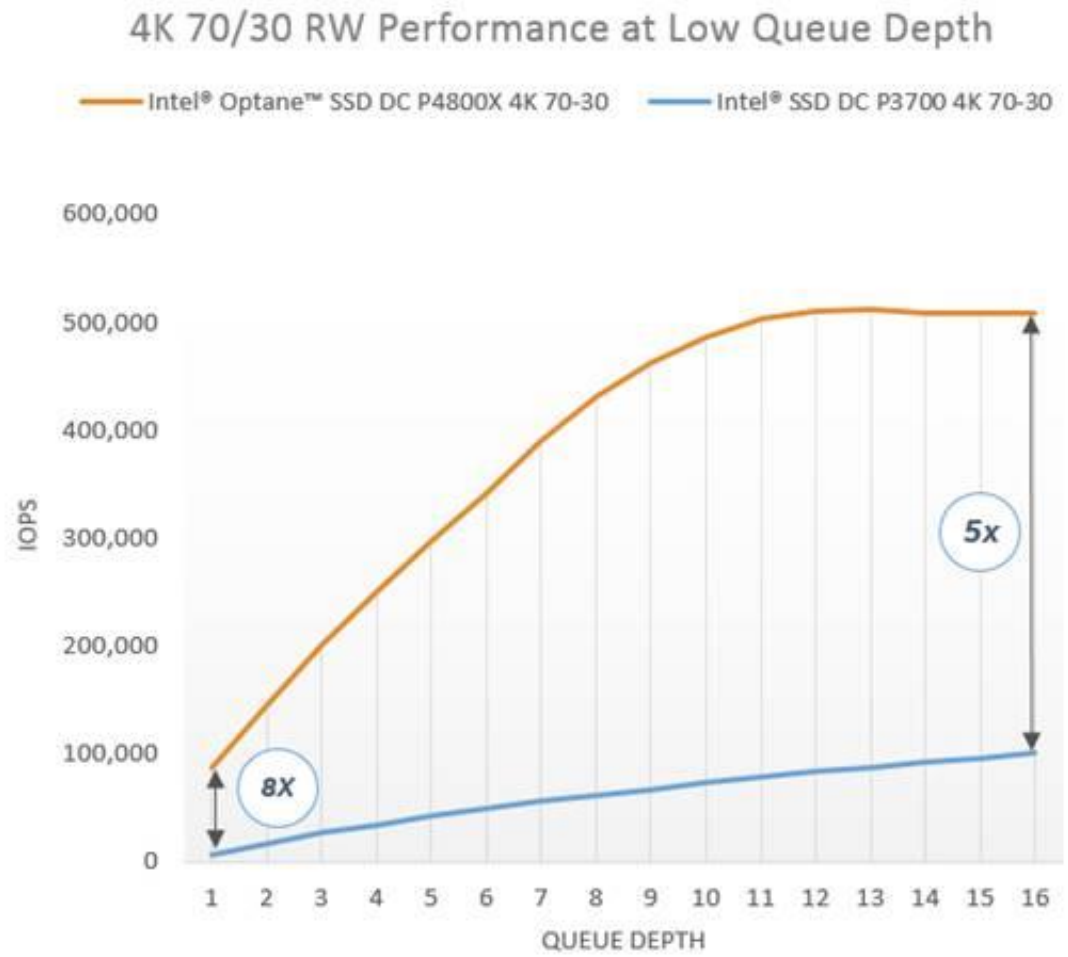
- < 10usec latency [2]

100x QoS improvement

- < 200usec 99.999th r/w [2]

1. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system. Common Configuration - Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Performance – measured under 4K 70-30 workload at QD1-16 using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.
2. Vs. NAND based SSD.

