HP StorageWorks DAT160 tape drive white paper

Answers to your top ten technical questions

Executive summary

DAT tape technology is the most prolific of all tape technologies with over 15 million drives shipped since the first products were introduced in 1989 and more than 6 million since 2000. This gives rise to a conservative estimate of a 6-million user installed base. The latest edition to the DAT family is the HP StorageWorks DAT160 tape drive, launched by HP in June 2007. The DAT160 drive is an evolution of existing DAT technology and has much in common with the previous five generations of DAT. Since differences do exist, this white paper answers the top ten technical questions on the DAT160 drive.

Figure 1. HP StorageWorks DAT160 USB external tape drive

The specific questions addressed in this white paper are:

1. The DAT160 drive reaches new levels of capacity without compromising reliability. How is that achieved?
2. How much further can DAT capacities grow?
3. The DAT160 drive has a much high transfer rate. How was that achieved?
4. The backwards compatibility with HP StorageWorks DAT72 and DAT40 tape drives is really important to customers. Can you explain how this works?
5. What is the new technology in the DAT160 drive and what has been leveraged from the DAT72 drive?
6. What have been the key time investments in developing this new product?
7. What is the reliability specification of the DAT160 drive?
8. The DAT160 drive will have a SAS interface as well as USB and SCSI. Why is that required?
9. Is the DAT160 drive suitable for an office environment?
10. What is next in the DAT roadmap?

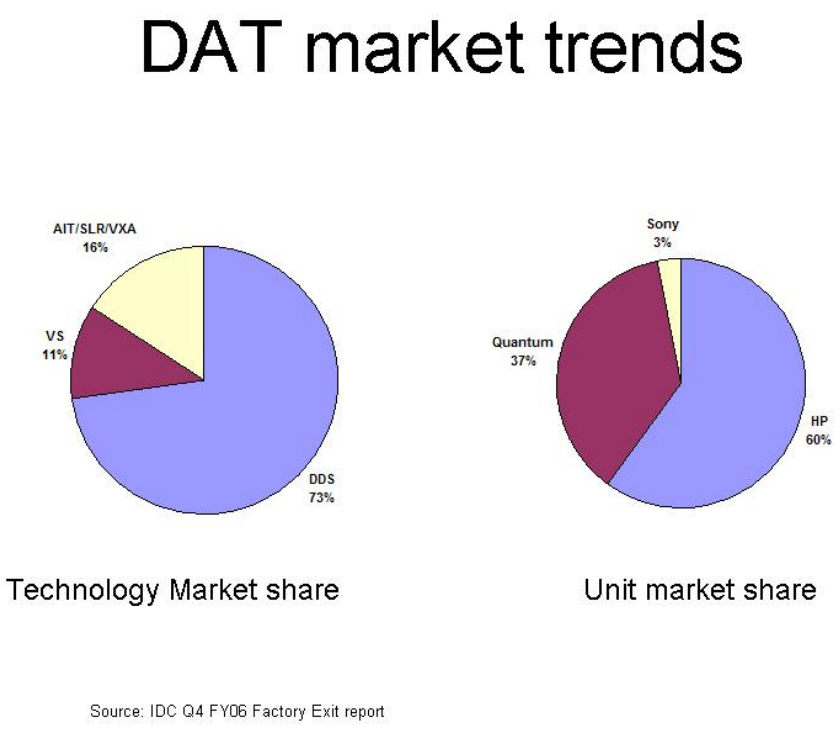
The answers to each of these questions with supporting technical explanations and data form the basis of this white paper.

Introduction

It is estimated that there are over 6 million DAT tape drives currently installed worldwide. DAT is the most prolific of all tape technologies because it has benefited from certain unique attributes:

- Low-cost media driving the lowest cost of ownership of any tape technology
- Reliable technology proven in the market
- Open industry standards—a history of multiple drive and media manufacturers
- Ongoing roadmap for customer confidence

Figure 2. HP has 60% of the DAT tape drive market



HP StorageWorks DAT160—Overview

Figure 3. HP DAT160 utilizes DAT160, DAT72 and DAT40 media

The HP StorageWorks DAT160 tape drive is the world's highest capacity and fastest DAT drive:

- Has 80-GB native capacity—up to 160 GB with 2:1 data compression
- Has a transfer rate of 6.9 MB/sec native, over 13.8 MB/sec with 2:1 data compression
  - Backing up approximately 160 GB in under 4 hours
- A higher capacity mainly achieved by using wider tape for DAT160, but still provides backwards write and read compatibility with DAT72 and DAT40 media. (This is achieved by having two independent threading mechanisms and tape paths inside the device.)
- Parallel SCSI and USB interfaces available at launch with a SAS interface following
- Supports HP StorageWorks One Button Disaster Recovery Solution when used with the relevant software and HP ProLiant servers, allowing total rebuild of a server from a single backup tape
- Includes a Single Server Edition of HP Data Protector Express backup/recovery and disaster recovery software
- Includes a DAT160 media cartridge and cleaning cartridge, along with the necessary connection cables
- Provided with a 3-year, next-day, parts exchange, limited warranty for the HP StorageWorks DAT160 tape drive, plus 9x5 phone support for the duration of the warranty

- Is supported on a wide range of operating system and backup applications (for more information, see http:/www.hp.com/go/connect)
- A wide variety of models is available—internal, external, rack mount, as well as the previously listed interfaces
- Media price expected to mature at $30, expect approximately $40 at launch
- The DAT160 USB external shown in Figure 3 will retail at approximately $999 at launch

Answers to your top ten technical questions

Q1. The DAT160 drive reaches new levels of capacity without compromising reliability. How is that achieved?

The DAT160 media is just a wider version of the DAT40 media using MP+++ (Metal Particle) technology 150 m in length. This is the same type of tape as has been shipping since 1994 in DAT40 cartridges. It has a proven track record of reliability. However, in DAT160 media, we have used a wider version of the tape to enable greater capacity.

