Executive Summary

Today’s IT organizations face exponential data growth and an endless demand for more performance from end-users. The lines of business expect IT to help them unlock value locked in their data—so they can identify trends, respond faster, reveal valuable insights, process more sales transactions, deliver a rich end-user experience, and stay ahead of the competition.

To complicate matters, IT organizations run a wide range of workloads. Typically, a small percentage of these business-critical workloads need consistently high performance and availability. The rest are mainstream applications and unstructured data that only occasionally need performance. In the past, organizations have tried to overcome this problem by deploying and managing multiple storage systems to meet the different service levels for each workload. This method is inefficient and adds cost and complexity.

Tegile IntelliFlash storage arrays are designed to deliver consistently high performance and low latency while maximizing uptime, streamlining data protection, and curbing storage costs. Built on a fast, flexible multi-tiered architecture, IntelliFlash arrays support both all-flash and hybrid configurations. As your performance and capacity needs change over time, you can scale up economically by adding just flash or a mixture of flash and disk. You can also replicate between all-flash and hybrid arrays for affordable disaster recovery. Each array supports block and file protocols, and includes inline data reduction, data protection, and flexible management capabilities, making them ideal for your entire organization.

This document provides a technical overview of the architecture and operating system used by all IntelliFlash storage arrays, including its key capabilities. It is intended for storage administrators who are familiar with data storage concepts, methods, and protocols, such as pools, LUNs, deduplication, NAS, SAN, NFS, CIFS, iSCSI, and Fibre Channel.
IntelliFlash OS

All Tegile™ arrays are powered by IntelliFlash™ OS, which provides the same feature set and a uniform user experience across the all-flash and hybrid storage product lines. This fast, flexible operating environment is designed to leverage different grades of storage media—hard disk, high-performance flash, high-density flash, and so on—within the same storage system. IntelliFlash uses patented technology to understand the inherent characteristics of the different storage media and intelligently manages the placement of data for optimal performance and economics.

It also includes advanced data services, multiprotocol support, and flexible management capabilities, enabling you to accelerate performance, significantly shrink your storage footprint, maximize uptime, consolidate workloads, and simplify storage administration.

Achieving High Performance & High Capacity

Tegile arrays feature a multi-tiered architecture and dual active/active controllers for simultaneous data access. Within each Tegile array, there’s a Performance Tier and a Capacity Tier. In the performance tier Tegile uses DRAM, NVDIMMs, and (NVMe) NAND flash. This gives users the highest performance and lowest latency for their mission-critical applications. The capacity tier takes full advantage of the evolution in media densities. In this tier we use either HDDs (e.g. IntelliFlash hybrid arrays) or high-density SAS NAND flash (e.g. IntelliFlash HD).

This architecture gives users extremely fast performance with much better economics.
The performance tier is logically divided into three sections:

1. Write Cache
2. Read Cache
3. Metadata

**Write Cache**

Since Tegile arrays use a combination of DRAM, NVDIMM, and (NVMe) NAND flash in the performance tier, they can process a write I/O extremely fast. The moment I/O hits memory it’s immediately synced to persistent memory and an acknowledgement is sent from the controller to the client. This process takes 100s microseconds.

Meanwhile, the I/O is processed in memory, calculating a checksum, compressing the data, checking dedupe pointers, and so on. Then the data is coalesced and streamed sequentially to the capacity tier.

To ensure data integrity and availability during a rare controller failure, the data in the NVDIMMs is mirrored across controllers.
Read Cache

There are two levels of Read Cache in an IntelliFlash array—both are self-tuning. The first level is the primary DRAM cache. The second level resides on NAND flash. The array proactively populates the Read Cache with the hottest, frequently used data. The data cached in flash media is stored in a compressed format to give you more cache space with no performance degradation. This all happens dynamically in real time, using intelligent, pre-fetch algorithms—without user intervention. In most customer cases, the cache-hit ratio is well over 90%. That means that most read requests are served from DRAM and flash.

Metadata Acceleration

IntelliFlash dedicates a portion of the performance tier exclusively for metadata. This includes block pointers, dedupe pointers, and the like. All of the metadata is organized, aggregated, and remains in the performance tier for optimizing I/O paths and accelerating all I/O operations in the array. This performance-optimization technique stands in stark contrast to traditional storage systems, which intersperse metadata with the rest of the data on disk. Over time, as data inevitably gets modified, deleted, and rewritten, the metadata becomes very fragmented, which negatively impacts performance.
Data Reduction

Tegile arrays provide inline compression and deduplication. Data is compressed and redundant blocks are removed before they are written to disk. These techniques not only reduce the storage footprint, they also act as a performance multiplier by maximizing the amount of data cached in high-speed media.

