

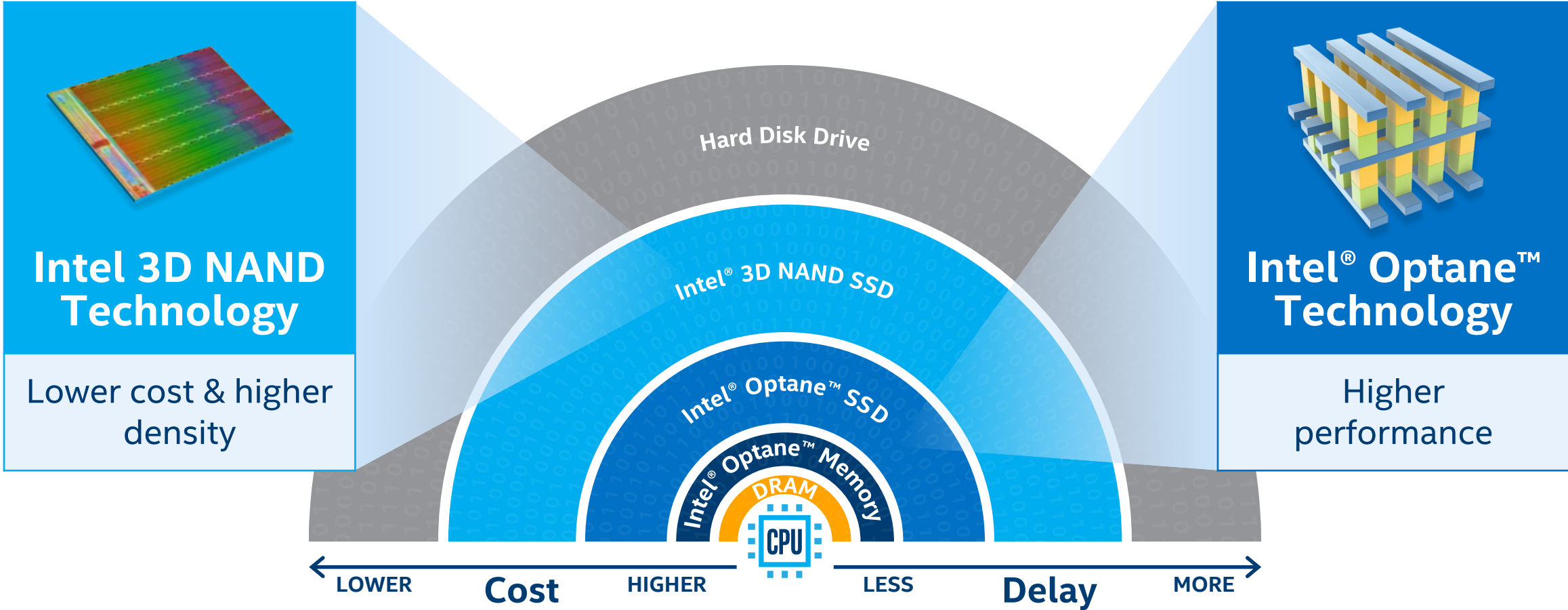
# INTEL<sup>®</sup> SSD DATA CENTER EVOLUTION

March 2018



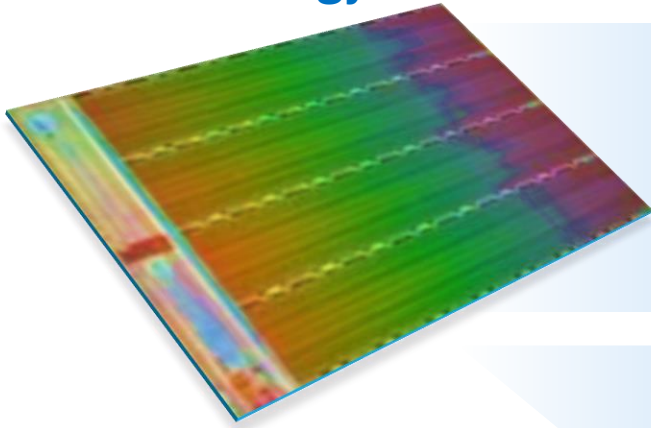
# Intel Technology Innovations Fill the Memory and Storage Gap

Performance and Capacity for Every Need



# Intel 3D NAND Leadership

Intel®  
3D NAND  
Technology



## Up to 20% Higher Areal Density<sup>1</sup> vs. Competition

**Denser memory array**  
Intel floating gate cell has a smaller footprint<sup>1</sup>

**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.**

<sup>1</sup>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



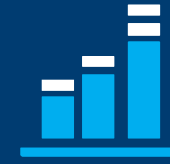
## Architected for capacity and cost

- Architected for highest areal density<sup>1</sup>
- Optimized for manufacturing efficiency



