StoreEngine™ and StorePak™ Applications Overview

- **Multi-GB/s Data Recorder**
- **High Performance RAID**
- **Network File Server**

Abstract

StoreEngine and StorePak provide flexible and scalable storage building blocks than can be used to implement complete turnkey data storage solutions. Multi-GB/s data recording, NAS file sharing, and high performance embedded RAID applications may be easily implemented, all with no development or custom software required. StoreEngine/StorePak architectures are easily scaled in capacity, bandwidth, and channels by adding StoreEngine/StorePak blades, which automatically aggregate the storage capacity and performance of the available blades.

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StoreEngine™ and StorePak™ – Flexible Data Storage Building Blocks

StoreEngine and StorePak are flexible storage building blocks that are used to implement flexible, scalable data storage systems. StoreEngine is an ultra-high performance *Storage Controller* blade that can also host up to 1.5 TB of non-removable on-board SSD storage. StorePak is a *Storage* blade that can host up to 3 TB of easily removable and hot swappable SSD storage. Various combinations of multiple StoreEngines and multiple StorePaks can be interconnected using PCIe backplane connections to support a large variety of easily scalable storage systems.

StoreEngine and StorePak leverage best-of-breed commercial storage technologies, and build on these technologies to adapt them to the needs of military recording systems. In addition to clear cost advantages, this approach allows system designers to take advantage of the latest commercial developments while still meeting the SWaP, performance, and environmental requirements of these systems.

- Small SWaP footprint (size, weight and power)
- Performance scalable to multi-GB/s rates
- Storage expandable to tens of Terabytes
- High Reliability
- Rugged and commercial versions
- Extended temperature range operation
- Support for both blade level and box level solutions
- Comprehensive management and support software

The flexibility of StoreEngine and StorePak allows them to be used for a large variety of embedded storage applications. Large, power hungry external recorder, RAID or NAS boxes can be replaced with compact, simple, and high performance blade based solutions.

- Intelligence, Surveillance, and Reconnaissance (ISR) systems recording
- SIGINT/COMINT/RADAR/SONAR data recording/playback
- Imaging system data recording/playback
- Linux/Unix/Solaris Network File Sharing using NFS or FTP
- Windows Network File Sharing using NFS or CIFS/SMB
- Data logging and system instrumentation
- Secure, encrypted data storage, with fast secure erase

StoreEngine™

StoreEngine is a scalable storage server designed for high performance embedded systems. The StoreEngine single slot storage blade can simultaneously serve block data (like a disk drive or RAID system) and file data (like a NFS/CIFS file server). StoreEngine is easily scalable in capacity and performance by simply adding additional StoreEngine blades. File level access to storage is often referred to as **Network Attached Storage (NAS),** while block level (RAID) access to storage is often referred to as **Direct Attached Storage (DAS)**. StoreEngine supports simultaneous use of both access methods. In addition, StoreEngine and StorePak support a **High Speed Recording** mode that allows aggregation of multiple StoreEngines/StorePaks to record data streams at aggregate rates of over 5 GB/s.

StoreEngine provides unmatched storage capability, ultra high performance and high capacity all within a small size, weight, and power (SWaP) footprint. StoreEngine is ideal for high bandwidth embedded data recording, general purpose file sharing, and high performance RAID applications.

- 1.5 TB solid state storage per StoreEngine
- Small SWaP footprint (33W typical)
- High Performance: 800 MBytes/s per slot
- Scalable in capacity and performance
- High speed recording functionality
- Embedded hardware assisted RAID 0/5
- Network file server (NFS/CIFS)
- Concurrent RAID, NAS, recording operation
- Standard I/O: PCIe and Gigabit Ethernet
- Optional RTM I/O: 1/10GbE, Fibre Channel
- Open VPX, VXS, VME64 versions

