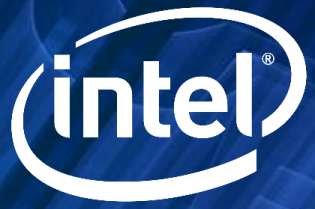


Break Through the Bottlenecks With

INTEL® OPTANE™ TECHNOLOGY

And Store More With

INTEL® QLC 3D NAND TECHNOLOGY

Rob Crooke

Senior Vice President, GM

Non-Volatile Memory (NVM) Solutions Group

NSG STRATEGY: ADJACENT, DISRUPTIVE GROWTH

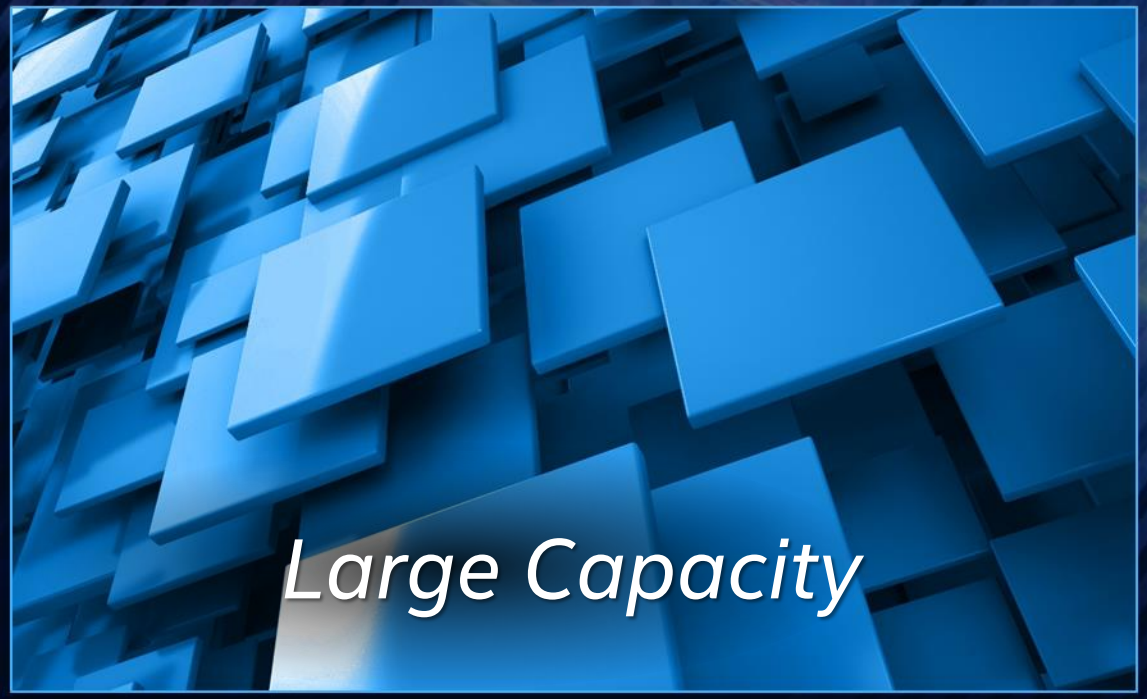