Breakthrough Performance

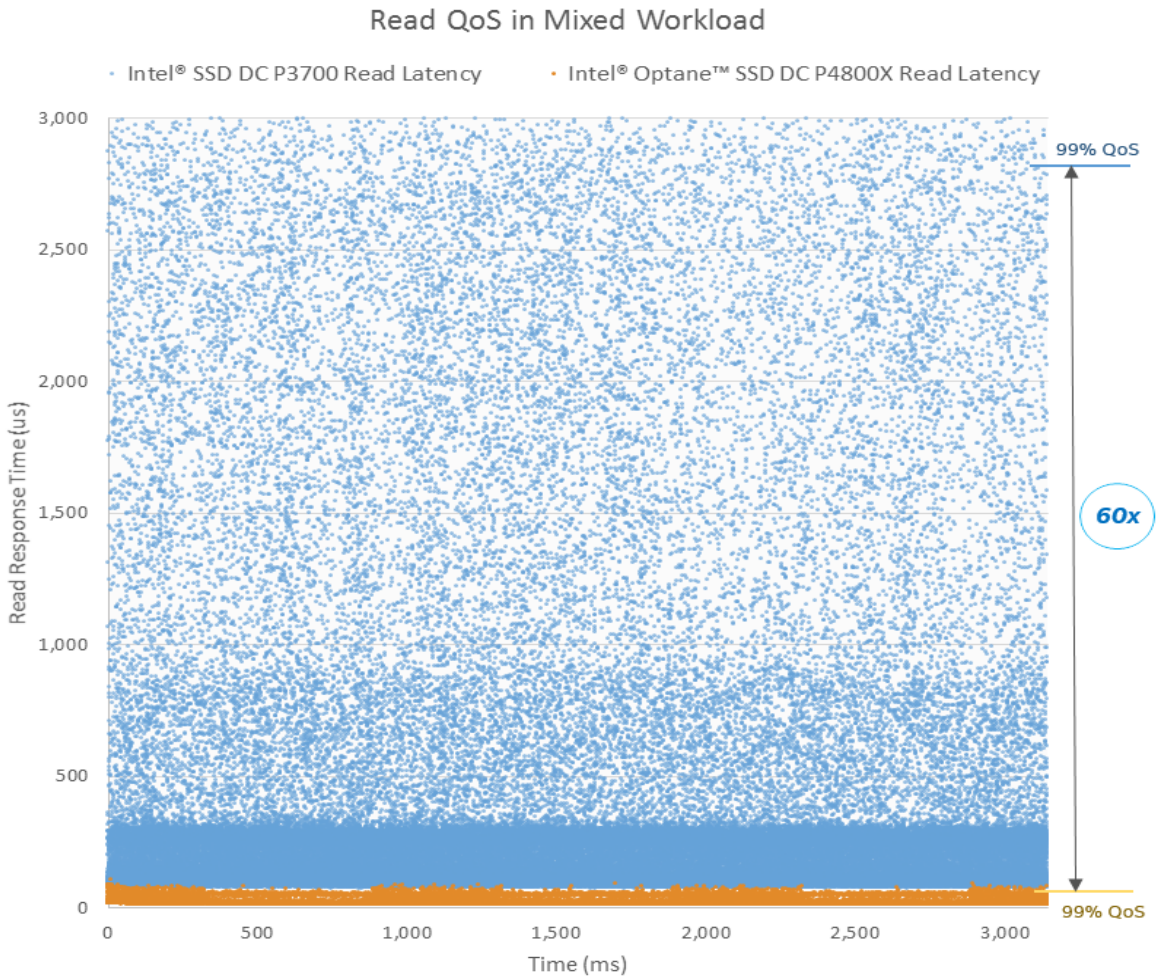


intel XEON inside + intel OPTANE™

- **5-8x faster** at low Queue Depths[1]
- Vast majority of **applications generate low QD** storage workloads

1. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system. Common Configuration - Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Performance – measured under 4K 70-30 workload at QD1-16 using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