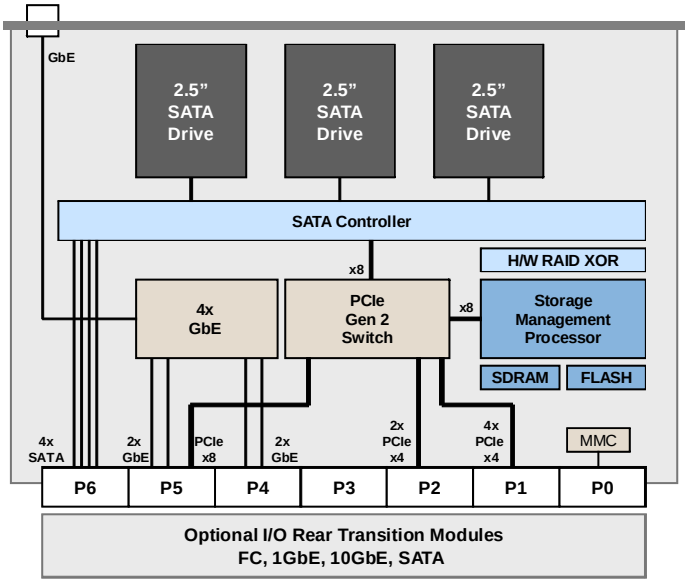

Figure 1. StoreEngine Blade

StorePak™

StorePak is a single slot blade with a **removable** SSD (solid state drive) drive carrier. StorePaks is designed to be used either in conjunction with Critical I/O's StoreEngine storage manager, or as stand-alone Direct Attached Storage. Since there are no cables to unplug or tools needed to remove StorePak, it is ideal for applications where removal of onboard storage must be accomplished quickly. StorePak provides high performance and high capacity rugged solid state storage all within a small size, weight, and power (SWaP) footprint. StorePak is ideal for high bandwidth data recording, file serving, and general purpose RAID applications where quick and simple removal of storage is essential.

A single StorePak blade provides up to 3TB of solid state storage in a single 6U slot. Multiple configurations of StorePak are available which feature various storage capacities, performance capabilities, and drive types.

- 3 TB solid state storage per StorePak
- Easily removable storage drive carrier
- Supports 100,000 insertion cycles
- Hot-plug and hot-swap support
- Small SWaP footprint (20W typical)
- High performance: 1400 MBytes/s per slot
- Embedded hardware assisted RAID 0/1
- Scalable in capacity and performance
- Six 4-lane PCIE data/expansion plane ports
- OpenVPX

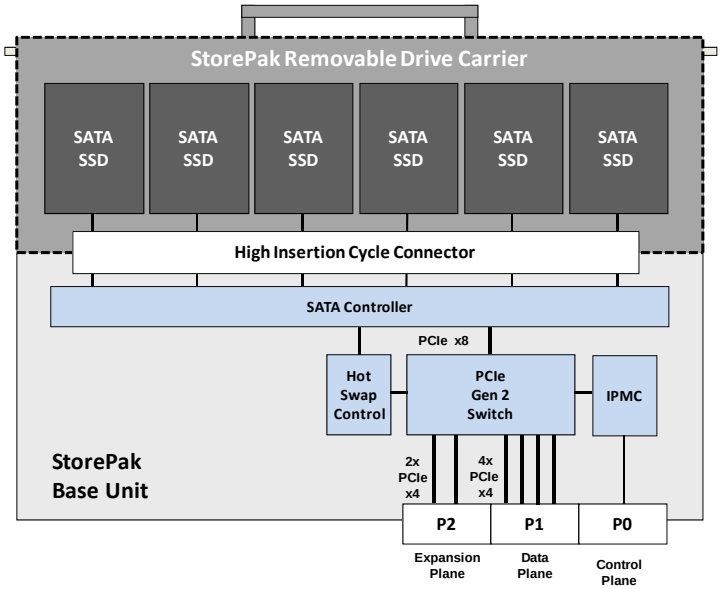

Figure 2. StorePak Blade

Fixed and Removable Media Options

All of the architectures described in this paper can be implemented in both fixed media and removable media versions, using combinations of StoreEngine and StorePak blades. Fixed media architectures are based on the StoreEngine blade, each blade hosting three fixed SATA drives. Removable media architectures utilize a combination of StoreEngine blades, along with StorePak removable drive assemblies. Each removable StorePak unit hosts six SATA drives, thus. The fixed vs. removable storage options are illustrated in figures 3 and 4.

