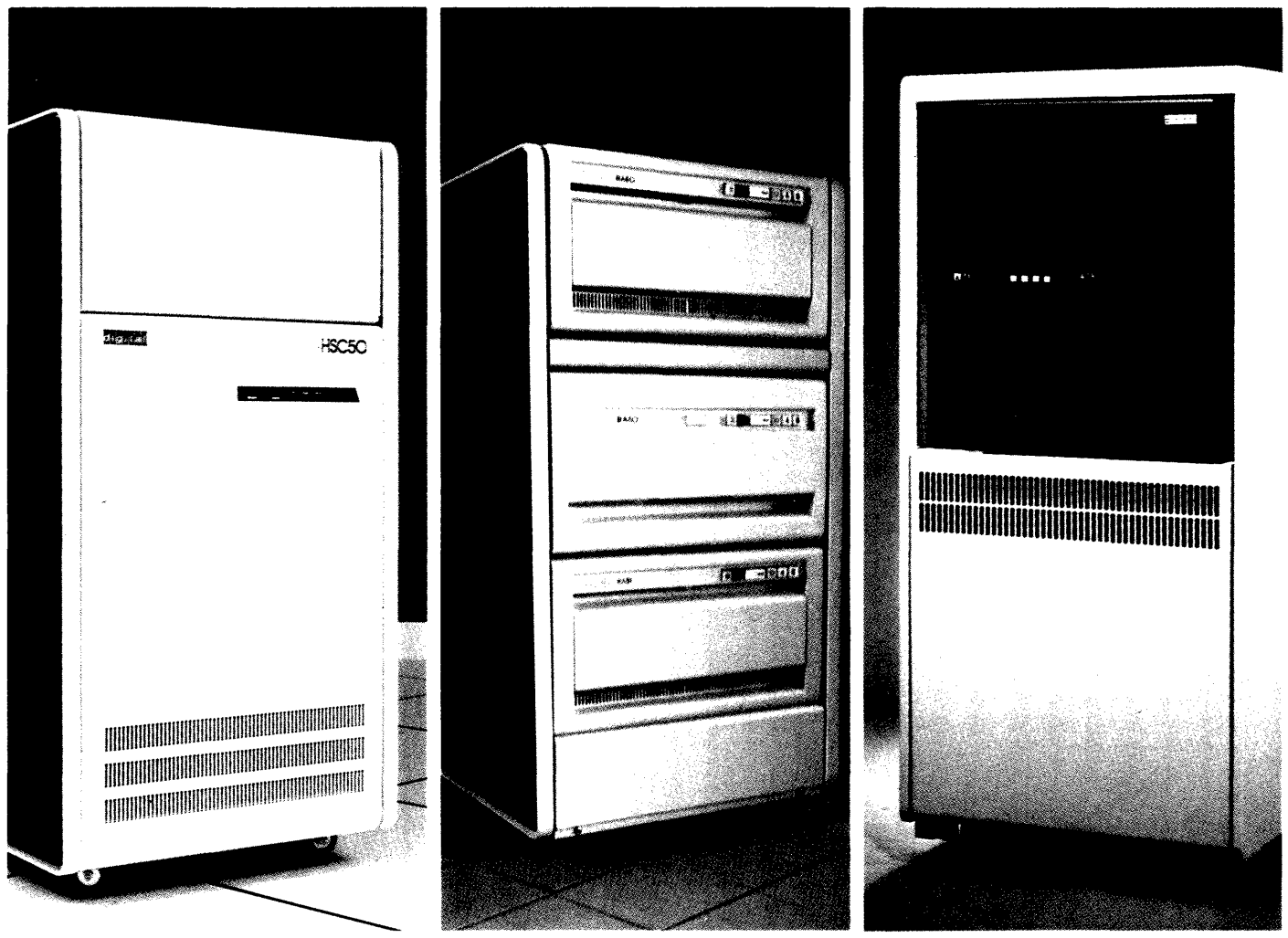
DIGITAL STORAGE ARCHITECTURE
PRODUCT SUMMARY



Storage Systems

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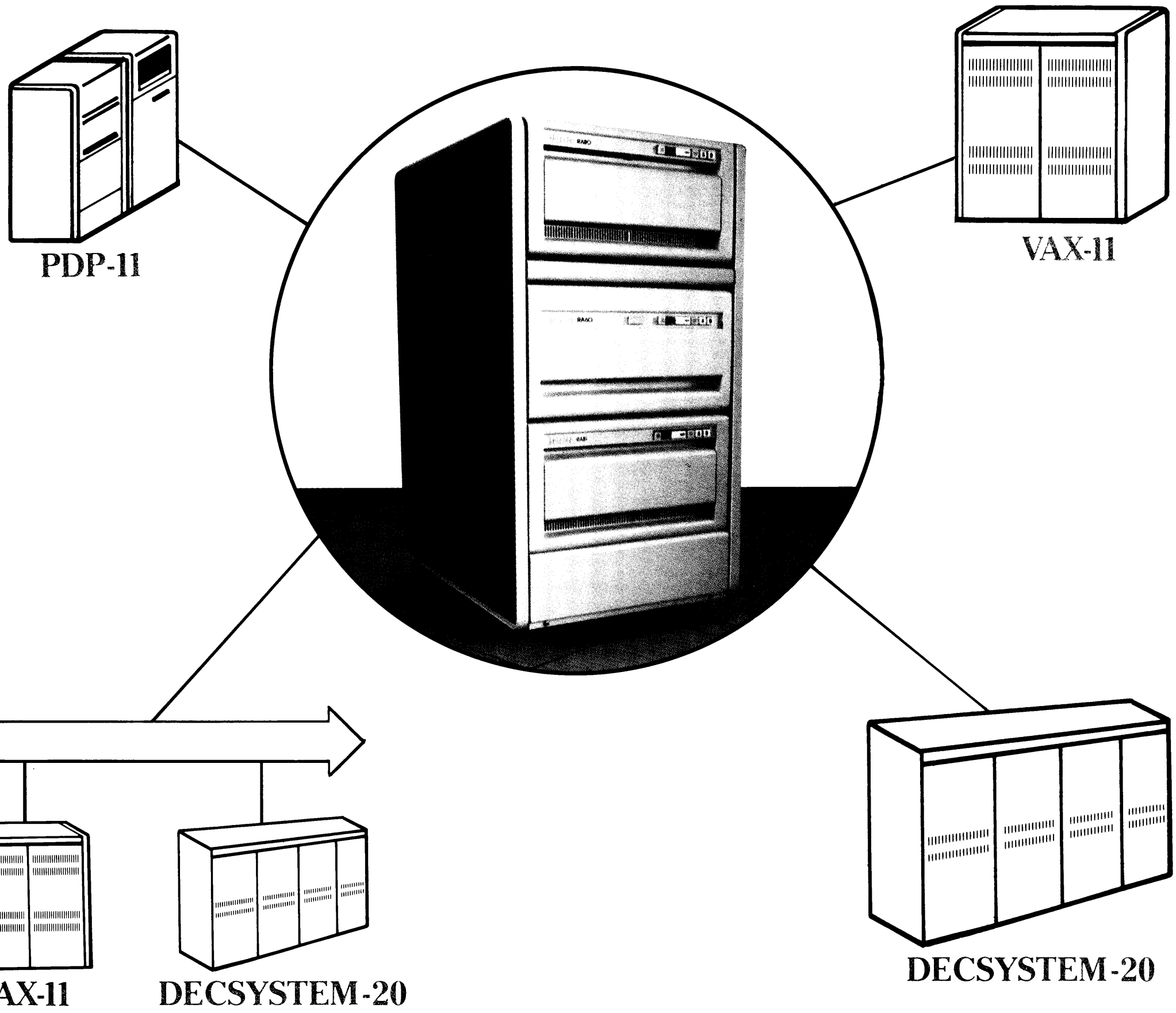
Why a DIGITAL Storage Architecture?

