SONY

Proof that not all data cartridges are created equal

Lab tests compare four brands of LTO-4 tapes

Lab tests cut through the clutter of claims

Almost as long as there have been data tape cartridges, competing vendors have been claiming that their cartridges are the best. Marketers point with pride to obscure technical achievements that appear at first glance to be far removed from end-user experience. Not only can these claims confuse non-specialists, but evaluating competing claims appears to be a hopeless exercise. It's no wonder that some users view certification by the format's licensor as a guarantee of quality. These users may well believe that one certified tape must be just as good as any other. Fortunately, there's a way to cut through the jargon and uncover meaningful performance differences: objective testing of error rates by a third-party laboratory. Sony engaged just such a laboratory to conduct comparison tests on one of the most popular cartridge types, LTO-4, pitting Sony against three leading competitive brands. This paper summarizes the results.

Fatal and non-fatal errors

Generally speaking, there are two types of data cartridge errors: the ones that trigger permanent data loss, called fatal errors, and the non-fatal errors of normal, everyday use. At first, non-fatal errors appear benign because they are detected and corrected by the data drive. This built-in fault tolerance can initially inspire confidence in your choice of data media. But it can also inspire overconfidence.

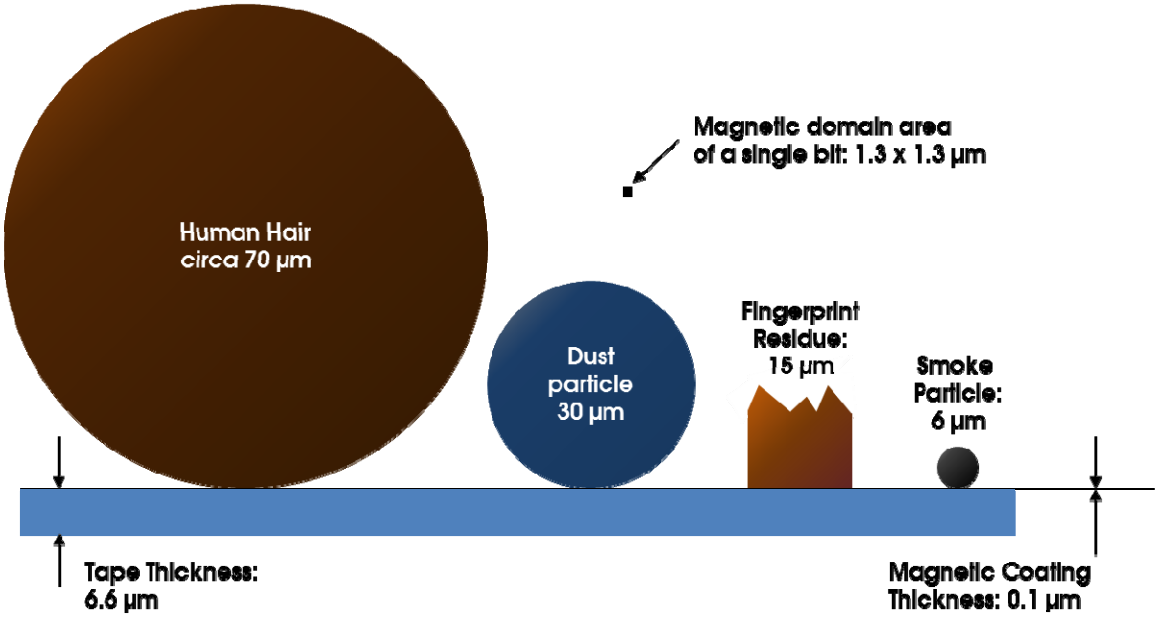
As with so many issues in technology, the error correction systems work... until they don't. Typically, the errors build up over time due to operating stresses on the tape, accumulated contaminants and shedding. At some point, accumulated errors exceed the capabilities of error correction. Then you get hit with unrecoverable data loss. In fact, fatal errors are so prevalent in real-world tape libraries that standard archival practice is to store everything in triplicate. The hope is to have a backup for the backup when essential data goes missing. Of course, it's still best to minimize fatal errors to begin with.

