



## Testing NVMe® Today and Tomorrow

Sponsored by NVM Express organization, the owner of NVMe specifications



### Speaker



#### Carter Snay

**Technical Manager** 

UNH-IOL







The UNH-IOL and the Beginning of IOL and ICC NVMe<sup>®</sup> Testing

**Test Tool Information** 

**Testing NVMe Technology** 

The Refactoring Effort

NVMe 2.0 Specifications and Beyond





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## What the UNH-IOL Does



Tests a wide variety of technologies, student driven, staff managed

Neutral 3rd-party testing facility

### Host Plugfests and Testing Events





# Origin of NVMe<sup>®</sup> Specification and Importance of Testing

- Started with PCIe<sup>®</sup> as only transport
  - Admin and NVM I/O Command Sets
  - Testing for the last decade
  - Conformance and Interoperability Testing
    - Why?
      - Making sure the product "just works!"





### **Test Plans Based on the Specifications**

- Test published by the UNH-IOL, written in conjunction with the NVMe<sup>®</sup> Interop and Compliance Work Group
- Originally, 2-3 test plans were required for listing on Integrator's List
  - UNH-IOL NVMe Conformance (NVMe-oF Conformance added later)
  - UNH-IOL NVMe Interoperability
  - UNH-IOL NVMe-MI<sup>™</sup> Conformance (if supported)



#### **Test Plan Development Process**

Updates to test plans happen twice a year in order to keep pace with updates to the NVMe® specifications being developed at <u>nvmexpress.org</u>

All test plan updates are created by NVMe Interop and Compliance Committee. All updates are approved and voted on by the NVMe Technical Work Group and the NVMe Board of Directors.



4

All new tests added are made FYI, since in many cases there are no existing product in the market. This gives time for the test plan, DUT, and test scripts to be vetted.



#### NVMe Test Plans

The test plans on this page may be downloaded and used for internal purposes only. The test plans may not be commercialized in any way without express permission of the UNH-IOL.

The NVMe testing service currently offers the following test plans. These documents are constantly being updated to improve readability and to reflect the current specifications. Please contact us if you would like more information or have questions about the NVMe testing service.

When testing based on the following test plans is performed, all reports generated will be digitally signed using an Adobe digital certificate. Upon reception of the report, the recipient can verify its authenticity using our document validation instructions.

#### IOL

#### Conformance

→ UNH-IOL NVMe Conformance v16.0 (PCIe based NVMe SSDs and NVMe-oF NVM Subsystems)

▶ UNH-IOL NVM Command Set Conformance v17.0

▶ UNH-IOL NVMe-MI Conformance v17.0

▶ UNH-IOL NVMe ZNS Command Set Conformance v17.0

▶ UNH-IOL NVMe PCIe Transport Conformance v17.0

• UNH-IOL NVMe Conformance v15.0 (PCIe based NVMe SSDs and NVMe-oF NVM Subsystems)

▶ UNH-IOL NVMe-ZNS Conformance v16.0

▶ UNH-IOL NVMe-ZNS Conformance v15.0

▶ UNH-IOL NVMe-MI Conformance v16.0

UNH-IOL NVMe-MI Conformance v15.0

#### Interoperability

▶ UNH-IOL NVMe Interoperability v16.0 (PCIe based NVMe Hosts and SSDs)

▶ UNH-IOL NVMe PCIe Interoperability v17.0

• UNH-IOL NVMe Interoperability v15.0 (PCIe based NVMe Hosts and SSDs)



#### The NVMe<sup>®</sup> Integrator's List

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#### NVMe<sup>™</sup> Integrator's List

The WMe Integrator's List (IU) contains useful information about MMe Products that UNH-IOL has performed interoperability and conformance testing during an WMe pulgetor of through test reservations are out als. Successful completion of such conformance tests when combined with statisticary operation in UNH-IOLS interoperability tests provides a reasonable level of confidence that the Product Under Erst will function property in many VMe environments.

UNH-IOL is happy to be collaborating with the NVMe Organization on the creation and maintenance of the NVMe Integrators List. More information on NVMe Products can be found at nvmexpress.org/products.

