FUJIFILM
Value from Innovation

THE ROLE OF

BARIUM FERRITE TECHNOLOGY 2018

IN DATA STORAGE

Data integrity,
floor space reduction,
tape cartridge capacity,
archive life,
writing speed.

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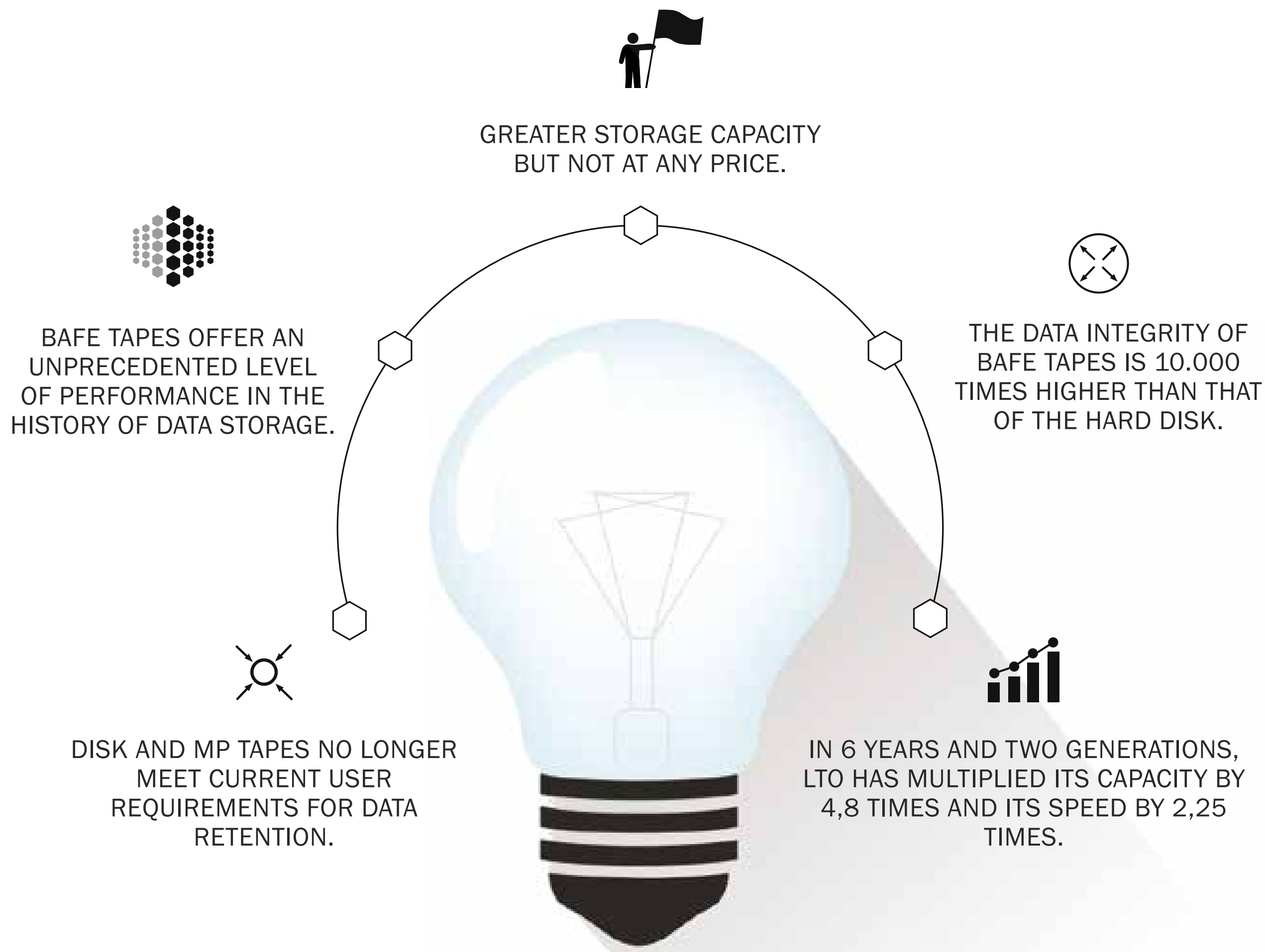
Introduction