In this context, high error rates for factory-fresh cartridges are warning flags for trouble down the road. Conversely, low initial error rates represent an important "overhead"—a margin of safety to protect the future of your data.

The microscopic margin of safety

The migration of data storage from the desktop to the data center to the cloud makes it easy to forget that data must still be housed in physical form. Over the decades, we've seen data tape capacities increase from Megabyte to Gigabyte to Terabyte range without any increase in cartridge size. Obviously, higher and higher capacity is the result of smaller and smaller magnetic domains used to represent each bit. For contemporary cartridges like LTO-4, the recorded bits are literally microscopic. They're measured in micrometers, millionths of a meter. There are more than 25,000 micrometers in a single inch.

- To accommodate a high volume of data, the LTO-4 cartridge must contain 820 meters (half a mile) of tape. For this to fit inside a four-inch cartridge, the tape must be extremely thin, just 6.6 micrometers. (For comparison, human hair is on the order of 70 micrometers thick.)
- Most of the tape thickness is composed of the plastic base film. Only a tiny fraction of the tape is the magnetic layer that actually retains the data. The magnetic layer is literally on the nanoscale—100 nanometers in thickness in the case of Sony LTO-4 tape. This 100 nanometer coating is so thin that if you needed to paint your car to this thickness, you'd require less than one teaspoon of paint.
- The recorded tracks are also microscopically thin. The half-inch width of an LTO-4 tape supports 896 parallel tracks, each of which is less than 15 micrometers wide.
- The ability of the drive to read data completely depends on the proper alignment of the read head with the recorded track. This in turn depends on the microscopic accuracy of the LTO servo tracks that are applied to the tape at the time of manufacturing.

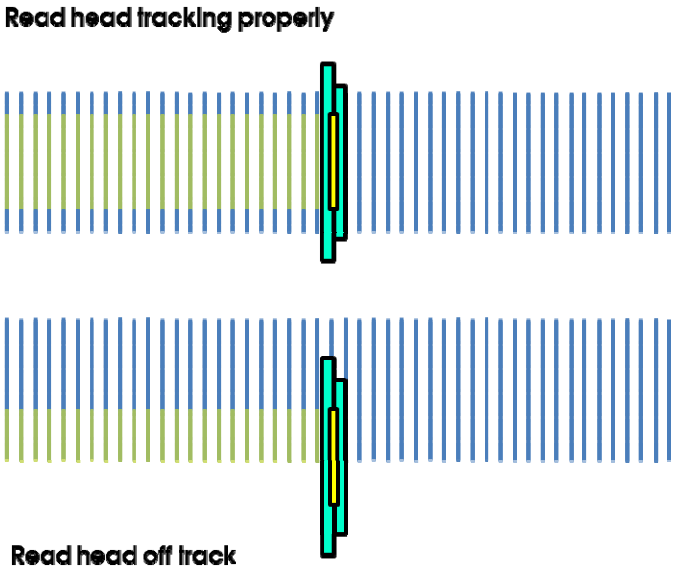


- At 800 GB native capacity, the density of bits on the LTO-4 tape is phenomenal. There are about 615 Kilobits per square millimeter of tape,

or 400 Megabits per square inch. You can visualize each recorded bit as occupying a square patch of tape measuring just 1.3 micrometers on each side. If you placed those bits onto a cross-section of human hair, you'd have enough room for about 2,400 bits. That's the data equivalent of a typical paragraph of text—inscribed on a cross section of human hair.

In short, the size of recorded bits is minuscule compared to the size of potential contaminants like hair, dust motes, smoke particles, fingerprint residue, insect debris and even material shed from the tape itself. This has practical implications for long-term storage. Over time, wear and tear subject your data to physical degradation and increasing error rates.