#### NVMe™ Integrator's List v16.0 | NVMe-oF™ Integrator's List

NVMe Integrator's List Policy v16.0

#### NVMe Devices

Product Name + Firmware Version	Product Type	PCIe Gen	NVMe Base Spec Version	NVMe- MI Spec Version	Form Factor	I/O Command Sets Supported	Interop Program Revision	Date Listed	Further Info
SK Hynix PC801 Firmware Version: 51020A20	NVMe SSD	Gen4	1.4	N/A	M.2	NVM	v16.0	May 10, 2022	www.skhynix.com
SK Hynix BC801 Firmware Version: C000H001	NVMe SSD	Gen4	1.4	N/A	M.2	NVM	v16.0	May 10, 2022	www.skhynix.com
Longsys XP2100 Firmware Version: V1.1.2	NVMe SSD	Gen4x4	1.4	N/A	M.2	NVM	v16.0	April 22, 2022	www.longsys.com
Longsys XP1000 Firmware Version: V1.22	NVMe SSD	Gen3x4	1.4	N/A	M.2	NVM	v16.0	April 22, 2022	www.longsys.com
Samsung PM174x Firmware Version: OPP70B54	NVMe SSD	Gen5	1.4	1.1	U.2/E3.S	NVM	v16.0	April 20, 2022	www.samsung.com/sec
Samsung PM9B1 Firmware Version: HVC7002U	NVMe SSD	Gen4	1.4	NA	M.2	NVM	v16.0	April 20, 2022	www.samsung.com/sec
Phison PS5015-E15T Firmware Version: EHFM80.0	NVMe SSD	Gen3	1.4	N/A	M2 2280	NVM	v16.0	April 11, 2022	https://www.phison.com/zh-tw
Phison PS5021-E21T Firmware Version: ELFMB0.2	NVMe SSD	Gen4x4	1.4	N/A	M2 2280	NVM	v16.0	April 11, 2022	https://www.phison.com/zh-tw
Shenzhen Unionmemory Information System Ltd. AM6A0 Firmware Version: 1.0C06A0	NVMe SSD	Gen4	1.4	N/A	M.2	NVM	v16.0	March 28th, 2022	http://www.unionmem.com/
Shenzhen Unionmemory Information System Ltd. AH660 Firmware Version: 1.0C0660	NVMe SSD	Gen4	1.4	N/A	M.2	NVM	v16.0	March 28th, 2022	http://www.unionmem.com/
Shenzhen Unionmemory Information System Ltd. AM6A1 Firmware Version: 1.0C06A1	NVMe SSD	PCIe Gen4	1.4	N/A	M.2	NVM	v16.0	March 28th, 2022	http://www.unionmem.com/
Seagate <sup>®</sup> Nytro <sup>®</sup> 5350 Firmware Version SE0SA300	NVMe SSD	Gen 4	1.4	1.1	U.2 and U.3	NVM	16.0	March 14th, 2022	https://www.seagate.com/as/er
Longsys FORESEE P709 Firmware Version: V0104A0	NVMe SSD	Gen 3x4	1.3	NA	M.2	NVM	16.0	March 8th, 2022	www.longsys.com
Longsys FORESEE XP2000	NVMe	Gen	1.4	NA	M.2	NVM	16.0	March	www.longsys.com