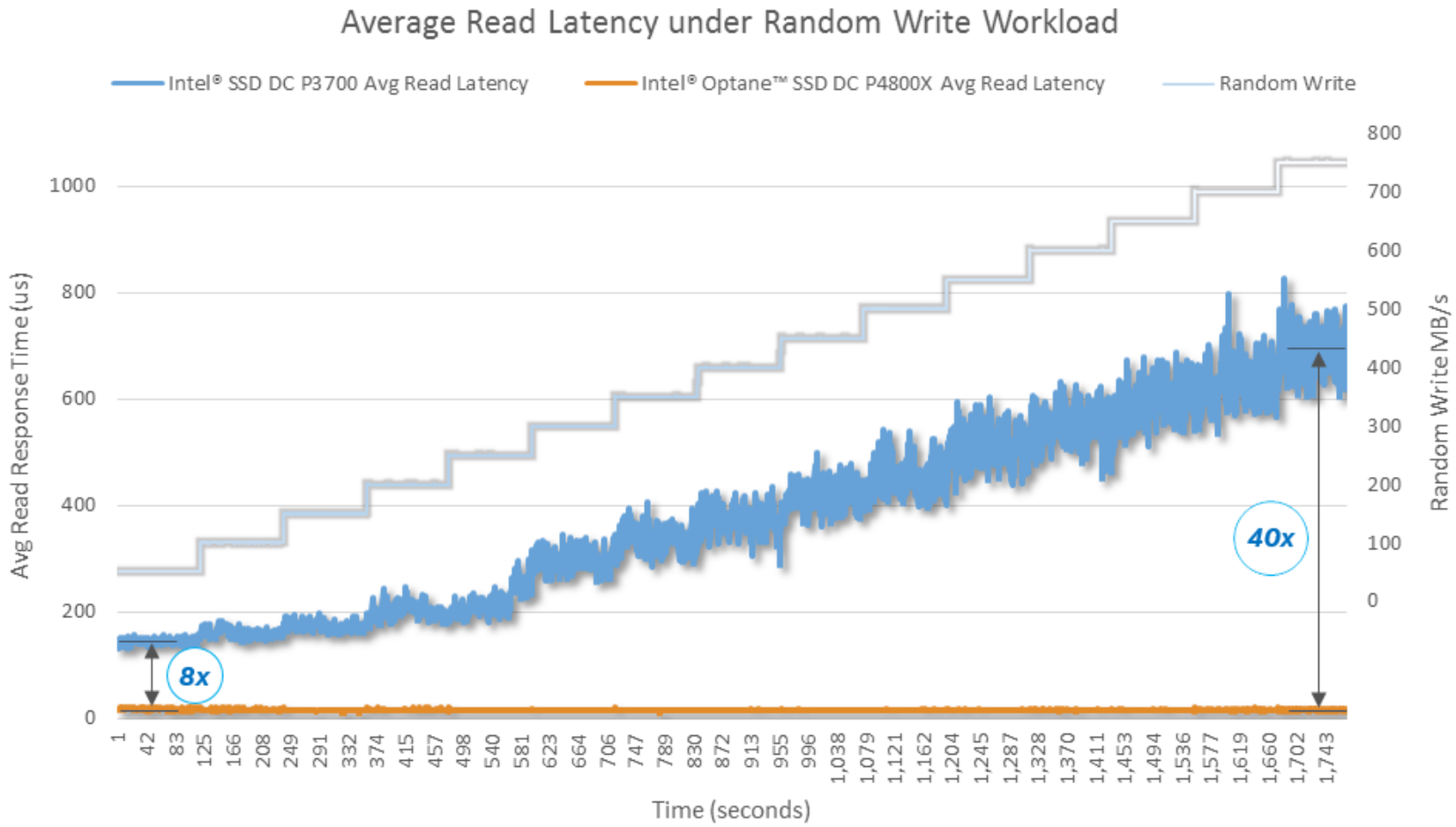
Predictably Fast Service



- ☑ up to **60x** better at 99% QoS[1]
- ☑ Ideal for critical applications with aggressive latency requirements

1. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system. Common Configuration – Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. QoS – measures 99% QoS under 4K 70-30 workload at QD1 using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

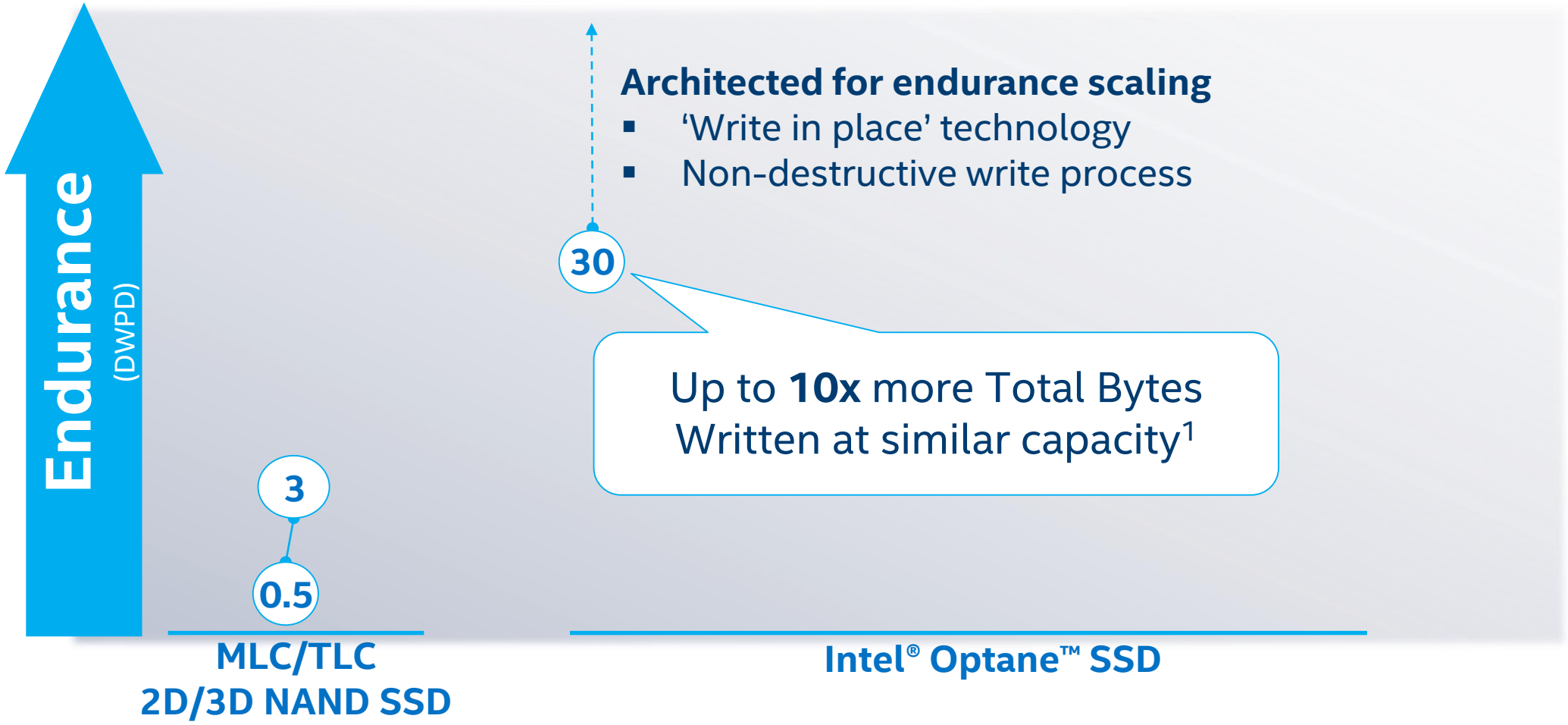
Responsive Under Load



- up to **40x faster response time** under workload[1]
- Consistently **amazing response time under load**

1. Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown." Implementation of these updates may make these results inapplicable to your device or system. Responsiveness defined as average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 2.15. Common Configuration - Intel 2U Server System, OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Latency – Average read latency measured at QD1 during 4K Random Write operations using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Ultra Endurance



1. Comparing projected Intel® Optane™ SSD 750GB specifications to actual Intel® SSD DC P4600 1.6TB specifications. Total Bytes Written (TBW) calculated by multiplying specified or projected DWPD x specified or projected warranty duration x 365 days/year. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Intel® Data Center SSDs – Current Product

Use Case	Endurance	Interface	March 2018
Intel® Optane™ Technology	Very High Endurance	PCIe*	Intel® Optane™ SSD DC P4800X: U.2 15mm: 375GB, 750GB AIC: 375GB, 750GB
			Intel® Optane™ SSD DC P4800X with Intel® Memory Drive Technology: U.2 15mm: 375GB, 750GB AIC: 375GB, 750GB
Server Performance	Mid	PCIe*	DC P4600: U.2 15mm: 1.6TB, 2TB, 3.2TB
			DC P4600: AIC: 2TB, 4TB
		SATA	DC S4600: 2.5": 240GB, 480GB, 960GB, 1.92TB
	Standard	PCIe*	DC P4510: U.2 15mm: 1TB, 2TB, 4TB, 8TB
			DC P4500: U.2 15mm: 1TB, 2TB, 4TB AIC: 4TB
		SATA	DC S4500: 2.5": 240GB, 480GB, 960GB, 1.92TB, 3.84TB
			DC S3520: M.2 80mm: 150GB, 240GB, 480GB, 760GB, 960GB
Low Power	Standard	PCIe*	DC P4501: U.2 7mm: 500GB, 1TB, 2TB, 4TB
Value Performance	Value	PCIe*	DC P3100: M.2 80mm: 128GB, 256GB, 512GB, 1TB
		SATA	DC S3110: M.2 80mm: 128GB, 256GB, 512GB

Intel® Optane™ Technology | 64-Layer, TLC, 3D NAND | 32-Layer, TLC, 3D NAND | 32-Layer, MLC, 3D NAND

HHHL (CEM3.0)

U.2 15mm

M.2 110mm

U.2 7mm

*Other names and brands may be claimed as the property of others.

PCI Express* SSD Form Factor Evolution

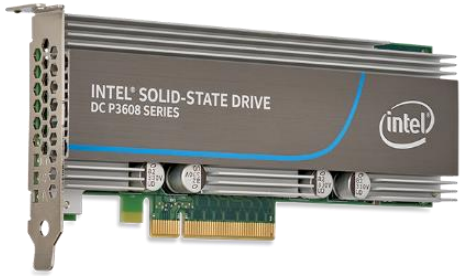
M.2

M.2 initially designed for client and mobile use. Used in data center for boot or compute nodes, but lacks hot-plug support and requires carrier cards / heatsinks to manage thermals

U.2

U.2 2.5in x 15mm and 7mm supports hot-plug and serviceability, designed to share physical dimensions with HDDs for hybrid HDD/SSD server designs. Mainstream PCIe* SSD form factor

AIC



PCIe* low profile add-in-cards have broadest compatibility with the most mature ecosystem and compliance. Shares same form factor with network cards, graphic cards, etc.

RULER

Built for data center racks
High per drive, per server and per rack capacity
Improved manageability and serviceability
Efficient thermal design
Integrated enclosure, latch, LEDs

*Other names and brands may be claimed as the property of others.

AN SSD REVOLUTION.

"RULER" FORM FACTOR FOR INTEL® SSDs.