Compression

IntelliFlash OS compresses data blocks in the DRAM before it writes the data to persistent media. Compressed data is decompressed before it is sent to the user or the requesting application. You can choose your compression rate based on your application. The following are the available compression algorithms:

- **Lz4** (Default compression algorithm) is the fastest lossless compression method. It provides a balance between performance and space savings. You can use this method for most types of data. Tegile recommends using Lz4 compression for speed, compression and balance.
- **Lzjb** provides better performance since CPU utilization is lower. You can use this compression algorithm on the data when you do not require high rates of data compression.
- **Gzip-2** provides maximum space savings and acceptable performance. Ideal for backup use cases.
- **Gzip-9** provides maximum space savings. However, it impacts performance due to high CPU usage.

By default, compression is enabled. If required, you can turn off compression. You can choose the compression method on your data while creating the project, share, or LUN and you can change the compression method after creating them.
Deduplication

Deduplication eliminates duplicate blocks of data and saves storage space. Deduplication in IntelliFlash OS is an in-line process and works at the block level on any protocol. It uses SHA-256 checksum type for identifying duplicate blocks and retaining unique blocks. The deduplication process takes place in the DRAM of the Tegile array. The deduplication pointer table is stored in in the performance tier for fast deduplication processing. Tegile's proprietary patented metadata acceleration technology plays a significant role in the deduplication process. It also allows Tegile to provide deduplication even on hybrid storage pools—not just on all-flash pools.

You can turn on deduplication at the project level or at the individual share or LUN. Deduplication runs only on the data received after it is turned on. You cannot run deduplication on the existing data. When you turn off deduplication, it stops checking for duplicate blocks in the new data. When you have data that contains a lot of duplicate data, and in applications such as VDI and Microsoft Exchange environments, turning on deduplication can be beneficial. If you have applications that do not contain a lot of duplicate data, enabling deduplication could impact performance.

Enterprise Resiliency & Capabilities

IntelliFlash arrays are designed for resiliency. Each array features dual active/active controllers and dual-ported storage media (SSDs and HDDs). A redundant I/O fabric between server hosts and the storage array for both SAN and NAS protocols ensures there’s no single point of failure.

In the event of a controller failure, or for live software upgrades, any associated storage pools can be failed-over transparently—with no perceived outage.
Capacity Expansion

You can expand storage capacity when needed by simply adding SAS-connected Tegile hybrid or all-flash expansion shelves. Adding expansion shelves is a non-disruptive operation. You can create new storage pools with the added capacity or expand the capacity of existing pools.
Data Protection

Built-in snapshots, replication, and instant restore capabilities provide efficient methods of recovery. You can also create read/write clones. Clones are space-efficient: similar to snapshots, they allocate storage only for changed blocks. Application awareness and integration provides VM and application-consistent snapshots for backup and recovery.

Disaster Recovery

Replication functionality in the IntelliFlash OS enables you to replicate data between all-flash arrays, between hybrid arrays, or between all-flash and hybrid arrays for a cost-effective DR solution.

Thin Provisioning

Thin provisioning is a method to optimize available storage capacity. IntelliFlash OS allows you to create thick LUNs and thin LUNs. A thin provisioned LUN does not reserve space for the LUN. You can create a thin provisioned LUN when creating a LUN. When you enable thin provisioning for a LUN, it creates the appearance to clients and servers that the specified storage space is allocated. However, it consumes only the amount of storage space that is required by the data in the LUN. The LUN expands as more data is written to it, until it reaches the specified LUN size. Using this method, you can provide more storage space than is actually available in a pool when creating a LUN, but IntelliFlash OS observes the actual storage usage and allocates space automatically to the LUN. With thin provisioning, the allocated, but
unused, space of a LUN is available in the pool for other LUNs or shares. You should regularly monitor the actual space used by LUNs and add physical storage when required.

**Data Integrity**

To protect against silent data corruption, IntelliFlash OS performs a checksum process to match data blocks for reads and writes and automatically fixes corrupt blocks. It also stores the checksum and data in separate nodes of the block tree for further protection.

The checksum calculation takes place in the DRAM. You can use one of the following checksum algorithms:

- Fletcher-4
- SHA-256

Fletcher-4 is the default checksum algorithm. It is a 32-bit Fletcher checksum. However, if deduplication is turned on, IntelliFlash OS uses the SHA-256 algorithm as the default checksum type on the shares and LUNs in the deduplication-enabled project. You can select checksum at the project level and at the individual share or LUN level.
**Flash Endurance**

IntelliFlash OS aligns writes to the geometry of the flash media, ensuring even wear and extending the life of the system’s SSDs. IntelliFlash is optimized for the underlying geometry of the medium (flash or disk) to ensure long life even under high I/O workload.