TECHNOLOGY DRIVEN

CUSTOMER INSPIRED

PLATFORM CONNECTED

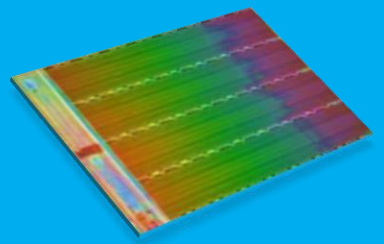
COMPUTER STORAGE ARCHITECTURE

CAPACITY DATA



WORKING DATA

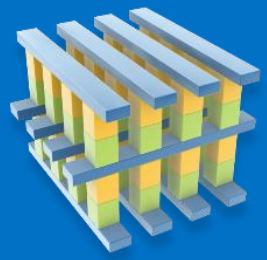
INTEL IS A LEADER IN TWO TECHNOLOGIES



INTEL® 3D NAND TECHNOLOGY

LOWER COST AND HIGHER DENSITY

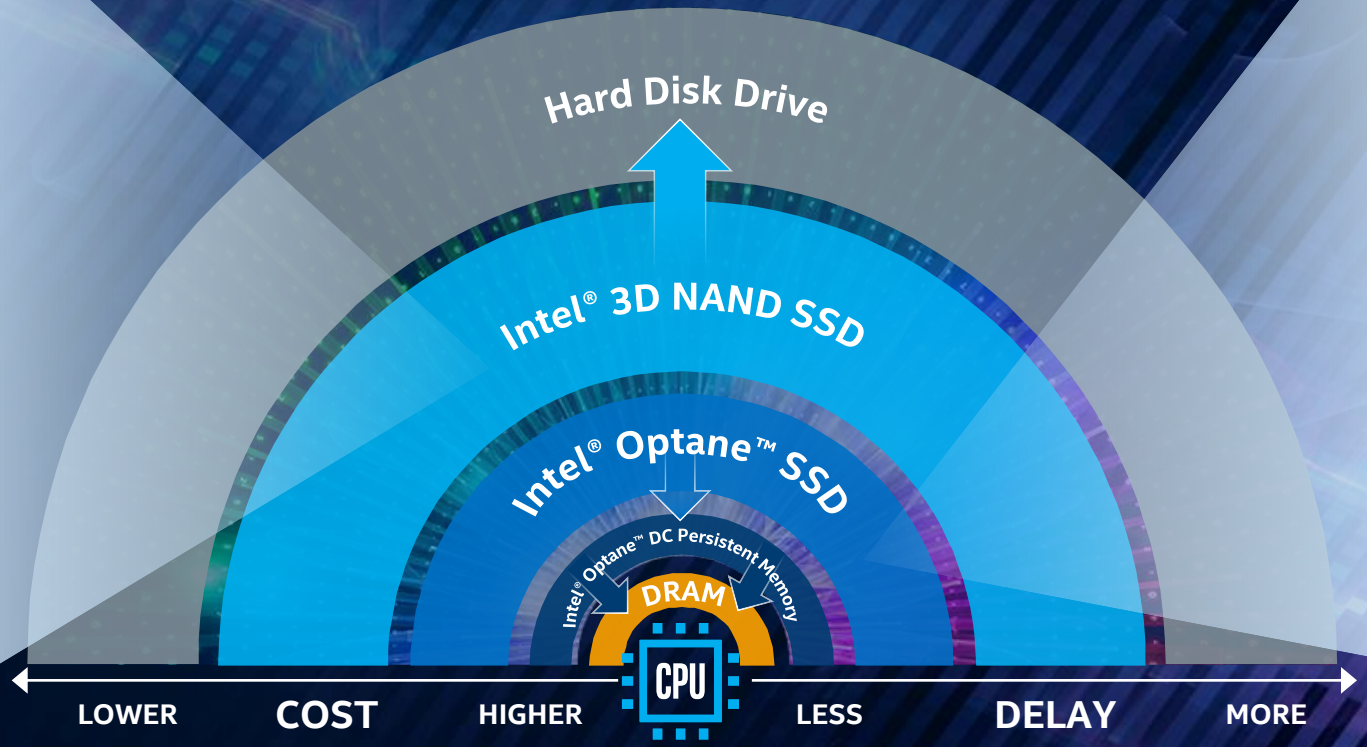