Long established as a leader in the manufacture of computer systems, Digital Equipment Corporation now sets the standard for the design and manufacture of storage systems. To meet the growing needs for storage systems, DIGITAL offers an exciting new approach to storage design, the DIGITAL Storage Architecture, DSA.

This carefully planned framework is the basis of a powerful new family of storage products. The architecture's design permits easy addition of new products and technology while preserving the investments you've made in current products.

With over 25 years of experience in the computer industry, DIGITAL understands the benefits of an architectural approach to system design. Specifically, the VAX-11 family and the DECnet products demonstrate the success of the architectural approach. For storage subsystems, this approach ensures you of flexible, expandable, migratable products with standardized interfaces to DIGITAL's major computer families.

Products based on the DSA—fixed and removable disks and magnetic tapes—fit into a solid structure that will remain constant across product generations. What's more, DSA products use state-of-the-art technology and give you the greatest space efficiency as well as the lowest cost of ownership.



What is the DIGITAL Storage Architecture?

The DIGITAL Storage Architecture is a framework for implementing an expanding group of mass storage products—disk and tape drives as well as intelligent I/O servers and controllers (described in the second section of this brochure). And because the computers and software as well as the mass storage devices all come from DIGITAL, each of the pieces fits smoothly and precisely within the DSA.

Clearly Defined Tasks for Each DSA Layer

Within the DSA framework, DIGITAL separates mass storage functions into three specific layers (as shown in the illustration). In addition, the DSA defines standard interfaces between the host computer system(s) and the controller(s), and between the controller(s) and the storage devices. Each of these clearly defined layers has its assigned tasks and performs them independently.

Simplified Host Layer Functions

The DSA greatly reduces the host computer's role in mass storage control. The central processor treats disk and tape drives as simply classes of devices, i.e., disk or tape. The *controller* handles all the specific characteristics of each device, for example, cylinders and tracks. The result of this approach is to offload storage functions from the host and free the central processor for handling other tasks such as user applications.

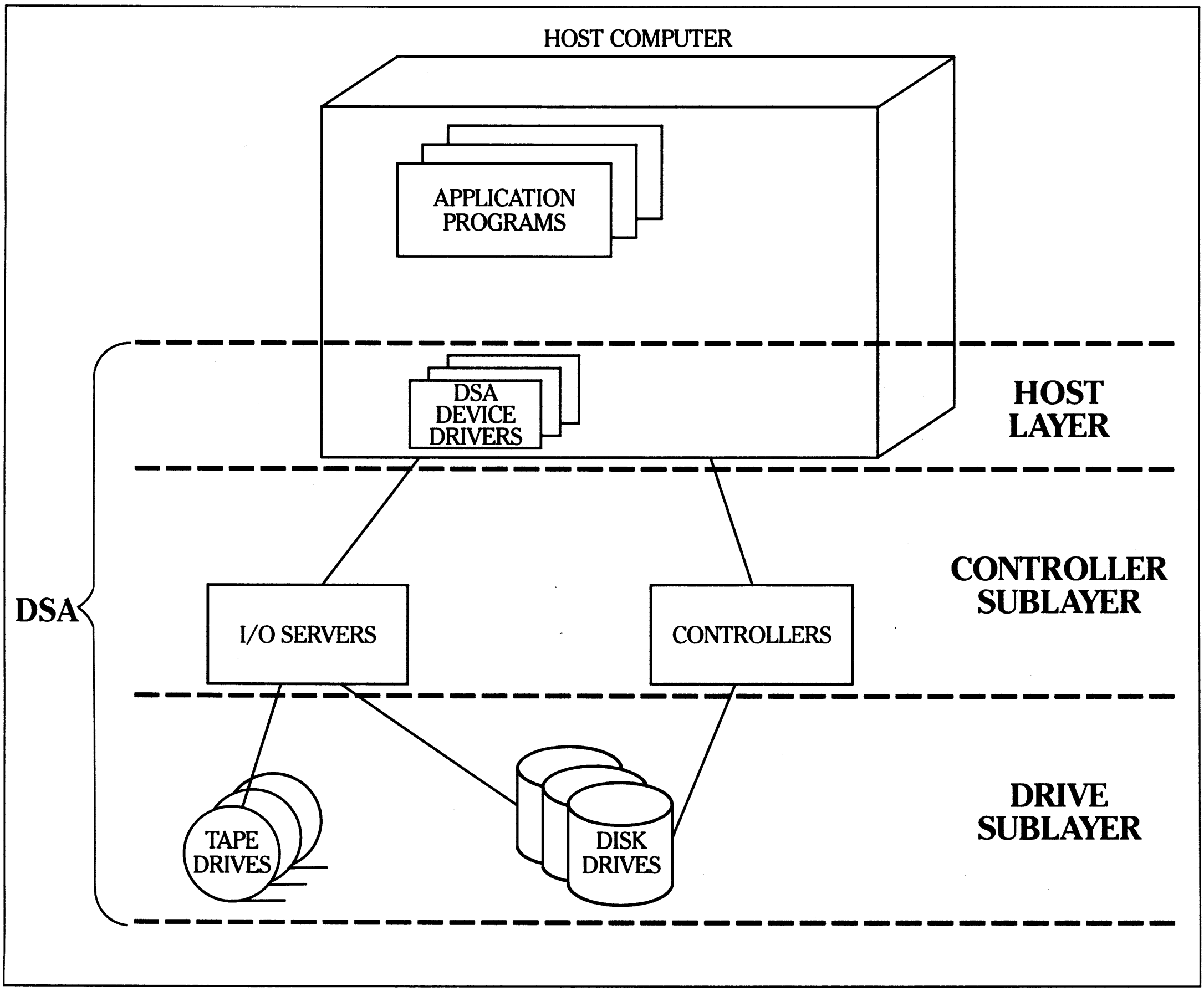
Increased Functionality at the Controller Layer

Under the DSA, the bulk of mass storage functions are handled within the intelligent controller layer. By coordinating the activities of all devices attached to it, the controller optimizes performance for the entire subsystem.

