White Paper

NetApp Storage Solutions for Processing, Exploitation, and Dissemination

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March 2012 | WP-XXXX

ABSTRACT

With the growing volumes of intelligence, surveillance, and reconnaissance (ISR) data captured by a myriad of sensors for motion imagery, satellite imagery and data, radar feeds, and aerial surveillance, government agencies need to address the challenges posed by these “big” datasets to ingest data, analyze content, and turn datasets into valuable intelligence. NetApp provides a scalable, modular, and flexible storage solution targeted at solving issues for the ISR space and focused on a unified single pool of storage that can handle the demanding workflow requirements of sophisticated ISR environments.

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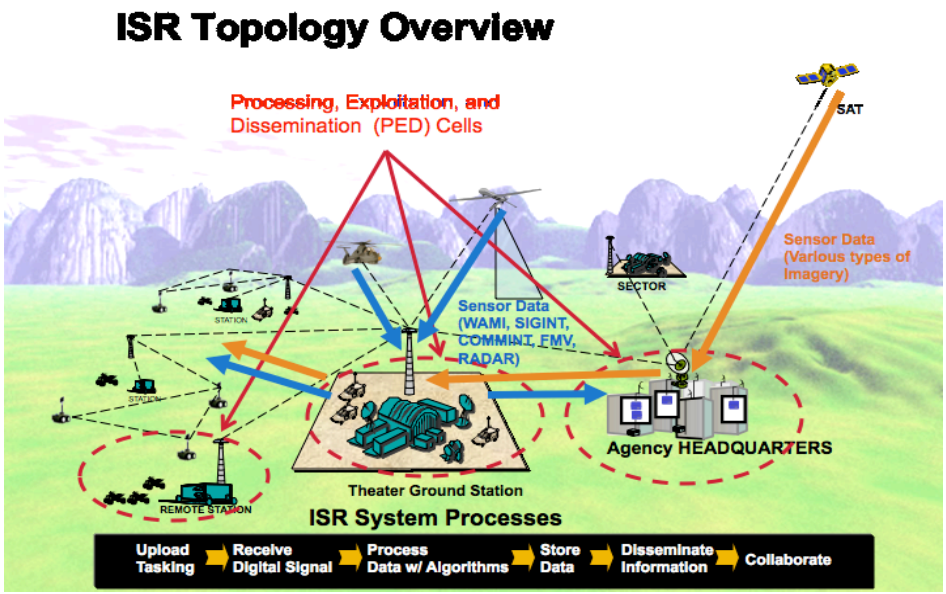
1 INTRODUCTION

Next generation multi-INT intelligence creation requires coordinating and combining data from many disparate sensor types and sources. Modern combat requirements have transformed sensor ingest, processing, storing, and dissemination of real time data that includes machine to machine and machine to human interactions. The demand for high bandwidth and large capacity solutions are a result of demanding workloads from these techniques applied to different sensors including wide area persistent imagery, full motion imagery, and satellite imagery.

Modern arrays of Electro-Optical (EO) and Infrared (IR) integrated camera systems on a single unmanned aerial vehicle (UAV) can produce more than 100GB/sec of data when tasked for wide area surveillance purposes. Figure 1 illustrates the use of multiple RF and terrestrial based communication channels to distribute the sensor data and related information to various communities of interest for exploitation. In this scenario high speed processing, data protection, information assurance, and unified metadata search capabilities significantly enhance operations and the production of secure actionable intelligence.

The sensor data originates in the aerial platforms and is distributed in various formats and to different entities.

Figure 1) ISR Concept of Operations CONOP.



COLLECTION OF DATA

While the ISR concept has remained relatively static and the data flow continues to remain the same, the number of platforms and associated sensors are growing linearly while the sensor sources and their resolutions are growing exponentially. Processing takes place in multiple locations where raw data is typically ingested and remains at the edge for tactical use while some encoded data is distributed for broader analytical use. An example of this scenario is within wide area surveillance platforms with multiple sensors where the motion imagery data is stored on the platform as 13.3Kx13.3K resolutions using JPEG2000 formats, but the distributed live feeds are full motion video encoded MPEG2 streams at 640x480 resolutions. The live distribution of video allows for immediate situational awareness for warfighters at much lower bandwidths and resolutions that are applicable to mobile viewing. The storage of the sensor data happens in multiple locations, but ultimately raw data stays at the edge and the meta

data that describes the content is created and exposed to the broader network of systems or users. Once searchable via this metadata, this raw data can be transferred or disseminated, on request over, dedicated terrestrial communications channels or satellite links to other relevant users. Generally speaking, the endpoints are known as the Processing, Exploitation, and Dissemination (PED) sites and may contain raw and/or processed sensor data. These sites are further defined by their processing and storage characteristics to include:

- Tactical Edge: Raw data from sensors typically stored local to the platform. This same raw data gets transferred and stays local to the remote stations that have access to the platform systems.
- Theater PED Sites: Processed data gets transferred to these PED sites where it can undergo processing for additional intelligence extraction or made available for broader high bandwidth distribution and future tactical planning. The raw and processed data are used for real time analysis at these PED sites and at headquarter locations. Another name commonly used for these sites is the forward operating bases (FOBs).
- Data Center Sites: The raw and processed data gets distributed to these datacenter locations that typically serve archival and massive analysis functions.