Figure 4.

DAT160—wide tape

14.7-mm high cartridge

DAT72/40—3.8-mm tape

10.5-mm high cartridge

The "footprint" of the two media types is identical and common parts are used throughout design and manufacture.

A DAT160 drive accepts both sizes of media but threads them around the drum in different ways.

Q2. How much further can DAT capacities grow?

The DAT manufacturers' group roadmap currently shows another two generations of DAT. Some of the enabling factors in the roadmap are:

- There is still room for significantly longer tape in the DAT160 media cartridge.
- The bit density on the DAT160 drive is only slightly more than that on the DAT72 drive, so there is significant capacity increase available through increasing the bit density on the existing DAT160 media. We expect this to be one of the enabling steps for generation 7 DAT.

For example:

DAT160	**DAT72**
150 m	170 m
174 Kbpi	162 Kbpi

The next capacity point for DAT is expected to be 320 GB (@2:1 compression) (see Appendix B—DAT roadmap).

Technology steps to bear in mind are:-

- The wider tape used from the DAT160 drive onwards has essentially given us a two-generation head start without any leading edge technology developments.
- Improvements in bit density will yield capacity and performance increases.
- Improvements in drum rotation speed and linear density will give the increased throughput.
- Improvements in tape length will give increased capacity.

Backwards compatibility to the DAT160 drive will be maintained and HP is already working on the next step in the DAT story, the DAT320 drive.

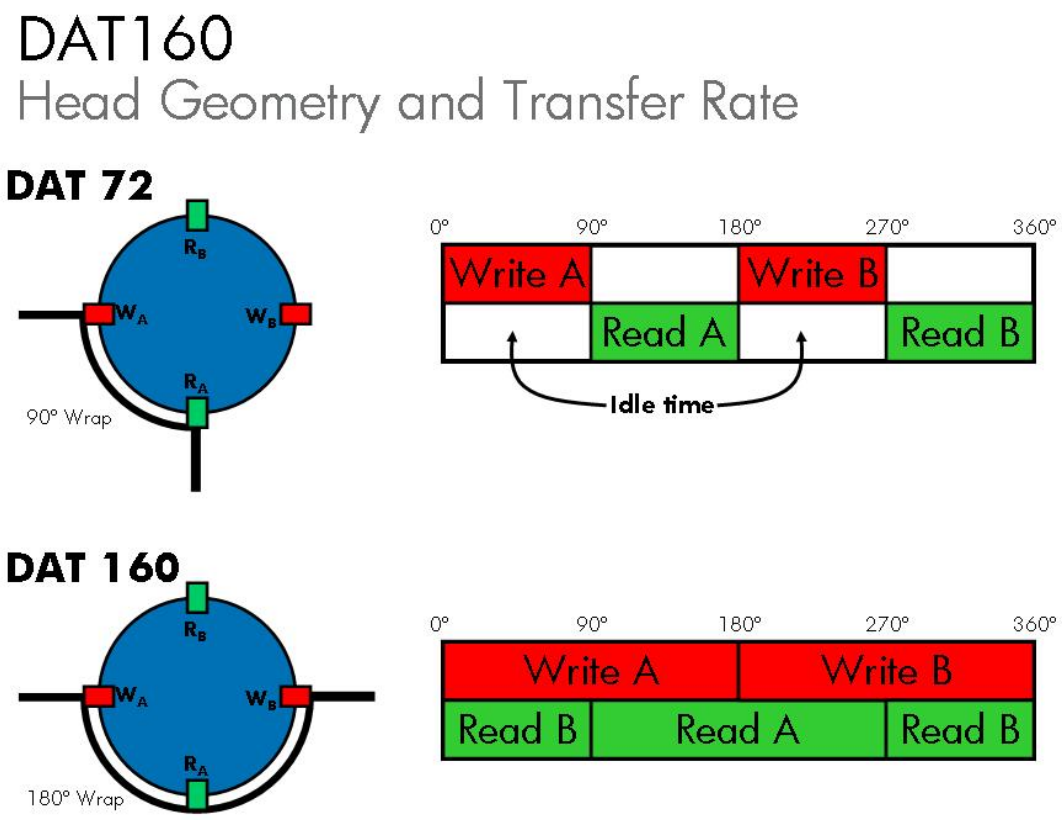
Q3. The DAT160 drive has a much high transfer rate. How was that achieved?

Transfer rate on DAT technology is determined partly by the wrap angle (amount of tape wrapped around the rotating helical scan drum) and the speed of rotation of the drum.

The wrap angle of the DAT160 drive is 180 degrees compared to only 90 degrees for previous generation DAT technologies, so the DAT160 drive actually makes more efficient use of tape in contact with the head to increase transfer rate. Further generations will increase the drum speed.

Figure 5 shows that with the DAT160 drive, we are writing and performing read after write verification simultaneously for a full 360 degrees of drum rotation. This is how the extra performance is derived. Because of the 180-degree wrap angle, the write cycle exists for longer so the throughput is doubled.

Figure 5. The DAT160 drive has increased performance through increased wrap angle



On the DAT72 drive, write head A is in contact with the drum for 90 degrees, followed by read head A to verify the data is written correctly. The same process is repeated for write head B and read head B. But as can be seen in Figure 5, this leaves an "idle" time where data is not being written, which limits the transfer rate. With the DAT160 drive, the writing and read verification is taking place for a full 360-degree revolution of the drum, making the whole write and verify process more efficient because there is no idle time. Restore rates also increase because the read process utilizes the whole 360-degree revolution for restore transfers also.