Another responsibility of the controller is to present the host computer with manageable data workloads. Because data transfers from storage devices typically occur in uneven bursts, the controller must first smooth these irregular bursts before presenting the data to the host. Another function assigned to the controller is that of enhancing data integrity by validating data transfers, performing error recovery, and reporting errors to the host. Under the DSA, therefore, only "clean" data is passed to the host.

Straightforward Drive and Media Layer Functions

At the drive level within the DSA, the actual recording and playback of data occurs. The drives are also responsible for controlling mechanical motions such as seeking.


HOST COMPUTER
APPLICATION PROGRAMS
DSA DEVICE DRIVERS
HOST LAYER
DSA
I/O SERVERS
CONTROLLERS
CONTROLLER SUBLAYER
TAPE DRIVES
DISK DRIVES
DRIVE SUBLAYER

What are the Features of the DIGITAL Storage Architecture?

The DSA specifies a variety of powerful features to enhance I/O performance, improve data integrity, and ensure superior reliability, availability, and maintainability of storage products.

High I/O Performance

Fast drive speeds and large storage capacities do not guarantee superior subsystem performance. DIGITAL's DSA provides many performance optimization features that greatly enhance I/O throughput.

The DSA specifies such high throughput capabilities as:

- Seek ordering which sorts all I/O requests from the host first by disk drive and then by cylinder address. As it receives new requests, the subsystem inserts them in the command queue by cylinder address rather than in arrival order. The result is a dramatic improvement in I/O throughput.
- If you wish to specify first-in, first-out (FIFO) execution of I/O requests, the DSA provides an express queue mechanism for this purpose. The express queue bypasses the seek ordering process and permits FIFO servicing of requests.
- In multidrive DSA disk systems, the controller initiates simultaneous seek operations to all disks with outstanding I/O requests. This "overlapped" seeking reduces effective seek times and improves throughput.
- In multidrive DSA tape systems, simultaneous read or write operations can be initiated. This reduces effective tape position time to improve data throughput.
- A feature called rotational optimization minimizes rotational latency. In other words, when multiple disks are positioned on requested cylinders, the controller selects the drive nearest its beginning requested sector to perform data transfer first.
- Data transfers typically occur in bursts, but the aggregate transfer rate is low (as shown in the illustration). Consequently, DSA controllers include data buffers to smooth out the data transfer load on the host.
- The DSA's direct revectoring specification enhances throughput because it eliminates time wasted in reseeking to a lookup table to determine the address of replacement sectors. When the drive encounters a retired sector, it automatically references the replacement sector, which typically is located on the same track. Also, since file structures never have to be rearranged to accommodate bad blocks, you can back up and restore disks with a high-speed volume copy.