Whether at the tactical level, theatre level, national asset level, ultimately, what's most crucial is the consistent access to the data with a scalable solution that adjusts in capacity and performance no matter what size, the interactions are the same.

PROCESSING, EXPLOITATION, AND DISSEMINATION

The gathering and accurate analysis of intelligence data are the foundation for effective decision making across government agencies. The ability to collect and retrieve raw data from multiple large data sensors is a critical step in providing the necessary information used in both manual and automated analysis. Images and sensor data become valuable when large quantities of high-quality information can be extracted from the raw data. Then that data can be effectively processed, exploited, analyzed, interpreted, and disseminated for faster and more effective action.

Processing and exploitation involve formatting and converting the immense amount of data collected into meaningful form that can be used by analysts. This is done through a variety of methods, including applying codecs, analytics algorithms, decryption, language translation, and data reduction all aimed at finding the information buried in the noisy raw data. The goal of dissemination is to get this relevant and accurate information to the decision makers and field operators in a timely fashion.

INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE

Actionable situational awareness in modern tactical environments is driving the demand for high-performance, rich imagery sensor systems. These supporting PED systems must support the resulting onslaught of data throughput and accumulated storage capacity required for multiple high-resolution, high–frame rate video streams. At the same time, these systems must be able to assist analysts in rapid interpretation of real-time events, provide mechanisms for distribution, support high tempo decision-making, and provide long-term aggregation and retention of data for more in-depth intelligence.

The variety of data resolutions and sources creates many different ISR workloads. The NetApp® Full-Motion Video (FMV) solution supports multistream video and imagery workflows with low-latency acquisition, storage, and transmission of ISR sensor feeds; this enables real-time decision making in battlefield conditions as well as intelligence analysis for longer range planning. The characteristics of the workloads vary based on the sensor implementation, but they all require large bandwidth, sequential writes per stream, and multistream random reads. These characteristics are similar to the world of full-motion video, where broadcast video systems require the same functionality, albeit at lesser bandwidths and higher numbers of streams.

The NetApp FMV solution provides a single storage pool for multistream ISR sensor content captured on the NetApp E5400 storage system and aggregated by the high performance Quantum StorNext shared file system, CIFS, or NFS file system. Using a single consistently accessed file system, for all content, rather than poorly integrated storage islands makes effective collaborations possible with the ability to compare and analyze real-time data. The NetApp Full Motion Video solution provides quick reference to critical information, enabling agencies to drive operational efficiencies and reduce time and energy. With better insight the data can be turned into quality information for better decision making in critical environments.

Based on the E-Series platform, the NetApp storage solution is optimized for capturing and examining rich video and sensor data. It's designed to handle the extreme bandwidth requirement for large sequential writes, aggregates end-to-end throughput, and scales linearly and independently in both capacity and bandwidth. Also, it's intuitive, scalable management and modular design simplifies scaling and increases flexibility for mixing and matching to suit different requirements with the same system.

2 ISR SENSOR TRENDS

Fast transfer and storage of ISR sensor content are crucial. It is critical to make video and images available for analysis and interpretation as quickly as possible to enable teams to make split-second decisions. Less time spent in ingesting data means more time spent in subsequent collections, processing, planning, on mission critical endeavors. High–frame rate video streams and low–frame rate motion imagery from multiple simultaneous sources are becoming more common, making the requirements for high-performance transfer and storage even more daunting.