Introduction

1. Challenges - what is the role of a manufacturer of data storage media?

The main challenge in the field of data storage is to enable end users to adapt to the evolution of the IT market and meet new business needs. In the field of data archiving, or in other words, the long-term retention of data, the key demand of market players is that storage technologies can enable them to address the very high growth of digital data creation, whilst improving the performance of storage systems. The Research and Development by Fujifilm and IBM on storage tape is in line with this request:

- How to increase data storage capacity and reduce floor space?
- How to increase the writing speed and reduce the backup time?
- How to reduce the number of write errors and improve data integrity?

2. What is the priority for technological innovation in the field of long-term retention of data?

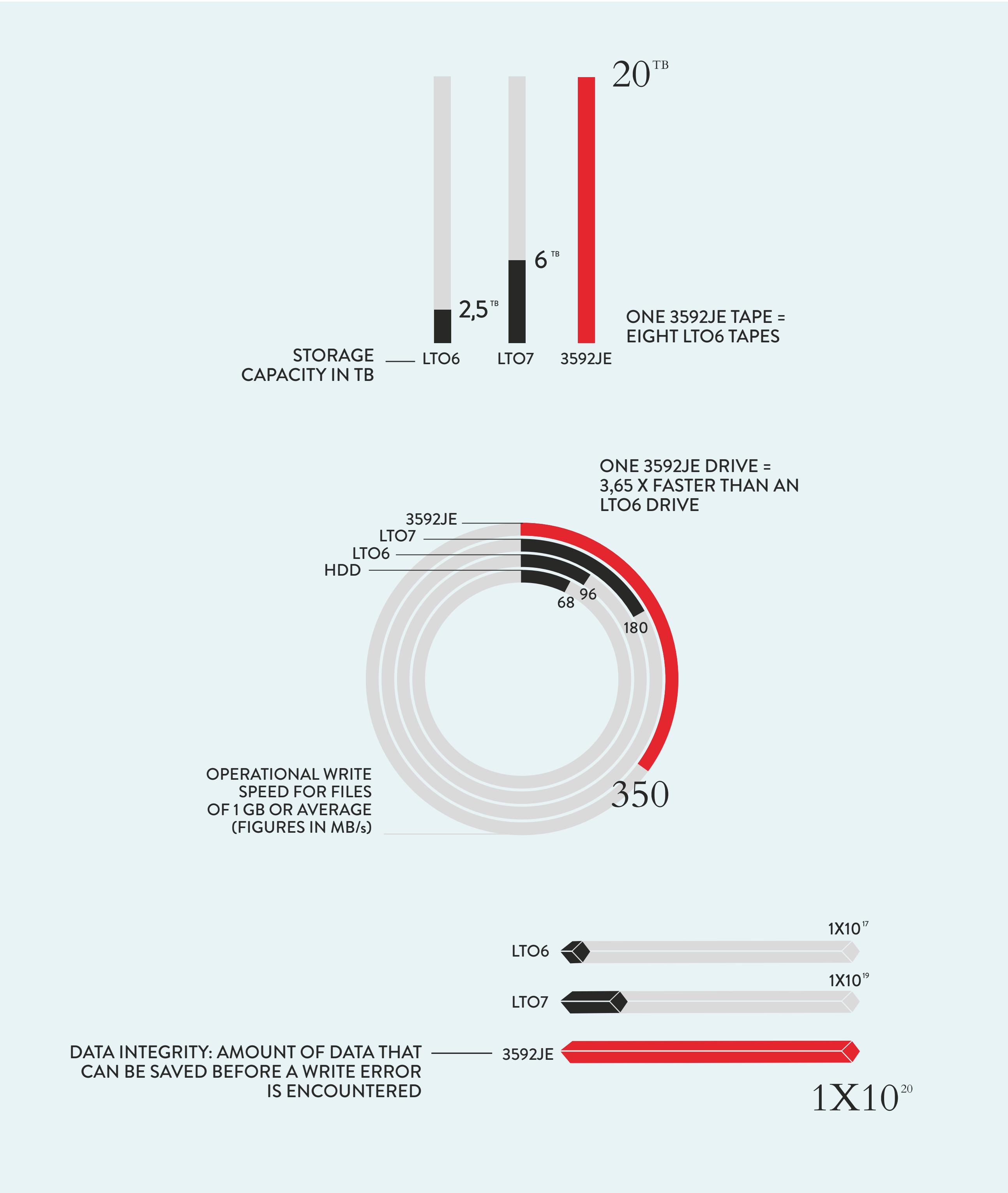
In the field of storage tape manufacturing, Barium Ferrite tape coating technology is a breakthrough that is able to generate tape cartridges with unprecedented storage capacities.
Without the developments made by IBM on drives, this innovation would have been simply impossible.