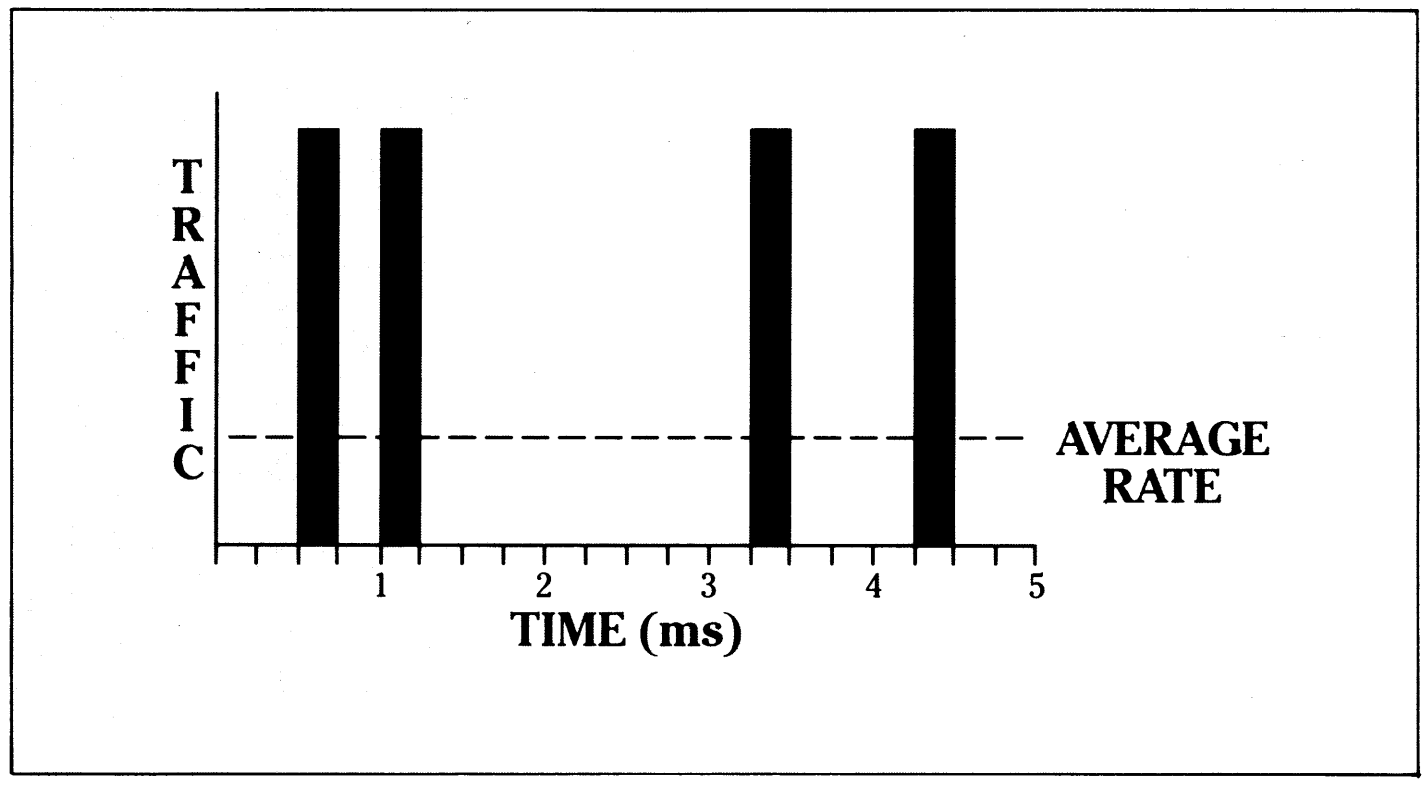
Industry-Leading Data Integrity

Data integrity is the most important characteristic of any storage system. High speeds and large capacities are irrelevant if the system stores your data inaccurately or inaccessibly. Recognizing this fact, DIGITAL built into the DSA the most powerful and comprehensive set of data integrity features in the industry.

It is unlikely that data loss will ever occur during the lifetime of DSA subsystems. This level of data protection is accomplished *without imposing any overhead on the host system.* The controller subsystem initiates and completes all DSA recovery operations.

Consider this impressive list of data integrity features:

- 170-bit Error Correction Code (ECC) for disks that is far more powerful than conventional 32-bit ECC's. The 170-bit ECC, which is applied to every sector, detects and corrects errors in either a single error burst of up to 80 bits or up to eight independent one-to-ten-bit error bursts. Other manufacturers typically offer ECC correction of a single 11-bit error burst.
- The DSA includes a 16-bit Error Detection Code (EDC) for tapes which is analogous to the disk ECC. The EDC is used during data transmission to protect the integrity of the data. It is not written on tape but is computed and checked by both controller and tape drive for write and read operations.



- The intelligent DSA controllers calculate an Error Detection Code and append it to each sector on disk. The EDC logic checks for controller memory errors and verifies proper functioning of the ECC hardware.
- The address verification algorithm within the DSA far outperforms conventional CRC checks. DSA specifies that four copies of the sector address be recorded directly preceding the data to verify accuracy of the seek operation. This system prevents data loss from hardware seek errors.
- The DSA's tape position system uses gaps from beginning of tape (BOT) to maintain accurate tape position and to allow quick recovery from a tape position lost condition.
- The DSA's error logging and automatic sector retirement systems provide for the controller to report errors to the operating system error log and to retire sectors if errors exceed a predetermined error severity threshold. In this way, the controller can retire sectors before recoverable errors become unrecoverable.
- The DSA's tape error threshold system allows the tape drive to determine its own error thresholds for a variety of error types. The tape subsystem can then report occurrences or errors exceeding the predetermined limits.
- With the DSA disk mapping scheme, the intelligent controller performs logical-to-physical sector address translation. For retired sectors, the controller automatically revectors to the replacement sector, usually on the same track. Header codes indicate replacement sector locations. As a failsafe procedure, the controller also copies revectoring addresses in a look-up table stored on the disk. This mapping system virtually eliminates data loss caused by revectoring errors.
- The DSA's Mass Storage Control Protocol specifies commands to perform read after write checking as well as to compare host memory data on a disk. This feature ensures an additional level of user-accessible data integrity.

Improved System Availability

The DSA storage subsystems provide a set of availability features not usually found in other subsystems. These features, together with extremely reliable hardware, provide high system uptime and, consequently, low maintenance prices.

- With their radial drive interconnects, DSA subsystems provide a point-to-point connection between each drive and its controller. This feature improves system uptime because a drive can be logically isolated and physically removed from the subsystem and repaired without disrupting the operation of other drives in the subsystem.
- All DSA drives and controllers contain a comprehensive set of on-board diagnostics whose goal is to isolate all failures to a single field-replaceable unit. High diagnostic fault isolation capability decreases mean time to repair (MTTR).
- Under the DSA, failure diagnosis occurs from within, i.e., controller diagnostics are within the controller and drive diagnostics are within the drive. Diagnostics can be invoked (1) locally with the drive off-line; (2) locally with the drive on-line through the system console; or (3) remotely with the drive on-line through DIGITAL's diagnostic service. This flexibility ensures that field engineers can quickly and easily step through diagnostic routines either locally or remotely, isolate failures, and replace parts in the minimum amount of time—whatever the customer environment.
- The DSA specifies functional tests to be run automatically upon startup of controllers and drives. For drives these include reading and writing on scratch tapes or reserved diagnostic cylinders, which are invisible to the user. Powerup disk verification and on-command tape verification prevent initiating a job stream with a malfunctioning drive. This is especially important in certain applications such as real-time process control.
- For larger DSA drives dual-access is a standard feature. Dual-access allows attachment of a drive to two controllers to provide the redundancy required for high-availability systems.

Optional Features of the DSA

Under the DSA, the powerful HSC50 controller provides several advanced features that require no host overhead. For example, the HSC50 performs on-line volume backup and restore (from disk to tape and tape to disk) as well as on-line volume copy (from disk to disk) without host involvement.

Another feature, shadow recording, is also controlled by the HSC50. With shadow recording, the HSC performs the same operations in parallel on two (or more) drives. This ensures a constantly updated copy of data for very high-availability applications where uninterrupted access to data is critical. And shadowing occurs without requiring host computer cycles, host memory resources, or CI bus traffic.

What Does the DIGITAL Storage Architecture Do for You?

The technologies for software, controllers, disks and tapes all advance at different rates. Consequently, the DIGITAL Storage Architecture separates these technologies so that we can incorporate specific technological advancements into the DSA family—quickly, easily, and non-disruptively. And, by making compatibility a criterion of DSA products, DIGITAL ensures you of easy growth, protection of your investment, and lower product costs.

Off-Loading of the Host System

By making throughput, data integrity, and availability the responsibilities of the storage subsystem, the DSA relieves the host of time-consuming tasks better performed at the storage subsystem level. DSA storage systems offload the host because disks and tapes appear as perfect logical volumes to the host, and the subsystem handles bad blocks transparently. This in turn can increase the overall performance of the host by freeing it for user applications.

