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Flexing SSD Strengths for High-Reliability Data Recorders

Flash SSDs are lightweight, rugged and able to survive high altitudes and varying temperatures. These characteristics, plus their ability to achieve faster sustained writes with no gap between reloads, makes them highly desirable for military data acquisition and recording.

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Data acquisition and recording technology has grown exponentially over the past years as data recorder manufacturers try to keep up with faster data gathering speeds and more precise measurements. Data recording for military and civilian applications is a major issue, since it could spell the success or failure of operations or, in worst-case scenarios such as the battlefield, the life or death of individuals.

One case that comes into mind is the deployment of Spirit and Opportunity, NASA's twin Mars Exploration Rovers. Equipped with a variety of spectrometers, cameras and other tools, their primary mission is to search for answers about the history of water on Mars. Data recording and transmission is an essential aspect of this mission, and failure to record/store data would mean billions of dollars and several years of research down the drain.

Another concrete example is the flight data recorder (popularly known as a "black box") installed in civilian and military aircraft. Implementation of stricter safety requirements for commercial airlines has led to the development of data recorder solutions that can gather more parameters with greater accuracy. More parameters mean less other resources are required to finish a crash investigation.

Aside from these cases, there are many circumstances in which data collection and recording is just a one-time opportunity, making it necessary to deploy reliable data recording equipment and a storage subsystem that can keep up with input coming from high-speed sensors. This article discusses the feasibility of using solid-state flash disks as storage media for these data recorders, both from performance as well as cost standpoints.

Issues with Legacy Data Recorders

Mass storage has undergone several transformations ever since the introduction of punch cards during the mid-1800s. The 1940s saw the introduction of vacuum tubes for storage, while tape drives began to make their presence felt in the early 1950s. A couple of years later, magnetic drums were introduced and, in 1957, IBM rolled out the first rotational hard disk drive (HDD).

Tape drives and HDDs have survived the onslaught of silicon-based storage devices and are still available in the market. However, even though these storage media are widely utilized in business enterprises, they have weak points that can make them susceptible to failure under certain data recording applications.

While the magnetic tape drive has been a mainstay in the data recorder industry, this storage solution has inherent weaknesses:

• Data retrieval is slow due to sequential access: To retrieve a file, it's necessary to start at the beginning of the tape and move forward until the file is located. This process of rotating the tape media back and forth over the drive head can disrupt the playback of non-sequential data segments.

• Susceptibility to damage: Tapes must be stored in climate-controlled locations, since they are highly susceptible to damage by humidity, dust, heat, light and magnetic fields.

• Storage space required: The size of the magnetic tape is so big that its storage space becomes bulky.

• Quality of recording degrades over time: The quality of magnetic tapes eventually degrades over time, affecting recorded data.

Magnetic disk drives, more popularly known as hard disk drives (HDDs), have solved performance and durability issues associated with tape drives. However, HDDs are not without their disadvantages. As files are written onto and deleted from a HDD, data fragmentation occurs. Fragmentation has a negative impact on performance, since disk heads require additional time to move around to various points on the disk to read scattered file parts, resulting in a gradual deterioration of system performance—longer reads and extended reboots. In addition, HDDs contain mechanical components such as the read/write heads and spindle motors which, when subjected to shock and vibration, may damage the hard disk platters, resulting in bad sectors.

Time recorded	25 hour continuous
Number of parameters	18 to 1000+
Impact tolerance	3400Gs / 6.5 ms
Fire resistance	1100°C / 30 min
Water pressure resistance	submerged @ 20,000 ft
Underwater locator beacon	37.5 KHz; battery has shelf life of 6 years or more, with 30-day operation capability upon activation

Table 1

Flight Data Recorder ("black box") specifications.
(Source: NTSB web site [http://www.ntsb.gov/aviation/cvr_fdr.htm])

A Cost Scenario

Let us a take look at one particular instance where the cost of operating a data recorder is estimated using tape drives as media. A good example of a data recording application is an aerial reconnaissance mission, capturing imagery. This mission may either be military (enemy detection and surveillance) or civilian (mapping, traffic monitoring, science and geological survey) in nature. Each military mission normally lasts three to four hours and may cost millions of dollars each. These flights require data recorders with a sustained write rate of up to 230 Mbytes/s.

To meet this spec, tape-based data recorders will need high-speed magnetic tape costing well over $1,000 per reel. Each reel can only be used once because recording quality degrades if used more than once.

Assuming that one reel has a recording time of 15 minutes, then:

60 minutes (1 hour) = 4 reels per hour

15 minutes (per reel)

If 1 mission = 4 hours

Then 4 reels per hour x 4 hours = 16 reels

Multiplying the figure by the cost per reel (about $1,000), the cost of tapes alone could reach $16,000 per mission. If 100 missions were performed in a year, about $1.6 million would be spent on tape media.

There are other disadvantages to tapes as well. The tape controller is expensive and may be very bulky and heavy. Since each tape reel can only record data for 15 minutes, a new reel has to be loaded four times per hour. This means that there is a gap between reloads when the data recorder will not be able to take pictures. In these cases, reconnaissance planes have to cover the same area twice, increasing their exposure to enemy fire.

SSD Technology

The solid-state disk (SSD) emerged as an alternative medium during the early 1980s as data storage solution providers searched for a reliable device that could withstand hostile environments (shock, vibration and temperature extremes) in military and industrial applications. A good example is the commercial airline industry. The National Transportation Safety Board has set stringent standards for flight data recorders ("black boxes") installed in aircraft (Table 1).

Another aspect to consider is recording speed. As time and technology move forward, there is a greater need to capture higher resolution information. Today's sensors are able to collect much more data in a shorter amount of time. This means that data storage must be faster and more reliable than ever before. To ensure that no data is lost during collection, the storage subsystem must always be able to outperform the data collection subsystem, even when the data collection is at its fastest. Otherwise, valuable information will be lost.