• In the space of six years, between LTO6 and the launch of LTO8, LTO tape technology will have multiplied:
- its native capacity per cartridge by 4,8
- its writing speed by 2,25
- the data integrity of its tape cartridges by 100

No other storage technology has succeeded in such a feat within two generations and within such a short time.

• What is even more impressive is IBM's 3592JE project. The new tape drive, which is scheduled to launch in Summer 2018, is expected to offer a capacity of 20TB per tape cartridge, a write speed of 500MB/s and a BER (data integrity) ten times that of the LTO7, 100 times higher than LTO6 and 100.000 times higher than Enterprise SATA Disks.

Description of a technological revolution: IBM 3592JE compared to its predecessors.



3. Greater storage capacity but not at any price

When it became necessary to increase the capacity of tapes, manufacturers were confronted to multiple problems:

• Traditionally, it was said that the magnetic output of a tape depended on its shape and, therefore, on its size. Producing higher capacity tapes involved the use of smaller particles, which could lead to producing tapes that would provide a lower magnetic output.
• In addition, increasing the capacity of a tape required an increase in the number of tracks, and therefore, the use of narrower tracks. However, a reduced track width inevitably reduces the overall strength of the magnetic field of this track.
• Finally, a higher capacity tape must naturally offer a higher writing speed. On the other hand, a higher writing speed may impair the quality of signal exchange between the drive's head and the particles on the tape.

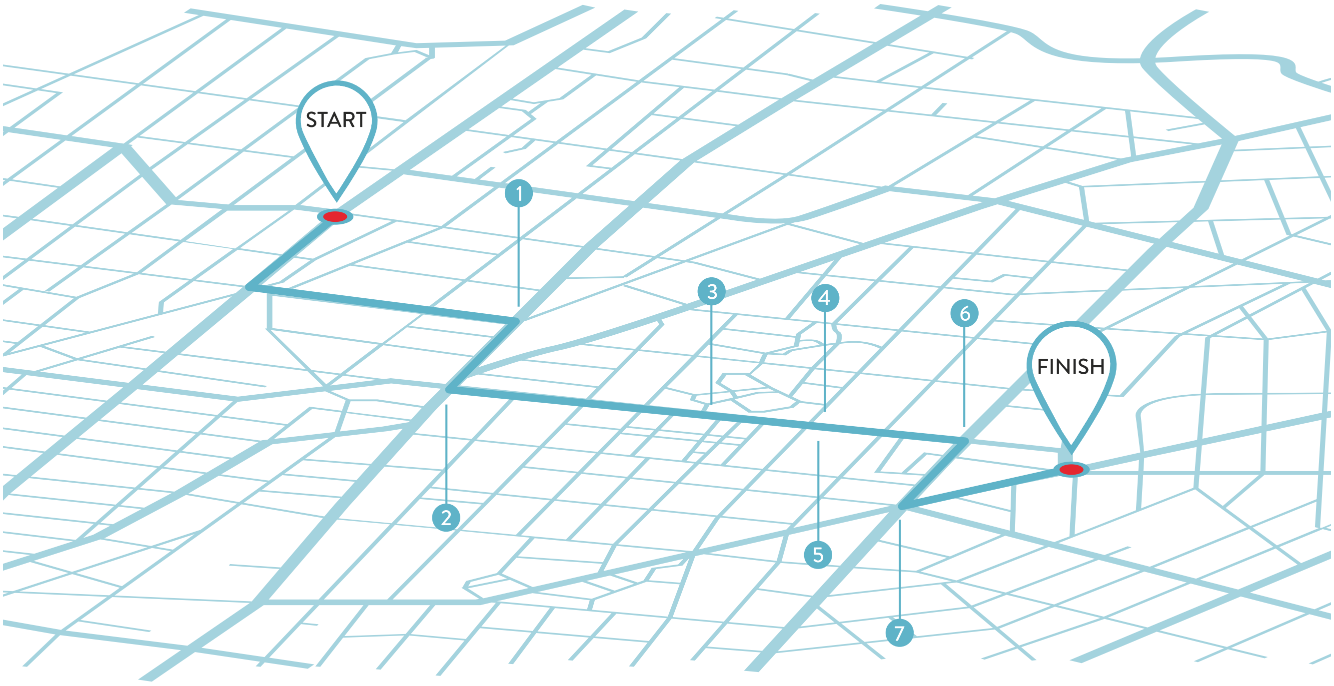
The three examples cited above are three fundamental issues for tape technology in the area of data integrity. A loss of magnetic power, a weaker magnetic field, difficulties in the perception of the signals emitted by the tapes: in all three cases, we are talking about dysfunctions in the transmission of the message within the drive. As a result, we are talking here, of an increased eventuality of read or write errors when using a magnetic tape.