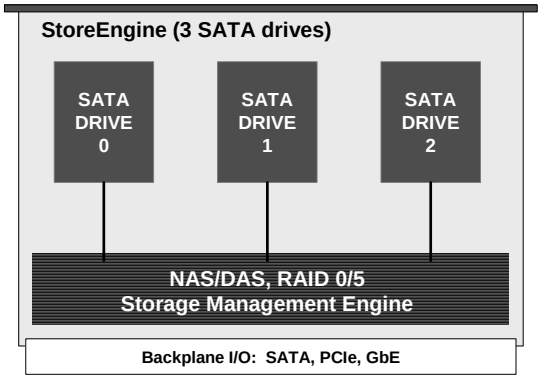

Figure 3. *Fixed* Media. A StoreEngine blade configured with three non-removable SATA drives provides up to 1.5 TB of storage in one 6U slot, and up to 6 TB in four slots

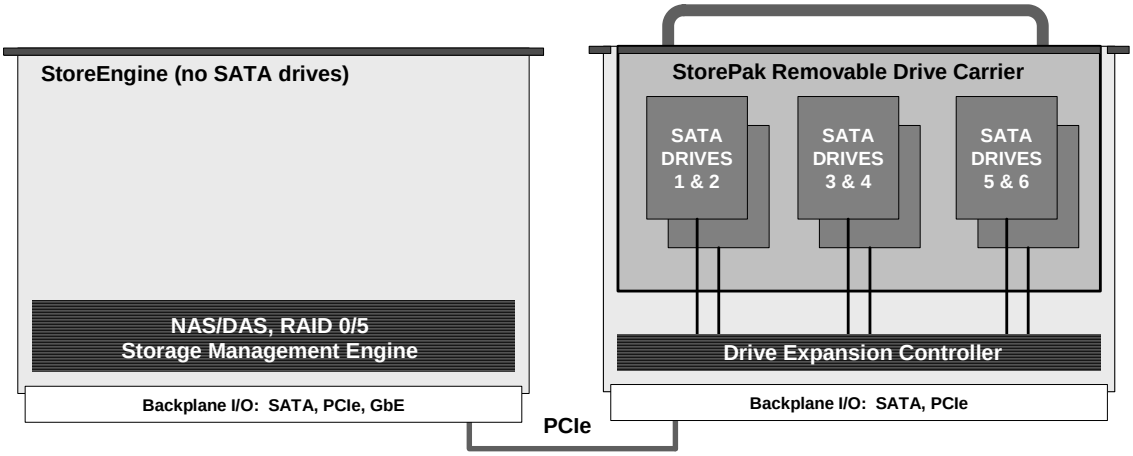

Figure 4. *Removable* media. A drive-less StoreEngine blade, combined with one or more six-drive StorePak blades. This provides up to 3 TB of *removable* SATA storage using two 6U slots, and up to 12 TB using 5 slots.

StoreEngine and StorePak -- Applications

StoreEngine and StorePak blades can be used separately or together to provide a flexible set of storage applications.

Application 1: Multi-GB/s Data Recording

The StoreEngine Giga-sample Data Recorder (GDR) is turn-key data recorder hardware and software that provides a powerful, flexible and highly scalable recording platform to continuously record high bandwidth data streams from ADCs, FPGAs, video streams, and other sources. The StoreEngine GDR platform provides a simplified architecture through seamless aggregation of multiple StoreEngine and/or StorePak storage blades that maintains a single entity operational and management view.

StoreEngine and StorePak can support a wide variety of recording and playback interfaces including PCIe, 10GbE, Fibre Channel, and supports recording in NAS, DAS, and Recorder modes. In Recorder mode, StoreEngine completely manages storage resources using a recording file system that runs on the StoreEngine(s). This file system allows striping data from a single data stream across multiple blades for increased capacity and performance as well as aggregating the additional removable storage provided by multiple StorePaks. Time stamps are added to each data block, and a provision for user extensible meta-data is provided.

The recorded data source may be a data stream from a PCIe connected ADC (or any other simple DMA capable PCIe data source such as an FPGA, or even a processor board with a PCIe capability), or it may consist of a raw Ethernet or UDP/IP data stream. The StoreEngine/StorePak blades, along with the data source, are typically hosted in a VPX rack, and are interconnected using a VPX mesh or VPX switched backplane. A VPX mesh backplane provides point-to-point “fat pipe” PCIe connections between boards, while a VPX switched backplane uses a PCIe switch board to provide slot to slot connectivity.