**Protocol Choice**

IntelliFlash OS supports both block protocols (iSCSI, Fibre Channel) and file protocols (NFS, SMBv3, and CIFS), providing true unified storage. This makes it possible to deploy Tegile arrays for high-performance, low latency virtualization environments as a NFS, SMBv3, Fibre Channel or iSCSI target, while simultaneously using the file share features of Tegile arrays, through CIFS, or NFS, for user file shares. This flexibility allows you to solve the business problems with a single storage platform. This is more effective and less expensive than attempting to compile multiple storage platforms to satisfy all data storage requirements.

**Management Flexibility**

IntelliFlash OS includes flexible management capabilities to streamline and simplify storage management.

**Web UI**

The IntelliFlash Web UI provides unified access to both controllers of a Tegile array and enables you to configure, monitor, and manage both controllers. You can view system settings, analytics, and notifications for both controllers. You can also apply the same configuration settings on both controllers. You can access the IntelliFlash Web UI using the array management name or IP address. From the Web UI dashboard, you can quickly and easily monitor space usage, performance, cache hits, CPU hits, and network throughput.
Application-optimized templates simplify provisioning. You can use these templates to choose the type of workload and IntelliFlash will preselect the optimum configuration properties for the LUNs and shares. Advanced settings are also available to customize and fine-tune storage attributes and properties.
Call-Home Alerts

IntelliFlash provides pro-active capacity and health alerts. Notifications are automatically sent to Tegile Technical Support and support cases are created for critical alerts. You can configure the arrays to send email notifications to other appropriate personnel.

VM Management

Tegile arrays can be managed through VMware vCenter, enabling you to provision datastores, manage snapshots and restores, and monitor I/O status, space usage and latency from within the vCenter interface.

RESTful API

A programmable, task-oriented RESTful API enables you to script and automate storage management.

IntelliCare Cloud-Based Analytics

IntelliFlash is able to send capacity, performance, and health-related statistics and notifications to the cloud-based, analytics portal of Tegile. The IntelliCare™ cloud portal uses this data to allow you to quickly and easily monitor the health, performance, and usage of all your Tegile arrays from anywhere. The portal also provides trend analysis for storage consumption for pro-active capacity planning. The array analytics are also sent to Tegile Technical Support for proactive customer care.
Data Security

Full Disk Encryption

All Tegile arrays have full data-at-rest 256-bit AES encryption. Tegile uses self-encrypting drives that support the TCG specification, ensuring all data is encrypted while at rest. There is no performance degradation since the encryption is handled by dedicated multichip crypto modules. The process is completely transparent to the storage admin, as well as your applications.

Each drive in the array has a unique encryption key. The drives are also tamperproof, which prevents hackers from attempting to steal their encryption keys.
Once the encryption is activated, the drive will not honor any data READ or WRITE requests until the corresponding bands have been unlocked. This prevents user data from being accessed without the appropriate credentials when the drive has been power cycled or removed from its slot in the array and installed in another system.

We also allow instant secure erase of one, few, or all drives, which essentially makes the existing data on that drive unrecoverable.

**Conclusion**

Tegile helps your organization eliminate storage silos, simplify storage management, and reduce costs by consolidating all of your workloads onto a single flash platform. Built on a fast, flexible architecture, Tegile IntelliFlash Arrays seamlessly support different grades of storage media, intelligently managing the placement of data to maximize performance and capacity. Deploy an all-flash or hybrid configuration today. As your needs change over time, scale up economically by simply adding a mixture of disk flash. You can also replicate between all-flash and hybrid arrays for affordable disaster recovery. Native multi-
protocol support, inline data reduction, built-in data protection, and flexible management capabilities make Tegile arrays ideal for your entire organization.

**About Tegile, a Western Digital brand**

Tegile, a Western Digital brand, is pioneering a new generation of persistent-memory storage solutions that deliver exceptional performance and economics for a wide range of enterprise applications. With Tegile’s line of unified all-flash and hybrid storage arrays, enterprise customers are running their mission-critical applications at the speed of memory while significantly consolidating their transaction processing, analytics, databases, virtualization, and file services onto a single platform.

**About Western Digital®**

Western Digital creates environments for data to thrive. The company is driving the innovation needed to help customers capture, preserve, access and transform an ever-increasing diversity of data. Everywhere data lives, from advanced data centers to mobile sensors to personal devices, our industry-leading solutions deliver the possibilities of data.

Western Digital® data-centric solutions are marketed under the G-Technology™, HGST, SanDisk®, Tegile™, Upthere™ and WD® brands.