FORM FACTOR INNOVATION
"RULER" FORM FACTOR FOR INTEL® SSDs

Jonmichael Hands, Roger Corell

Intel Non-volatile Memory Solutions Group (NSG)

August 2017

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 hotplug support and requires carrier cards / heatsinks to manage thermals

U.2

U.2 2.5in x 15mm and 7mm supports hotplug 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 capacity per drive and per server and per rack
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.**

"Ruler" form factor for Intel® SSD DC P4500 available by end of 2017.

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**

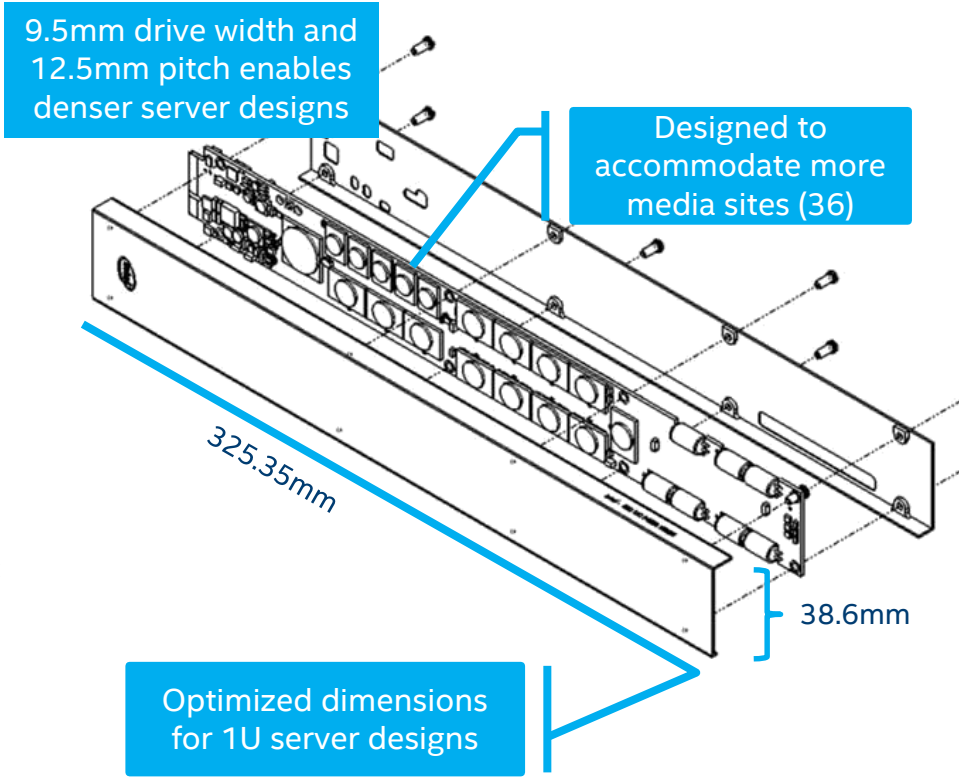
1. Source – Intel. Results have been estimated or simulated using internal analysis or architecture simulation or modeling, and provided for informational purposes. Simulation includes "ruler" form factor for Intel® SSD DC P4500 4TB ruler, U.2 15mm Intel® SSD DC P4500, 3 drives in sheet metal representation 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 per Drive

U.2 2.5in designed to share physical dimensions with HDDs, platter size dictated form factor

High capacity U.2 SSDs require more complex flex PCB

M.2 designed for thin and light client and mobile systems, not intended to be serviced (hot-plug) during operation. Limited NAND sites, 110mm has 6



