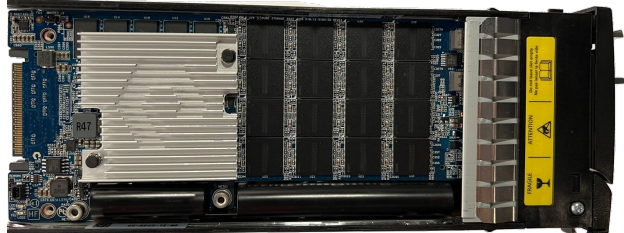


Flash storage is clearly superior to disk. If it also cost less, would there be any reason to buy disk-based systems?

PURE STORAGE AND SOLID-STATE DEVICES

Pure Storage has over a decade of experience in delivering all-flash storage systems. Since 2016, its systems have used flash devices of its own design called *DirectFlash® Modules* (DFMs), combined with custom Purity software in its controllers.



A 75TB DFM

The integrated Purity-DFM design performs each task once, in the most suitable location.

DFMs therefore differ from SSDs in two important respects:

- ▶ They expose all of their flash to Purity; they do not overprovision, or relocate data internally, so they do not need extensive DRAM to cache data location maps. This greatly increases reliability and reduces write amplification for better endurance.
- ▶ They are not self-contained. They cooperate closely with Purity software, which optimizes I/O scheduling, data placement, and fault recovery, across multiple devices.

Because Purity software does most of the data management, DFMs are much simpler than conventional SSDs, and therefore more robust. From a user perspective, this integration makes the performance of Pure Storage systems more *consistent* than that of SSD-based ones. Moreover, a single DFM can perform over a hundred concurrent data transfers, so Pure Storage systems deliver better *performance per device* than SSD-based ones. For example, a FlashArray//XL system is capable of 36GB/s of random I/O, a FlashBlade//S system of consistent 66GB/s of streaming throughput.

THE FUTURE OF DFMs

In 2023, the company will deliver 75TB DFMs, and with flash manufacturers' planned enhancements, by 2026 Pure Storage systems will contain 150TB, and 300TB DFMs. Even larger devices will follow in the years beyond, vastly outstripping contemporaneous disks.

Obviously, there will also be higher-capacity SSDs, but they will continue to emulate disks, masking their complex internals. One important consequence of this is that they will require extensive DRAM—about a tenth of a percent of their flash capacity—along with supercapacitors to flush it when external power fails.

Pure Storage DFMs require only about 1/1000th as much DRAM per GB of flash as SSDs, and they are much simpler internally, keeping cost low and increasing reliability. Moreover, the company

analyzes DFM failures and uses the results to improve its software in regular updates, so the reliability of installed DFMs *improves* over time.

TCO: THE *REAL* ADVANTAGE OF FLASH

Vendors of disk-based storage systems argue that because disk storage currently costs less per TB than flash, disks continue to be relevant. But this fails to consider *total cost of ownership*:

POWER AND COOLING

In the past two years, many data centers have seen their power costs double. Today, DFMs use only about 40% as much power per TB as disks. Future higher-density devices decrease the power per TB, so Pure Storage systems will use only 10% of the power and cooling required by disk-based systems.

DATA CENTER SPACE

Today, Pure Storage systems deliver slightly more capacity per rack unit than the densest disk-based systems. With expected increases in DFM and disk capacity in the coming years, the systems will pack six times the capacity per rack unit as the densest disk-based ones.

RELIABILITY AND MAINTENANCE

Based on industry and internal data, over a five-year lifespan, today's Pure Storage systems will experience only about 1/50th as many device failures as disk-based ones. Larger DFMs will improve the ratio to 1/160th.

Disk failures have a major impact on system performance and data center operations. Many DFM failures affect only a small part of their capacity. This, plus significantly greater reliability and faster I/O make error recovery a much smaller issue for systems from Pure Storage.

END-OF-LIFE CONSIDERATIONS

Because DFMs are more reliable than disks, Pure Storage systems' lifetimes are typically 50-100% longer than those of disk-based ones. With fewer devices per PB, systems that weigh much less, and longer lifetimes, retiring a Pure Storage system today creates only about 20% as much e-waste as a disk-based one. DFM capacity increases will reduce this to about 5%.

The company's Evergreen™ program provides additional advantages to its customers:

- ▶ Regular non-disruptive hardware upgrades replace controllers as technology evolves, without data migration or parallel operation.
- ▶ Users can add or consolidate capacity non-disruptively, with credit for returned DFMs.
- ▶ The company guarantees the DFMs in its systems for life.

AT THE SYSTEM LEVEL....

Pure Storage systems are much simpler to manage than disk-based ones. Fewer components, longer lifetimes, and non-disruptive upgrades greatly simplify operations and eliminate data migrations. Consistent performance means less troubleshooting. Customer experience suggests that a person can manage 10 times as much storage with systems from Pure Storage as with disk systems.

Finally, data reduction, made feasible by DFMs' random-access speed, increases system efficiency and multiplies all the aforementioned benefits. Disk I/O latency makes data reduction difficult.

SUMMING UP

This paper makes two points:

- ▶ Today, enterprises have every reason to replace disk storage, including nearline systems. With higher performance, greater reliability, and lower space, power, and cooling requirements, the TCO of flash-based systems is already lower than that of disk, and the gap will only widen in the future.
- ▶ As an early proponent of flash, Pure Storage gained the expertise that led the company to develop Purity software and DFMs, both optimized for large-scale storage systems. The two innovations provide synergies that are impossible with SSD-based systems. Thus, the company's long-standing advantage in flash-based storage systems for the enterprise will persist across multiple generations of flash technology.

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