In other words, we can summarize the question by saying that, it is easy to develop tapes of superior capacities. These tapes still have to function and meet the criteria of excellence established by IT users. We can see here that one of the main challenges in the development of a higher storage capacity device is to achieve a level of data integrity that is at least equal to, and at best better than previous generations of magnetic tapes.

Consequently, we will approach our analysis as follows:

• We will initially address data integrity as an essential condition for the development of future generations of storage products.
• We will then address the issue of storage capacity as such.
• Finally, we will review other areas where Barium Ferrite contributes to the advancement of storage tape technology, such as the archive life, or the writing speed.

Data Integrity



.1
Basic principles:
AN OFFICIAL MEASURE OF DATA INTEGRITY, IS THE BIT ERROR RATE (BER).

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Data integrity depends essentially
ON THE SNR LEVEL OF YOUR STORAGE SYSTEM.

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Improved data integrity =
LESS DATA LOSS AND LESS WRITE ERRORS.

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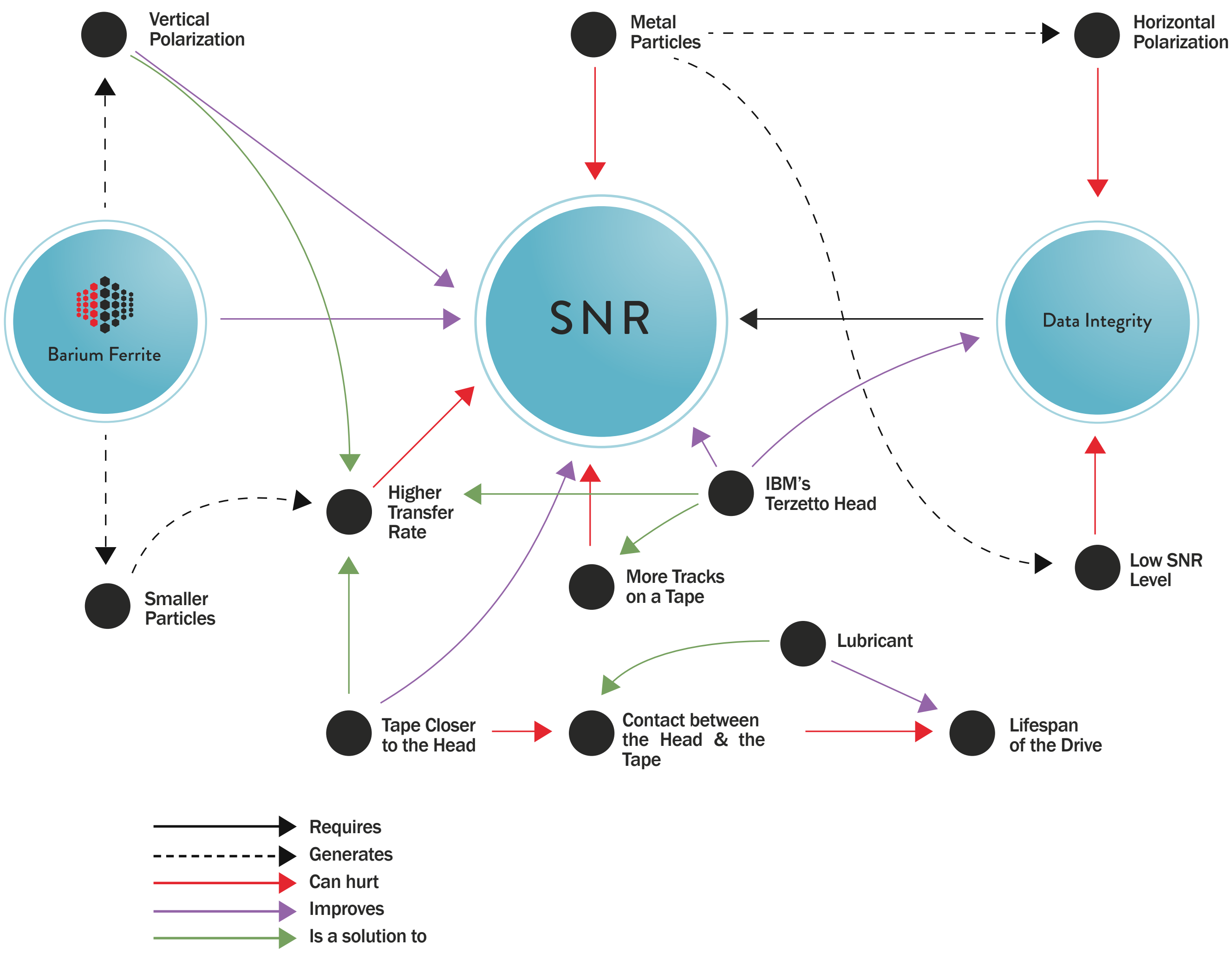
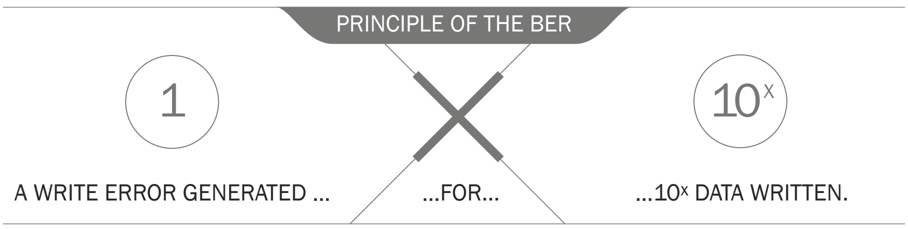
Data Integrity

Data integrity is the ability to access and read data that has been written to a storage medium, regardless of the time difference between the moment the data was written and the moment the user decides to access the data. It, therefore, involves both the quality of verification of the writing in real time and the retention of the data over the long term. Below, is a summary of data integrity related issues.