## Built on a proven process

- Leader in flash cell technology evolution and scaling
- Accelerated development<sup>2</sup>
- First to high volume manufacturing with 64-Layer TLC<sup>3</sup>



## Enabling disruptive opportunities

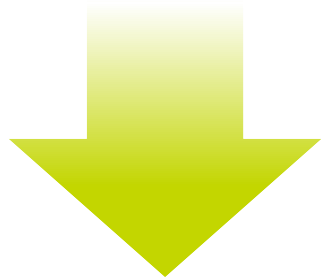
- Growing capacity faster than the market<sup>4</sup>
- Rapid portfolio expansion
- Space and power efficient capacities reduce TCO

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™ Memory Media

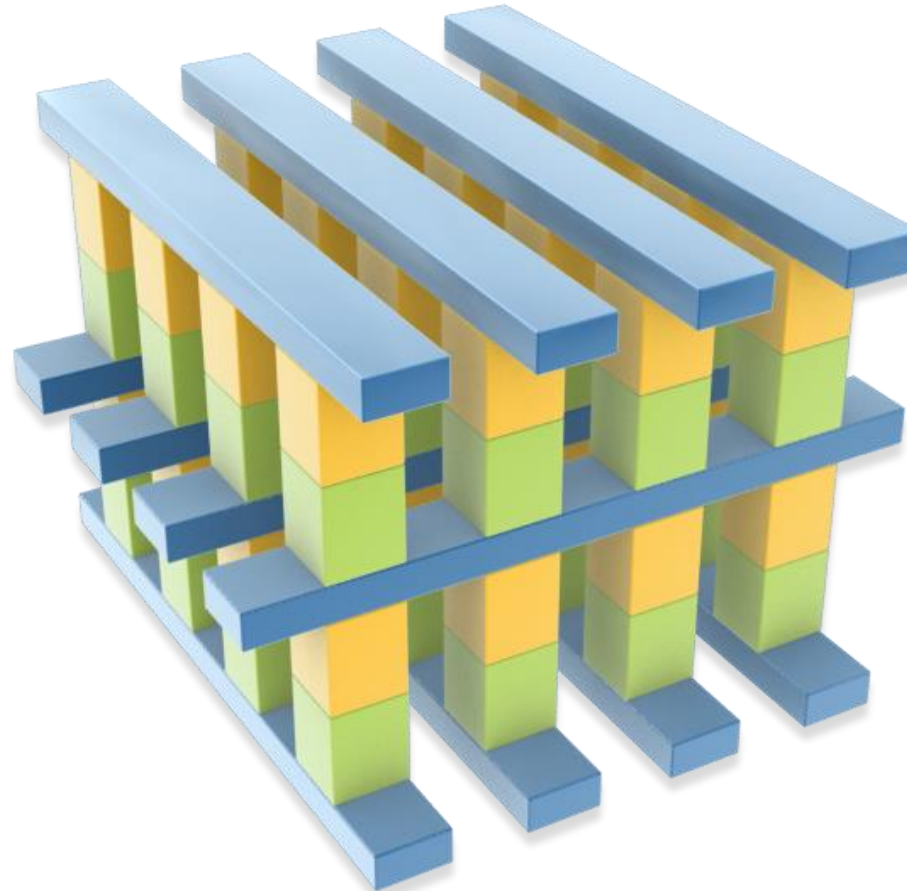
## Cross Point Structure

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



