First things first . . .

an announcement
Next week our name changes to....
KIOXIA Corporation

KIOKU + AXIA

KIOXIA is a combination of the Japanese word kioku meaning “memory” and the Greek word axia meaning “value.” Kioku, which underpins our mission and vision, goes beyond the notion of memory as mere data to broadly encompass experiences, emotions and ideas.
And now, for something completely different..
our storage world continues changing and the change is accelerating...
Cloud Storage is Inescapable (nearly)

Source: https://www.statista.com/study/26788/data-storage-statista-dossier/
...and the majority of Exabytes sold will shift to Cloud vendors
Cloud will consume majority of new flash storage.

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud</td>
<td>25,512</td>
<td>27,729</td>
<td>43,500</td>
<td>58,164</td>
<td>82,178</td>
<td>117,733</td>
</tr>
<tr>
<td>Enterprise</td>
<td>19,524</td>
<td>28,112</td>
<td>34,767</td>
<td>51,174</td>
<td>68,216</td>
<td>85,373</td>
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</table>

Source: Forward Insights Aug 2019
The majority of Cloud bytes will go to the Hyperscale providers
Hyperscalers
(we’ve noticed)
use storage differently...
Hyperscale cloud is application-driven (software-defined)
Storage devices are NOT (software-driven)
So, the Hyperscale cloud providers began defining their own flash storage devices.
These devices are host-controlled, application-driven and highly integrated into the stack.
The host and application control many of the flash-unique processes.

- Garbage Collection
- Data Placement
- Wear Leveling
As developers you know this.
Storage, as a device, has evolved at its own pace.
For so long it was just “rotating rust”
The big new “innovation” was enabling FLASH for storage
Solid-state storage is digital, yet it is still delivered like a drive.
Solid-state storage must be enabled for **Software Control**
Hyperscale cloud is already doing it.

Storage vendors need to pay attention.
Today's innovations in storage are driven by cloud applications.
Yet today’s storage devices define their own mode of access...
Cloud operators require their applications to define how data is stored...
and these storage-related factors impact Hyperscale service quality

Performance
Parallelism

(orchestration)

Predictable Latency
Data Placement
This is where Hyperscale is innovating with storage
Solid-state devices are digital.

A software-enabled device can control these features

- Performance
- Parallelism
- (orchestration)
- Predictable Latency
- Data Placement

AND MORE...
As developers,
You know a
new paradigm
is coming to solid-state storage.
In the new paradigm the application is king. Solid-state storage must embrace this.
Cloud-based applications are the new normal.

This will drive further innovation demands for solid-state storage.
Future versions of software-enabled solid-state storage may support:

- Workload-driven aggregation and disaggregation of a storage pool
- Multi-mode capability/functionality
- Latency control by software
- Host control over garbage collection and wear leveling
The Cloud is eating into Enterprise. Hyperscale cloud is software-driven. Their applications are king [for storage].

This new paradigm is at our heels.
You’ve talked about these concepts before...
We’re exploring how to make flash more valuable in a software-defined world.
Two examples:

1. Software can be drive-aware
2. Software can be “media-aware”
Toshiba Memory’s KumoScale™

Software that deploys SSDs at cloud-scale
...enables NVMe™ Flash as a Service

*NVMe is a trademark of NVM Express, Inc.*
What is KumoScale?

- **A Software product**
  - Implements a fast, networked block storage service
  - Disaggregation based on NVMe™-over-Fabrics standard
  - Focused on speed, very low cost

- **Target**
  - Mid to large-scale (50k-500k nodes) on-prem data center
  - Bare metal or containerized

- **Architected for Private Clouds (not enterprise)**
  - Integrates with (not replaces) management infrastructure
  - Tight integration with Kubernetes®/CSI
  - Zero touch deployment at scale

“kumo”

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<tr>
<th>Cloud</th>
<th>Spider</th>
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Software enabling NVMe™ Flash as a Service
Storage Node Architecture

Telemetry & Logging Frameworks
- Volume management
- ACL, QoS administration
- Telemetry
- API

Provisioning & Orchestration Frameworks

Mapper
- Drive + offset
- Namespace

Management Engine

Network (logical volumes)
- NIC Driver
- NVMe-oF™ Target

Local PCIe® (Physical SSD's)
- NVMe™ Driver
- NVMe™ Initiator

Telemetry & Logging
- JSON, etc.
- REST API

Software
- Toshiba

NVMe and NVMe-oF are trademarks of NVM Express, Inc. PCIe is a registered trademark of PCI-SIG.
Storage Node Architecture