SENSOR RESOLUTIONS AND WORKFLOWS

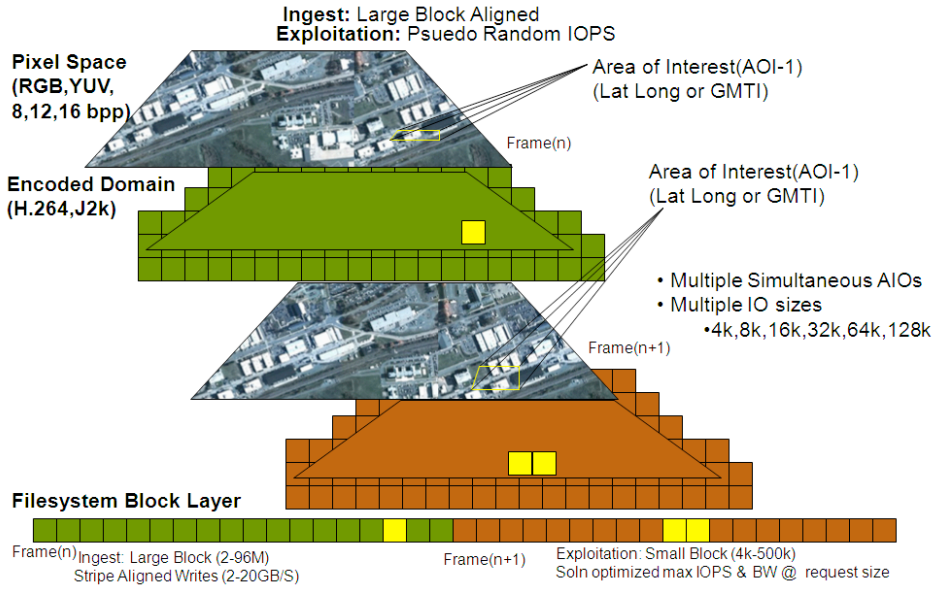
Sensor data, such as video, includes video displays at many different resolution and sampling rates depending upon whether it is focused on a number of separate video observations or wide area motion imaging. This video may be sent by radio frequency (RF) transmission at 1.5 to 100Mbps or through Ku-band satellite feeds at 10 to 100Mbps. It can also be downloaded from aerial platforms and unmanned aerial vehicles (UAVs) carrying surveillance equipment after a mission. The data can be used locally for logistical work or at great distances for intelligence aggregation and analysis. Sensor data varies greatly due to specialized uses of the sensors, but a high level view of the various resolutions illustrates some of the variety available for different, yet concurrent, uses. This means the compute and storage platforms require the ability to support converged sensor data at the various tiers.

Table 1) Resolution for various sensor types.

Sensor Type	Resolutions	Raw Data Bandwidth	TB/Hour
FMV	SD) 640x480 HD) 1920x1080	HD @ 16bit color, 30fps ~1 Gbps	~.450 TB
WAMI	Angel Fire = 66 Mpixel Constant Hawk = 96 Mpixel Gorgon Stare = 460 Mpixel Argus = 1.8 Gpixel	Gorgon Stare @ 16bit color, 2fps ~15.3 Gbps Argus @ 16bit color, 12fps ~345.6 Gbps	~6.89 TB ~155 TB
Satellite	GEOTIFF/JPEG2000 resolutions 32Kx32K pixels 432Kx216K pixels	32Kx32K, 8bit color, 1 frame every 5 minutes ~27 Gbps	~12.15 TB

Tradeoffs of frame rate and resolution can be specified for each individual sensor depending on the usage, such as low bandwidth microwave links requiring lower resolution and frame rate imagery for tactical viewers and analysts. Low frame rates for a given available bandwidth for a video channel allow more details to be viewed, but higher frame rates provide better interpretation of apparent motion, even if the resolution is reduced. Higher resolutions are typically used at acquisition and ingest, where processing, exploitation, and dissemination will often use clipping to create subsets of the smaller resolution imagery. Many ISR systems contain multiple sensors; WAMI (larger resolution lower frame rate) is typically used and stored locally, and FMV (smaller resolution higher frame rates) is distributed to the ground stations.

Figure 2: Imagery Ingest and Exploitation IO Patterns



The various needs for ISR sensor data workflows results in different requirements for the storage system. As is show above, the imagery data ingest and playout typically manifests as large sequential writes where as both exploitation will manifest as small block IO due to evaluation of multiple areas of interest (AOI) inside an image.

With increasing reliance of machines/technology for some of the processing, there is greater emphasis on supporting this mixed storage workloads of partial writes and reads. If the full bandwidth of a surveillance device is focused on a limited number of observed images (soda straws), higher resolution images can be coupled with higher frame rate image capture to create both high-detail images as well as good playback motion.

Testing of the various workload requirements emulating the combined ingest, processing, exploitation, and dissemination results in high useable bandwidth for mixed read/write at approximately 3.2 GBps (see Table 4). This numerical value can be used as an elemental number for scaling out the storage and processing platform in linear manner using the FMV solution from NetApp. The cost effective scaling is made possible by using a shared/parallel file system with Quantum StorNext. The high density and performance provided by the E-Series storage is coupled by a shared file system that provides robust features for dissemination and tiering, but also for cost effective scale out for larger workloads from sensor data.

ISR SENSOR THROUGHPUT REQUIREMENTS ARE INCREASING

ISR platforms and the aforementioned PED units typically process multiple streams of data simultaneously. This increases the throughput demand and is trending toward more simultaneous streams of higher resolution and frame rates in next-generation sensors.

These high-resolution, high–frame rate, multiple-stream videos are having a net impact on the supporting storage systems, requiring an expansion of throughput and storage capacity to effectively handle the size and volume of video captured. A single modern drone aircraft can generate combined video stream data rates of over 32Gbps and 145TB/hour. Table 2 gives examples that show the growth in these requirements.