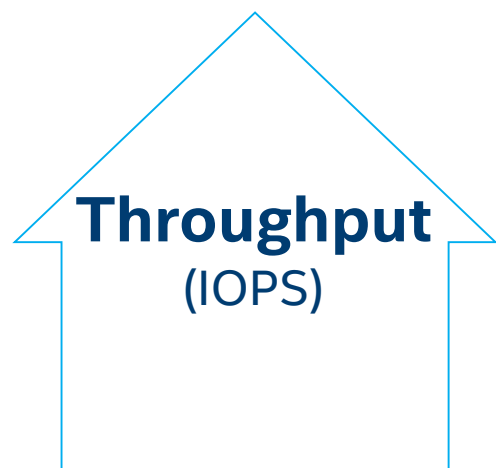
## High Performance

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



# Intel® Optane™ SSD DC P4800X

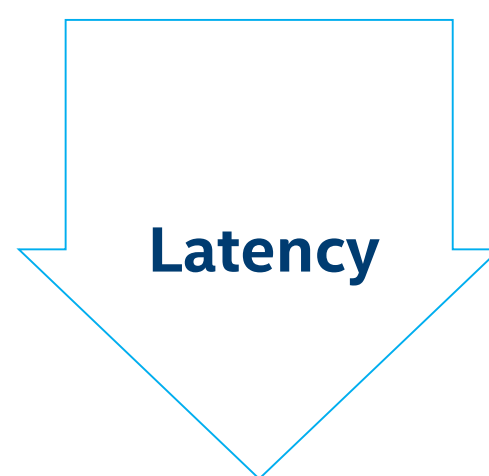
**Breakthrough  
Performance**



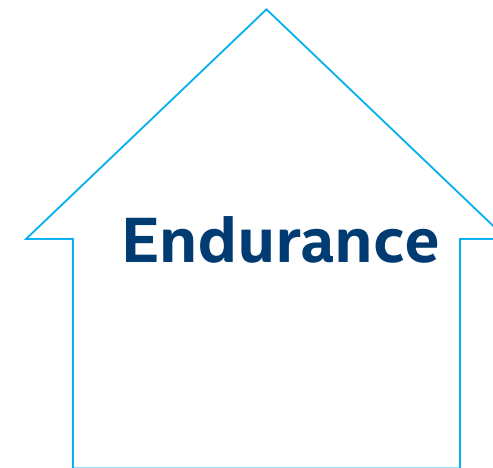
**Predictably  
Fast Service**



**Responsive  
Under Load**



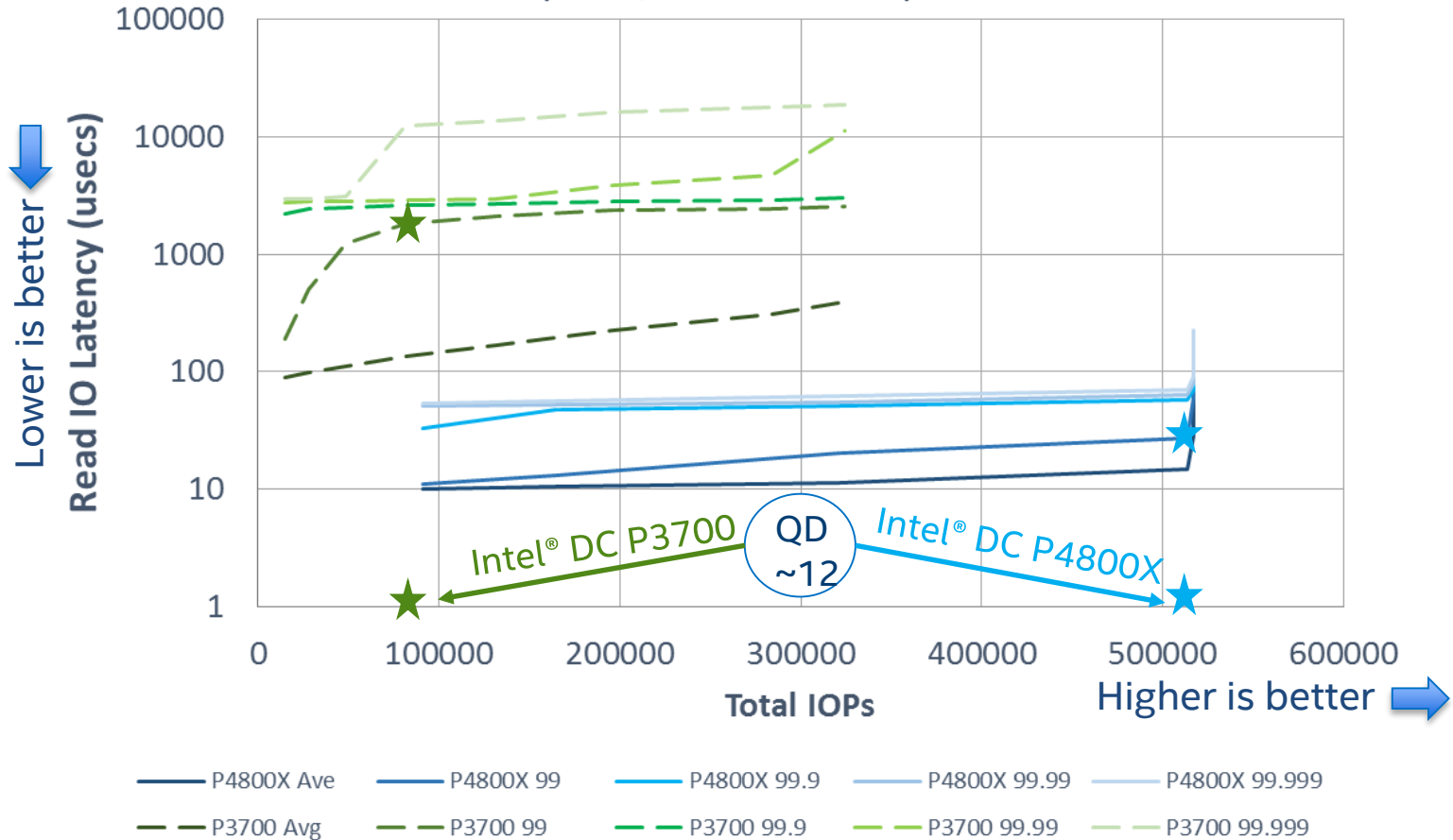
**Ultra  
Endurance**



# Storage Performance Characterization

Latency vs. Load<sup>1</sup>: NAND SSD vs. Intel® Optane™ SSD (Intel® SSD DC P3700 vs. Intel® Optane™ SSD DC P4800X)

