KIOXIA

Technical Brief

How SSDs Enable Experiments in Space on the ISS

Lessons Learned from the Hewlett Packard Enterprise Spaceborne Computer-2 Program

As we all can imagine, there are tremendous challenges with sending a spacecraft into space from the launch activities to navigating travel to the International Space Station (ISS), or the moon, and then returning to Earth. What can be learned from space exploration can be invaluable to humanity with technologies that can become commercialized and used by all of us. We learn by conducting computer experiments in space, particularly on the ISS, which includes servers loaded with CPUs/GPUs, networking, DRAM and of course, data storage.

Operating a computer in a spacecraft with radiation, microgravity, shock and vibration, extreme compactness, and constraints on size, weight, power and cooling can create an exceptionally challenging computing environment. Hewlett Packard Enterprise (HPE) developed Spaceborne Computer which was the first commercial in-space edge computing server intended to run on the ISS. This early system captured and processed raw data from scientific experiments, produced results and transmitted them back to Earth.

The refresh of HPE's Spaceborne Computer-2 was launched in 2024 to explore practical applications for conducting on-station compute, especially AI-driven data analysis. Data storage is a critical component of Spaceborne Computer-2 which uses fast and power-efficient KIOXIA SSDs for data processing/analysis, back-ups and redundancy. With proven success in space, the Spaceborne Computer-2 edge supercomputer is a game changer that delivers faster completed experiments which equate to faster and more meaningful insights. As noted by Dr. Mark Fernandez, principal investigator for HPE Spaceborne Computer-2, "in one example, what used to take 5 days to transfer data from experiments is now reduced to 45 seconds."

This technical brief discusses how KIOXIA SSDs are being used on Spaceborne Computer-2, what factors were considered in selecting these SSDs, and a use case covering astronaut safety.

What Storage Media is Space Ready?

Given the harsh conditions of space exploration, mechanical hard disk drives (HDDs) are not well suited for the journey. They use SAS and/or SATA interfaces and are limited by slow rotational speeds that search data using electronic read and write magnetic heads which can cause high latency and low throughput. These heads are sensitive to shock and vibration making spacecraft launches potentially damaging.

Compared to HDDs, SSDs are the best readily available option for data storage in space applications. There are no moving parts, they are smaller, consume less power per gigabyte[1] (GB), and provide significantly higher performance. As it relates to space exploration, there are several factors to consider such as performance, capacity, form factor, power consumption, weight and cooling requirements, all of which are discussed in the next section.

Another factor to consider is whether the storage media is ready for space travels given Technology Readiness Levels (TRL) (see image). For example, the TRL-9 level signifies that a technology has been successfully tested and proven in an operational space environment. The technology has been developed and validated in laboratory and relevant environments (TRL-1 to TRL-7 levels) but has also flown on a spacecraft and performed as expected during a real mission. TRL-9 is the highest level of readiness indicating that the technology is mature and ready for widespread use in space missions.

TRL 9: Actual system 'flight proven' through successful mission operations
TRL 8: Actual system completed and 'flight qualified' through test and demonstration (ground or space)
TRL 7: System prototype demonstration in a space environment
TRL 6: System/subsystem model or prototype demonstration in a relevant environment (ground or space)
TRL 5: Component and/or breadboard validation in a relevant environment
TRL 4: Component and/or breadboard validation in a laboratory environment
TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 2: Technology concept and/or application formulated
TRL 1: Basic principles observed and reported

SSD Usage in Spaceborne Computer-2

HPE's Spaceborne Computer-2 is the ultimate edge server supercomputer platform that allows astronauts to run experiments aboard the ISS while it circles 254 miles above Earth at 17,500 miles per hour. The computer platform consists of two twin lockers each containing two HPE servers designed to conduct scientific experiments. There are three models of KIOXIA SSDs supplied for the two HPE servers as follows:

Platform 1 HPE Edgeline EL4000 *(edge server with GPU)*	***Platform 2*** HPE ProLiant DL360 Gen10 *(2-socket HPC compute node)*
8 x 1,024 GB KIOXIA XG6 Series NVMe™ SSDs *(M.2 2280)* *Total capacity = ~8 terabytes[1] (TB)*	*4 x 960 GB KIOXIA RM6 Series Value SAS SSDs* *(2.5-inch)* *Total capacity = ~4 TB* *4 x 30.72 GB KIOXIA PM6 Series Enterprise SAS SSDs* *(2.5-inch)* *Total capacity = ~122 TB*

Total HPE Spaceborne Computer-2 system capacity = ~134 TB

For Platform 1, KIOXIA XG6 Series NVMe SSDs in M.2 2880 form factors were chosen for their fast transfer rates, compactness, light weight and low power consumption. They are used to store data from the scientific experiments conducted on the HPE EdgeLine EL4000 server.

For Platform 2, KIOXIA PM6 Series Enterprise SAS SSDs and KIOXIA RM6 Series Value SAS SSDs are used in 2.5-inch form factors.

The KIOXIA PM6 Series Enterprise SAS SSDs were chosen for their superb balance of performance, reliability and especially power efficiency. With the astronauts having to utilize a shared power budget across two servers, every single watt counts to conserve power for other priorities that may be needed. The average load consumption of a 30.72 TB capacity KIOXIA PM6 Series SSD is about 10 watts versus an enterprise NVMe SSD at the same capacity at about 21 watts, making the KIOXIA PM6 Series SSDs not only fast, but highly power efficient in comparison. The four deployed SSDs provide over 122 TB of total storage capacity used to store the scientific data from the experiments conducted on the HPE ProLiant DL360 Gen10 server, as well as for backups.