Bulk storage



INTEL® OPTANE™ TECHNOLOGY

HIGHER PERFORMANCE

Working storage and memory



INTEL® OPTANE™ TECHNOLOGY

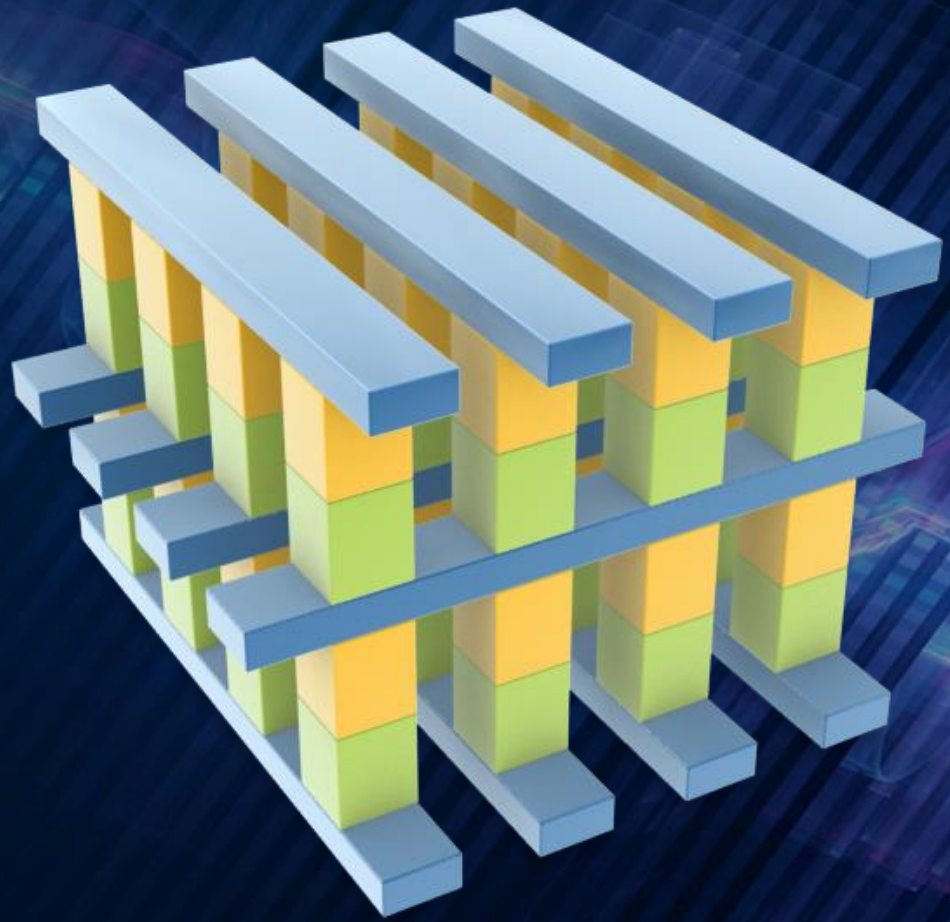
INTEL® 3D XPOINT™ MEMORY MEDIA

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

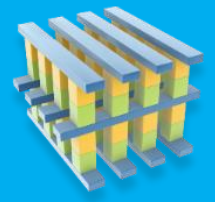
Compatible switch and memory cell materials