(70Read/30Write Random 4kB)



**10x latency reduction**

- < 10usec latency<sup>2</sup>

**100x QoS improvement**

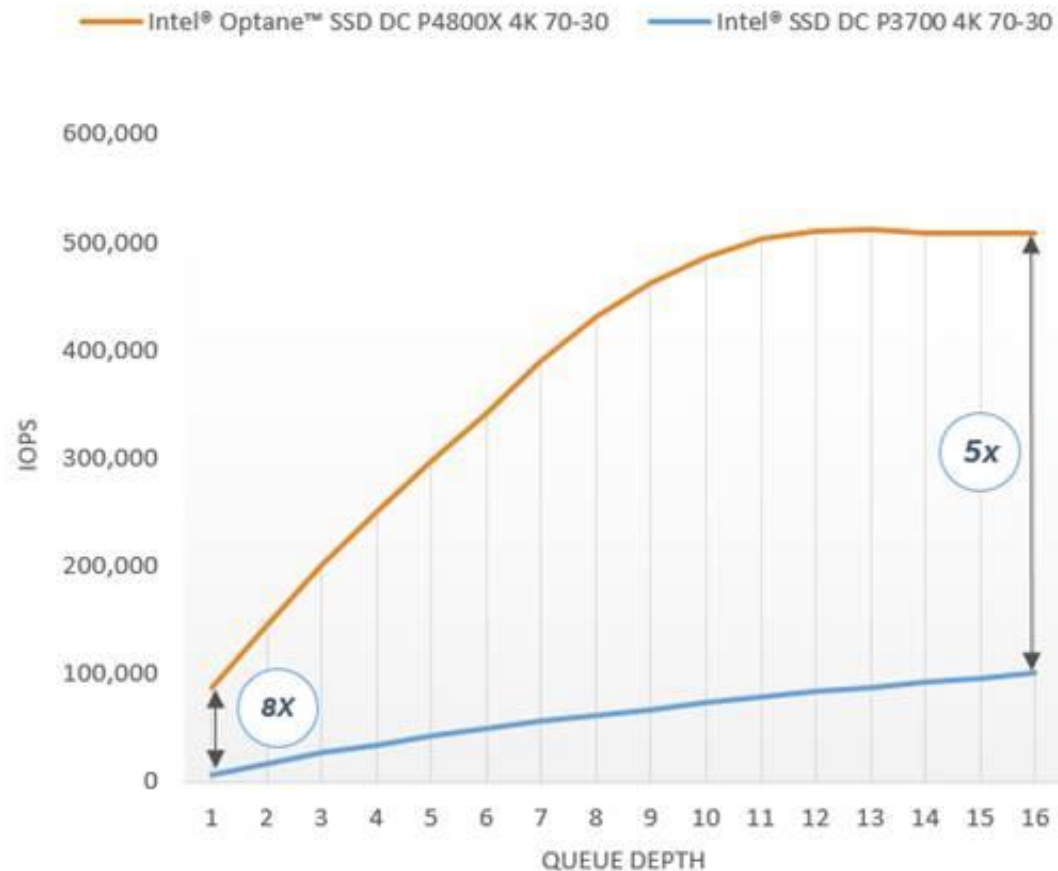
- < 200usec 99.999th r/w<sup>2</sup>

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

4K 70/30 RW Performance at Low Queue Depth



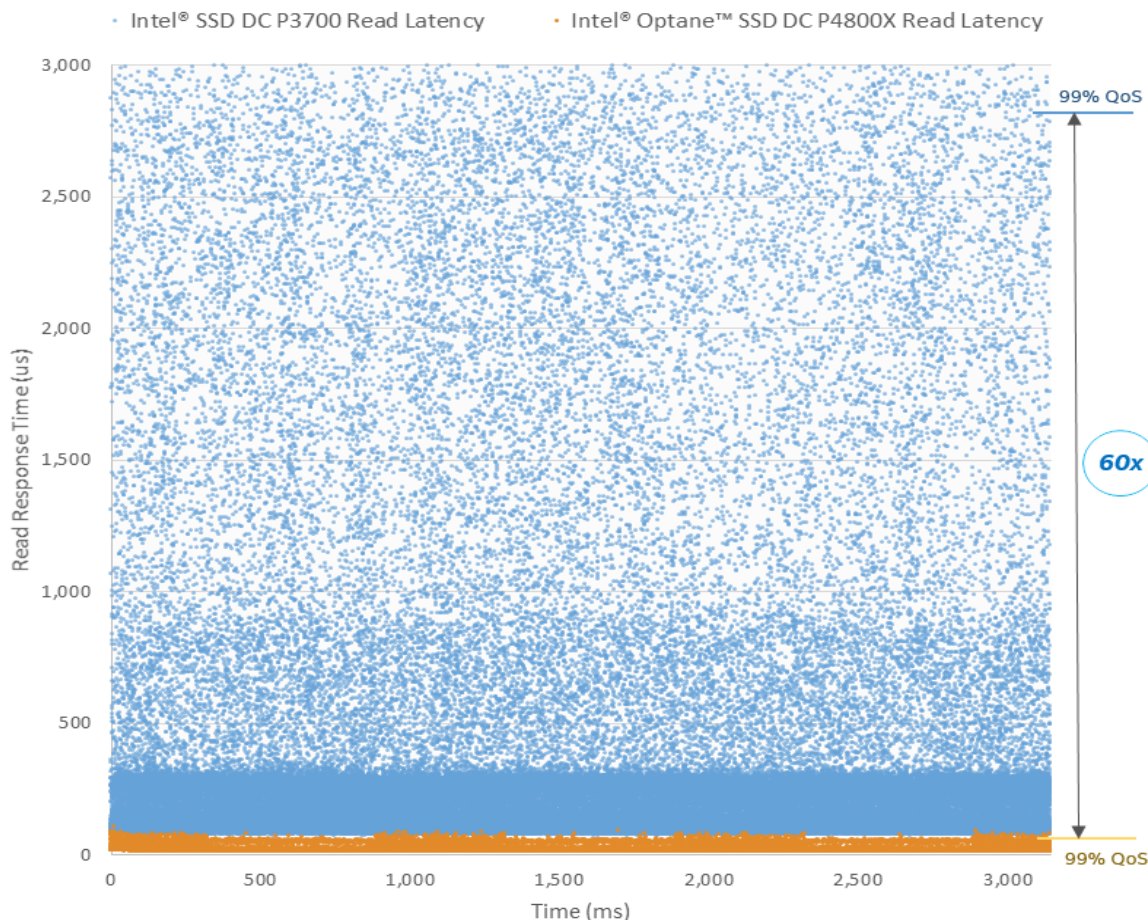