Designed from the ground up to optimize rack efficiency, the new **Ruler Form Factor** delivers unparalleled **Space-Efficient Capacity**, **Operationally- Efficient Design** and **Scalable Manageability.** Now available with the cloud-inspired Intel® SSD DC P4500 Series.

Optimized Storage for Data Center Racks.

Space Efficient Capacity

- Storage density optimized design delivers **higher per drive capacity**
- 1U optimized form factor delivers up to 32 drives per U for **higher per server capacity**

Operationally Efficient Design

- Up to **55% more thermally efficient** than 15mm U.2[1]
- Consolidate racks to **reduce opex**
- System-based design approach enables **more efficient solutions**

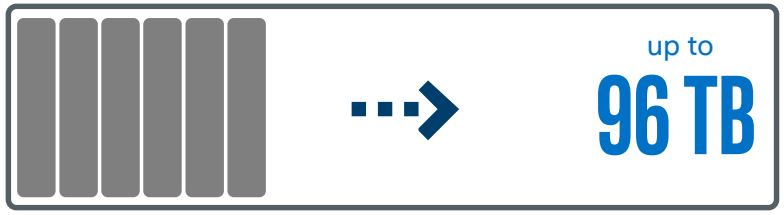
Efficient Management at Scale

- **Front loading** and **hot swappable**
- Integrated power cycling enables **remote, drive specific reboot**
- Expanded and programmable LEDs enable **indication of more device states**

1. Source – Intel. Results have been estimated or simulated using internal analysis or architecture simulation or modeling, and provided for informational purposes. Simulation includes "ruler" form factor for Intel® SSD DC P4500 4TB ruler, U.2 15mm Intel® SSD DC P4500, 3 drives in sheet metal representation of server, 12.5mm pitch for "ruler", 1000m elevation, limiting SSD on case temp of 70C or thermal throttling performance, whichever comes first. 5C guardband.

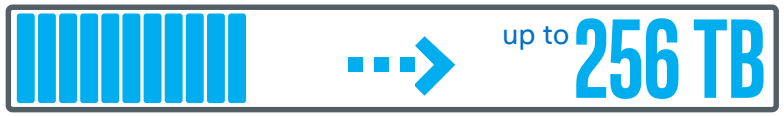
Optimized for Space Efficient Capacity pe

2U SERVER



U.2 15MM 4TB

1U SERVER



RULER 8TB

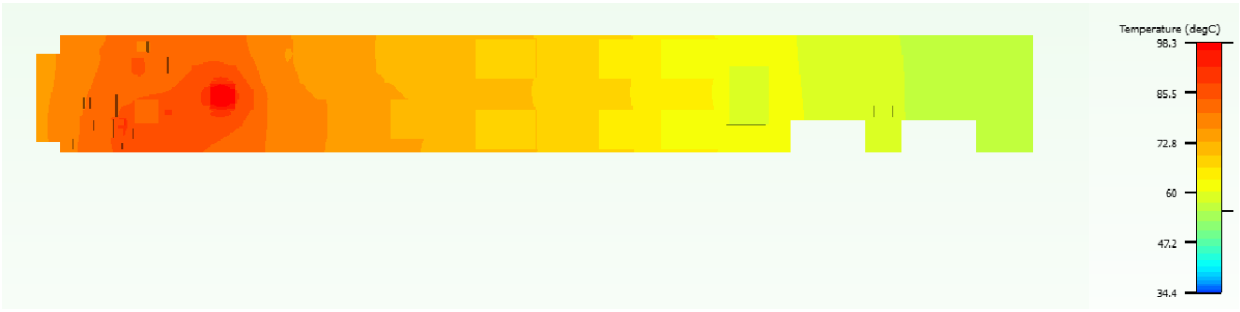
STORAGE CAPACITY

5.3X MORE TB PER RACK UNIT[1]