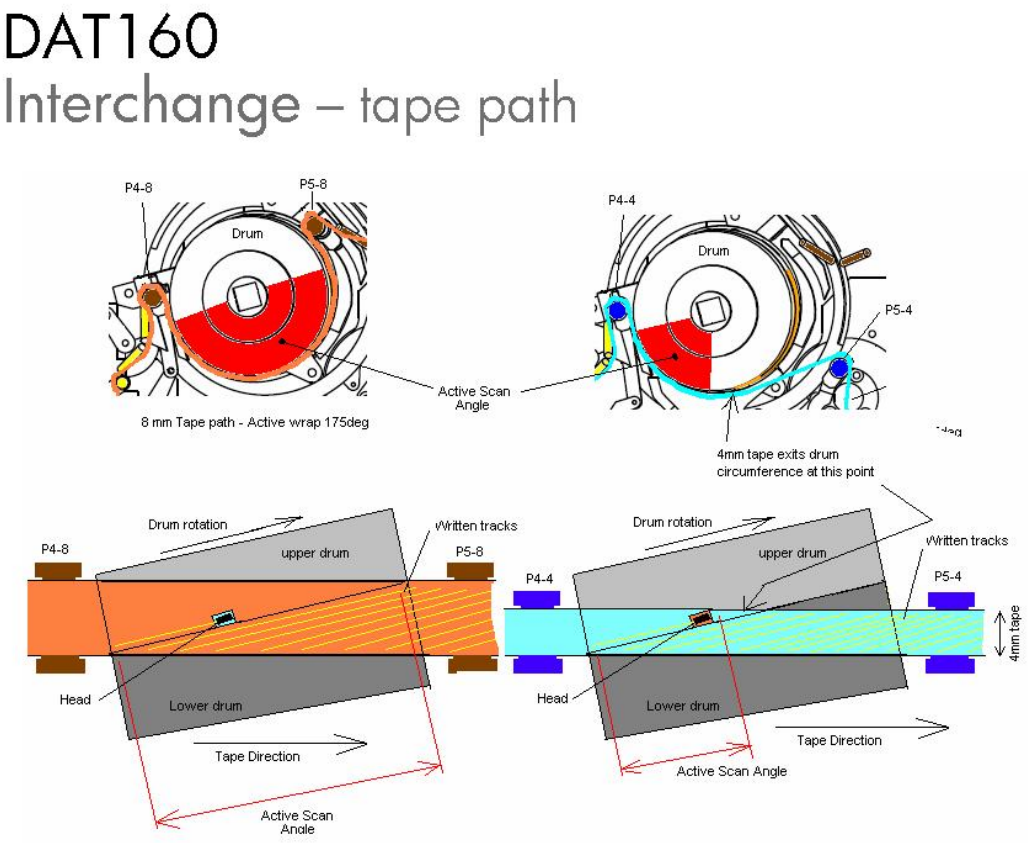
Q4. The backwards compatibility with the HP StorageWorks DAT72 and DAT40 tape drives is really important to customers. Can you explain how this works?

The ability of the DAT160 drive to write and read DAT72 and DAT40 media has been a challenge, but the pre-design simulations showed it was possible with margin to spare. The HP approach of using independent tape threading mechanisms was the breakthrough that enabled this part of the design to become a reality.

An explanation of the threading/tape loading process is shown in Figure 7.

- Separate guides are used to load DAT160 media or DAT72/DAT40 media, shown in brown for DAT160 and blue for DAT72/DAT40.
- Only one guide, shown in yellow, is common. This allows more control to accurately position the tape around the drum than a design that shares many guides.
- Guides can be set and adjusted for optimum performance with each tape format.

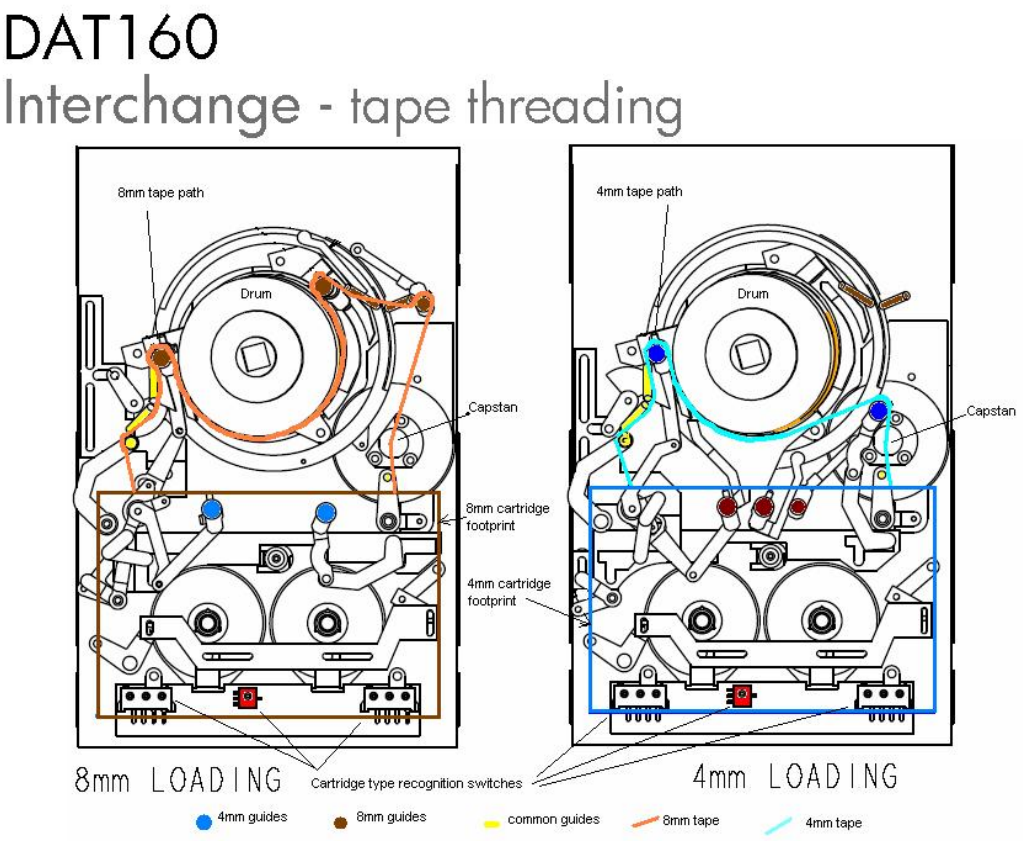
Figure 6. DAT160 drive maintaining interchange—the same drum is used for both 4-mm and 8-mm tapes



At first sight, the ability for any tape drive to accommodate two different tape widths looks daunting, if not difficult. However, the ability for the DAT160 drive to read and write to earlier DAT72 and DAT40 media was always a project "must." As a consequence, the drive was designed from the outset with the needs of two different tape types in mind.