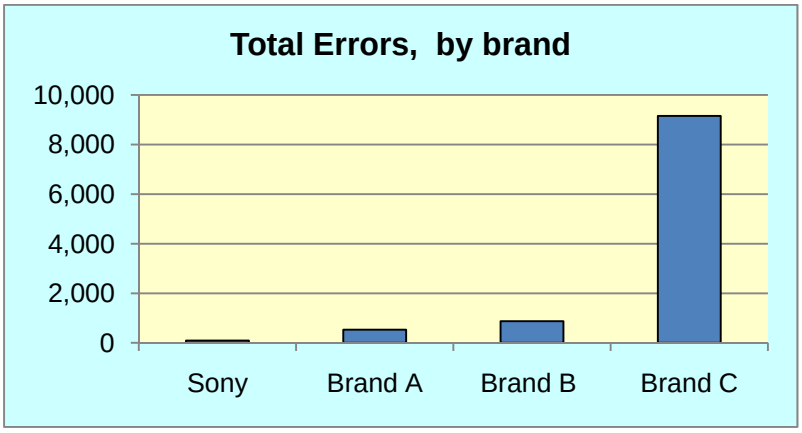
- Because the tracks are so thin and the magnetic domains that represent bits are so small, even microscopic particles can interfere with proper tape-to-head contact, triggering significant incremental errors.
- Writing a complete LTO-4 cartridge requires 56 passes through the drive. Each pass exposes the tape to contact with guide rollers in addition to the read/write head.
- The simple passage of time can degrade the chemical stability of the binders that hold the magnetic layer together.
- Humidity and especially temperature variation can cause the tape to elongate or shrink, degrading the critical spacing of servo tracks. This can cause the read heads to slip off the recorded data track.



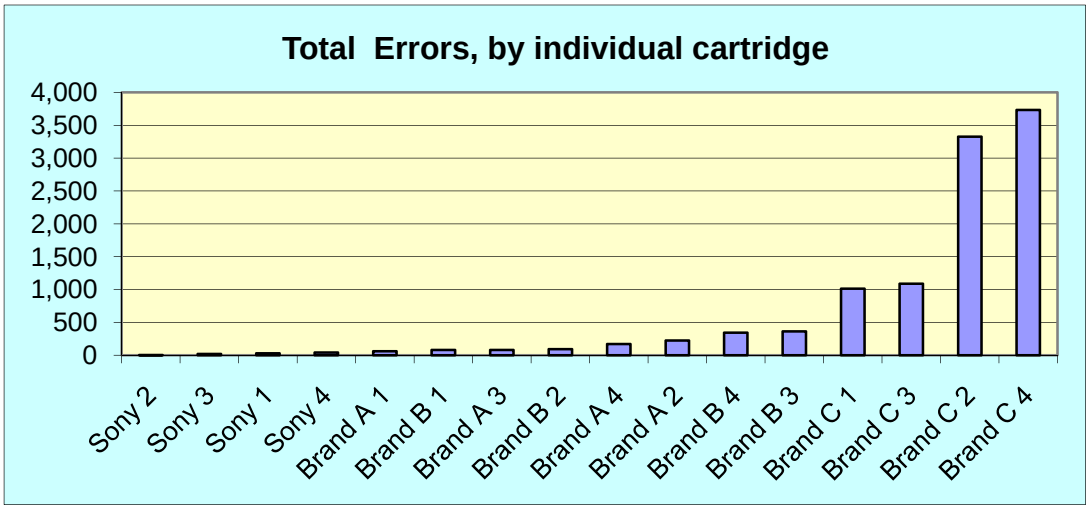
Because a data tape is never better than when it's factory fresh and because the passage of time can exert such a toll, your data is safest with cartridges that offer the lowest initial data errors.

Laboratory test results

Sony engaged Mountain Engineering II, Inc., a highly-regarded specialist in data storage technology to test Sony tape cartridges against three other leading brands. To give the test broad applicability, we chose one of today's most popular cartridge formats: LTO-4. Four cartridges from each tape vendor were put to the test in two IBM and two HP drives, for a total of sixteen tests per tape company. As you would expect for brand-new tapes, there were no fatal errors. Instead, the laboratory measured total errors, which is the sum of read retries, write retries and servo errors.

