Solid-state storage is fast, cool and consumes little power—but it’s still pricey, so determining the best place to deploy the technology in your environment is critical.
SOLID-STATE STORAGE in storage arrays has evolved from a rare high-end array feature to a performance-boosting option in a large number of midrange and high-end storage systems. Most storage array vendors now offer solid-state options and there’s a growing list of commercially available, purpose-built, solid-state appliances.

Excluding capacity and price, a solid-state drive (SSD) outperforms a mechanical disk drive in most areas:

- It’s an order of magnitude faster than disk drives.
- It’s 100% integrated circuitry, so it’s more robust and durable than disk drives that depend on vulnerable mechanical parts.
- It generates less heat, consumes less power and requires less space than disk spindles.
- Challenges related to NAND flash—the underlying semiconductor technology used in SSDs—such as the wear-out of NAND cells, have largely been overcome through a variety of techniques, from overprovisioning of NAND cells to sophisticated wear-level algorithms.
that reduce the number of writes and distribute writes evenly among flash cells. As a result, contemporary SSDs match and, in some cases, exceed the warranty periods and mean time between failures (MTBF) of high-end disk drives. Were it not for its high per-gigabyte cost, solid-state storage would all but replace mechanical disk drives. At an order of magnitude higher per-gigabyte cost, however, the purchase decision and implementation approach of solid-state storage boils down to a diligent cost-benefit analysis that balances requirements and cost.

**KEY PURCHASING CONSIDERATIONS**

*Determine reason and objective.* Determining the reason for deploying solid-state storage should top any solid-state storage evaluation checklist. In too many cases, NAND flash is brought into the mix to overcome a performance bottleneck without first doing a thorough analysis of what’s causing the slowdown. Today’s systems and applications are complex, and only by examining all involved components, including processing power, memory, controllers, bandwidth, type of workloads and the circumstances under which performance suffers, can a performance problem be addressed appropriately without wasting valuable IT dollars on an inapt cure. “You should buy solid-state storage the same way you buy any other system—by first determining if it’s the right tool to solve your problem,” said Mark Peters, a senior analyst at Milford, Mass.-based Enterprise Strategy Group (ESG).

While performance is the most obvious reason for deploying solid-state storage, environmental challenges can be another motive for deploying SSDs. Because SSDs don’t have mechanical parts, and have smaller space requirements and lower power consumption than disk drives, this makes them a perfect fit for challenging environments. For instance, solid-state storage
is better suited to cope with the challenges of rugged surroundings and mobile deployments than disk drives. In places with limited data center space and power, solid-state storage may deliver comparable or better performance at a cost equal to that of a high-end disk array.

**Impact of SSD.** Once the case for solid-state storage is made, it’s important to determine the impact it will have on an application or system. To start, you need to clearly understand performance numbers in the vendor’s specifications. Manufacturers are likely to cite performance numbers in a favorable light without necessarily referring to the circumstances (block size, reads vs. writes, maximum vs. sustained performance) under which they were achieved.

Inherent to NAND flash, reads outperform writes and write performance is high initially when all cells are blank. “Since NAND flash shows great write performance the first 15 to 20 minutes, it’s important to compare their sustainable performance rather than their inflated burst performance,” said Greg Schulz, founder and senior analyst at Stillwater, Minn.-based StorageIO.

You should request independent performance benchmarks from the likes of the Storage Performance Council (SPC) and Standard Performance Evaluation Corp. (SPEC).
Startups and smaller vendor vs. established storage system vendors. Purpose-built solid-state drive (SSD) appliances are mostly available from startups and smaller companies. Obviously, there’s more risk associated with buying an enterprise storage system from a less established vendor. From interviewing customer references, reviewing company background and financials, and analyzing support and warranty options to contingency planning in case the vendor vanishes, meticulous due diligence is an absolute must.

Existing storage infrastructure. The storage you have installed plays an important role when selecting a solid-state storage option. It’s always preferred to extend an existing storage system with SSD if possible, and if the SSD performance of the current storage system suffices. If you need to opt for a heterogeneous SSD solution, you need to understand to what extent your existing system needs to interface with SSD storage: Will the SSD system run independently or will you need to move data between the two systems? In the latter case, you need to clearly define how data will be migrated.

Inquire about roadmaps. Solid-state storage is still a relatively new technology, especially in disk-based storage arrays, and the support of SSD and its functionality varies significantly among vendors. It’s important to understand a vendor’s roadmap during the evaluation process. This is especially true when you research SSD options for your existing storage system; if your current vendor doesn’t support SSD, you need to find out about future plans. If SSD is supported but falls short on features, you need to determine if the vendor’s planned enhancements are adequate or if you need to consider a different product.
offerings from different vendors. While system specifications and benchmark results are storage-centric and generic, they may have little validity for your specific application and issue. Therefore, some storage vendors offer analytical applications that analyze storage I/O, as well as the impact and performance gain of your specific application prior to purchasing and deploying SSDs. If those tools are available, they may help to reduce risk and prevent unpleasant surprises.