- ✓ **5-8x faster** at low Queue Depths<sup>1</sup>
- ✓ Vast majority of **applications generate low QD** storage workloads

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

Read QoS in Mixed Workload



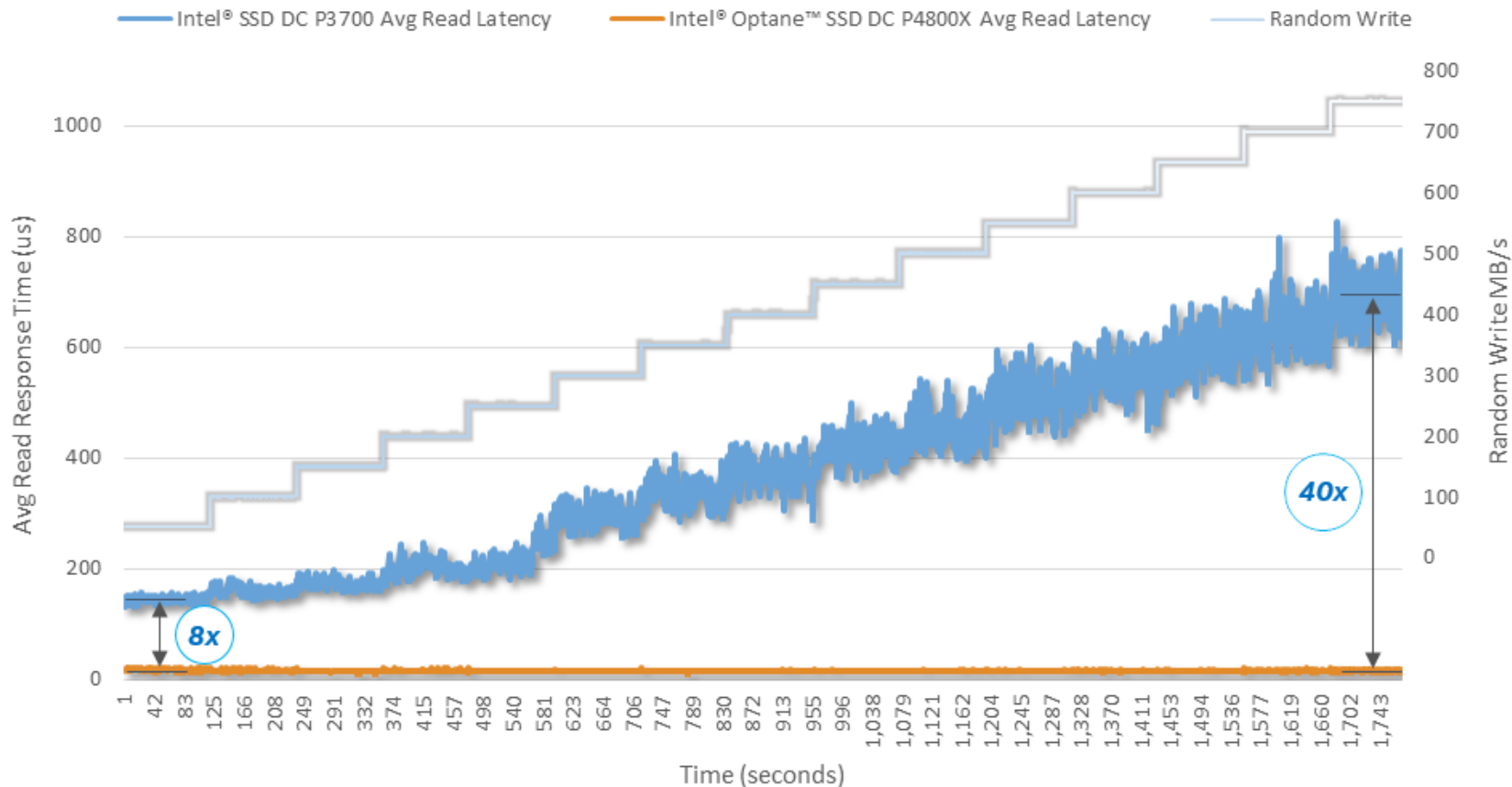
✓ up to **60x** better at 99% QoS<sup>1</sup>