Lower Lifetime Cost of Ownership

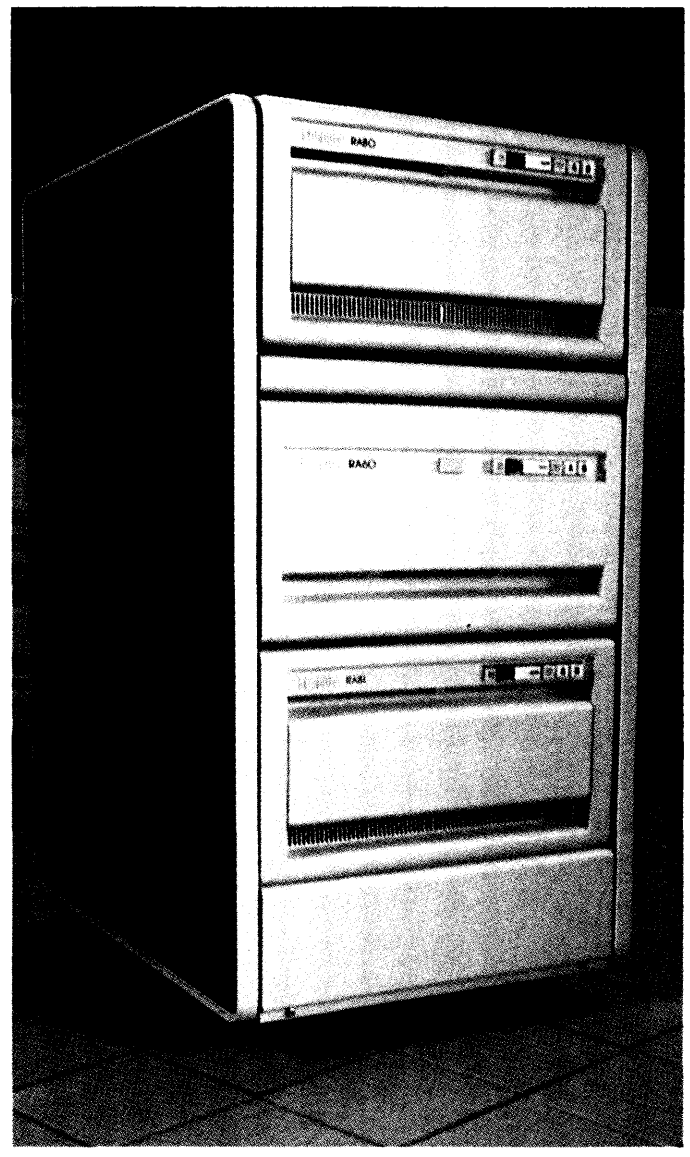
The DSA provides a balanced integration of hardware, software, and reliability features that focus on lowering the total cost of buying, installing, and maintaining storage subsystems. By assuring support for new products and technologies as well as the continued support of existing products, the DSA helps you keep tight control of current costs and future budgets.

Hardware/Software Independence

The DIGITAL Storage Architecture's standard software allows the introduction of new controllers (compatible with existing drives) without requiring new host operating system software. Similarly, new drives can be introduced without requiring any changes to either the host system software or the subsystem controller. This independence of elements guarantees easy inclusion of new products along with current products. It also means that DIGITAL can incorporate new technological advances quickly, and you can enjoy the benefits.

Support for a Wide Range of Products—both Current and Future

One of the most exciting features of the DIGITAL Storage Architecture is the steadily expanding range of products it includes. Intelligent controllers and mass storage servers, removable as well as fixed (Winchester) technology disks of varying capacities and transfer rates, plus tape products are all part of the DIGITAL Storage Architecture. The DSA will support higher densities and transfer rates as they become reality. It can accommodate increased media defects associated with future higher disks and tape areal densities, and it will automatically adapt to tape formats or disk drive specific geometries.




HSC50
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What are the Products Within the DIGITAL Storage Architecture?

Products implemented under the DIGITAL Storage Architecture include several disks, tapes, and controllers. As DIGITAL storage engineers develop more advanced products, these, too, will be added to the DSA product family. Currently available are the following:

Controllers	Disks	Tape
• UDA50—for UNIBUS systems	• RA60	• TA78
• HSC50—for CI systems	• RA80	
	• RA81	

UDA50 Intelligent Controller

The UDA50 (UNIBUS Disk Adaptor) is a microprocessor-based disk controller. It permits you to connect any combination of four RA60, RA80, and RA81 drives to the UNIBUS data path on DIGITAL's PDP-11 and VAX-11 computer systems.

Two UDA50 controllers can be attached to a single UNIBUS for a maximum of eight disk drives per UNIBUS. On a 2-UNIBUS VAX-11/750 system, you can attach up to 16 disk drives via four UDA50s, and on a 4-UNIBUS VAX-11/780, you can attach up to 32 disk drives via eight UDA50s.

The UDA50 can be used with RA81, RA60, and RA80 disks in any mix or match your application, or budget, dictates.

A summary of UDA50 performance and reliability features includes:

- Overlapped seeks on multiple drives
- Command queuing for up to twenty I/O requests
- Ordered seek performance optimization
- Express queue for optional FIFO execution of I/O requests
- Rotational optimization across disk drives
- Speed-matching buffer (25.5 kilobytes)
- Automatic revectoring (with no host involvement)
- DSA Error Correction Code and Error Detection Code
- Microcode to perform error detection, correction, and retry
- Address verification
- Automatic sector retirement
- DSA dynamic bad block handling
- On-board Read-only Memory (ROM) diagnostics
- Radial drive interconnects

HSC50 Intelligent Disk and Tape Server

The HSC50 (Hierarchical Storage Controller) is a high-performance, mass storage I/O server for attaching large numbers of DSA disk and tape products to multiple host CPUs (up to 15). The HSC50 attaches to the host CPUs through DIGITAL's high-speed (70 Mb/second), multidrop I/O bus, the CI (Computer Interconnect). With one HSC50, you can connect up to 24 mass storage units (disk drives and/or tape formatters) on the same subsystem. That means a typical maximum configuration might include 20 disk drives and four tape formatters with 16 tape drives attached.

Through its closely-coupled multi-microprocessor architecture, the HSC50 utilizes fast parallel processing to achieve high-throughput servicing of disk and tape I/O requests. The HSC50 also provides locally-executed utility and diagnostic functions and a wide set of design features that simplify maintenance while ensuring the integrity and accessibility of mass-stored data.