Table 2) Growth of throughput and storage capacity demand to support drone surveillance.

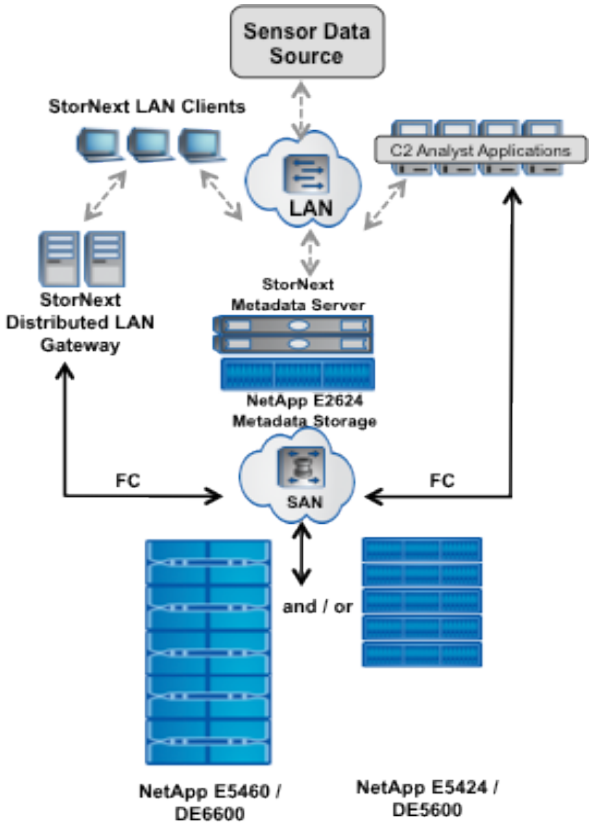
	IOCYr	Mbits/Sec	TB/Hr	Growth
Predator	1998	9	0.004	
Angel Fire	2005	1,584	0.7	175x
ARGUS	2010	324,000	145.8	208x

3 NETAPP FULL-MOTION VIDEO SOLUTION

The ability to effectively and quickly capture, store, and analyze video collected from satellites and aerial surveillance platforms (such as UAVs) is essential to making informed decisions. To meet the continually expanding needs of ISR sensor systems, the NetApp FMV solution delivers an optimized storage solution that captures and supports examining video feeds for better in-theater decision making.

The components of the NetApp FMV architecture are depicted in Figure 2.

Figure 3) NetApp FMV architecture.



The FMV solution provides a high-performance file system in Quantum StorNext with the highest performance and modularity storage in the marketplace, the NetApp E5400. Together a boundless container for applications to write and read, large sensor files can be accommodated.

The ISR applications for ingest and automated or manual analysis resides on the hosts running the StorNext LAN and SAN clients. These clients can be implemented concurrently on Windows®, Linux®, and OS-X operating systems for maximum flexibility, and present a defacto standard POSIX interface or NFS mount point for access to the imagery.

The NetApp E5400 storage systems can be implemented in the following echelons:

- **Tactical edge,** Ultradense form factor, high bandwidth, support for SSDs, is well suited to meet environmental requirements such as dust and vibration.
- **Theater PED sites.** Depending on the PED requirements, the modular capabilities for the E5400 can be used in small–form factor, high-performance and capacity, or denser larger platforms.
- **Data center.** With the highest density and industry leading performance, the E5460 can provide the density and bandwidth needs for ISR sensor data center sites.