✓ 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

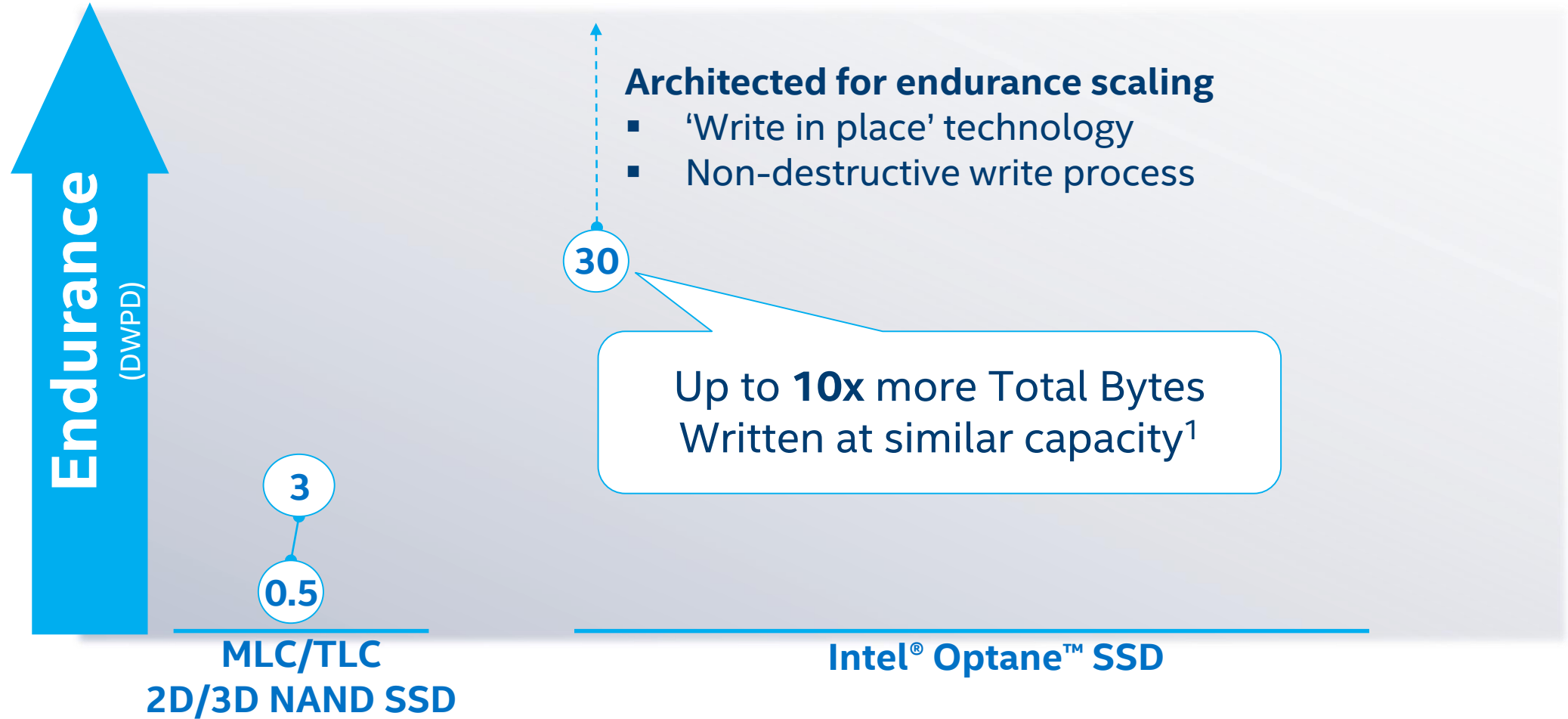
Average Read Latency under Random Write Workload