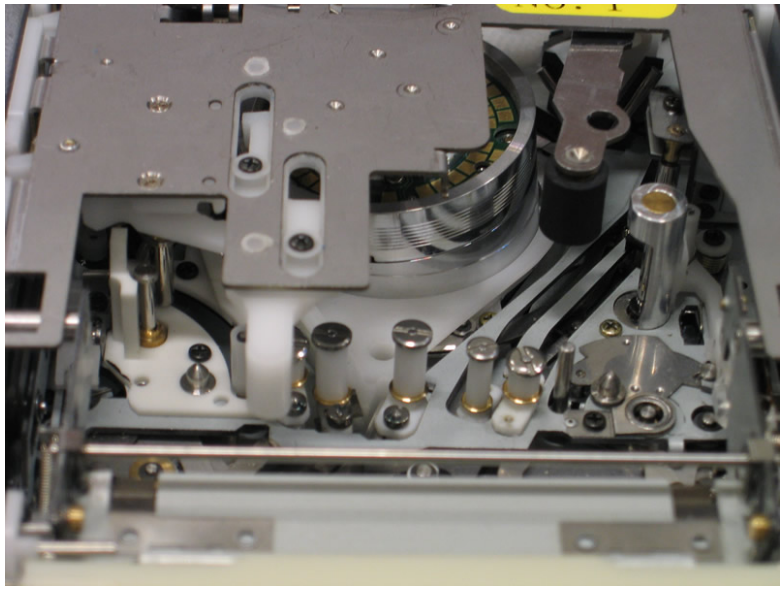
When the concept of loading two different heights of cartridge with two different tape widths was invented, HP used extensive computer simulation techniques to model the tape threading and routing for each tape type. The results of these simulations indicated that the design concepts were both practical and yielded good levels of margin in allowing the design to be successful.

Figure 7. DAT160 drive maintaining interchange—using separate loading guides for DAT160 and DAT72/DAT40



The most difficult challenge has been accommodating all the mechanical components in the physical space available as can be seen in Figure 8. However, using the HP standard product design and testing methodology, the necessary mechanical solutions and enhancements have been evolved.

Figure 8.



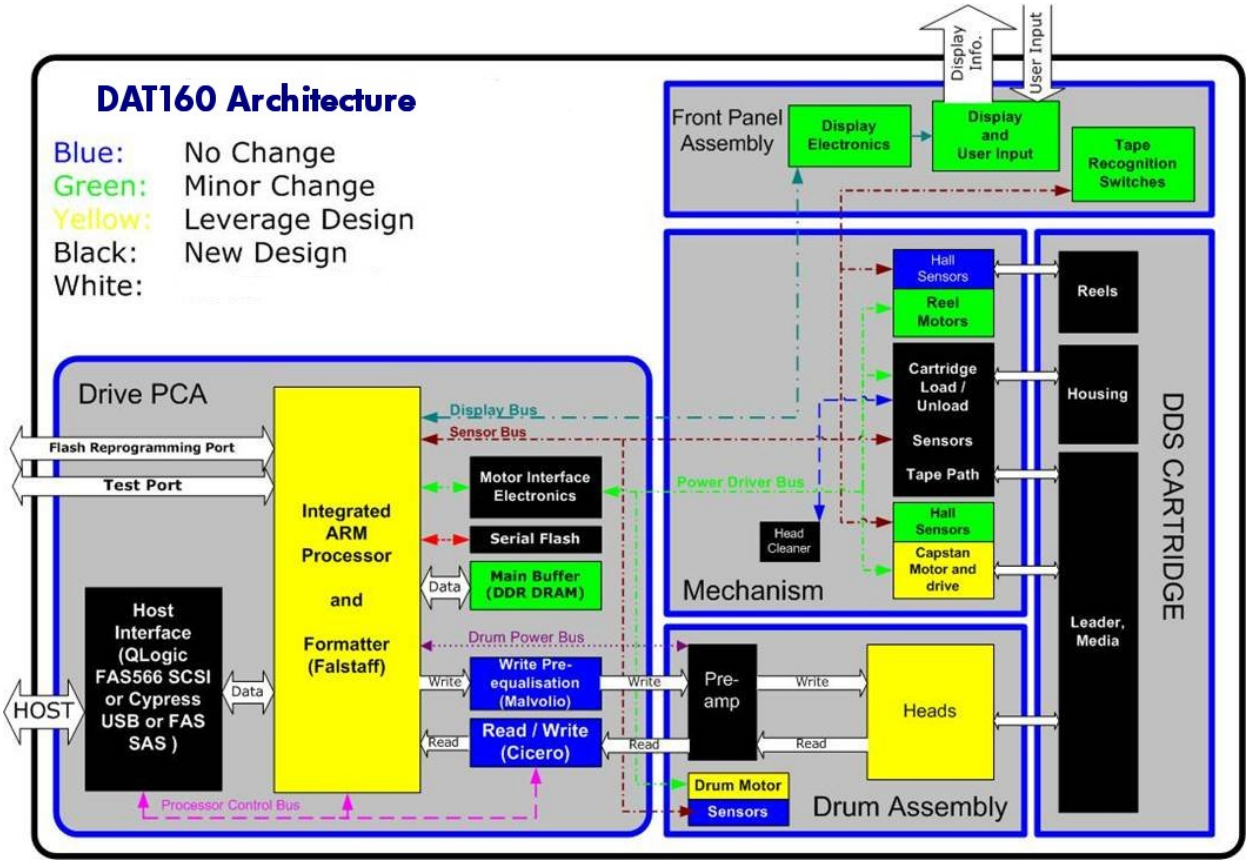
Each of the guides shown in Figure 8 has two key attributes:

- They are free to rotate in the "y" axis as they pick the tape out of the cartridge to ensure minimum tape edge damage as the tape is loaded.
- When they reach their final travel position, they "lock" firmly in place at a very precise angle to accurately position the tape around the drum.

The robust engineering and margin in these tape guides are the keys of a successful interchange.

Q5. What is actually the new technology in the DAT160 drive and what has been leveraged from the DAT72 drive?

Figure 9. Key components of the DAT160 tape drive



In Figure 9, the areas in black indicate where new design was required and these account for approximately 25% of the total design of the drive, the other parts of the design involved no change or minor change or a "leveraged design" from an existing piece of development work.

New design areas include:

- The DAT160 media (essentially wider DAT40 media in a new cartridge height)
- Tape path for DAT160 media with 180-degree wrap
  - DAT72/DAT40 tape path is well defined and proven in millions of drives
- Interface ASICS, SCSI, USB, and SAS
  - HP designs and develops these ASICS in-house.
  - DAT72 USB has been shipping for 2 years and LTO Ultrium SAS drives for 1 year.
- Pre-amp to cover both tape formats
- Cartridge sensors to detect which tape path to operate; these were part of the new design and worked the first time.

The majority of the engineering effort on the DAT160 drive has gone into the DAT160 cartridge load and unload, and DAT160 media threading and tape path. The ultimate measure of how good the tape path and threading is can be conveyed in what is known as the base error rate (ERT) of the drive. Minor deviations in tape tracking and tape edge damage manifest themselves in a degradation of ERT. The drive met all its low ERT specifications in high-volume production before being released.

Q6. What have been the key time investments in developing this new product?

Fundamentally the design and development of a tape drive that could accommodate two tape widths in a single mechanism took longer to perfect than HP initially estimated.

A key design brief of the DAT160 tape drive is that it is a transition step to higher capacity DAT technology and HP wanted to ensure that the installed base had a good backwards compatibility experience. Ensuring existing users of DAT72 and DAT40 media see a good return on their investment in the technology is seen as being crucial to the ongoing success of DAT. HP sees backwards compatibility as being a fundamental element of the DAT160's return on investment equation, unlike other technologies that offer increased capacity/performance but offer no backwards compatibility.

A significant element of any development program is testing. Design Verification and Test (DVT) reports are developed testing each specification. Because of the complexities of the two formats, the test plan for the DAT160 drive was much larger and longer than for previous generations of DAT. In total 450,000 hours (more than 5 years) of testing were performed on the DAT160 drive before release.

As mentioned in Question 4, the tape guide locking and tape guide angle parameters are critical to robust reliable interchange and low ERT, but these components are all inter-related so a strict process of consolidating improvements and re-testing had to be adopted, which took time.

The diagram below illustrates this. When a multi-facet issue was found, individual teams worked on the possible contributors to the issue. Changes were recommended reviewed and then consolidated into a new design. The original tests were then re-run to ensure the issue was resolved satisfactorily.

Figure 10. Test, analyze, consolidate, and re-test process

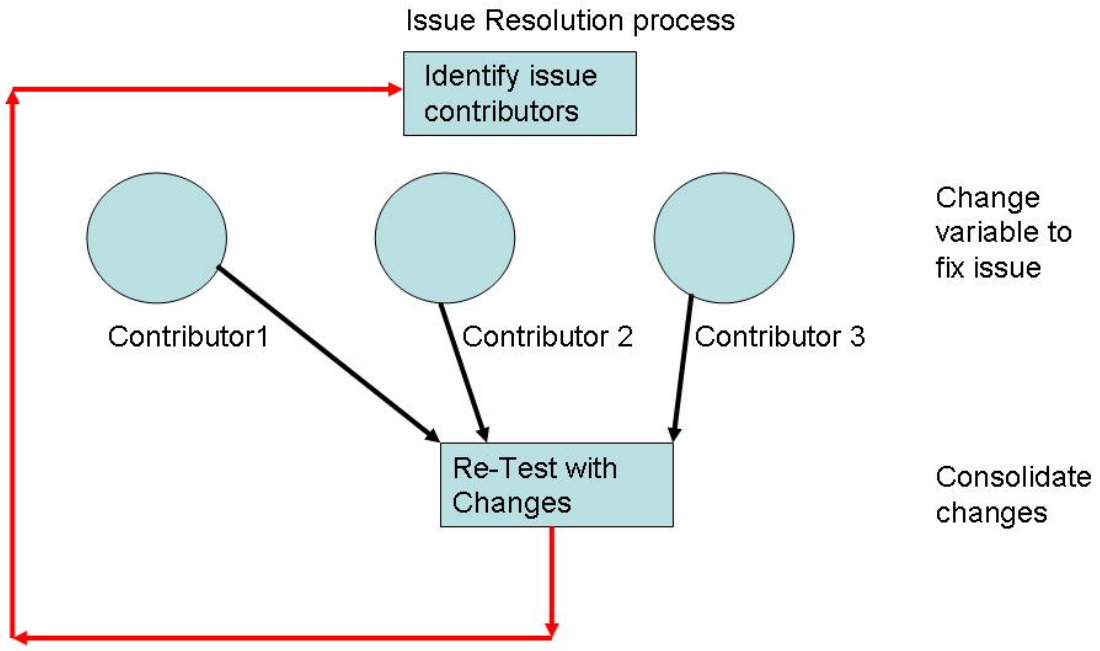


Figure 10 illustrates the typical issue resolution and test process.