A summary of HSC50 features includes:

Flexibility of Configuration
- CI connection to multiple host CPUs (up to 15)
- 24 ports for disk drives and/or tape formatters

Disk and Tape Server Functions
- Implements generic, uniform, and device-independent interfaces for both disk and tape I/O

Server-Managed Local Utilities
- Fast volume backup/restore
- Format and format-verify utilities

Data Integrity and Availability
- Positional verification through quad-ruplicated headers
- Disk shadowing
- Automatic replacement of bad disk blocks (done entirely by HSC)
- DSA ECC and EDC protection of stored data
- Drive connections totally independent of each other
- Partitioning of server resources for fail-soft operation
- On-line drive (dis-)connections and repairs
- Automatic invocation of extensive error-recovery procedures

DSA Disk Drives

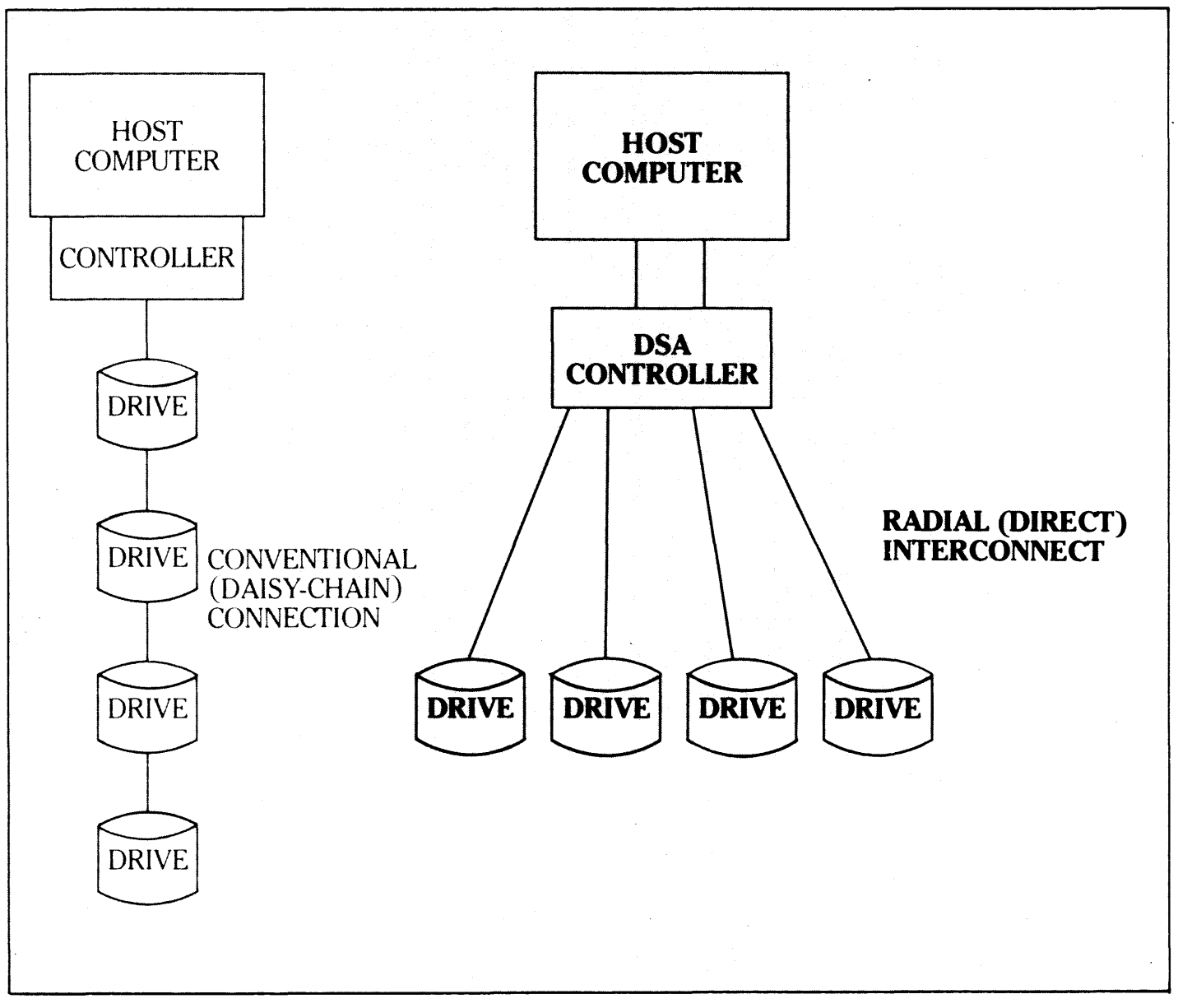
Under the DSA, DIGITAL has defined a standard disk interconnect (SDI) from drive to controller for medium and large storage products. Its properties include radial interconnections (see illustration) which allow you to disconnect a drive for maintenance or repair without disturbing operation of other drives in the subsystem. And, because it's a serial connection you can place drives up to 80 feet away from the controller.

All SDI drives are implemented with standard dual-access which lets you connect a drive to two controllers. Drives monitor their environment and will shut down if there are environmental threats to data integrity. Onboard diagnostics, i.e., diagnostics from within, simplify repair because they isolate faults down to field-replaceable units.

The state-of-the-art disk drives available under the DIGITAL Storage Architecture offer a selection of capacities, speeds, and disk types. The fact that DSA controllers (UDA50 and HSC50) accept a mix of any three drives in a 40-inch high cabinet gives you the greatest storage flexibility and floor-space utilization in the industry.

Briefly, DSA disk capacities are:

Media Type		RA60 Removable	RA80 Fixed	RA81 Fixed
Storage Capacity	Per drive	205 MB	121 MB	456 MB
	Per cabinet	615 MB	363 MB	1,368 MB
	Per sq. ft.	115 MB	68 MB	257 MB

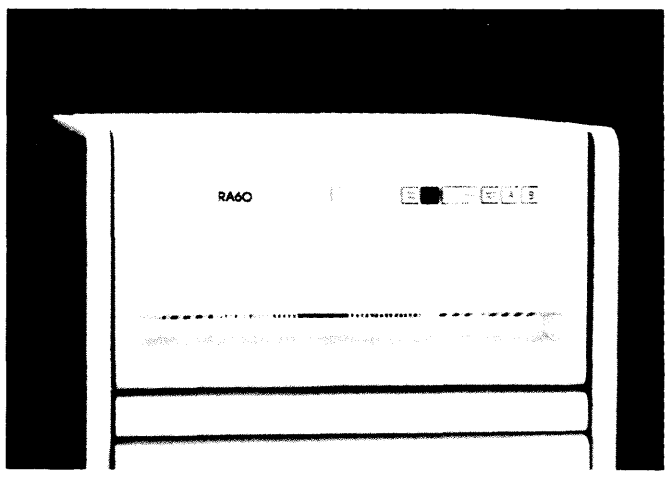


I/O Throughput Optimizations

- Multiple speed-matching buffers
- Overlapped disk seeks
- Optimized disk seek ordering
- Concurrent transfers to/from multiple disks/tapes
- Rotational position sensing dynamically switches data transfer channels
- Long transfers commence at the first available "fragment" boundary
- Shadowed-reads from closest unit
- High bandwidth internal data paths capable of overlapping data transfers with parallel error-handling