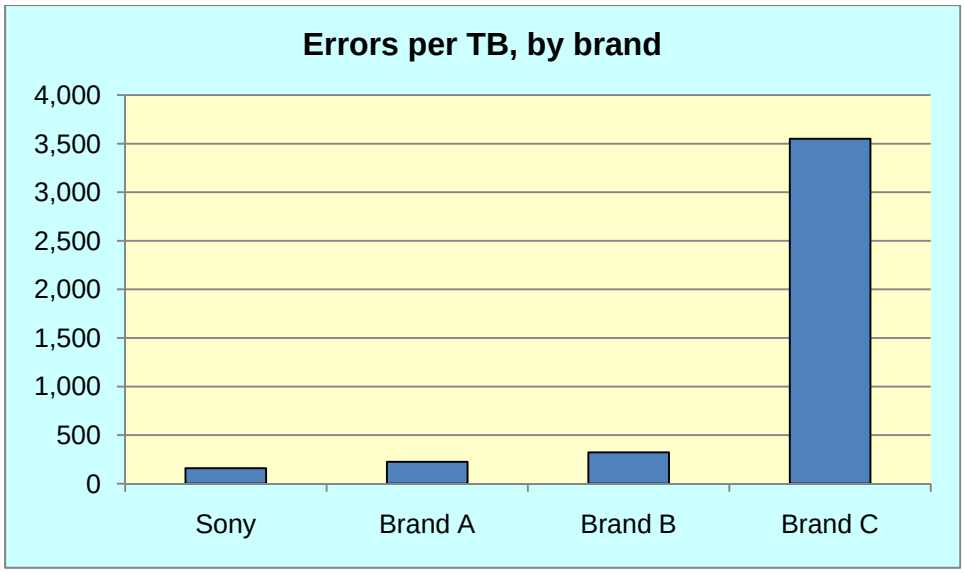


The results were dramatic. In sixteen trials, the Sony cartridges incurred 80% fewer errors than the next-best brand—and an eye-opening 99% fewer errors than the worst brand.

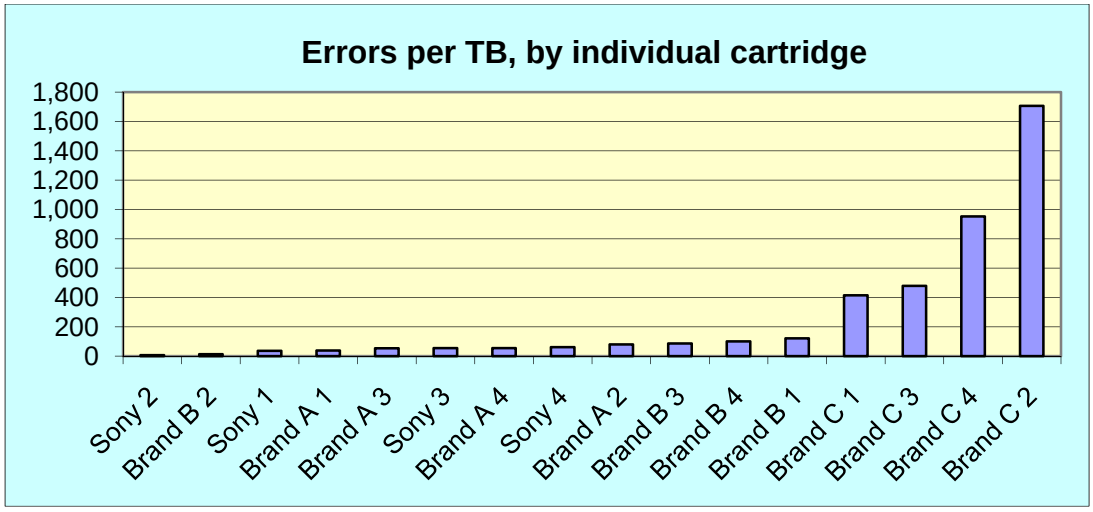


Breaking the results out by individual cartridge, the four Sony cartridges took all four of the top spots.