For a given problem, different contributing factors are identified. Engineers then work on fixing individual contributing causes. All the fixes are brought together. The product is enhanced, and then re-tested. Sometimes the fix for issue contributor 1 could have adverse effects on the fix developed for issue contributor 3. Over time, it was a matter of patience and winning a series of little victories, while all the time building increased margin into the product until the DVT specifications could be achieved.

Q7. What is the reliability specification of the DAT160 drive?

The formal reliability specification for the DAT160 drive is 125,000 hours at 100% duty cycle.

Note
This is not a theoretical value or "specmanship." It is derived from field failure rates for HP DAT products already in the field. The manufacturing release (MR) MTBF launch criteria shown in Figure 11 for the DAT160 drive are the same as for previous HP DAT products at launch. Therefore, we can accurately predict that the DAT160 drive will achieve 125,000 hours MTBF at 100% because we know other DAT products achieved that from the same starting point.

For more information, refer to the July, 2004, "HP DAT40 and 72 MTBF specification change" white paper (http://h71028.www7.hp.com/ERC/downloads/5982-8021EN.pdf?jumpid=reg_R1002_USEN).

Following is a summary from this white paper.

HP provides an MTBF and bit ERT specification for its DDS products as a guide to the reliability that can be expected during customer use of these products. These specifications have, in the past, been generated using pre-production testing during the development of products.

The existing specifications for the DDS products (pre 2004) were:

MTBF: 400,000 hours at a 12% duty cycle

Unrecoverable bit ERT: 1 in $1x10^{-15}$

Based on field data gathered for the HP DDS-4 and DAT72 products, these specifications have now been revised to bring them inline with the reliability seen in the field by end users based on an assumed duty cycle. Therefore, this gives a much more representative measure of the real reliability of the product.

The revised specifications are:

MTBF: 125,000 hours at a 100% duty cycle

Unrecoverable bit ERT: 1 in $1x10^{-17}$

So HP changed its reliability metrics from being "predicted" from in-house testing before launch to being based on actual field data based on returns after the total return population. Given an actual measure achieved "in-house" at product release time, HP can accurately predict what the real-world reliability will be based on trend analysis from previous generations and millions of users.

The test bed of release quality DAT160 products within HP has achieved 70,000 hours at 100% duty cycle.

Figure 11. The steady growth in DAT160 drive reliability with HP in-house test over the duration of the product development cycle

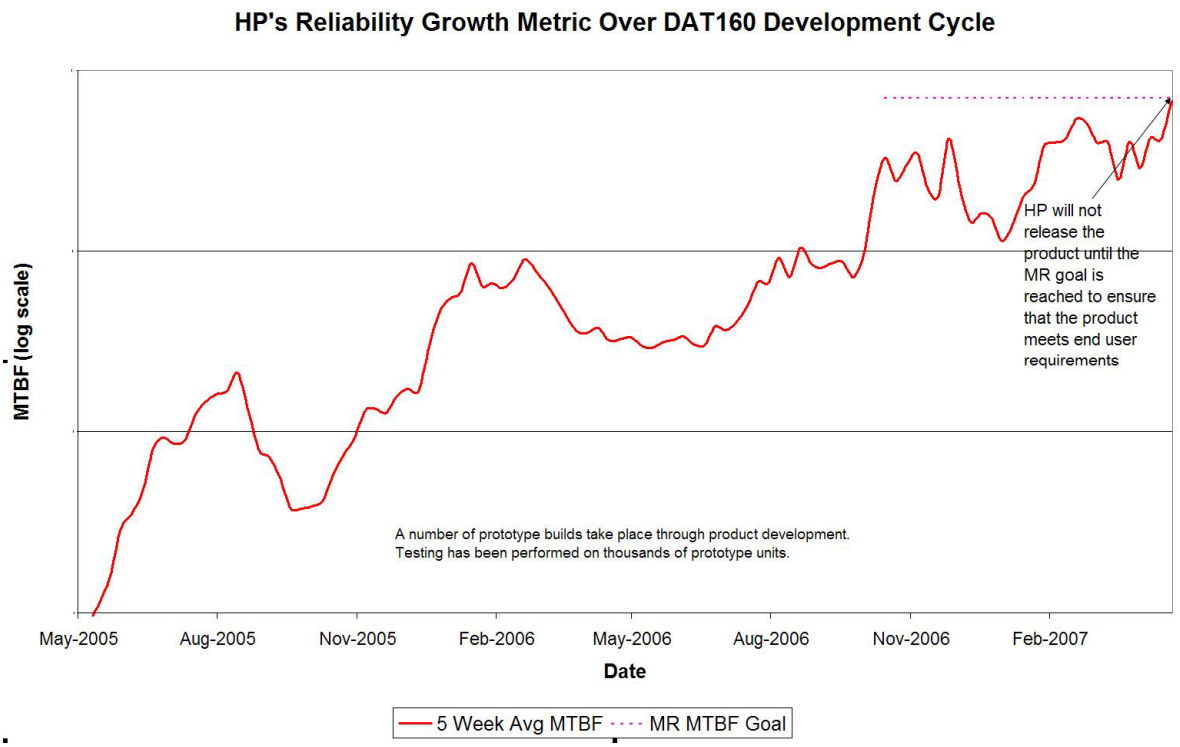
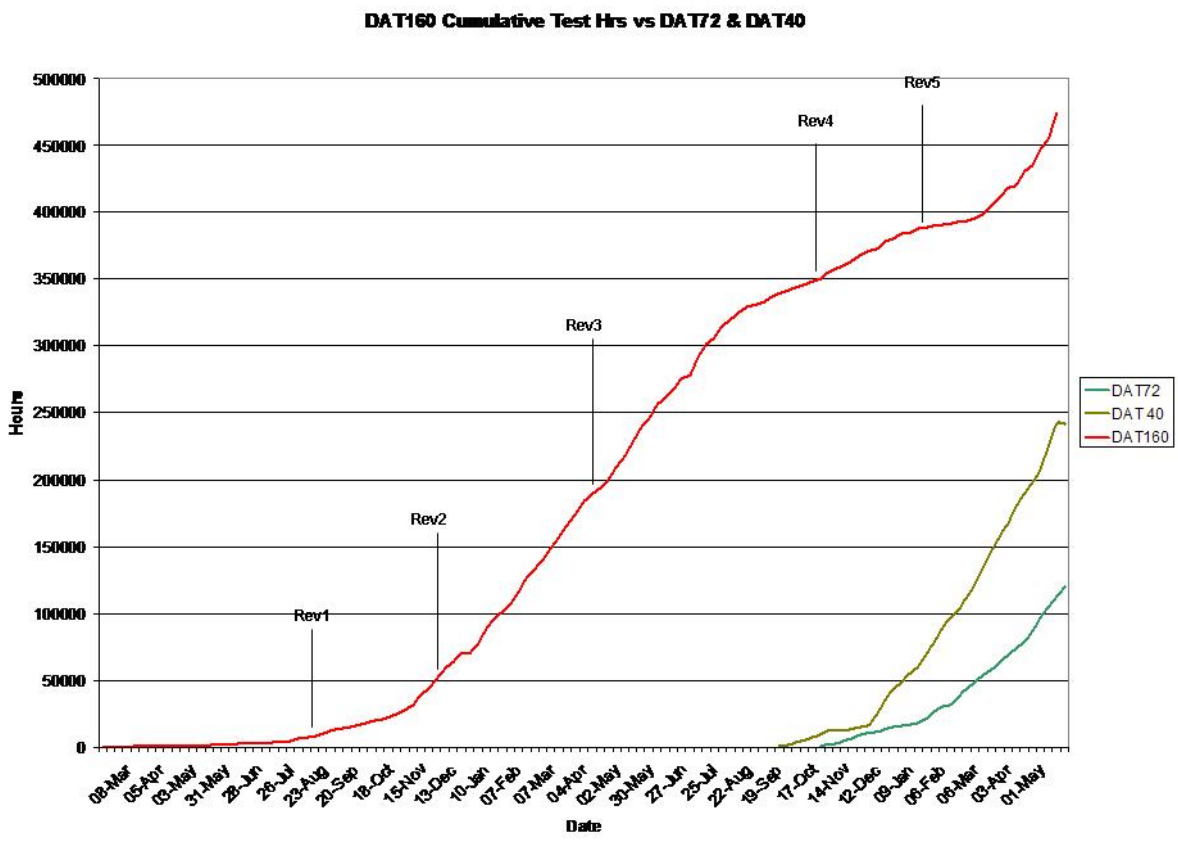