Playback of recorded data may be via a PCIe connection, via Ethernet (NFS, FTP, CIFS, streaming), or via Fibre Channel. To the playback data consumer, the multiple StoreEngine/StorePak blades that comprise the recorder appear as a single data source. For Ethernet playback, an exported pseudo file system is used, where each file in this file system represents an aggregated recording. This allows the use of standard network file sharing protocols such as FTP, NFS, or CIFS to access the aggregated recorded data.

Core to the GDR is the Critical I/O GDR Manager software, which runs directly on the StoreEngine blades and provides turn-key data recording operation. The GDR Manager coordinates the striping of data across multiple StoreEngine blades, and also coordinates unified playback of recorded data. This allows the multiple StoreEngines in the data recorder to appear as a single data source when data is replayed. All of the functionality to control both the recording of data and the play back of data from multiple blades is built into the GDR Manager software. Utilizing the Critical I/O StoreEngine GDR and GDR Manager software greatly reduces the effort required to field a scalable wide band data recorder.

The StoreEngine GDR currently supports recording from several types of data sources:

- ADC: recording data from ADC XMCs via PCIe connection.
- FPGA: recording data from FPGA signal processor modules via a PCIe connection.
- 1/10 Gb Ethernet: recording either raw Ethernet frames, or a sequence of UDP datagrams

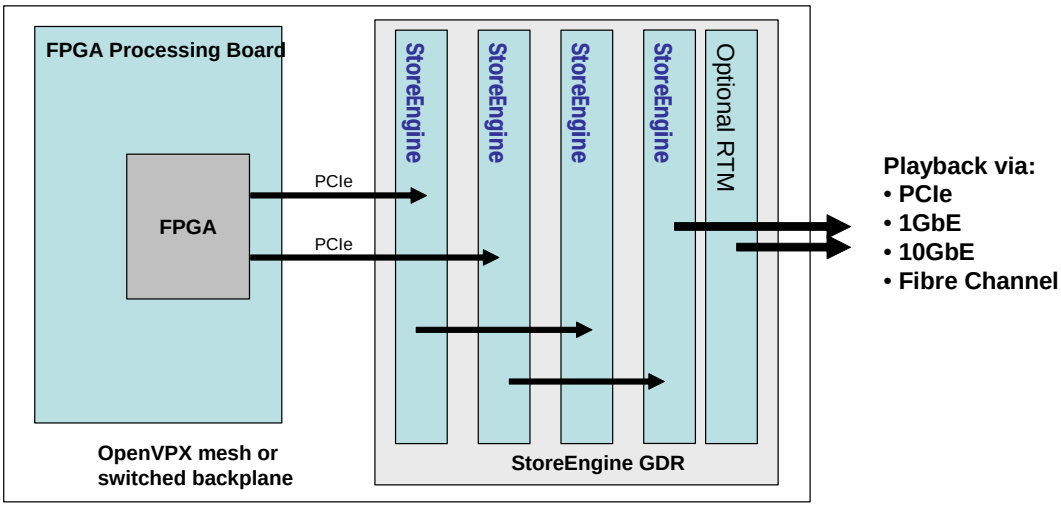

Figure 5. Single Channel - Four blade StoreEngine Data Recorder recording from a single-channel FPGA / ADC data source at up to 2.0 GB/s.

The GDR manager stores recorded data on the blades SATA storage drives as a series of "files". A file is defined as a continuous recording of data between a "start" command and a "stop" command. Each file may optionally be distributed among all of the StoreEngine/StorePak blades that comprise the data recorder, and are further distributed across all of the SATA drives with each blade. Files are recorded contiguously and can be replayed on a file-by-file basis.

A higher performance application of the StorePak/StoreEngine recorder combination is shown in figure 6. Here one StoreEngine is managing three StorePaks, each StorePak receiving a different channel of data. This system provides 9 TB of hot-swappable solid state recording capacity, with an aggregate recording rate of up to 4 GBytes/s.