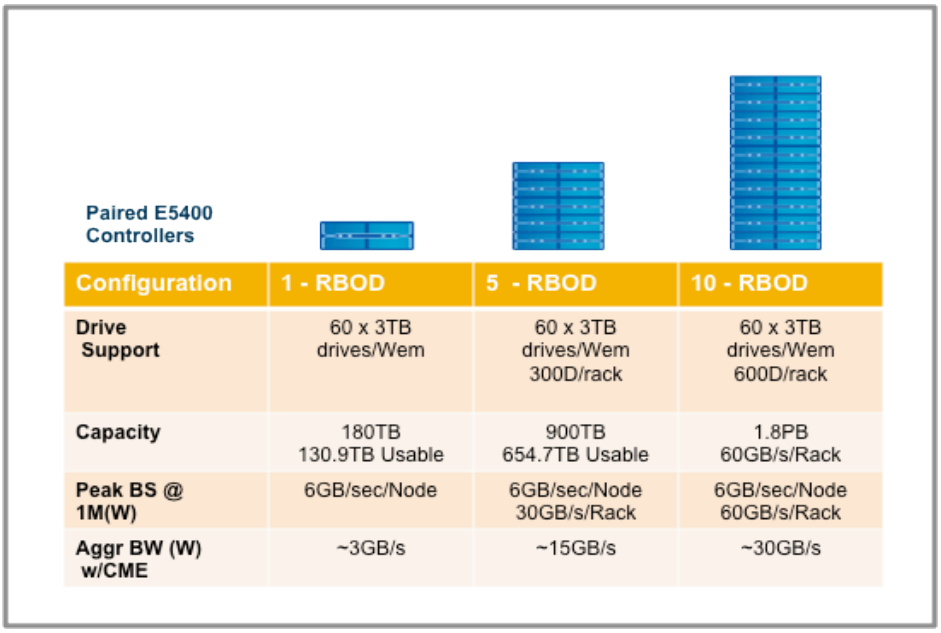
NETAPP E-SERIES STORAGE PLATFORM

The NetApp E5400 meets the demanding performance and capacity requirements of ISR environments without sacrificing simplicity and efficiency. Backed by over 20 years of storage development experience, the E5400 is based on a field-proven architecture that uses standard redundant components to provide the utmost availability of critical data.

- **E5424: Optimized for performance and low form factor**. The NetApp E5424 delivers both high bandwidth (6GBps) and high IOPS (350K) with leading price performance. The E5424 also saves cost by consuming 50% less power, using up to 24 2.5-inch SAS drives in a 2U form factor. A fully loaded rack delivers performance of up to 100GB/sec sustained disk read throughput, 70GB/sec sustained disk write throughput, 325 TB of useable capacity, and 1,500,000 sustained IOPS.
- **E5460: Delivers industry-leading density**. The NetApp E5460 delivers optimized storage density for maximum capacity with excellent performance, supporting up to 60 drives in each 4U enclosure. The E5460 supports high-capacity near-line SAS disk options that are superior to SATA drives for high capacity and lower cost per MB/sec, and they are an excellent choice for throughput-intensive applications. The 4U enclosure holds 60 disk drives in five drawers, delivering roughly 30GB/sec of aggregate read/write bandwidth per petabyte of usable capacity.
- **E2624: Metadata storage**. Best practices dictate a dedicated storage system that provides client access to file metadata (name, size, access times, data locations, and so on). NetApp offers the E2624, a cost-effective SAS-connected disk system that can be attached directly to the metadata controllers, delivering the maximum performance demanded by ISR applications.
- **Flexibility and choice**. The modular design of the E5400 allows you to mix drive types in a single enclosure to address different requirements with the same system. This lets you create a storage deployment tailored to your specific big bandwidth requirements that will grow with your needs and keep you within your budget.

Figure 4 shows some scaled options with the NetApp E5460 that will be important to full-motion video users depending upon their FMV workloads. The NetApp E5460 storage system is part of an overall full-motion video solution that combines the storage system with a StorNext file system to support common full-motion video workflows, allowing rapid video ingest, quick viewing for analysis, and long-term content retention.

Figure 4) NetApp E5460 storage systems for ISR applications.



Configuration	1 - RBOD	5 - RBOD	10 - RBOD
Drive Support	60 x 3TB drives/Wem	60 x 3TB drives/Wem 300D/rack	60 x 3TB drives/Wem 600D/rack
Capacity	180TB 130.9TB Usable	900TB 654.7TB Usable	1.8PB 60GB/s/Rack
Peak BS @ 1M(W)	6GB/sec/Node	6GB/sec/Node 30GB/s/Rack	6GB/sec/Node 60GB/s/Rack
Aggr BW (W) w/CME	~3GB/s	~15GB/s	~30GB/s

The E5460 provides large-block, random-access reads and writes that can support multiple video streams and sources simultaneously. Tens of higher bandwidth simultaneous client write streams and hundreds of lower resolution or smaller simultaneous read streams are possible with a single rack. This makes it possible to use a single NetApp 5460 rack to support multiple video sources as well as project collaboration, exploitation and analysis.

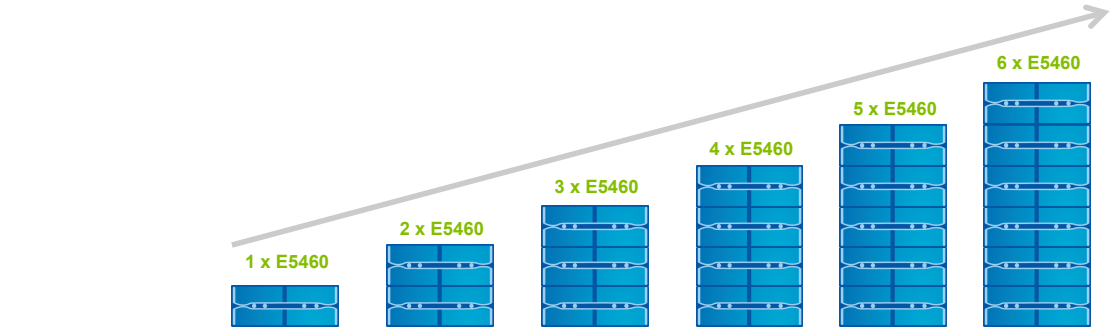
Because of its combination of high throughput and low latency, the E5460 supports demanding video workflows that include ingest, editing, and management—as well as content transcoding. Ingest rates of up to 300GB/sec with no dropped frames are possible by linearly scaling100 E5460's as part of the FMV solution.