High Performance

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

INTEL® OPTANE™ TECHNOLOGY

BUILDING BLOCKS



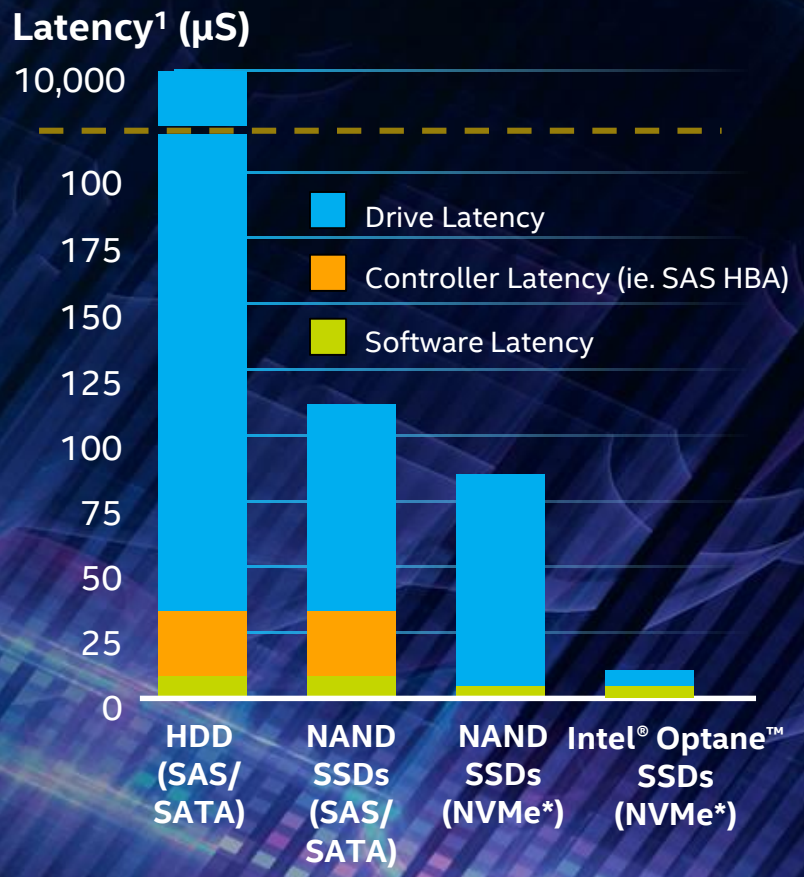
Intel® 3D XPoint™ Memory Media

+

- **Intel Interconnect IP**
- **Intel Software**
- **Intel Memory and Storage Controllers**

END-USER VALUE[1]

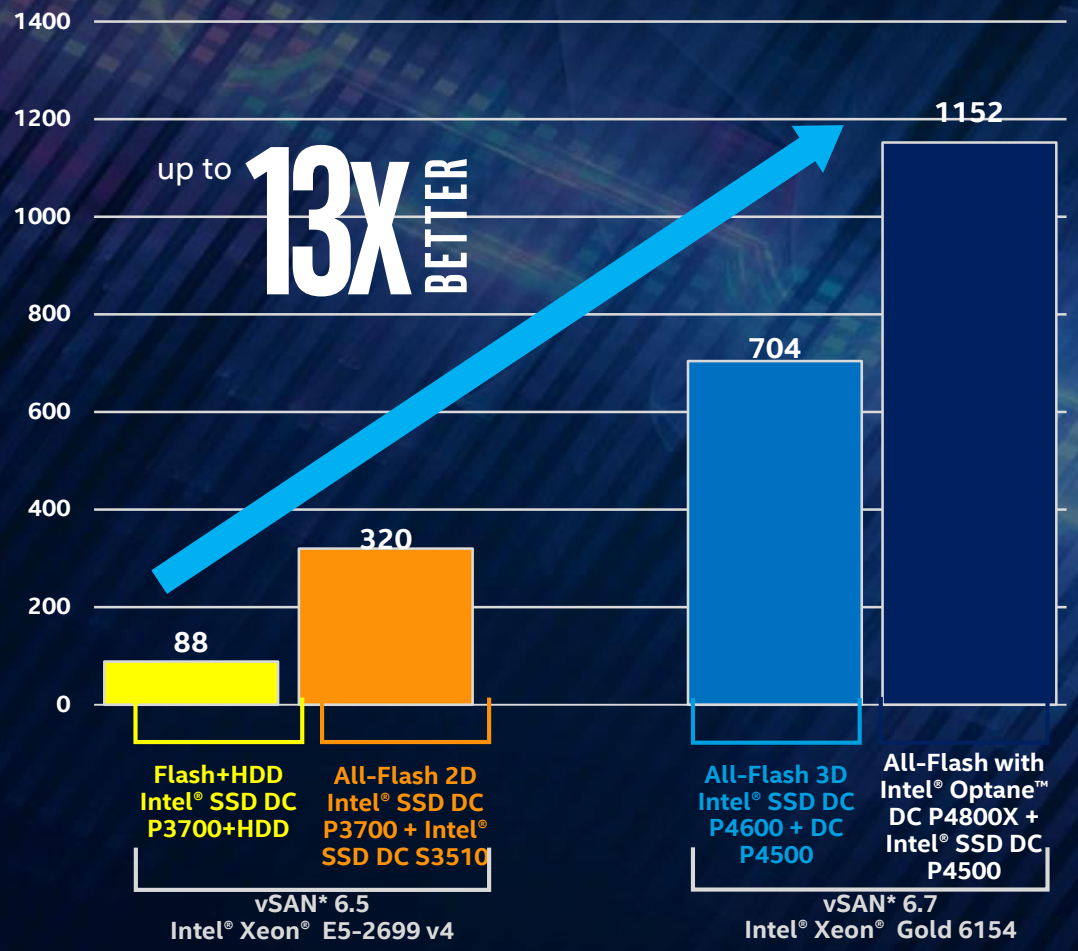
- **High** Endurance
- **Responsive under load** Low latency
- **Predictably fast service** QoS
- **Breakthrough performance** IOPS