Also deployed in this server are KIOXIA RM6 Series Value SAS SSDs chosen for their performance, and their low-latency data storage capabilities over SATA SSDs. Two of the four drives operate in a redundant data mirror, while the other two drives wait for action in the event of an SSD failure. This level of data redundancy is needed in space, since shipping a replacement drive is not a reasonable capability.

The entire Spaceborne Computer-2 Project features over 134 TB of data storage for server-based scientific experiments, and to date according to Dr. Fernandez, "has provided valuable insights into healthcare, image processing, natural disaster recovery, 3D printing, and 5G networking, to name a few."

From a data storage perspective, all KIOXIA SSDs deployed in the Spaceborne Computer-2 system have not experienced any issues and are operating as expected[2]. The drives have proven to be a success so far on the ISS and can be deemed TRL-9 ready for space, positioning Kioxia Corporation as an SSD manufacturer with multiple TRL-9 capable SSDs.

Use Case: AI-based Space Glove Analysis

From previous research captured from the Spaceborne program in 2016, the extra vehicle activity (EVA) gloves worn by astronauts during spacewalks were responsible for over half of their recorded injuries. Given these findings and to ensure integrity of the gloves between usages, NASA requires each astronaut in the crew to take hundreds of photos of their gloves from various angles. These photos were transmitted back to Earth where analyses were performed on the glove photos for scratches and imperfections.

The big challenge was sending the glove images back to Earth which took 5 days to complete given the network bandwidth limitations. With Spaceborne Computer-2, the gloves can be analyzed on the ISS with the help of AI, and the data transfer of the results was reduced to 45 seconds, according to Dr. Fernandez. Additionally, the limited network bandwidth became freed up for other higher priority crew requirements.

Summary

The HPE Spaceborne Computer-2 Project represents the ultimate edge platform (in space) designed to conduct scientific experiments aboard the ISS as it orbits the Earth. With plenty of data storage onboard, the system is used to capture and process raw data from the experiments, produce results and transmit them back to Earth.

For space applications where several challenges are present (i.e., radiation, microgravity, shock, vibration, extreme compactness, constraints on weight, power and cooling, etc.), SSDs are the best option as they have no moving parts, are small and compact, consume less power per GB and deliver much higher performance than HDDs. A good way to determine if an SSD is ready for space travel is to follow the Technology Readiness Levels developed by NASA.

Data storage is a critical component of the Spaceborne Computer-2 system which deploys fast and power-efficient KIOXIA SSDs for data processing/analysis, back-ups and redundancy as depicted below. “It would be virtually impossible to perform the variety and range of tests aboard the ISS without flash technology,” said Dr. Fernandez.

	KIOXIA XG6 NVMe™ SSD[3] Client/M.2 2880	KIOXIA PM6 SAS SSD[3] Enterprise/2.5-inch	KIOXIA RM6 Value SAS SSD[3] Enterprise/2.5-inch
Server	HPE Edgeline EL4000	HPE ProLiant DL360 Gen10	HPE ProLiant DL360 Gen10
SSDs Deployed	8	4	4
Capacity per SSD	~1 TB	~30 TB	~1 TB
Total SSD Capacity	~8 TB	~122 TB	~4 TB
Sequential Read per SSD	3,180 MB/s	4,150 MB/s	840 MB/s
Sequential Write per SSD	2,960 MB/s	3,200 MB/s	710 MB/s
Random Read per SSD	355,000 IOPS	595,000 IOPS	135,000 IOPS
Random Write per SSD	365,000 IOPS*	80,000 IOPS	105,000 IOPS
Active Power per SSD	up to 4.7 watts	9 to 14 watts (in low power mode)	up to 9 watts
Use Case	Data storage	Data storage Data backups	Data storage Data redundancy

**Represents fresh out of the box performance and not steady state performance*
MB/s = megabytes per second
IOPS = Input/output operations per second

The system has provided valuable insights into healthcare, image processing, natural disaster recovery, 3D printing, and 5G networking, and will become a model system for other space-oriented applications.

Additional Resources (select link):

HPE Spaceborne Computer Website – Hewlett Packard Enterprise dedicated website
SSDs in HPE Spaceborne Computer-2 – KIOXIA Memory Maker - Dr. Mark Fernandez, Principal Investigator for HPE Spaceborne Computer-2
Linus Tech Tips: here's why it's so hard to put a computer into SPACE – YouTuber Linus Sebastian visits the ISS to check out Spaceborne Computer-2
KIOXIA PM Series Enterprise SAS SSDs
KIOXIA RM Series Value SAS SSDs
KIOXIA XG Series Client NVMe SSDs
Accelerate HPE Servers with KIOXIA SSDs

FOOTNOTES:

[1] Definition of capacity: Kioxia Corporation defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes, a terabyte (TB) as 1,000,000,000,000 bytes and a petabyte (PB) as 1,000,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1Gbit = 2^{30} bits = 1,073,741,824 bits, 1GB = 2^{30} bytes = 1,073,741,824 bytes, 1TB = 2^{40} bytes = 1,099,511,627,776 bytes and 1PB = 2^{40} bytes = 1,125,899,906,842,624 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, and/or pre-installed software applications, or media content. Actual formatted capacity may vary.

[2] As of this publication date.

[3] The KIOXIA XG6 Series Client NVMe SSD, KIOXIA PM6 Series Enterprise SAS SSD and KIOXIA RM6 Series Value SAS SSD product images shown are representations of the design model and not accurate product depictions.

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