Optimized for Space Efficient Capacity per Server

2U SERVER

U.2 15MM 4TB

1U SERVER

RULER 8TB

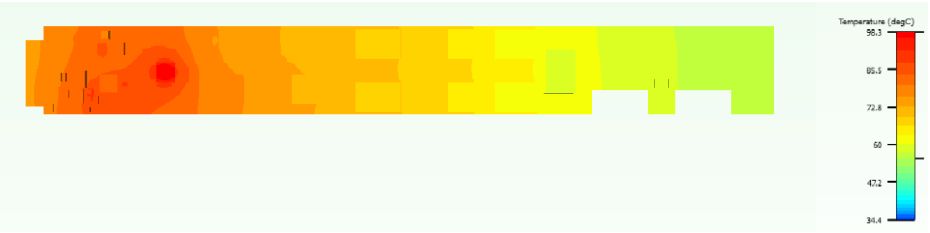
STORAGE CAPACITY

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

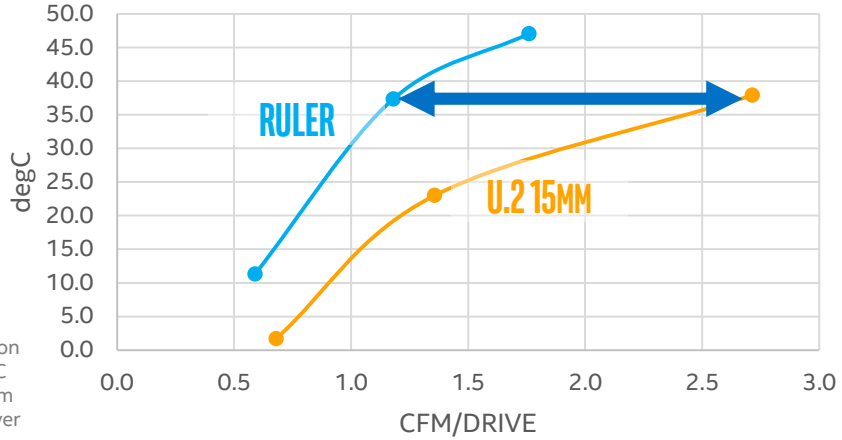
1. Source – Intel. Comparing maximum capacity per 1 rack unit of Intel® Server Board S2600WP Family, 24 U.2 bay option using 4TB U.2 15mm Intel® SSD DC P4500 to8TB Intel® AF1000 Server design, 32 "ruler" drive bays using 8TB "ruler" form factor for Intel® SSD DC P4500.

Thermal Efficient Design



THERMAL EFFICIENCY

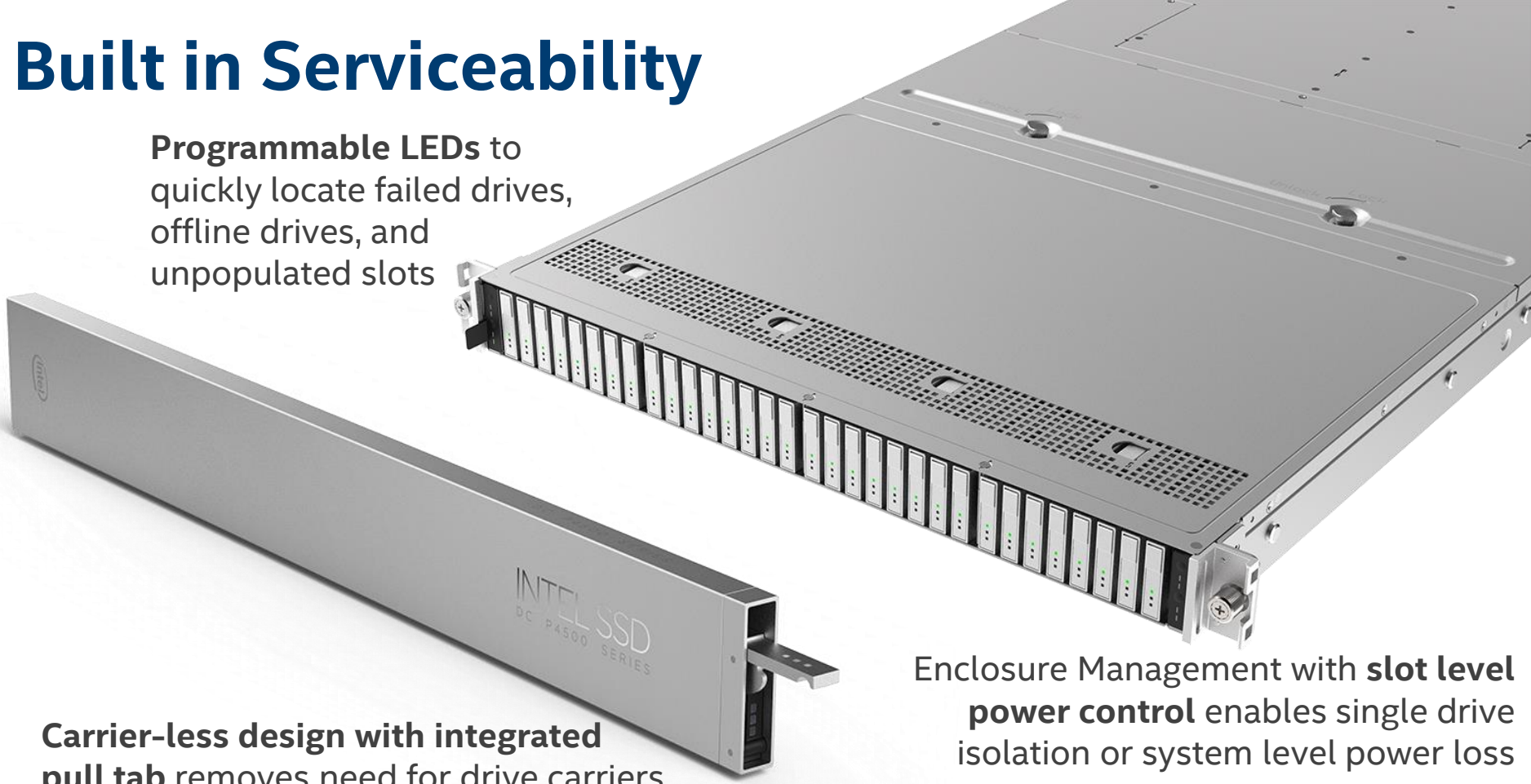
UP TO 55% LESS AIRFLOW[1] VS U.2 15MM



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

Roadmap to 1PB in 1U in 2018

1PB IN 42U
w/2 TB HDDs

STORAGE CAPACITY

1PB IN 1U

INTEL® 3D NAND SSD, 32TB RULER IN 2018

Opening up new use cases in warm storage with disruptive total cost of ownership

“Ruler” form factor for Intel SSDs roadmap

- Move Ruler to compliance with EDSFF specifications once they are finalized and released.
- Expand portfolio to include Intel® Optane™ SSDs in 2018