To accommodate projected data growth, NetApp has designed the Full Motion Video solution to scale linearly and independently in both bandwidth and capacity.

The NetApp E5400 storage platform provides 29GBps write for FMV data per 40U rack. Each of the 4RU chassis that make up a full rack system can support approximately 132TB of usable storage capacity, making the total storage capacity of a full rack of these chassis about 1.3PB today (and more in the future as hard disk drive capacities increase).

Entire libraries of content can be part of a single addressable volume, as shown in Figure 4 (in this figure 50% read and write traffic is assumed). Total expandable content in one library can be 100 billion objects of arbitrary size. The E5460 can provide both an active archive of content that can be readily accessed when needed and current tactical content storage. This system can support all elements of a collaborative, modern, full-motion video workflow—from ingest through display, content distribution, and analysis.

Figure 5) NetApp E5400 scales bandwidth and capacity to meet changing requirements.



Drives (n)	30 - 60	90 - 120	150 - 180	210 - 240	270 - 300	330 - 360
Capacity (TB)	60 - 180	180 - 360	300 - 540	420 - 720	540 - 900	660 – 1080
Bandwidth when scaling systems (GB/s, writes)*	2.9	5.8	8.7	11.6	14.5	17.4

*With StorNext File System and representative workload

4 TESTING OF THE FMV SOLUTION

Demartek[i1] audited performance tests showing the value of the combined NetApp E5400 storage and Quantum StorNext solution in a multi-sensor ISR environment. The test objective was to prove linear scaling for various ISR sensor system workloads. The design of the test configuration, including E-Series firmware and hardware architecture coupled with a parallel file system, demonstrated that the necessary bandwidth would be provided across a range of use cases. These tests, performed in the NetApp labs in Wichita, Kansas, were designed to evaluate the following workloads:

- High-speed ingest
- High-speed file transfers
- Large numbers of simultaneous input/output streams

Table 3) Test objectives and results.

Test Case	Objective	Results
Ingest	~3GBps per scalable unit	~2.9 GBps per E5460 with 7200 rpm drives
Exploitation and Dissemination	~3 GBps per 4Uscalable unit	~3.2 GBps per E5460 using 3TB with 7200 rpm drives.

[1] Demartek, Arvarda, CO, www.demartek.com.

Test Case	Objective	Results
All Use Cases	Scale linearly as scalable units are added such that (4) scalable elements will provide ~12 GBps of bandwidth for writes	Scale linearly as scalable units are added such that (4) E5460s will provide ~11.6 GBps of bandwidth for writes and ~18 GBps for reads (at 256 KB block sizes).

TEST METHODOLOGY AND DETAILED RESULTS

The tests shown here are only an example of what can be done with this FMV solution. Further expansion of the number of switches, servers, and E5460 storage boxes would allow additional performance and capacity capabilities beyond those shown here.

The tests involve multiple mixes of workstreams and file sizes to accommodate the variety of ISR workflows for the storage systems.

The use of mixed read-write profiles for the workloads emulates the environment expected in a theater PED or datacenter site. At these sites, archiving and analysis of the sensor data by multiple analysts is common. Similarly, the constant need to support large sensor data ingests and processing is present. This can result in numerous read: write ratios as well as differing block sizes which varies from the tactical edge, where write only and read only workloads are commonly seen for ingest during a mission or copy functions at the end of a mission.

The single scalable unit test environment:

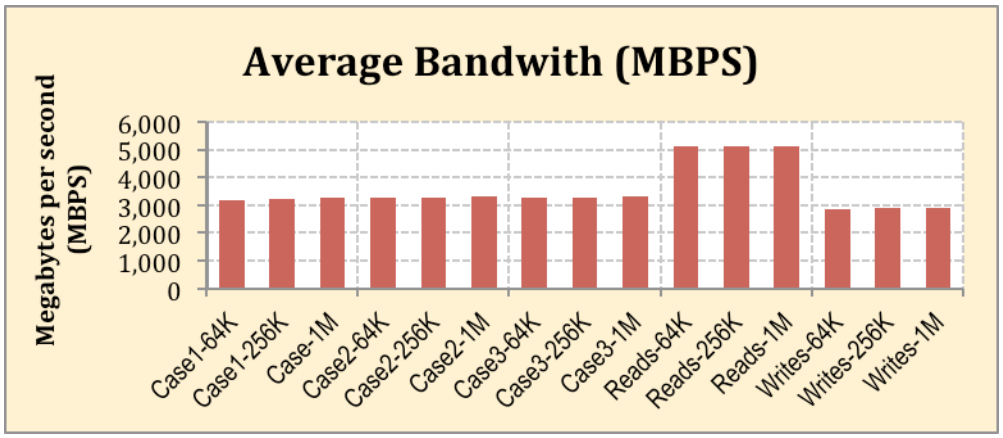
- 3 SAN client servers with 4 Fibre Channel ports server connected to a connected to either a Fibre Channel fabric of four FC switches
- Quantum StorNext and NetApp E5400 storage solution consisting of a Quantum M330 appliance (acting as a meta data controller) with one NetApp E5460 array configured into 6 file stripe groups