System Type	Standard 2U Server	Intel® AF1000 Server
Rack space	2U	1U
SSD form factor	U.2 15mm	Intel ruler
Number of SSDs per server	24	32
Capacity per drive	4TB	8TB
TB/rack unit	48TB	256TB

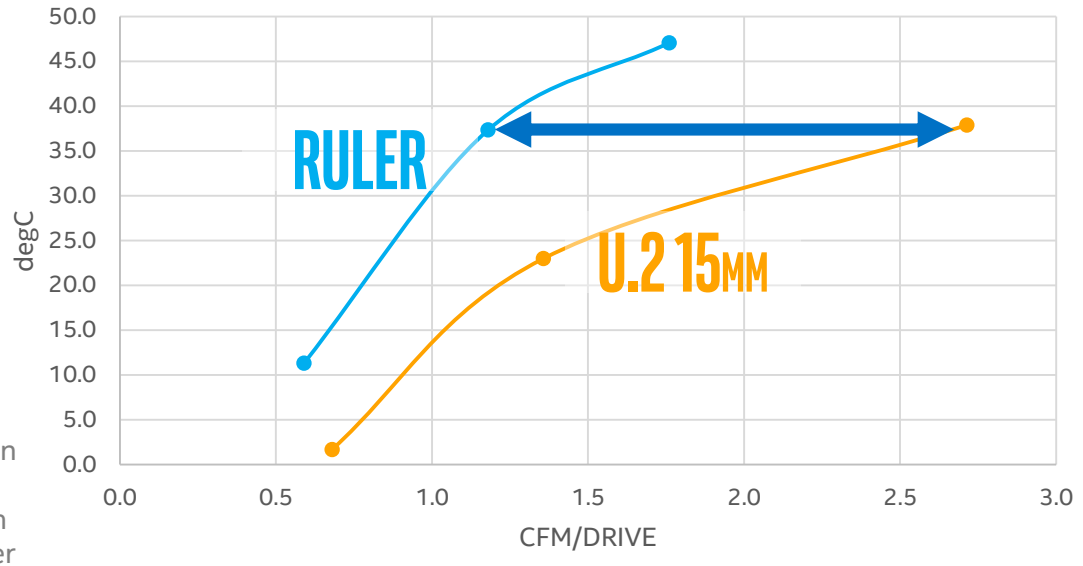
1. Source – Intel. Comparing maximum capacity per 1 rack unit of Intel® Server Board S2600WP Family, 24 U.2 bay option using 4TB U.2 15mm Intel® SSD DC P4500 to 8TB Intel® AF1000 Server design, 32 "ruler" drive bays using 8TB "ruler" form factor for Intel® SSD DC P4500.