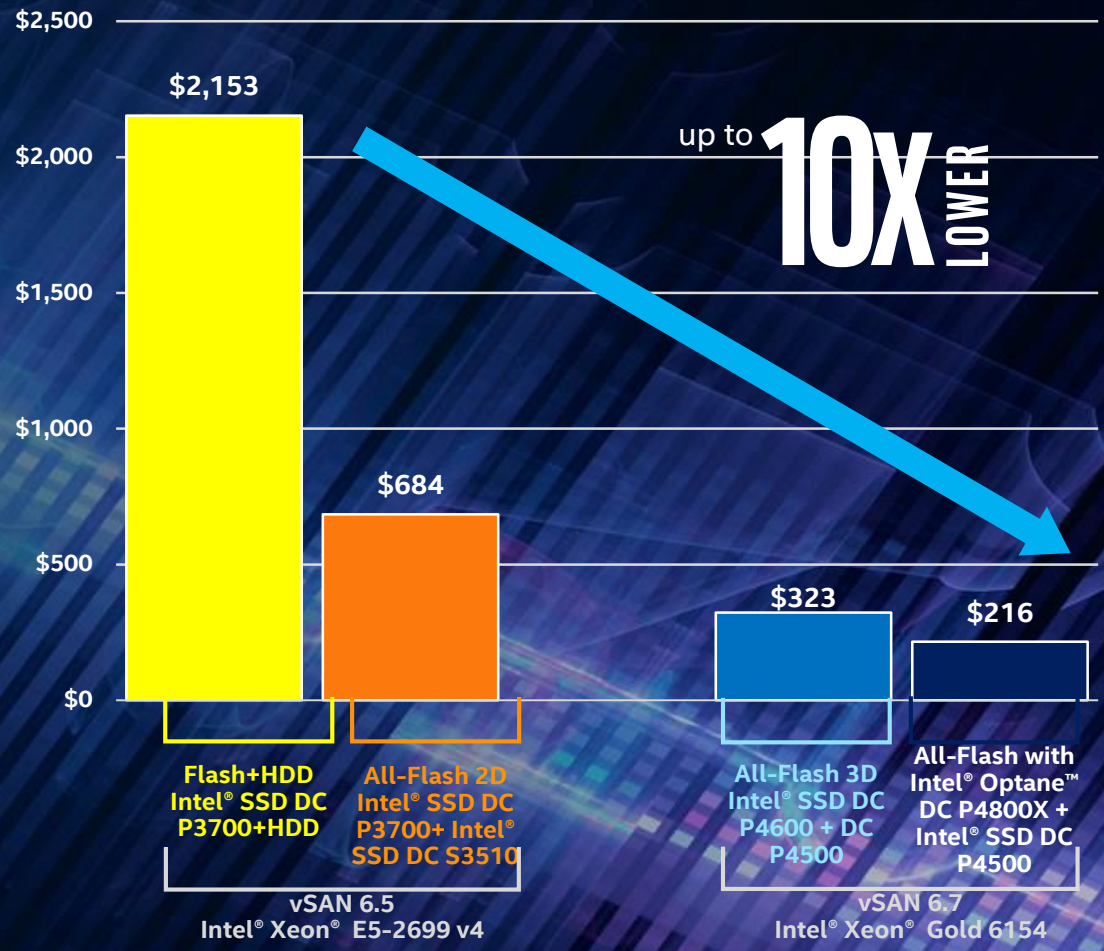
[1] Source – Intel-tested: Average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 3.1. Common Configuration - Intel 2U Server System, OS CentOS 7.5, kernel 4.17.6-1.el7.x86_64, CPU 2 x Intel® Xeon® 6154 Gold @ 3.0GHz (18 cores), RAM 256GB DDR4 @ 2666MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P4600 1.6TB. Latency – Average read latency measured at QD1 during 4K Random Write operations using FIO 3.1. Intel Microcode: 0x2000043; System BIOS: 00.01.0013; ME Firmware: 04.00.04.294; BMC Firmware: 1.43.91f76955; FRUSDR: 1.43. SSDs tested were commercially available at time of test. The benchmark results may need to be revised as additional testing is conducted. Performance results are based on testing as of July 24, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. 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 www.intel.com/benchmarks. *Other names and brands may be claimed as the property of others