Today, many recorders capture data to a RAID stripe on multiple disk drives. This is effective, but the reliability of disks can be a problem in harsh environments. Another aspect to consider is that traditional RAID controllers are managed by operating systems, and their disks frequently hold system files as well as recorded data. Thus, disk space and performance for "real-time" recording are shared with other applications and services in the system. For this reason, it can be difficult for a RAID subsystem to guarantee instantaneous performance at any given time as is required in real-time applications.

These demanding requirements are starting to dictate the need for a new storage medium, and SSD is an ideal technology to answer the call. SSDs offer a lot of features that makes them desirable for use in data recorders. First, an SSD is much more robust than a disk or a tape media as it has no moving parts. Second, the speed of an SSD is much faster than all other storage devices available, in terms of both data throughput and access speed. This is because there are no platters to spin nor heads that seek, resulting in immediate access to any data located in the SSD.

Taking SSD Technology to the Next Level

SSDs commonly use two types of memory: DRAM and flash. DRAM-based SSDs are based on volatile memory components and need some data retention mechanism (built-in batteries, non-volatile mechanical backup such as rotational HDDs) when the power supply is removed.

On the other hand, flash memory-based SSDs make use of non-volatile memory chips. If power is lost, the drive can preserve acquired data in excess of ten years even in extreme temperature changes without the need for additional backup components. This inherent non-volatility of flash SSDs not only means safer data but also makes them much lighter, smaller and quieter than DRAM SSDs. This is ideal for embedded data recording applications that often have limited capacity for space and power. Table 2 compares the physical aspects of a SCSI Wide DRAM-SSD from Curtis, Inc., to a SCSI Wide Flash-SSD from BiTMICRO.

	SCSI Wide DRAM-SSD	SCSI Wide Flash-SSD
Form-Factor	3.5 inch	3.5 inch
Maximum Capacity	12 Gbyte	147 Gbyte
Maximum Weight	2 lbs (0.17 lbs per Gbyte)	2.35 lbs (0.015 lbs per Gbyte)
Power Consumption	6 watts	≤ 4.5 watts

Table 2

Curtis Nitro!XE vs. BiTMICRO E-Disk Ultra Wide SCSI
(Source: Curtis and BiTMICRO web sites)

The volatile nature of DRAM suggests that in order for DRAM SSDs to ensure data preservation even in the absence of power, additional components such as backup batteries and hard disk drives are required. However, the mechanical nature of such devices makes them prone to damages from shock, vibration and extreme temperatures. Flash SSDs do not have mechanical parts, allowing them to withstand tremendous shock and temperature extremes without affecting operation or reliability of the data. Table 3 compares the operating characteristics of the Curtis SCSI Wide DRAM-SSD to a BiTMICRO SCSI Wide Flash-SSD.

Every storage device also needs some level of error checking to ensure data integrity. This is critical to any data recording application because it would be very costly, if not catastrophic in some applications, to have incorrect or corrupted data. Some SSDs implement a proprietary application of the Reed-Solomon Error Correction Circuitry (RS-ECC) specifically designed for flash memories with a bit error rate of 10-20. This order of magnitude difference means that for every 512-byte block, nine byte errors can be detected, and six byte errors can be corrected. The best that other storage devices can do is to detect only three byte errors, and properly correct it only 20 percent of the time.

	SCSI Wide DRAM-SSD	SCSI Wide Flash-SSD
Operating Temperature (max)	5 to 45°C	-60 to 95°C
Humidity	10% to 90% non-condensing	5% to 95% non-condensing
Altitude	10,000 feet	-1,200 to 120,000 feet

Table 3

Curtis Nitro!XE vs. BiTMICRO E-Disk Ultra Wide SCSI
(Source: Curtis and BiTMICRO web sites)

Security and Ease of Use

Some data recorders, especially military, capture highly sensitive data. Unmanned aerial vehicles (Figure 1), fighter planes and tanks in enemy territory run the risk of capture and therefore put their sensitive data at risk. This makes data security a high priority in these types of applications. SSD manufacturer, BiTMICRO Networks, offers a technology that allows users to irretrievably destroy stored memory on demand or automatically, even in the absence of an external power source, in compliance with the remanence security requirements of the DoD, NSA, Air Force, Army and Navy.

Ease of deployment is another consideration when it comes to using new technologies in traditional applications. Data recorders have long been using magnetic media; thus, incorporation of newer technologies should be simple. Flash SSDs come in the same form-factors as HDDs and support the most common interfaces. They are plug-and-play compatible with HDDs and are easily deployable in applications that use disk arrays or disk groups.

Figure 1

Data recorders are often deployed in unmanned aerial vehicles such as Global Hawk.

Flash SSDs bring other benefits as well. Users can save money, since flash SSDs are reusable. Faster sustained writes allow flash SSDs to take twice as many shots. There is no gap between reloads, so planes don't have to fly around twice. When recorded images are viewed for evaluation, multiple users can look at different frames simultaneously (no rewinding). Flash SSD solutions are lightweight, ruggedized and can survive high altitudes and varying temperatures.

With the ever-increasing demand for more reliable and higher-resolution data collection, SSDs are now becoming the storage of choice for data recorder professionals. With its advanced data protection technology and extremely low bit error rates, the integrity of stored data in flash SSDs is ensured even in the most critical of applications. Rapidly declining prices and improved production efficiencies have made flash memory nearly ubiquitous in digital consumer electronics. As manufacturers realize the huge price/performance benefits of flash SSDs, solid-state flash storage will steamroll into enterprise, military and industrial applications, and data recorders will never be the same again.

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