Maintainability

- Fault codes flashed on operator control panel
- On-board LEDs indicate good and bad module status
- In-line diagnostics, automatic and demand-initiated or error-triggered
- Comprehensive error logging messages
- Terminal interface for maintenance
- Environmental sensors



RA60 Removable-Media Disk

The RA60 is the highest-capacity, rack-mounted, removable-media disk available today. The recording density of the RA60 is three times that of the most commonly available removable disk. This adds up to the lowest life-time cost-of-ownership per megabyte of all removable-media disks in the industry. The RA60 can be used with both the HSC50 and UDA50 I/O controllers.

With the RA60's embedded servo system, track location is done by the same heads that read the data. Each read/write head self-positions on the track center line before transferring the data. This means that there's never a need for head or spindle alignment, and you'll never face pack interchange problems.

- 205 MB formatted capacity per disk
- 615 MB formatted capacity per cabinet
- 10.5-inch high drive
- 42-millisecond average seek time*
- 50-millisecond average access time*
- 2.0 MB/second data transfer rate
- Universal power supply

*These are "raw" drive performance figures. They do not take into account controller optimization.

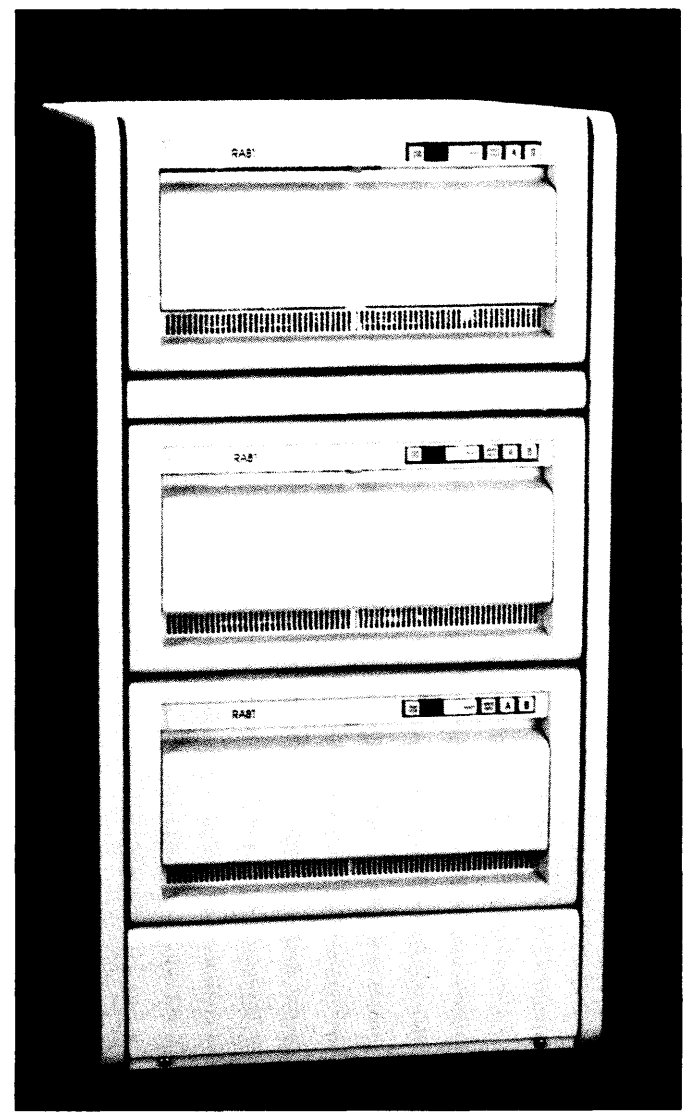
RA80 Winchester Disk

As the entry-level DSA disk drive, the RA80 uses Winchester technology to provide 121 megabytes of fixed-media storage in a 10.5-inch high package. The RA80 can combine with the RL02 removable disk cartridge to provide a low-cost, complete mass storage solution in a single cabinet.

A sealed Head Disk Assembly (HDA) encloses the recording surfaces and positioner for the life of the drive. It protects the unit from environmental contamination and eliminates the need for head alignment adjustment procedures.

The RA80 is available with both the UDA50 and HSC50 controllers.

- 121 MB formatted capacity per disk
- 363 MB formatted capacity per cabinet
- 10.5-inch high drive
- 25-millisecond average seek time*
- 33-millisecond average access time*
- 1.2 MB/second data transfer rate



RA81 Winchester Disk

The RA81 disk is the highest-capacity, rack-mounted Winchester disk available today. Offered in a single-drive configuration (456 MB) or in a 3-drive configuration (1.4 GB) that takes only 5 square feet of floor space, the RA81 is the most space-efficient disk drive of its kind. It is available on both UDA50 and HSC50 controllers.

The sealed Head Disk Assembly in the RA81 contains four disk platters, dual read/write heads on each surface, speed/thermal sensors, and a rotary positioner. The RA81 includes microdiagnostics for quick fault-isolation and fold-out modules to ensure an extremely short time to repair.