A CLEAR ADVANTAGE : INTEL® XEON® AND INTEL® OPTANE™ TECHNOLOGY

VM Performance (IOmark-VM): 4-Node HCI



$/VM (IOmark-VM): 4-Node HCI



Tests by The Evaluator Group. See config details at https://www.evaluatorgroup.com/document/lab-insight-latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. Tested using IOmark-VM. Performance results are based on testing as of August 20, 2018 and may not reflect all publicly available security updates. See product configuration disclosure details. No product can be absolutely secure. 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 sstems, 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 www.intel.com/benchmarks.
* Other names and brands may be claimed as the property of others.

VMware vSAN* Storage Consolidation vs. 3D NAND SSDs

Goal: Achieve about 1000 IOMark VMs*

	Current-Gen All-Flash Solution	Intel® Optane™ DC SSD-Based Solution	Intel Optane DC Solid State Drive
# of Nodes Required	6 Node Cluster	4 Node Cluster	up to **30%** the storage consolidation
IOMark* VMs (higher is better)	1056	1152	up to **60%** the IOMark* VMs per Node[1]
Estimated 3-year Server Costs (lower is better)	~$365,000[2] USD	~$270,000[3] USD	about **25%** Lower 3-year estimated cost
	CPU: Intel® Xeon® Gold 6154 Processor **Cache:** Intel® SSD DC P4600 (PCIe*) **Capacity:** Intel® SSD DC P4500 (PCIe*) **Software:** VMware vSAN* 6.7	**CPU:** Intel® Xeon® Gold 6154 Processor **Cache:** Intel® Optane™ SSD DC P4800X **Capacity:** Intel® SSD DC P4500 (PCIe*) **Software:** VMware vSAN* 6.7	• **Same CPU** • **Swapped in Intel® Optane™ SSD**

[1] Tests by The Evaluator Group. 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 www.intel.com/benchmarks. Configuration details available from The Evaluator Group at https://www.evaluatorgroup.com/document/lab-insight-latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. See Appendix A for server cost estimate details and assumptions.

[2] Source – Intel. Estimated HW,SW,MEDIA,MAINT costs = $348,000.; Estimated power & infrastructure costs = $17,000. 6-node 3D NAND-based cluster needed to support the approximate same number of VMs vs. 4-Node Intel® Optane™ SSD Configuration

[3] Source – Intel. Estimated HW,SW,MEDIA,MAINT costs = $255,000 ; Estimated power & infrastructure costs = $15,000

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

VMware vSAN* Storage Consolidation Upgrade Scenario

Goal: Achieve about 1000 IOMark VMs*

	PRIOR-GEN ALL-FLASH SOLUTION	INTEL® OPTANE™ DC SSD-BASED SOLUTION	
# of Nodes Required	14 NODE CLUSTER	4 NODE CLUSTER	up to **3X** the storage consolidation
IOMark VMs (higher is better)	1120	1152	up to **3.5X** the IOMark VMs per Node[1]
Estimated 3-year Server Costs (lower is better)	~$810,000[2] USD	~$270,000[3] USD	about **65%** Lower 3-year estimated cost
	CPU: Intel® Xeon® E5-2699 v4 Processor **Cache:** Intel® SSD DC P3700 (PCIe*) **Capacity:** Intel® SSD DC S3510 (SATA) **Software:** VMware vSAN* 6.2	**CPU:** Intel® Xeon® Gold 6154 Processor **Cache:** Intel® Optane™ SSD DC P4800X **Capacity:** Intel® SSD DC P4500 (PCIe*) **Software:** VMware vSAN* 6.7	**Swapped in next-gen CPU and Intel® Optane™ SSD**

intel OPTANE™ DC SOLID STATE DRIVE

[1] Tests by The Evaluator Group. 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 www.intel.com/benchmarks. Configuration details available from The Evaluator Group at https://www.evaluatorgroup.com/document/lab-insight-latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. See Appendix A for server cost estimate details and assumptions.