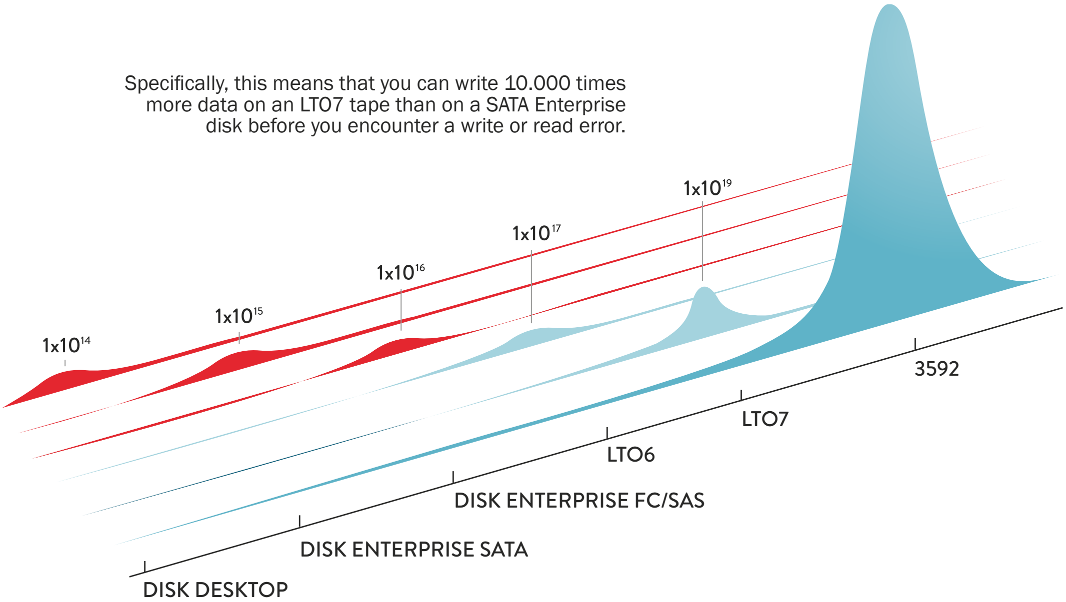


1. Basic principles: an official measurement of data integrity, the BER

The most well-known measurement of the data integrity of storage media is the Bit-Error-Rate (BER). The BER measures the amount of data that we can write before risking a write error. It is described in the following manner:



Below, you will find the BER of the main storage media:



Please Note:
the BER figures for the LTO tapes are those reported by the LTO Consortium.
When reading this data, the first impression that could be perceived is that all tapes from the same generation are equal. We know, on the one hand, that there are several manufacturers of the same generation and that, on the other hand, the very nature of a magnetic tape makes it possible to find quality variances between different cartridges produced by the same manufacturer.

Therefore, we can understand that the BER values communicated by the Consortium are an estimate of the minimum BER value for each tape generation. We can also see that this notion of a “minimum level” of quality was often invoked by the manufacturers of LTO6 MP:

- When talking about the intrinsic quality of a tape, what is the value or measure that matters?
- Is it the highest value of the quality criterion, its average value, or its minimum value?
- In other words, if a tape barely passes quality tests, can it be considered as equal in terms of quality to any other tape?