**SOLID-STATE ARCHITECTURES AND DEPLOYMENT OPTIONS**

The next step in your solid-state storage purchasing process is to identify the deployment option that best fits your requirements. There are several SSD implementation choices, each with its pros and cons:

- Adding solid-state storage to servers
- Via a purpose-built SSD appliance
- Adding SSD to disk-based storage arrays

Adding solid-state storage to servers. Available as PCI Express (PCIe) cards, NAND flash can be added directly to servers to provide high-performance direct-attached storage (DAS). By replacing the interface to an external storage system with its own storage transaction processor, NAND flash in the server yields the biggest performance gain. Just like L2 cache extends memory on the CPU and DRAM extends L2 cache, flash memory extends DRAM. The biggest drawback of adding SSD to the server is that it's non-shared and only available to applications on the specific server. This approach is a good choice if the intention is to provide high-performance storage for a specific application. NAND flash cards are also used by some storage vendors, especially those based on x86 architectures, to provide a high-performance, solid-state storage tier.
Purpose-built SSD appliances. Purpose-built all-flash appliances represent another rung on the performance ladder. Unlike NAND flash in servers, they provide high-performance shared storage via Fibre Channel (FC), InfiniBand or Serial Attached SCSI (SAS) interfaces. They’re architected for NAND flash and therefore usually outperform disk-based arrays equipped with solid-state drives. They’re generally deployed as very high-performance storage for specific applications that are strategic for an organization.

“The ROI calculation for an all-flash array can easily be made if the added performance is in direct relation to revenue, as is the case with many transactional applications, such as a trading site,” StorageIO’s Schulz said.

On the downside, purpose-built SSD appliances lack many of the storage features found in traditional storage arrays, such as snapshots, replication, thin provisioning, compression and deduplication. While high availability is taken for granted in high-end disk arrays, high-availability options such as active-passive clustering and system-level RAID options are simply missing in some of the available all-flash appliances. If lacking, features like high-availability instant failover will need to be performed by apps rather than the storage system. As a result, an all-flash appliance is more likely to be deployed to provide the highest performance money can buy for a specific application, and less likely to be deployed as a general-purpose storage system.

Adding SSD to disk-based storage arrays. Finally, solid-state storage can be added to an existing disk-based storage array. There are currently two approaches to adding NAND flash to a traditional storage array:

- As NAND flash cache
- As solid-state drives in place of mechanical disks

NAND flash cache is located on the storage controller. Like
traditional DRAM cache, it buffers recently accessed data. As a result, all applications and data on the storage array benefit from the solid-state cache. Unlike SSDs that replace mechanical hard disks, a flash cache doesn’t require automated storage tiering to move data between hard disk and SSD tiers. Therefore, a solid-state cache makes a storage system less complex by not having to support automated storage tiering; instead, it relies on the SSD cache to keep recent and active data in solid-state storage. While some vendors support NAND flash cache for reads only, others are able to leverage SSD cache for both reads and writes. With the NAND flash cache woven into the architecture of a disk-based storage array, it’s less susceptible to potential problems than replacing mechanical disks with solid-state drives.

Adding solid-state drives to an array to take the place of mechanical disks is the simpler method of adding solid-state storage to a disk-based array. Usually available as FC, SAS or SATA drives, SSDs can literally replace mechanical disk drives. In reality, it’s not quite as simple and requires extensive testing to ensure that SSDs work under all circumstances and with all apps.

Bringing SSDs into a traditional storage array raises two challenges. First, even today most storage arrays are designed for mechanical disks and are only able to support a certain number of SSD devices. Hence, it’s crucial to heed the guidelines of storage array vendors on how many SSDs you can put...
into a traditional disk-based storage system before overwhelming it. Eventually, storage array architectures will catch up to support 100% solid-state storage and, at that point, purpose-built SSD appliances are likely to vanish.

The second challenge of adding solid-state drives to a traditional storage array is keeping active data on SSDs and moving inactive data to slower mechanical disk tiers. While some vendors depend on manually relocating data, a few provide automated storage tiering at a sub-volume level. To maximize performance and minimize cost, being able to relocate active data at small block sizes—not volumes—is instrumental.

Contrary to purpose-built SSD appliances that are targeted at specific apps, SSDs in traditional storage arrays are more likely to serve a host of apps. “Usually, you wouldn’t buy an all-flash array for Microsoft Exchange or SQL Server, but you may add SSD to an existing storage array to hold Exchange and Microsoft SQL Server log files,” ESG’s Peters said. While traditional storage arrays may not match the performance of a purpose-built SSD appliance, they come with all the storage features expected in contemporary storage arrays, from snapshots and replication, to thin provisioning and versatile RAID options.
## Buyer’s feature checklist