Thermal Efficient Design



THERMAL EFFICIENCY

UP TO 55% LESS AIRFLOW[1] VS U.2 15MM



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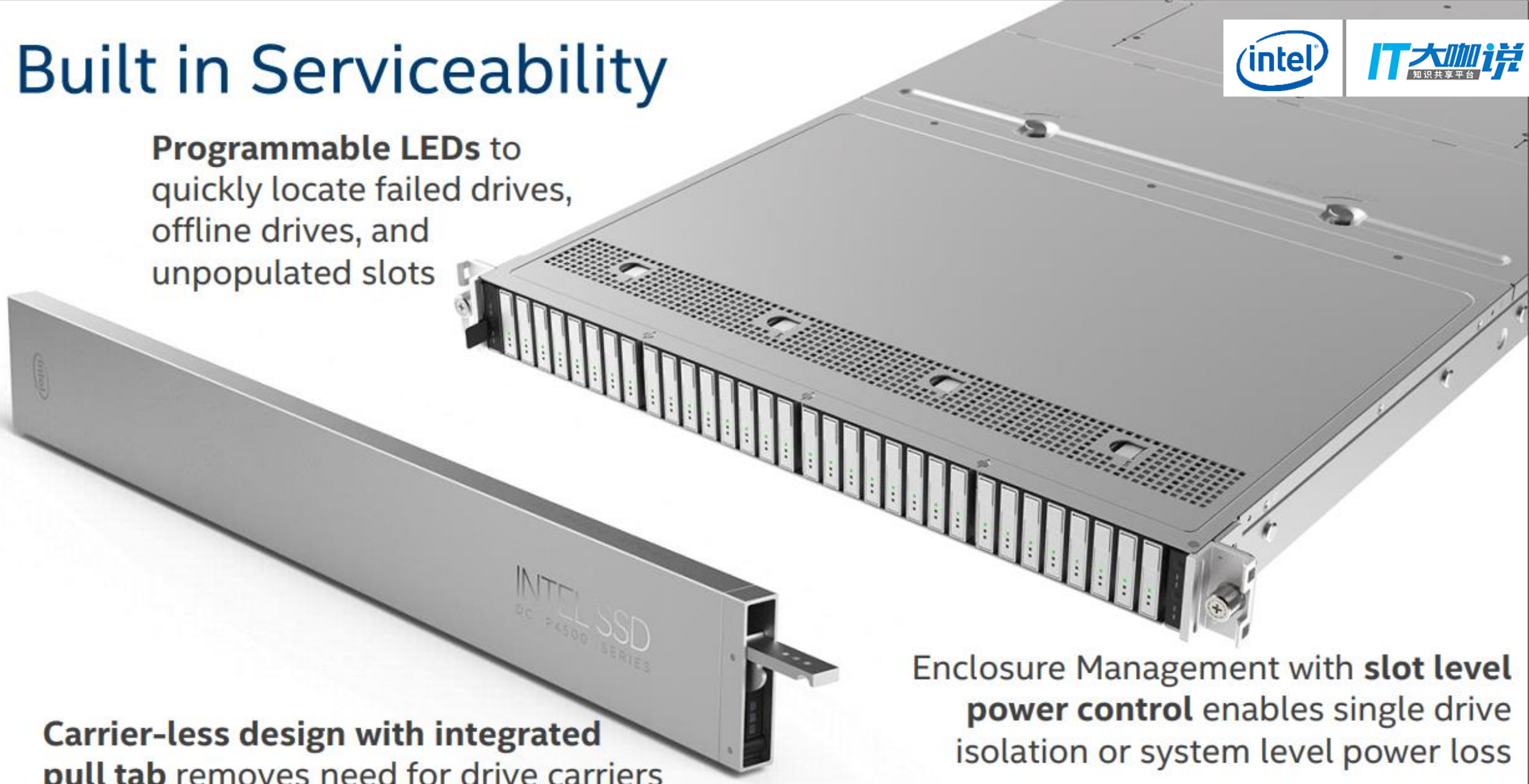
Built in Serviceability

Programmable LEDs to quickly locate failed drives, offline drives, and unpopulated slots



Carrier-less design with integrated pull tab removes need for drive carriers

Enclosure Management with **slot level power control** enables single drive isolation or system level power loss

“Ruler” Form Factor for Intel SSDs Roadm

- Move Ruler to compliance with EDSFF specifications
- Expand portfolio to include Intel® Optane™ SSDs in 2018


intel
experience
what's inside™

Notices & Disclaimers

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software or service activation. Performance varies depending on system configuration.
No computer system can be absolutely secure.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. For more complete information about performance and benchmark results, visit http://www.intel.com/benchmarks .
Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit http://www.intel.com/benchmarks .
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Intel® Advanced Vector Extensions (Intel® AVX)* provides higher throughput to certain processor operations. Due to varying processor power characteristics, utilizing AVX instructions may cause a) some parts to operate at less than the rated frequency and b) some parts with Intel® Turbo Boost Technology 2.0 to not achieve any or maximum turbo frequencies. Performance varies depending on hardware, software, and system configuration and you can learn more at http://www.intel.com/go/turbo.
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