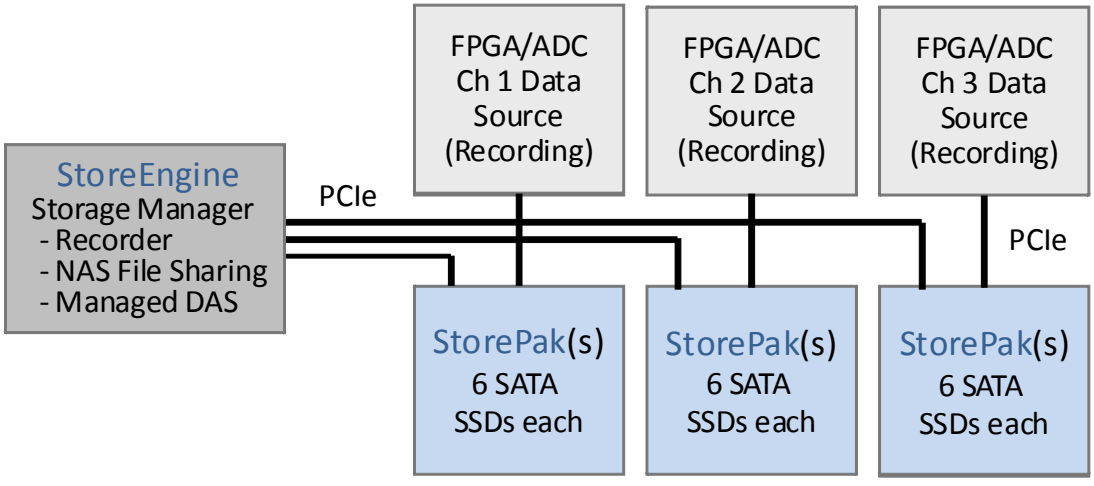

Figure 6. Multi Channel - Four blade StoreEngine/StorePak Data Recorder recording 3 channels of FPGA / ADC sourced data (aggregate rate of 4.0 GB/s)

Application 2: File Sharing (NAS)

StoreEngine's NAS (Network Attached Storage) capability provides file-level access to onboard storage volumes in a network environment. This allows data storage to be accessed and shared via standard file access protocols including NFS, CIFS/SMB and FTP by NAS client devices that are connected to StoreEngine via standard Ethernet networks. A unique ultra high performance UDP based streaming NAS protocol, running over a 1 or 10 Gb Ethernet network, is also available.

Because NAS storage access is always file based, NAS managed data can easily be shared among multiple clients. Data transfer rates for NAS storage are more moderate (as compared to DAS usage), due to the additional complexity of the NAS protocol stacks. StoreEngine typically supports NAS data access rates of up to 200 MBytes/s.

Figure 7 illustrates several different Ethernet connection options that StoreEngine supports for NAS operation. These include support for front panel connection to an external Ethernet network, backplane internal fabric direct client-to-StoreEngine connection, backplane internal fabric connection to an embedded Ethernet switch, and optional RTM based rear I/O connections to an external 1 or 10 Gb Ethernet network.

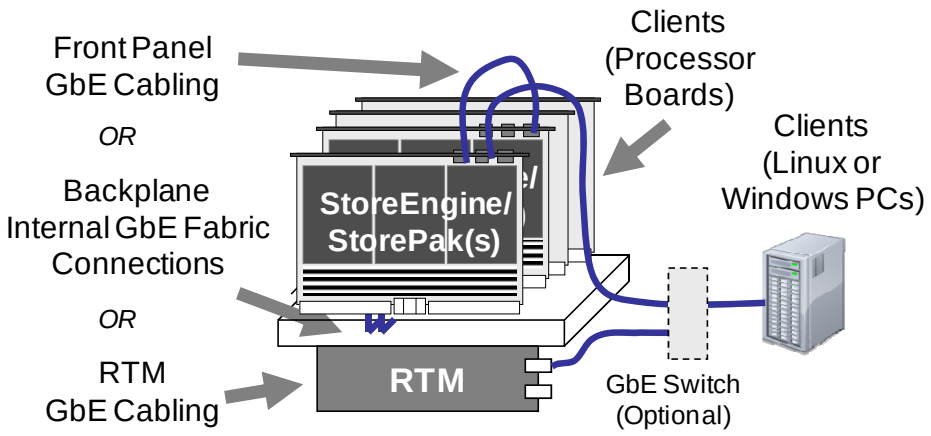

Figure 7. NAS Ethernet connectivity options

Application 3: StoreEngine Embedded RAID (DAS)