Figure 12. The accumulation of 450,000 hours testing on the DAT160 drive over the duration of the product development cycle, with different revisions of the mechanism (the most thoroughly tested HP DAT drive)



DAT72 drive architecture was highly leveraged from DAT40 drive architecture, so less testing was required.

Q8. The DAT160 drive will have a SAS interface as well as USB and SCSI. Why is that required?

Parallel SCSI (Ultra 320) is being superseded by SAS interfaces on systems and servers. This trend is being followed by the tape drive industry. In almost all ProLiant servers, parallel SCSI is being phased out and Serial Attach SCSI (SAS) is taking its place.

HP is providing the DAT160 drive in three variants to assist users in the change over. We see SCSI variants being used in traditional legacy situations.

SAS DAT160 tape drives can connect either to an embedded SAS RAID controller or to a dedicated SAS HBA.

All desktops, laptops, and servers now have more than one USB port.

So with these three connectivity options, SCSI (for installed base), SAS for future server connect, and USB (for universal connect), the DAT160 drive is assured to protect customers' investment in DAT technology.

Q9. Is the DAT160 drive suitable for an office environment?

HP has thought of everything with the DAT160 drive. When we launched the latest versions of the DAT72 drive—especially the DAT72 USB—some customers considered the fan too loud for typical office environments. We have re-engineered the solution and the DAT160 drive will benefit from this.

The original fan in the DAT72 enclosure ran at 8200 rpm and generated noise of 28.0 dBA.

The new fan in the DAT160 enclosure is larger than in the previous DAT72 enclosures and hence gives more airflow at a lower noise level. The fan runs at 3700 rpm and generates noise of 22 dBA, which is now much more "office friendly."

Some other engineering adjustments also enabled the slower fan to provide the effective cooling required by the DAT160 drive:

- Improved stability of air flowing into the fan by increasing the length of the enclosure (so more space behind drive)
- Improved air exhaust efficiency by increasing the size of the vent holes at the rear of the enclosure
- Minimized impeller cavitations by "dishing" the fan vent, so creating a space between the rear panel and the fan

Figure 13. New DAT enclosure with quieter fan

Q10. What is next on the DAT roadmap?

If you consider that the DAT160 drive is DAT40 format on wider tape, then generation 7 DDS is equivalent to DAT72 format on the wider tape. Generation 7 is expected to be released in 2009 and will leverage the tape width enhancements made with generation 6 (DAT160 drive).

Tape length, track width, and linear bit density will increase capacity. Increased drum rotation speed will increase performance.

The major technical challenge will be preserving "linearity" (straightness) as the head travels along the helical track on the wider tape. The generation 7 DDS tracks will be thinner (to give higher capacity) and therefore will require better tracking capability from the servo system.