Another assessment is the rate of errors per Terabyte of data written or read. This yields slightly different results, with Sony again in the forefront.

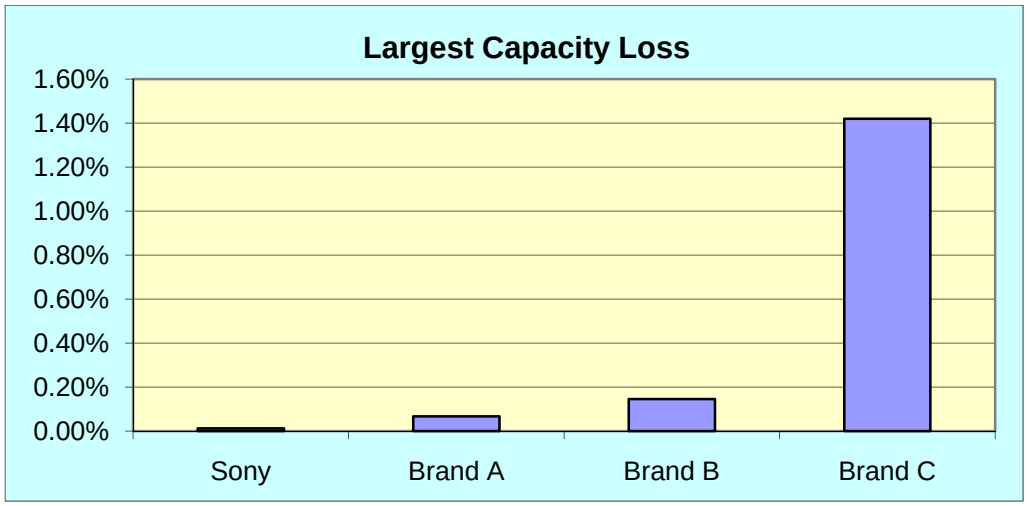


If we look at errors per TB by individual cartridge, all four Sony cartridges place in the top eight. Brand A runs a close second, while all four Brand C cartridges place last.

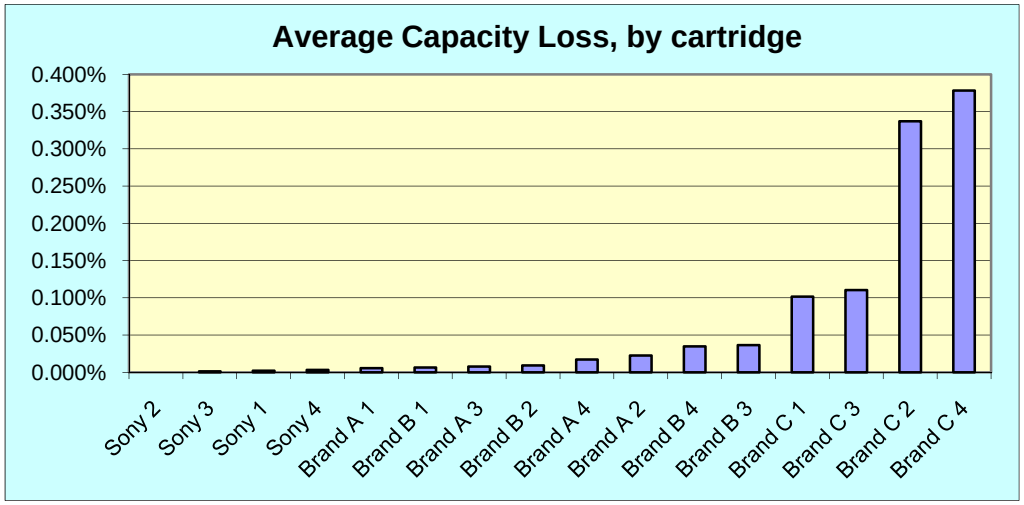


Capacity loss

When write retries are required and when write servo errors occur, LTO drives rewrite the missing data. Obviously, this procedure causes some loss of capacity. The extent of the lost capacity serves as another indication of tape quality.