Longsys XP1000(P100B) 2230 Firmware Version: 1.21	NVMe SSD	Gen 3x4	1.4	NA	M.2	NVM	16.0	March 8th, 2022	www.longsys.com
YMTC PE320 Firmware Version: Y4001T28	NVMe SSD	Gen4	1.4	NA	U.2	NVM	v16.0	March 3rd, 2022	TBA
DERA D6000 Series NVMe SSD (D6436/D6437/D6456/D6457) Firmware Version: D6K0000Q	NVMe SSD	Gen3	14	NA	U.2	NVM	v16.0	February 28, 2022	www.derastorage.com
Micron 2400 NVMe SSD Firmware Version: 23A2400U	NVMe SSD	Gen4	1.4	NA	M.2	NVM	v16.0	February 22th, 2022	www.micron.com
ADATA Technology IM2P32A8 NVMe SSD Firmware Version: D211202a	NVMe SSD	Gen3 x4	1.4	NA	М.2	NVN	v16.0	February 9th, 2022	industrial.adata.com
Phison PS5020-E20 Firmware Version: EKFM30E7	NVMe SSD	Gen4	1.4	1.1	U.2 and U.3	NVM	v16.0	January 31, 2022	https://www.phison.com/zh-tw/
Inspur NS8500/NS8600 G2 Firmware Version: MM5N8024	NVMe SSD	Gen4	1.4	NA	U.2	NVN	v16.0	January 27, 2022	https://inspur.com/
Dapustor Corporation J5100 Firmware Version: FF00202A	NVMe SSD	Gen4	1.4	NA	U.2	NVM	v16.0	January 21, 2022	dapustor.com
Dapustor Corporation R5100 Firmware Version: FF00202A	NVMe SSD	Gen4	1.4	NA	U.2	NVM	v16.0	January 21, 2022	dapustor.com
Dapustor Corporation X2900 Firmware Version: FF00202A	NVMe SSD	Gen4	1.4	NA	U.2	NVM	v16.0	January 21, 2022	dapustor.com
Dapustor Corporation R5110 Firmware Version: FF00202A	NVMe SSD	Gen4	1.4	NA	AIC	NVM	v16.0	January 21, 2022	dapustor.com
Dapustor Corporation J5110 Firmware Version: FF00202A	NVMe SSD	Gen4	1.4	NA	AIC	NVM	v16.0	January 21, 2022	dapustor.com
Western Digital Ultrastar DC SN650 Firmware Version: LA103300	NVMe SSD	Gen4	1.4	MI 1.1	U.2	NVN	v16.0	January 18, 2022	https://www.westerndigital.com/
Intel <sup>®</sup> Optane <sup>™</sup> SSD DC P5810X Series Firmware Version: L0310353	NVMe SSD	Gen4	1.4	MI 1.1	U.2	NVN	v16.0	January 13, 2022	https://www.intel.com/
Intel <sup>®</sup> Optane <sup>™</sup> SSD DC P5811X Series Firmware Version: L0310353	NVMe SSD	Gen4	1.4	MI 1.1	E1.5	NVN	v16.0	January 13, 2022	https://www.intel.com/
Kioxia XG8 NVMe SSD	NVMe SSD	Gen4	1.4	NA	M.2	NVM	v16.0	January 11, 2022	https://www.kioxia.com/en- us/top.html
Micron 7450 Firmware Version: M032, E2MU010, E2MP000	NVMe SSD	Gen4	1.4	1.1	М.2	NVN	v16.0	December 21, 2021	www.micron.com
Longsys FORESEE XP2100 Firmware Version: 1.0.1	NVMe SSD	Gen4	1.4	NA	M.2	NVM	v16.0	December 13, 2021	https://www.longsys.com/
SK Hynix PE8110 Firmware Version: 41090A10	NVMe SSD	Gen4	1.4	1.1b	E1.S	NVM	v16.0	December 7, 2021	www.skhynix.com
KIOXIA CD7 E3.5 Firmware Version: 01A4	NVMe SSD	Gen5	1.4	1.1	E3.5	NVN	v16.0	November 19, 2021	https://business.kioxia.com/en- us/news/2021/ssd-20211108- 2.html
TenaFe TC2200 Dramless SSD Firmware Version: 1030C0F0	NVMe SSD	Gen4	1.4	NA	М.2	NVN	v16.0	November 16, 2021	SSD   TenaFe   Campbell
Micron 3460 Firmware Version: V12RA013	BGA NVMe SSD	Gen4	1.4	NA	M.2	NVM	v16.0	November 23, 2021	www.micron.com
Solid State Storage Technology CL4 NVMe SSD Firmware Version: ET2DQ01	NVMe SSD	Gen4	1.4	NA	M.2	NVM	v16.0	November 17, 2021	www.ssstc.com

Western Digital Ultrastar DC ZN540 Firmware Version:	ZNS NVMe	Gen3	1.3	1.1	U.2	NVM, ZNS	v16.0	November 22, 2021	www.westerndigital.com
R6Z10009	SSD								