- **Provisioning & Orchestration Frameworks**
  - JSON, etc.
  - REST API

- **Telemetry & Logging Frameworks**
  - JSON, etc.
  - REST API

- **Management Engine**
  - Volume management
  - ACL, QoS administration
  - Telemetry
  - API

- **Mapper**
  - Drive + offset
  - Namespace

- **KUMOSCALE™**

- **NVMe™ Initiator**

- **NVMe™ Driver**

- **Local PCIe® (Physical SSD’s)**

- **NVMe-oF™ Target**

- **NIC Driver**

- **Network (logical volumes)**
KumoScale™: Storage Software Enabling NVMe™ Flash as a Service

Your Provisioning Tools or Orchestration Infrastructure

Provisioner Service

Analytics Service
- Drive performance & wear modelling
- Storage-class I/O characterization
- Storage Node QoS scoring
- Closed-loop optimization

Mapping Advisories

Management Service
- Active license counter
- Phone-home telemetry
- GUI server (optional)

Customer
- Control Plane Monitoring
- Live I/O Traffic

Toshiba Memory
- Control Plane Monitoring

Data Center Telemetry & Logging

Data Center Telemetry

Data Center Logging

Storage Data

Telemetry

Mapping

Storage Nodes

CSI

Phone-home
TRocksDB

Modified RocksDB to be more “media-aware” for better TCO
RocksDB

- A popular data storage engine
- Used by a wide range of database applications:

- Cassandra®
- Ceph™
- MariaDB®
- Python®
- MyRocks
- ArangoDB
- Rockset

Cassandra is a registered trademark of The Apache Software Foundation. Ceph is a trademark of Red Hat, Inc. or its subsidiaries in the United States and other countries. Python is a registered trademark of the Python Software Foundation. MariaDB is a registered trademark of MariaDB in the European Union and other regions. All other company names, product names and service names may be trademarks of their respective companies.
RocksDB

- Good for HDD and small database values
- Not “flash media-aware”
  - Compaction layer heavily rewritten
  - Generates write-amp of 20x to 30x
  - This degrades flash memory endurance
But... there is a better way
Toshiba Memory America re-architected RocksDB to be more flash media-aware.
...all done in software; no changes to the SSD necessary.
We want to show you what software can do if it’s media-aware.
How does TRocksDB work?

<table>
<thead>
<tr>
<th>RocksDB</th>
<th>TRocksDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keys &amp; Values are paired together</td>
<td>Keys &amp; Values are split</td>
</tr>
<tr>
<td>Compaction layers updated regularly by rewriting keys &amp; values together</td>
<td>Keys go into compaction layers</td>
</tr>
<tr>
<td>WRITE AMP</td>
<td>Values are stored separately in a ring buffer</td>
</tr>
</tbody>
</table>

**Value Log**

- **Level 0**  
  - Key: K
  - Data: V
  - Value is unaffected by compactions

- **Level 1**  
  - Target: 1GB

- **Level 2**  
  - Target: 10 GB

- **Level 3**  
  - Target: 100 GB

- **Level 4**  
  - Target: 1000 GB

**WRITE AMP**

- Keys go into compaction layers
- Values are stored separately in a ring buffer

**Ring Buffer**

- Add new Data
- Fetch most recent Data
- Release old Data
By being cognizant of media characteristics, a developer can enhance storage value.
The greatest value: improved endurance at no performance cost.
Greater SSD Endurance: Better TCO

Improved Write Amplification

Write Amplification (lower is better)

- Test 1: Random Bulk Load
- Test 2: Bulk Sequential Load
- Test 3: Random Overwrites

TRocks 1.2.5.23
Rocks FB 6.4

Same or Better Performance

Performance Comparison (lower is better)

- Test 1: Random Bulk Load
- Test 2: Bulk Sequential Load
- Test 3: Random Overwrites
- Test 4: Random Key Reads

TRocks 1.2.5.23
Rocks FB 6.4

Improved Write Amplification: Same or Better Performance
Toshiba Memory wants to show examples of how software can enhance solid-state storage...
So, we developed TRocks as Open Source software available today:

https://github.com/ToshibaMemoryAmerica
Join the project; improve and contribute to the code:

https://github.com/ToshibaMemoryAmerica
To conclude, a new paradigm shift in storage is coming...
Continued innovations in software are necessary and...
...Solid-state storage has a big role to play...
...but, it needs to be software-enabled to take advantage of its digital nature.
I shared two modest examples of Toshiba Memory’s efforts in this direction.
We are investing in these and other methods on a larger scale in both media and software.
There’s more to discuss in future.
Thank You