A series of test workloads performed parallel sequential read and write operations to the six file stripe groups, which represents parallel video streaming operations. Three block sizes were used: 64KB, 256KB and 1MB.

Table 4) Test case workloads.

Test Case	Read Threads	Write Threads	Concurrent Threads	Stripe Groups
Case1	1	1	12	6
Case 2	2	2	24	6
Case 3	10	10	120	6
Read	1	0	6	6
Write	0	1	6	6

Figure 6) Single E5460 Test Results

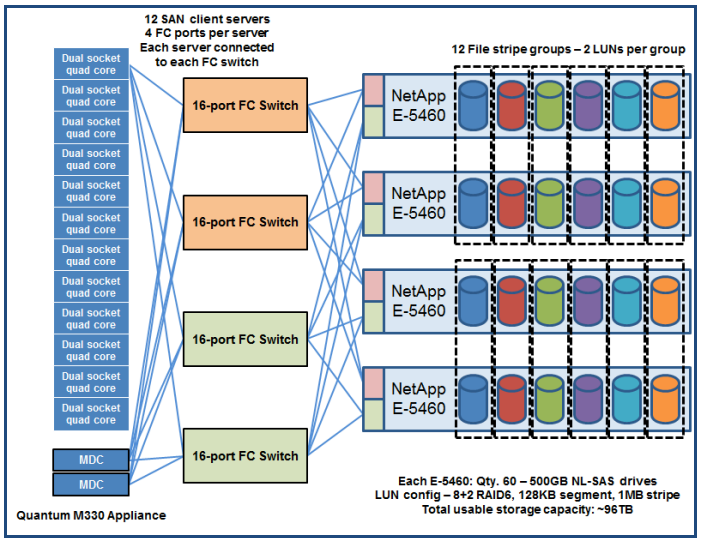


In addition to the average bandwidths of the single E5460, the linear scaling of storage elements (NetApp E5460s in the test case) within the FMV solution presents proof of the ability to increase scale in bandwidth and capacity linearly, therefore supporting small to large environments from the tactical edge to the Datacenter for ISR sensor data.

The larger test environment for the scale out results is outlined below. The test environment consisted of a workflow emulation test bed:

- 12 SAN client servers with 4 Fibre Channel ports
- Fibre Channel fabric of four FC switches (as shown in Figure 7)
- Quantum StorNext
- NetApp E5400 storage solution, consisting of four NetApp E5460 configured to 12 file stripe groups, corresponding with the 12 SAN client servers
- Quantum M330 appliance (acting as metadata controller)

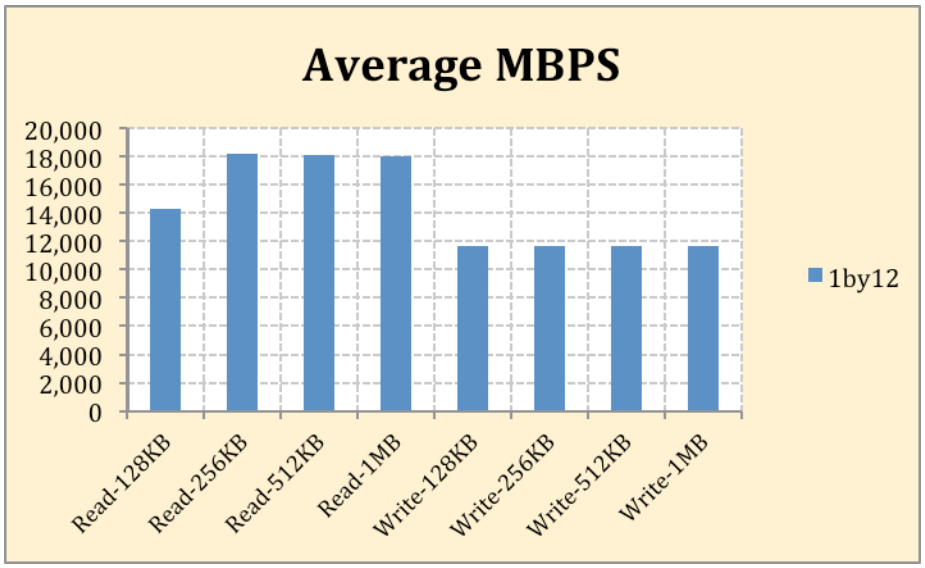
Figure 7) Multiple E5460's Test Bed



The Quantum StorNext appliance operates with file stripe groups to maximize the performance of each application workload. In these tests, 10GB files were assigned to each file stripe group, and each of the 12 servers was assigned a file stripe group.