Summary

- The DAT160 drive is a genuinely low-risk tape technology because so much of the design is leveraged from previous generations and so much testing has been performed on the new parts of the design—mainly in the interchange area.
- The DAT160 drive forms the stable platform for further generations of DAT technology.
- A low media price ($40) ensures DAT160 drive technology remains the favorite tape technology with small and medium businesses.
- Backwards compatibility with an estimated 6 million installed base of DAT users has been preserved through robust engineering.
- A wide range of interfaces are available to protect customer interface investments both today and tomorrow.
- The DAT160 drive has undergone extensive testing and quality assurance processes—the only downside of which was extra development time.

Appendix A—DAT160 detailed specifications

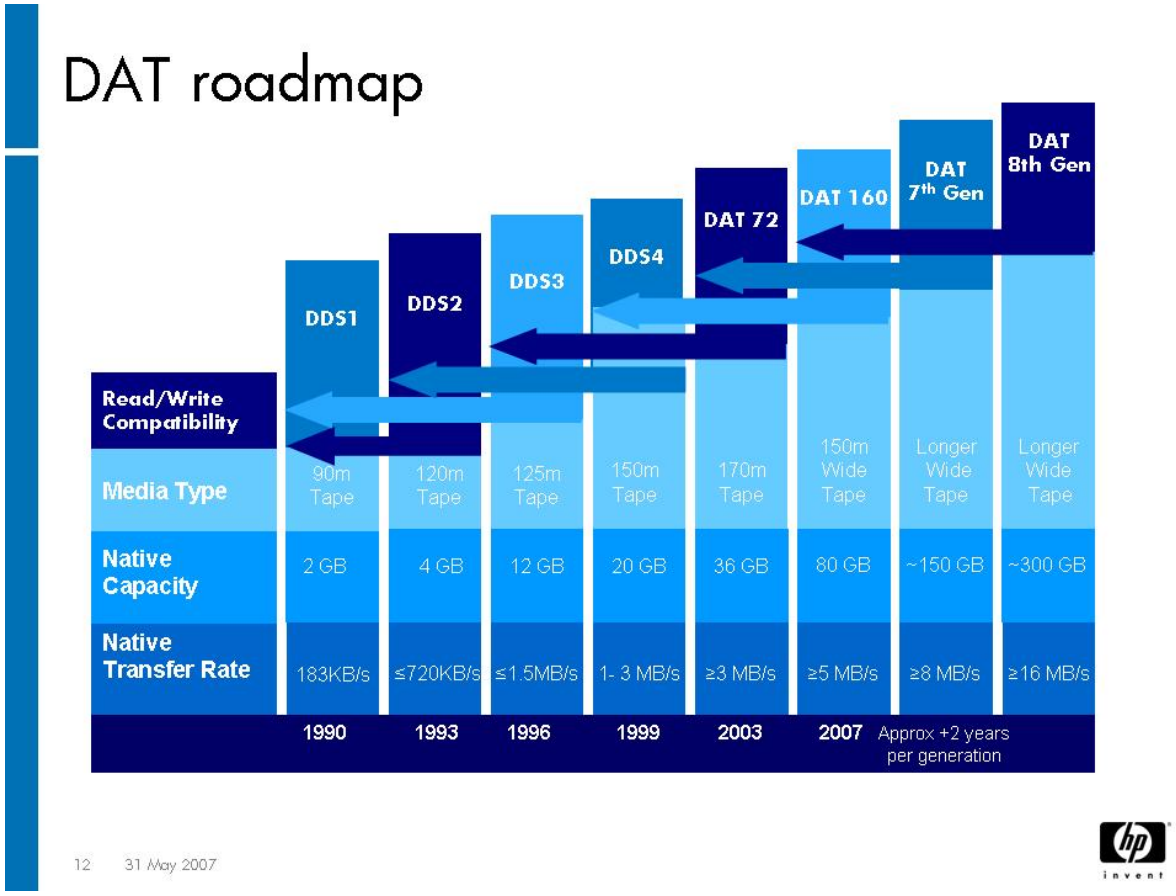
The following table provides a summary of specifications that show the subtle differences between the DAT72 and DAT160 drives. General drive dimensions, operating environment, media environment, and electromagnetic compatibility are the same for both technologies. The table also shows some areas where specifications are identical.

Feature	DAT72 drive	DAT160 drive
LEDs	2	4
Number of tape guides	7	10
Normal tape speed	14.03 mm/s (0.551 ips)	12.25 mm/s (0.482 ips)
Fast search/rewind speed	1600 mm/s	1600 mm/s
Drum speed	8609.7 rpm	6457 rpm
Forced air cooling recommended	1 cu ft/min	1.5 cu ft/min
Power consumption typical	7.1 W	10 W
Power consumption worst case	16 W	25 W
Tape length	170 m	150 m
W/R format compatibility	DAT40 and DAT24	DAT72 and DAT40
Bit density	163,000 bpi	174,500 bpi
Track density	4678 tpi	3742 tpi
Track width	5.4 microns	6.8 microns
Linear bit density	6.4 Kb/mm	6.8 Kb/mm
Media	MP4+	MP+++
Time to fast search entire media	130 s	120 s
Reliability	125,000 hours @100% duty cycle	125,000 hours @100% duty cycle
Uncorrectable ERT	< 1 in 10^{17} bits transferred	< 1 in 10^{17} bits transferred
Head life	6,000 hours of tape pulling—equates to 4.4 yrs with a full length backup everyday	6,000 hours of tape pulling—equates to 4.4 yrs with a full length backup everyday
Cartridge load life (loads)	6,000	6,000

MTBF = (Cumulative hours of all drives shipped)/(Number of units returned due to end-user failures)

Appendix B—DAT roadmap

Figure B-1.



For more information

- www.hp.com/go/tape
- http://www.datmgm.com/

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