#### NVMe™ Integrator's List v15.0 | NVMe-oF™ Integrator's List

NVMe Integrator's List Policy v15.0

#### NVMe Devices

Product Name + Firmware Version	Product Type	PCIe Gen	NVMe Base Spec Version	NVMe- MI Spec Version	Form Factor	Interop Program Revision	Date Listed	Further info
FADU XSH2121 Firmware Version: 2J0044VE	NVMe SSD	Gen4	1.4	NA	U.2	v15.0	February 18, 2022	fadutec.com
FADU XDH2121 Firmware Version: ILZ044VE	NVMe SSD	Gen4	1.4	NA	U.2	v15.0	February 18, 2022	fadutec.com
INEX Labs CNX-8800CA Firmware Version: RTR02060	NVMe SSD	Gen4	1.4	NA	U.2	v15.0	November 16, 2021	www.cnexlabs.com
Kioxia BG5	NVMe SSD	Gen4	1.4	NA	M.2	v15.0	July 15, 2021	https://www.kioxia.com/en- us/top.html
Kioxia XDG-AL Firmware Version: 1EALW02A	NVMe SSD	Gen4	1.3	11	U.2	v15.0	July 15, 2021	https://www.kioxia.com/en- us/top.html
FORESEE P709 Firmware Version:U0506B0	NVMe SSD	Gen3x4	1.3	NA	M.2 2280	v15.0	July 28, 2021	https://www.longsys.com/
FORESEE XP1000 Firmware Version:V1.6	NVMe SSD	Gen3x4	1.4	NA	M.2 2280	v15.0	July 28, 2021	https://www.longsys.com/
Intel SSD D5-P5316 Firmware Version: ACV10101	NVMe SSD	Gen4	1.3	1.0	U.2	v15.0	August 2, 2021	https://www.intel.com/
SK Hynix PC801 Firmware Version: ANZA00V0	NVMe SSD	Gen4	1.4	NA	M.2	v15.0	July 15, 2021	www.skhynix.com
SK Hynix PE8110 Firmware Version: 41191A10	NVMe SSD	Gen4	1.4	NA	E1.S	v15.0	August 8th, 2021	www.skhynix.com
SK Hynix PE8111 Firmware Version: 31281A10	NVMe SSD	Gen3	1.4	NA	E1.L	v15.0	September 7th, 2021	www.skhynix.com
SK Hynix PE9110 Firmware Version: 41092A30	NVMe SSD	Gen4x4	1.4	NA	E1.5	v15.0	September 20th, 2021	www.skhynix.com
SK Hynix BC901 Firmware Version: U0727A	NVMe SSD	Gen4	1.4	NA	M.2	v15.0	August 11th, 2021	www.skhynix.com
Western Digital SN740 Firmware Version: 73035000, 73101000, HPS1	NVMe SSD	Gen4	1.4	NA	M.2 2230, 2242, 2280	v15.0	October 5, 2021	https://www.westerndigital.com/
Western Digital Ultrastar DC ZN540 Firmware Version: L6Z07019	NVMe SSD	Gen3	1.3	ц	U.2	v15.0	July 15, 2021	https://www.westerndigital.com/
Western Digital Blue SN570 Firmware Version: 234060WD, 234090WD	NVMe SSD	Gen 3x4	1.4	NA	М.2	v15.0	July 15, 2021	https://www.westerndigital.com/
Western Digital Green SN350 Firmware Version: 231040WD, 231050WD	NVMe SSD	Gen 3x4	1.4	NA	М.2	v15.0	July 15, 2021	https://www.westerndigital.com/





https://www.iol.unh.edu/registry/nvme



The UNH-IOL and the Beginning of IOL and ICC NVMe<sup>®</sup> Testing

**Test Tool Information** 

**Testing NVMe Technology** 

The Refactoring Effort

NVMe 2.0 Specifications and Beyond





Summit

#### The Test Tools





Conformance testing done with IOL INTERACT PC Edition and LeCroy Edition for automated testing

LinkExpert 3.80				
File Diagnostics Options Tools	Help			
Diagnostics			Analysis Results	
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UNH NVMe Compliance Tests 16.0c			Status	
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1.4 Create and Delete IO Queues Case 2	NOT STARTED	<b>o</b> ×		
1.4 Create and Delete IO Queues Case 3	NOT STARTED	<b>o</b> ×		
1.4 Create and Delete IO Queues Case 4	NOT STARTED	<b>o</b> ×		
Analyzer/Exerciser Device	es			





#### The Test Tools

Make	Model	<b>BIOS Version</b>	Operating System	Driver Version	CPU Model
ASRock	ASRock Z270 Extreme4	P2.3	Ubuntu Linux	Inbox Microsoft NVMe Driver	Intel i5-4690K @3.50 GHz
ASRock	ASRock Z97 Extreme 6	P2.3	Ubuntu Linux	Inbox Microsoft NVMe Driver	Intel i5-4690K @3.50 GHz
ASUSTeK Computer Inc.	ASUS ROG STRIX B350-F	0809	Windows 10	Inbox Microsoft NVMe Driver	AMD Ryzen 3 1300X @ 3.50 GHz
ASUSTeK Computer Inc.	ASUS Z170-A	1902	Ubuntu Linux	Linux Kernel NVMe Driver 1.0	Intel Core i5-6500 @ 3.20 GHz
Dell EMC	Dell PowerEdge R740xd	2.3.10	Windows Server 2016	Inbox Microsoft NVMe Driver	Intel Xeon Bronze 3104 CPU @1.7 GHz x 6
Dell, Inc.	Dell PowerEdge R720	2.2.2	Windows Server 2012 R2	Inbox Microsoft NVMe Driver	Intel Xeon CPU E5-2640 @ 2.5GHz
GIGABYTE	AorusElite X570	F36e	Ubuntu Linux		AMD Ryzen 5600G
GIGABYTE	Gigabyte H170 Gaming G3 H170 Gaming G3	F22e	Ubuntu Linux	Linux Kernel 4.4 NVMe Driver 1.0	Intel Core I3-6100 @ 3.7 GHz
Intel Corporation	Intel Server #1 S2600WT (Wildcat Pass)	2.7	Windows 10, Build 10240	Inbox Microsoft NVMe Driver	Intel Xeon CPU E5-2678W v4 @ 3.00 GHz
Intel Corporation	Intel Server #2 S2600WT (Wildcat Pass)	2.7	CentOS 6.7, Kernel 2.6.32	Linux Kernel 2.6.32 NVMe Driver	Intel Xeon CPU E5-2678W v4 @ 3.00 GHz