We will attempt to answer these questions in this chapter on data integrity.

2. Data integrity depends essentially on the SNR level of your storage system.

A. What is the SNR?

The SNR or Signal-to-Noise Ratio expresses the clarity of the signal emitted by the tape towards the drive head. It measures the ratio between the magnetic output of the particle and some form of noise pollution generated during the use of the drive. So we have a measure of a positive value and a measure of a negative value.

The signal is that which the head must pick up in order to be able to read or write, and the noise pollution is that which prevents the head from capturing the signals emitted.
Over the next few pages, you will see that the quality of a data tape contributes to both criteria of measurement of the SNR:

- In as much as regards the quality of the output (or power) of the emitted signal
- as the hubbub generated by a poor polarization of the particles.

B. On the importance of SNR:

SNR is fundamental. We can even say that it is the factor, which most strongly impacts the data integrity. Writing errors and data loss are two corollaries of the SNR.

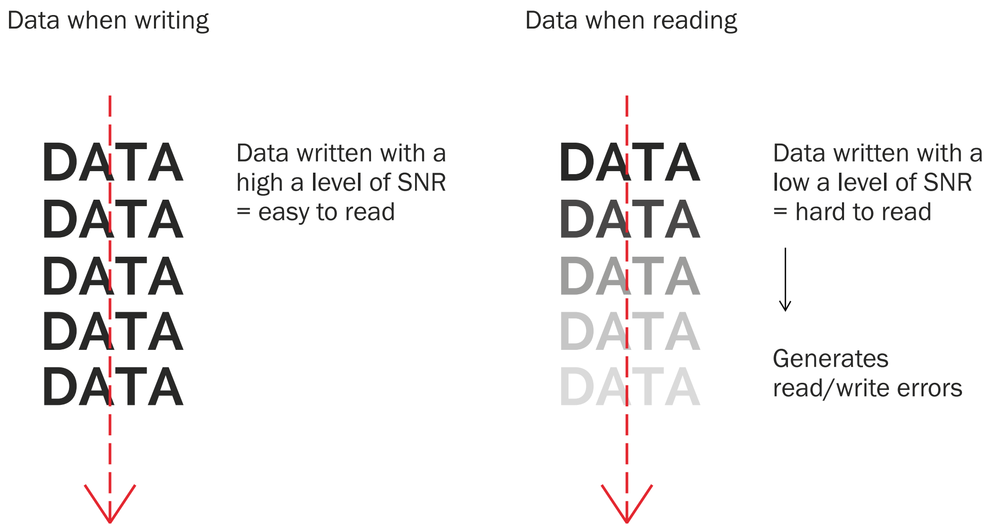
A symbolical way of illustrating the central role played by the SNR in data backup would be to imagine that recording data with a high level of SNR would be equivalent to writing on paper with a thick ink that would not fade over time.