StoreEngine's embedded RAID Direct Attached Storage (DAS) capability provides block-level access to StoreEngines onboard storage for bandwidth driven applications. Access to storage is provided via a standard backplane PCIe fabric, as well as support for multiple optional interfaces such as Fibre Channel, Ethernet/iSCSI, and Ethernet/FCoE. StoreEngine's embedded RAID can support up to 800 MBytes/s of sustained read or write performance for a single blade and can be scaled to higher levels through the use of additional StoreEngines or StorePaks.

In DAS applications, the client processor hosts a file system that is provided by the client's operating system. The client thus utilizes StoreEngine/StorePak storage in a low level block mode. The allocation and use of these low level storage blocks is controlled completely by the client file system, thus (unlike NAS storage) DAS stored data cannot typically be shared between multiple clients.

PCIe connected DAS architectures leverage standard PCIe fabrics for client connectivity to StoreEngine. The PCIe connections are often made using embedded backplane high speed fabrics (figure 8). In some situations the connections may also be made using optional RTM PCIe access.

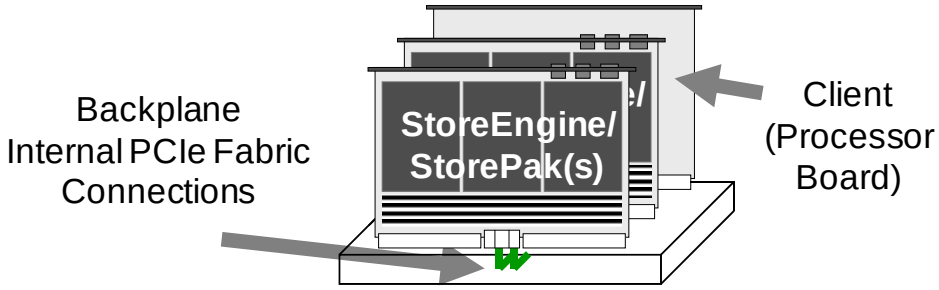

Figure 8. PCIe connection through internal backplane high-speed fabric

Fibre Channel DAS requires the use of the optional Fibre Channel Rear Transition Module in conjunction with StoreEngine. Client boards may use standard Fibre Channel HBA adapters to access StoreEngine using these protocols, along with use of standard Fibre Channel initiator drivers.

Application 4: Concurrent Multi-mode Operation

The StorePak/StoreEngine combination illustrated in figure 9 provides concurrently:

- High performance data recording capabilities at rates of over 1200 MB/s per StorePak.
- NAS file sharing capabilities using NFS, CIFS, or FTP over 1/10 Gb Ethernet.
- Fully managed Direct Attached Storage (DAS, aka RAID) capabilities using PCIe or Fibre Channel.

An example of using the StorePak/StoreEngine combination is shown below. In this example StorePak/StoreEngine is being used concurrently for three different modes of operation: NAS file sharing, high performance data recording, and DAS RAID.