View map														
Test Running Told Analysis														
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Vdbench Users Guide

Version: 5.04.07

May 2018

Author: Henk Vandenbergh







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## NVMe<sup>®</sup> and NVMe-oF<sup>™</sup> Plugfests









## Early NVMe® Specifications Testing

- NVMe PCIe<sup>®</sup> SSD testing requires
  - Conformance
  - Interoperability
- NVMe-oF<sup>™</sup> Target testing requires
  - Conformance
  - Interoperability
- NVMe-oF<sup>™</sup> Initiator and Switch testing is only interoperability

Device Type	Conformance	Interoperability
NVMe Storage Device	$\checkmark$	$\checkmark$
NVMe Host Platform		$\checkmark$
NVMe-oF™ Target	$\checkmark$	$\checkmark$
NVMe-oF™ Initiator		$\checkmark$
NVMe-oF™ Switch		$\checkmark$



### **Conformance Testing**

Testing cutting edge features, new to the industry

Both test tool and feature application being tested Failing results are not always a bad thing

Issues at this stage can be fixed

Trends of Features being Implemented

Never a shortage of TPs, but which ones are being implemented



#### Interoperability Testing

Will the product work in various environments?

Recent Issues of Unique Identifiers PCIe vs Other Transports complexity





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Summit

## The Refactoring Effort

- Why the Refactor?
- "A simplified format, easing the development of NVMe technology and allowing for rapid innovation."
  - Create scalable speciation intrastate to allow further growth of NVMe<sup>®</sup> technology as it becomes more common in storage applications
- Test plan changes required







### **New Command Set Specifications**

#### **Command Sets Defined**

Zoned Namespace Command Set							
NVM Command Set							
Key Value Command Set							
Application 1 Application 2 Application 3	Application 1 Application 2 Application 3 Application 1 Application 2 Application 3						
Conventional SSD Controller		ZN	S SSD Controll	er			
Flash	<b>&gt;</b>	Flash					

Upcoming Command Sets for Test

Computational Programs





## NVMe<sup>®</sup> 2.0 Specification New Features: Currently Testing in Test Plan 17



## NVMe<sup>®</sup> 2.0 Specification New Features: To Be Tested in Test Plan 18

Endurance Group Management	TP4052c: 48 New Tests	
New Log Page Index Offsets	TP4075a: 9 New Tests	
Namespace Capability Reporting	TP4095: 7 New Tests	
Host Specifying Telemetry Host- Initiated Data Area	TP4109: 3 New Tests	Flash Memory Summit

## NVMe<sup>®</sup> Testing Now

389 Tests in NVM Conformance Test Plan

265 Tests in ZNS Conformance Test Plan

107 Tests in MI Test Plan

29 Tests in RDMA Transport Conformance Test Plan

43 Tests in TCP Transport Conformance Test Plan

16 Tests in Interoperability Suites (PCIe and oF)

**849 Total Tests** 





The UNH-IOL and the Beginning of IOL and ICC NVMe<sup>®</sup> Testing

**Test Tool Information** 

Testing NVMe Technology

The Refactoring Effort

**NVMe 2.0 Specifications and Beyond** 





Summit

### **Future Testing Items**

NVMe<sup>®</sup> 2.0 specifications and beyond

## Based on the NVM Express<sup>®</sup> Road Map



#### **Computational Programs**

#### Key Per IO

**Cross Namespace Copy** 

NVMe-oF<sup>™</sup> Discovery Automation



Ratified Feature (left edge indicates ratification quarter)

Planned Feature (left edge

indicates planned ratification

Planned New Specification (left edge indicates planned

ratification quarter)

quarter)

# The Overarching Goal is Confidence in the NVMe<sup>®</sup> Product

- When all devices are conformant, the storage industry performs better
- All caught issues are communicated such that they can be resolved prior to market release
- The UNH-IOL and ICC work directly with the TWG to test the most important and widely adopted features
- Your customers can see **standardized reports** showing which features are supported and conformant to the specification
- Certify with confidence that the product conforms to the applicable NVMe<sup>®</sup> specifications



## **Questions?**







Architected for Performance