<table>
<thead>
<tr>
<th>KEY FEATURE</th>
<th>WHY IT’S IMPORTANT</th>
<th>YOUR OPTIONS</th>
</tr>
</thead>
</table>
| Deployment options   | Determines cost, performance and capabilities.                                                                                                                                                                     | • Add solid-state drives (SSDs) to the server via PCI Express (PCIe) card  
                                                                              • Purpose-built all-flash SSD appliances  
                                                                              • NAND flash cache in disk-based storage arrays  
                                                                              • Add SSD to disk-based storage arrays                                                                                                           |
| Performance          | Determines the number of I/Os, throughput and latency a system can support.                                                                                                                                         | • SSD PCIe cards in the server and purpose-built all-flash SSD appliances deliver the best performance  
                                                                              • SSD in disk-based storage systems delivers the better combination of performance, cost and features |
| Cost                 | Determines the total cost of ownership (TCO).                                                                                                                                                                     | • Purpose-built all-flash appliances are usually more expensive than complementing disk-based arrays with SSDs  
                                                                              • Enterprise multi-level cell (eMLC) flash is less expensive than single-level cell (SLC) flash but offers similar characteristics  
                                                                              • Look at TCO and ROI rather than the per-gigabyte cost of SSD                                                                                     |
| Applications         | Applications for which SSD is targeted impact deployment options.                                                                                                                                                 | • SSD PCIe cards in the server and purpose-built all-flash SSD appliances are more likely used to deliver the fastest storage performance for very specific applications  
                                                                              • SSD in disk-based arrays usually benefits a host of applications, if not all applications and data on the array                                                                                          |
| Features             | Ensures that SSD storage comes with all the required features.                                                                                                                                                   | • Purpose-built all-flash SSD appliances focus on delivering very high performance, but lack many of the now standard storage features  
                                                                              • SSD in disk-based arrays inherit all storage features available in the array                                                                                                                                |
| Integration with disk storage tiers | Ability to keep active and frequently accessed data on SSDs and move static data to less expensive disk tiers to minimize the amount of required SSD to lower overall cost. | • Purpose-built all-flash SSD appliances are more likely deployed as storage islands, and any integration with disk-based storage requires additional software  
                                                                              • NAND flash in disk-based storage systems benefits all data without the need of automatic storage tiering features  
                                                                              • SSDs in disk-based storage systems depend on additional mechanisms in firmware or via external software to move data between SSD and disk tiers based on data usage or policies |
**SLC vs. EMLC**

Having determined the architecture and approach you’re taking, it’s time to look at the different types of available solid-state storage because they differ greatly in cost and characteristics. Until recently, enterprise storage systems almost exclusively used single-level cell (SLC) flash. SLC NAND flash stores one bit per cell and is the most robust available NAND flash, supporting 100,000 writes per cell before a cell becomes unusable. In comparison, multi-level cell (MLC) NAND flash uses two bits per cell. With about one-tenth the endurance of SLC NAND flash and a fraction of the cost of SLC flash, MLC has mostly been used in consumer products.

In an effort to bring the price down, storage vendors are now shipping enterprise MLC (eMLC) in many of their newer storage systems. eMLC still uses the same two-bit NAND cells, but through techniques like spare flash cells and advanced wear-level algorithms, storage vendors are able to use them in enterprise storage arrays. With eMLC NAND priced between SLC and MLC flash, and with characteristics approaching those of SLC flash, the use of eMLC SSDs is one way of keeping the cost down when selecting solid-state storage.

**ROI, TCO, CAPEX AND OPEX**

Given its high per-gigabyte cost, an SSD purchasing decision often becomes a financial decision. There are several financial measures you should look at to determine if and what type of solid-state option makes the most financial sense for your organization.

**Return on investment (ROI).** ROI is a performance measure used to evaluate the efficiency of an investment by comparing the benefit (return) of an investment with its cost and determining the time it takes for an investment to pay for itself. If the purchase of solid-state storage results in additional rev-
enue—as may be the case with a revenue-generating transac-
tional application where higher performance directly results in additional revenue—the ROI calculation is simple. In most cases, though, cost savings and revenue impact are more difficult to determine and are many times based on assumptions. Regardless, an ROI calculation is a key measure to get buy-in from the chief financial officer.

**Total cost of ownership (TCO).** TCO is another measure that can help make the case for solid-state storage. SSD’s smaller size, lower power consumption and reduced heat dissipation can result in substantial cost savings in facility and electricity costs. It’s important to look at the total cost of a storage system rather than getting caught up in the high per-gigabyte cost of SSDs. For example, a high-end disk array that may require hundreds of disks and techniques like short stroking to minimize head repositioning to achieve shorter access times and improved I/O incurs significant additional costs. Equivalent capacity and performance can be achieved with significantly fewer SSDs at less cost (fewer drives, fewer racks, less power consumption).

**Capital expenditure (Capex) and operational expenditure (Opex).** To determine TCO, it’s important to look at both Capex and Opex to operate and support a storage system. While the acquisition cost of solid-state storage is high, ongoing support costs are usually lower than those of a disk-based storage system as a result of its smaller size and lower power requirements.

*Jacob N. Gsoedl* is a freelance writer and a corporate director for business systems.