Figure 8 shows the resulting storage system throughput for single stream content written and read at the four block file sizes. The single stream reads and writes saturate in terms of throughput at 256 KB block sizes and above – and read is considerably faster than write. This exceptionally fast write performance is due to the intelligent writing algorithm in the NetApp E5460 that results in consistently high performance writes for sequential writing. On the other hand, reads tend to be more transaction based, harder to predict and ultimately slower for the multi-stream environment.

Figure 8) Test Results for (4) 5460s



5 SUMMARY

As shown in this paper, the NetApp FMV solution supports ISR sensor feeds as well as longer term intelligence gathering operations, which match the capabilities of the most advanced sensor systems. The scalability of a single-pool storage system enables local and remote collaborative interactions, speeding decisions and implementation of decisions as well an aggregate sensor content storage and analysis. The resulting ISR workflow uses a single scalable storage pool to allow a complete workflow, including collection, processing, exploitation, dissemination, and archiving multi sensor content. The multistream performance of this solution, combined with the Quantum StorNext file system, enables collaborative workflows that require high-bandwidth multistream writing and reading combined with highly random reading. With the increasing requirements for content resolution for video surveillance and intelligence gathering, a scalable storage and bandwidth capable ISR solution provides growth potential to handle additional traffic streams as well as richer content for several years to come.

To accommodate the growing volume of streamed video and rapid data growth, the NetApp Full Motion Vide solution is designed to scale linearly in both capacity and bandwidth. High frame rate video stream from multiple simultaneous sources are becoming more common making the requirements for video transfer and storage even more daunting. As illustrated by Demartek testing, the FMV solution allows you to expand to the size required, but also the functionality required by the environment under various workloads for an ISR sensor system which requires consistently accessible, scalable growth and support ever expanding multi-int. environments. We meet these challenges through:

- High bandwidth and high IOPS with leading performance
- Linear scalability and consistent performance across workload types (11.6 GBps writes for (4) 5460s)
- Large sequential writes during ingest (2.9GBps per single 5460)
- Frequent reads during processing and exploitation
- Extreme density to support the increasing data volumes and retention times (Usable capacity of 528 TB for (4) 5460s)

The NetApp Full-Motion Video solution delivers an optimized storage solution for capturing and examining video feeds for better in-theater decision-making. With its ultradense form factor, data can be stored for longer periods of time, helping to improve decision support.

- **Bandwidth.** The solution handles the rigors of heavy computational workloads and bandwidth-sensitive streaming environments.
- **Reliability.** Advanced thermal and power features provide fast and confident deployment with preconfigured, pretested options.
- **Availability.** Standard redundant components provide the utmost availability of critical data.
- **Manageability**. By integrating Quantum StorNext data management software, the FMV solution is optimized for managing large datasets.
- **Scalability.** Accommodate growing data streams and access requirements.
- **End to end aggregation.** Provides a single container for linear scaling and performance while enabling all workflows to access raw and or processed data. Ultimately, enabling linear scalability and consistent performance across workload types.

While the emphasis of this paper has been on balanced performance and streaming sequential writes followed by random reads, this does not minimize the importance of management, scalability, reliability, availability and sustainability that comprises NetApp's Full Motion Video Solutions.

ABOUT THE AUTHOR

Dr. Tom Coughlin, president, Coughlin Associates, is a widely respected storage analyst and consultant. He has over 30 years in the data storage industry with multiple engineering and management positions at high-profile companies.

Tom has many publications and six patents to his credit. He is also the author of *Digital Storage in Consumer Electronics: The Essential Guide*, which was published by Newnes Press. Coughlin Associates provides market and technology analysis (including reports on several digital storage technologies and applications and a newsletter) as well as data storage technical consulting services. Tom publishes the *Self-Encrypted Drive Market and Technology Report, Media and Entertainment Storage Report*, and *Capital Equipment and Technology Report for the Hard Disk Drive Industry*.

Tom is active with SMPTE, SNIA, IDEMA, the IEEE Magnetics Society, IEEE CE Society, and other professional organizations. He is the founder and organizer of the Annual Storage Visions Conference (www.storagevisions.com) and a partner to the International Consumer Electronics Show and the Creative Storage Conference (www.creativestorage.org). He is also a senior member of the IEEE, a leader in the Gerson Lehrman Group Councils of Advisors, and a member of the Consultants Network of Silicon Valley (CNSV). For more information on Tom Coughlin and his publications, go to www.tomcoughlin.com.