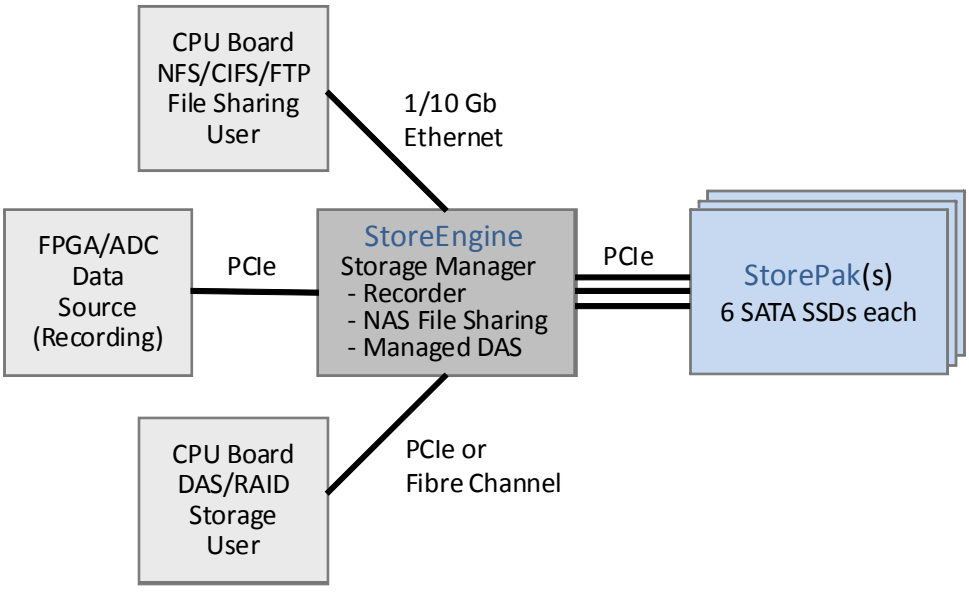

Figure 9. Concurrent multi-mode operation

Application 5: StorePak Unmanaged Direct Attached (Raw) Storage

When used stand-alone, StorePak provides a simple unmanaged DAS capability (i.e. storage appears to host as raw drives), connected to the host CPU board using PCIe.

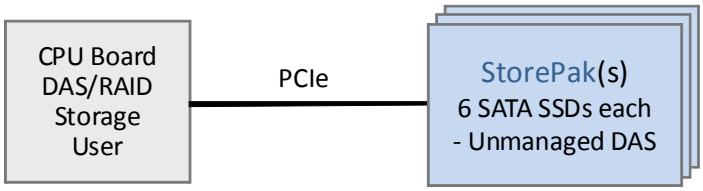

Figure 10. Unmanaged PCIe connected raw storage

StoreEngine/StorePak – Storage Management Features/Options

Web Management Interface

StoreEngine NAS functionality is enabled and managed via a simple yet comprehensive web based management interface. This supports configuration and monitoring of all StoreEngine interfaces, operating modes, and storage options. Some specific web management capabilities include:

- BIT status (self test, voltages, currents, temperatures)
- Storage status (available/used capacity, status, errors)
- Network statistics
- Interface Status (link status, errors)
- Enable/Disable protocols & options
- Manage NAS and DAS exports
- Security and permissions
- Secure erase
- Storage benchmarking
- Recorder setup and control
- Configuration snapshots

RAID Options

StoreEngine storage can be configured to operate as either RAID 0 or RAID 5. Both RAID 0 and RAID 5 modes aggregate the storage of all of the StoreEngine drives into one or more “logical drives”. RAID 0 and RAID 5 differ in levels of write performance and data protection.

RAID 0 stripes data across all of the StoreEngine drives, which provides the highest possible read and write performance, as well as the highest usable capacity. RAID 5 also stripes data across drives, but in addition creates a parity block for each data stripe, which provides data protection and continued operation (at a lower performance level) in the event of a drive failure. Since one “drives worth” of performance and capacity is reserved for parity in RAID 5, the capacity and write performance when using RAID 5 is approximately 2/3 that of RAID 0 for a standard three drive StoreEngine configuration (or 5/6 for a standard six drive StorePak configuration).

Encryption

StoreEngine provides a option to encrypt all data as it is written to disk. Note that while StoreEngine has hardware-accelerated encryption, the use of encryption may affect performance in some situations.

Secure Erase

Store Engine provides a Secure Erase operation which may be invoked via the Web Management interface. Secure Erase fully erases all data on the selected drive, restoring the drive to an unused condition. Note that Secure Erase can take several minutes to performance on a Solid State drive, and up to several hours to perform on a rotating hard drive.

Quick Config

StoreEngine provides two “quick configuration” options. The first is as set of pre-defined configurations that can, with a single mouse click, fully configure StoreEngine to one of six commonly used configurations. The second method allows users to create and store “configuration snapshots”. These configuration snapshots can be reapplied with a mouse click to restore a StoreEngine to a known configuration. These configuration snapshots can also be transported to other StoreEngines, allowing users an easy way to “clone” configurations to additional StoreEngine units.