- ✓ up to **40x faster response time** under workload<sup>1</sup>
- ✓ Consistently **amazing response time under load**

<sup>1</sup> 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

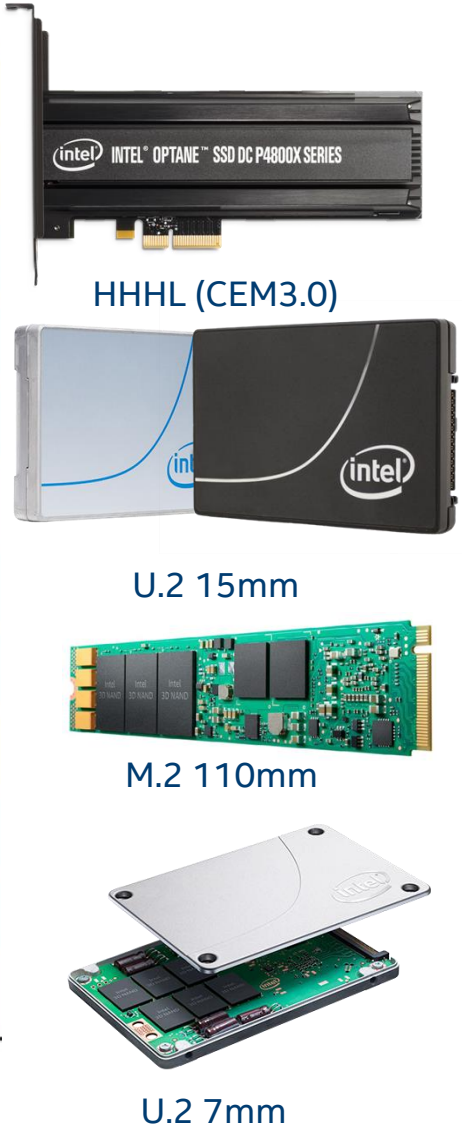


1. Comparing projected Intel® Optane™ SSD 750GB specifications to actual Intel® SSD DC P4600 1.6TB specifications. Total Bytes Written (TBW) calculated by multiplying specified or projected DWPD x specified or projected warranty duration x 365 days/year. Tests document performance of components on a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

# Intel® Data Center SSDs – Current Products

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
	Standard	SATA	DC S4600; 2.5": 240GB, 480GB, 960GB, 1.92TB
			DC P4510; U.2 15mm: 1TB, 2TB, 4TB, 8TB
		PCIe*	DC P4500; U.2 15mm: 1TB, 2TB, 4TB AIC: 4TB
			SATA
		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



\*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<sup>1</sup>
- Consolidate racks to **reduce opex**
- System-based design approach enables **more efficient solutions**

## Efficient Management at Scale

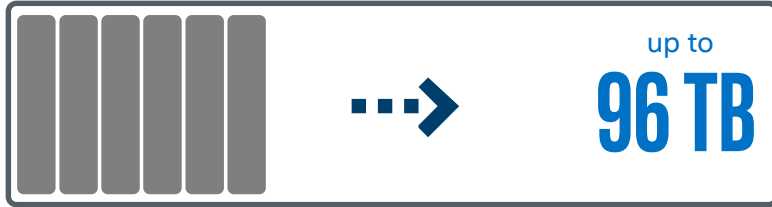


- **Front loading** and **hot swappable**
- Integrated power cycling enables **remote, drive specific reboot**
- Expanded and programmable LEDs enable **indication of more device states**