[2] Source – Intel. Estimated HW,SW,MEDIA,MAINT costs = $785,000.; Estimated power & infrastructure costs = $25,000. 14-node 2D NAND-based cluster needed to support the approximate same number of VMs vs. 4-Node Intel® Optane™ SSD Configuration

[3] Source – Intel. Estimated HW,SW,MEDIA,MAINT costs = $255,000 ; Estimated power & infrastructure costs = $15,000

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

INTEL® PORTFOLIO FOCUS

CLIENT

DATA CENTER

DRAM		
INTEL® OPTANE™ MEMORY	Expanded Memory	INTEL® OPTANE™ DC PERSISTENT MEMORY
INTEL® OPTANE™ SSDs	Working Data	INTEL® OPTANE™ DC SSDs
INTEL® 3D QLC NAND SSDs	Capacity Data	INTEL® 3D QLC NAND SSDs
HDD		

Products not shown to scale

NEXT GENERATION DATA CENTER STORAGE

INNOVATIVE FORM FACTORS

1PB IN 42U

w/2 TB HDDs

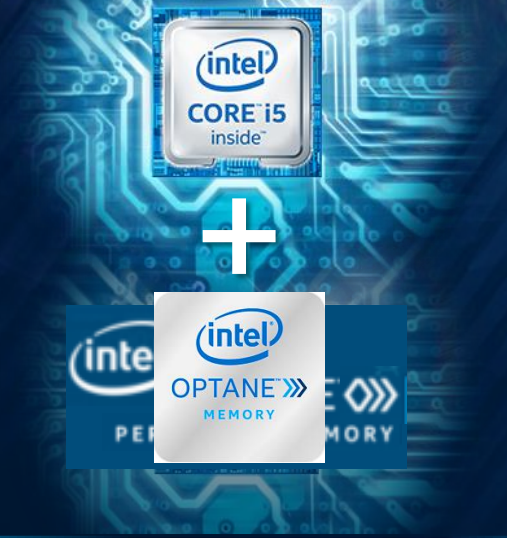
1PB IN 1U

w/INTEL® 3D NAND SSDs

THE FUTURE OF CLIENT STORAGE & MEMORY

Higher Performance, Lower Cost, Easier Migration

WORKING DATA



OPTIONS FOR CAPACITY DATA

DISRUPT WITH INTEL® OPTANE™ TECHNOLOGY

DISCIPLINED INVESTMENT

INTEL® OPTANE™ TECHNOLOGY

Intel Fab 11X: Rio Rancho, New Mexico

INTEL® 3D NAND TECHNOLOGY

Intel Fab 68: China

CAPACITY FOR OUR DEMAND

Based on internal forecasting 2016-2017. Forecasts are Intel estimates, based upon current expectations and available information and are subject to change without notice.


intel®

APPENDIX A – VMWARE VSAN* SERVER TESTING AND COST ESTIMATES

Source: The Evaluator Group tested. Config details at https://www.evaluatorgroup.com/document/lab-insight-latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. Tested using IOmark-VM*. System Cost based on publicly available list prices for storage, CPU, memory, networking, chassis, software as of October 16, 2018. Networking switches/cabling costs not considered. Licensing cost included as appropriate. Operating Expenses calculated over 3 year window, factoring in: System Power is sum of the system TDP (CPU TDP and 90/10 read/write active power for SSD as shown at ark.intel.com). A 1.2 (20% inefficiency) Power Usage Effectiveness (PUE) multiplier is applied across total cluster wattage. $0.12 KW/hour price is applied over 3 year 24/7/365 usage. Footprint is estimated cost of solution rack space. $96/sq ft/yr cost is applied with each rack using 25 sq ft. One rack has maximum 24 KW power limit, up to 42U available rack height. Full and partial racks incur same footprint cost. Cluster Size - a target performance metric is chosen based on example customer requirements, and per system performance is applied to estimate number of servers to meet requirement. 100% performance scaling assumed unless otherwise noted. 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. Performance results are based on testing as of August 20, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. 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.

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