When looking at largest capacity loss, Sony comes out on top.



In terms of average capacity loss per cartridge, the four Sony cartridges once again swept the top spots.

Some fine print

The conditions of the test were rigorous. For example, to eliminate potential bias from the choice of tape drives, all tapes were tested in all drives and cycled through in a random sequence. To control the variable of drive cleanliness, whenever a drive requested cleaning, it was treated with a Sony cleaning cartridge. Room temperature was maintained within a range 18°C to 20°C (64°F to 68°F). Relative humidity was held within a range of 12% to 30%.

What the results say—and what they mean to you

To a dramatic degree, the laboratory tests were dominated by just one tape vendor: Sony.

- Compared to three other leading brands, Sony LTO-4 cartridges came out number one in total errors by a wide margin, with 80% fewer errors than the next-best brand.
- All four of the top four cartridges in the test were from Sony.
- On a scale of error per Terabyte of data written or read, Sony also came out number one.
- In terms of capacity lost to write errors, Sony again finished first.

These third-party tests confirm what we've found in the spot checks and quality surveys conducted by our own staff. The best protection for your precious data is the tape with the lowest error rates, tape from Sony.

The secrets of our success

Sony's outstanding laboratory test results are the direct consequence of advanced materials science, state-of-the-art magnetics and amazingly precise process control. Even a short list of Sony refinements brings us to those "obscure technical achievements that appear at first glance to be far removed from end-user experience."

- The magnetic particles of Sony LTO-4 tape are 30% smaller than the particles used in Sony LTO-3. Each metal particle measures just 30 nanometers in diameter, that is 30 *billionths* of a meter.
- Each particle is encapsulated twice. The first prevents the metal material from oxidizing. The second promotes firm bonding, vital to the tape's long-term integrity.
- The entire magnetic coating of the tape is just 100 nanometers thick. High "dispersal" enables the coating to be supremely consistent, minimizing gaps or high spots.
- Specially developed tape surface smoothing technology maintains smoothness within tens of nanometers.
- The seemingly simple process of slitting the master roll into individual 1/2-inch tapes has been improved with a high-accuracy process.
- Based on our expertise in manufacturing data drives, Sony took special precautions in applying the all-important servo tracks, which factories must pre-record onto LTO tapes.
- For optimum strength, the servo tracks are applied with a proprietary Sony technique.
- The base film has been specially formulated for a strength balance that resists elongation and shrinkage despite temperature and humidity variations. This dimensional stability is critically important for maintaining the physical spacing of the servo tracks. If the tracks were train rails spaced at 1400 millimeters (1.4 meters or 55 inches), Sony tape would

maintain spacing accuracy within two millimeters (about 1/12 inch). On the actual tape, this accuracy equates to tens of nanometers.

- Static electric discharge from the tape can severely damage the magneto resistive heads of LTO drives. Sony controls static electricity with a carefully-maintained electrical resistance of 1×10^6 ohms/sq. across the magnetic layer.
- The reel that holds the tape also has a role to play in reducing errors. Sony has refined the reel hub for higher concentricity, while we've re-shaped the reel flange to better protect the tape edge.
- When a drive accepts an LTO cartridge, it pulls out the tape by a metal leader pin. Sony's pin has been tested for stable operation up to 20,000 load cycles.
- Even the cartridge shell is optimized to protect your data. The shell uses polycarbonate materials fastened with a combination of screws and ultrasonic welding.

Given these technical refinements, plus other manufacturing advantages that we prefer to keep secret, it's no wonder that Sony data cartridges perform so well.

Sony and data cartridges

Sony's prowess in tape is no surprise to long-time observers of data storage. After all, Sony has been a leader in tape manufacturing for over 60 years. We got our start in data media back in 1965, when IBM called us for help in tape manufacturing. We're experts in both data tapes and data drives. And we're particularly adept at the metal particle technology on which LTO tapes depend. All this helps explain why Sony data cartridges outperform the others in both laboratory testing and the data center.

SONY

sony.com/lto