- 456 MB formatted capacity per disk
- 1.4 GB formatted capacity per cabinet
- 10.5-inch high drive
- 28-millisecond average seek time*
- 36-millisecond average access time*
- 2.2 MB/second data transfer rate

DSA Tape Drives

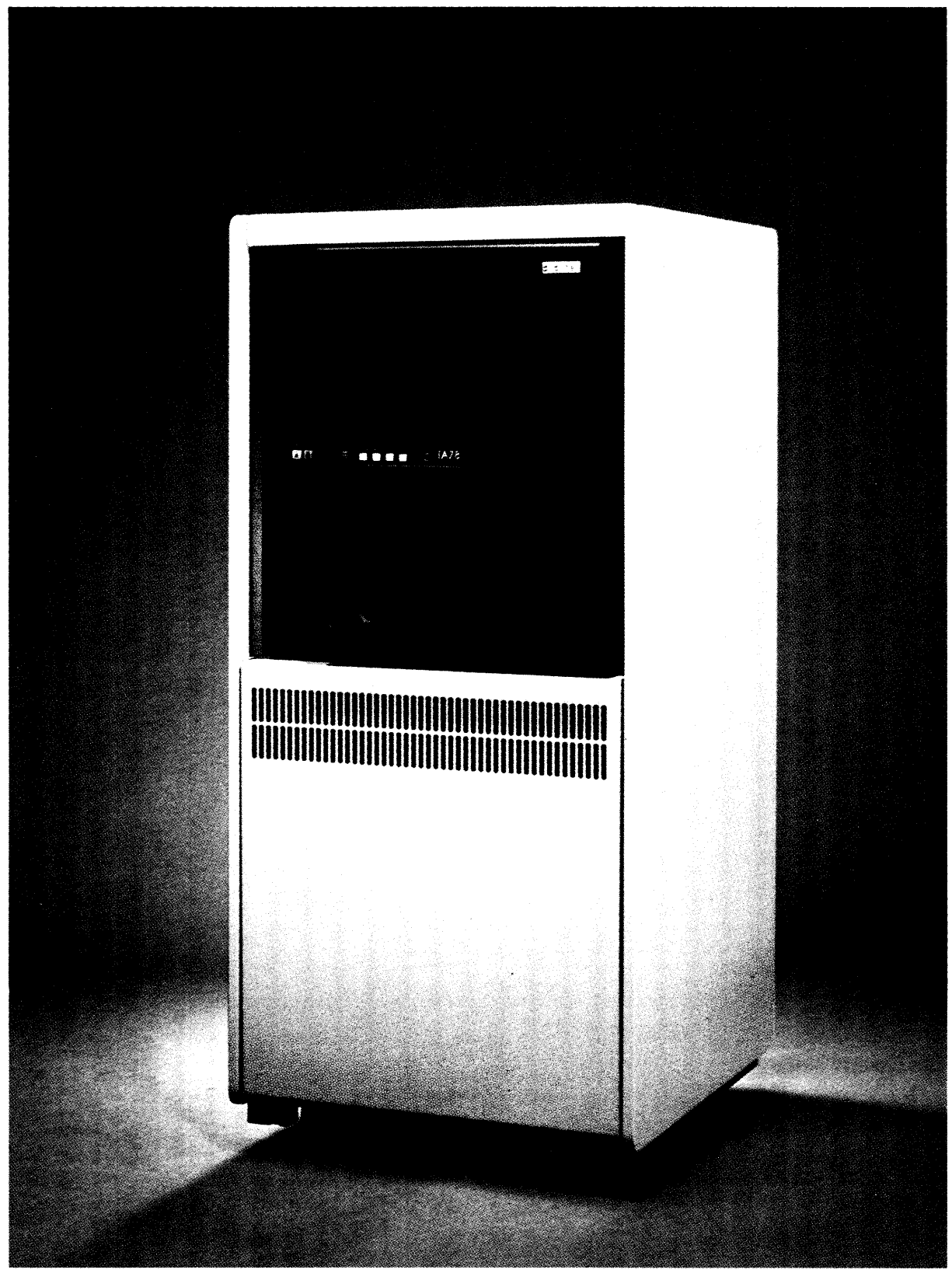
Tape is an inexpensive, yet reliable medium for disk backup in many applications. Currently available for use with the HSC50 is the TA78 Tape Subsystem. The TA78 tape units can be attached to the same HSC50 along with the disk drives.

TA78 Tape Subsystem

The TA78 is DIGITAL's high-performance, top-of-the-line magnetic tape drive for all applications. With ANSI-standard read/write recording densities of 1600 bpi (Phase Encoded) and 6250 bpi (Group Code Recording), the TA78 reads and writes tapes for interchange on other vendors' systems.

With its automatic threading, high speed, and reliability features, the TA78 is ideally suited for disk-to-tape backup operations, particularly with the high-capacity RA81 disk drive. It includes self-test features, on line diagnostics, and fault-isolation diagnostics for easy maintainability and high reliability. Radial (direct) cabling between drives and formatter ensures continued system operation even if a tape drive fails. And there's easy access to field-replaceable units through the front of the cabinet.

Up to four TA78 Formatters can be attached to one HSC50 data channel. Each TA78 Tape Formatter, in turn, can accommodate four tape drives.



• Read/write speed	125 inches/second
• Maximum data transfer rate	781 Kbytes/second
• Rewind speed	440 inches/second
• Rewind time	60 seconds/2400-ft reel
• Maximum capacity	GCR 145 Mbytes/2400-ft reel (8KB blocks)
• Recording method	GCR at 6250 bits/inch PE at 1600 bits/inch
• Format	IBM/ANSI-compatible
• Tape handling	Automatic threading—10½ inch reels and Easy Load Cartridges*

*Easy Load is a trademark of IBM Corporation.

Shopper's Guide to Storage Subsystems

Consider the following guide when comparing disk and tape subsystems.

Cost of ownership	Some subsystems are inexpensive to buy but expensive to own. DSA subsystems not only carry low hardware price tags but also offer low maintenance prices. Consequently, lifetime cost-of-ownership figures are lowest for DSA subsystems.
Actual capacity	Some disk and tape suppliers advertise gross, unformatted capacity that includes a significant amount of space unavailable for user data. The advertised capacities on DSA disks are 100% available for user data. In addition, since all DSA disks have space reserved for replacement blocks, user capacities never shrink. DSA tape, with its high recording density, results in the use of fewer tapes and precludes frequent operator handling.
Data integrity	How much does it cost you to reconstruct a file because the subsystem cannot find or cannot read a block of data? To preclude such costly and time-wasting dilemmas from occurring, DSA storage subsystems include the industry's most comprehensive set of data protection features.
I/O throughput	Impressive specifications and speeds are important, but even more relevant are the subsystem performance optimization features. Such features as seek ordering, overlapped seeking, and rotational optimization in DSA subsystems combine with powerful specifications to significantly increase overall I/O throughput.
Subsystem availability	System downtime is disruptive, frustrating, and expensive. To prevent downtime, all DSA disk and tape subsystems include built-in automatic self-testing and fault-isolating microdiagnostics. Our radial interconnect prevents a problem in one storage device from affecting the operation of others.
Extra charges	A removable media disk is not very useful without a pack; likewise a magnetic tape drive without a tape or a subsystem without cabinetry and cabling. With some products these are optional features. In DSA products, they are standard, as is drive dual access. This means that any of your DSA disks and tapes can be shared between two controllers.

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