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 **per Server**

## 2U SERVER



## U.2 15MM 4TB



**STORAGE CAPACITY**  
**5.3x MORE TB PER RACK UNIT<sup>1</sup>**

## 1U SERVER



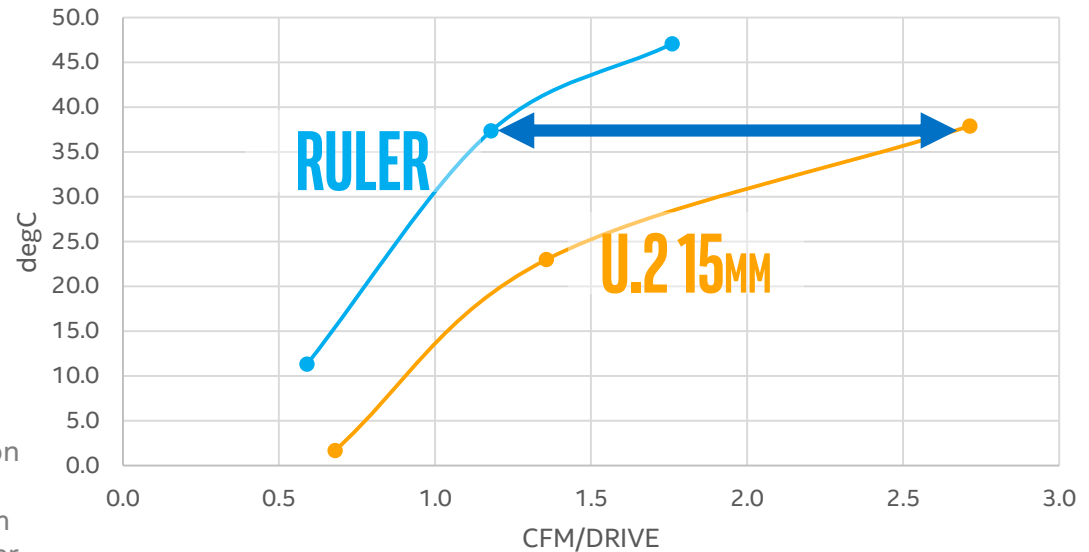
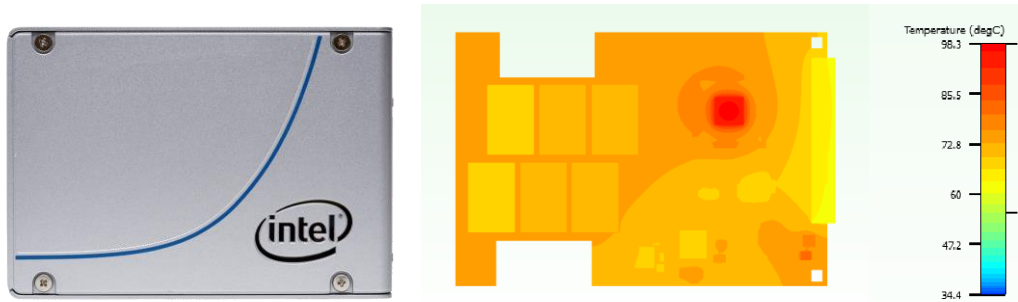
## RULER 8TB



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<sup>1</sup> vs U.2 15MM**

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.

# Built in Serviceability

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



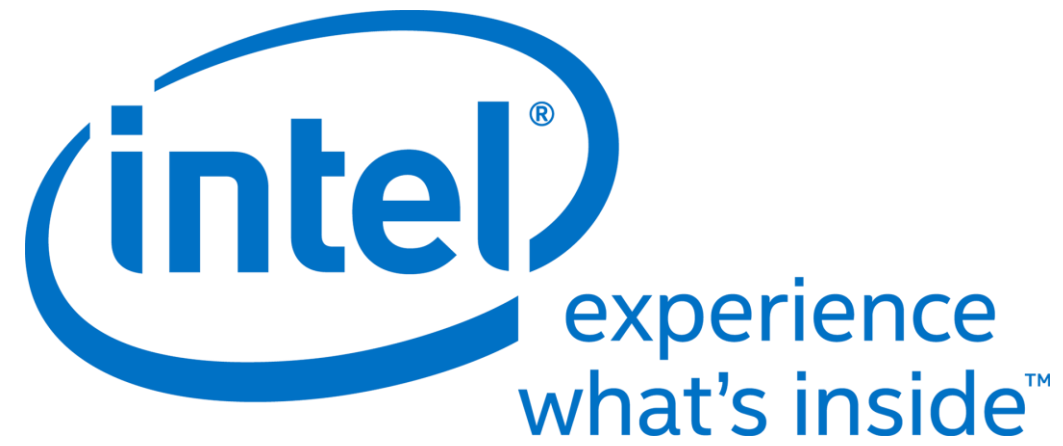
**Carrier-less design with integrated pull tab** removes need for drive carriers



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

# “Ruler” Form Factor for Intel SSDs Roadmap

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





# 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>.

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.

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>.

Intel's compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations not specific to Intel microarchitecture are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice.

Cost reduction scenarios described are intended as examples of how a given Intel-based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction.

Intel does not control or audit third-party benchmark data or the web sites referenced in this document. You should visit the referenced web site and confirm whether referenced data are accurate.

© 2018 Intel Corporation.

Intel, the Intel logo, and Intel Xeon are trademarks of Intel Corporation in the U.S. and/or other countries.

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