At this point, we can define what constitutes a strong idea in the write/read process: it is that the key element of measuring data integrity is in the reading of data. **It is evaluated at the moment of the restoration of the files:**

- If the data is written with a low level of SNR, the drive head will have difficulties recognizing the data.

- Unlike human beings who have deductive capacities, the drive head cannot reconstitute data - a nanaometer sized error, a spot, a small line, or a tiny missing portion of the head can be enough for the drive to declare a write/read error.

The Data Integrity depends largely on the readability of the written data



C. Measuring data integrity over time

Another important point on this subject is that this phenomenon of read or write errors can occur as much when writing the data, as when reading the data over the long term. Here, we are confronted with various risks such as the loss of data over time, or the loss of storage capacity of a single tape cartridge, depending on the circumstances.
The precise analysis of the various phenomena that can affect Data Integrity was the main challenge of the research undertaken by Fujifilm and IBM when drawing up the specifications of new tape generations:

• Degradation in the readability of data over time: **data written with a low level of SNR can be declared as readable at the time of writing, but become a write/read error in the space of a few weeks.**
An example of the deterioration mechanism of SNR can be given by evoking the large number of particles and the multiple layers of particles on a tape. These particles, when they are polarized horizontally, and thus in the direction of one another, generate opposite magnetic forces.
These opposed magnetic forces emit an organic form of noise which disturbs the reception of the magnetic signals emitted by the particles towards the head of the drive.
This is the very principle of the SNR calculation - what is the quality of the connection between the head and the tape? Does the head correctly interpret the signals emitted by the particles? If the particles intended for writing data are of low magnetic output (or magnetic power), their SNRs can get diluted within the sound magma emitted by the other particles.
In a very concrete manner, there is then, a degradation of the quality of the SNR.
Returning to the ink symbol on the paper, we could say that the ink is diluted and the writing tends to fade or disappear.

⟶ Therefore, we need to assume that when data is written on a magnetic medium, there is a risk that it will become unreadable over time, when written with a technology that is not adapted to the needs of the user. On page 16 of this document, we will see that this is precisely the case of MP (Metal Particle) technology, from the moment we are required to produce tapes with native capacities greater than 1,5TB.

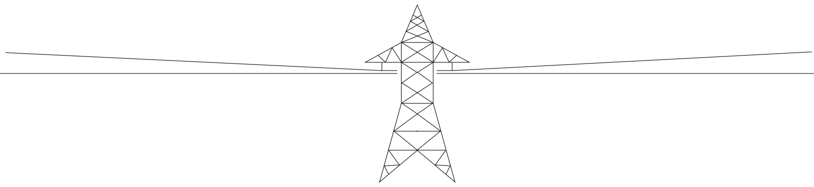
Finally in regards to this point, it is also evident on page 27, that the physical nature of the particles influences their resistance in time, and some particles have a longer duration of existence than others. This is a major factor in the field of Data Integrity, when it comes to restoring data weeks or months after the Backup.

In order to conclude this point, we are talking here, about cases of data loss over time.

• Data may be unreadable at the time of writing. Another scenario is that the SNR level of an LTO tape may be low at the time of writing.

A drive head is dual, and is composed of two elements: a writing head and a reading head. The role of the read head is to check the quality and accuracy of the writing for each recorded data. Specifically, the write head cannot continue to write new data until the read head has checked and approved the data written previously.

However, whatever the reason may be, if the read head is confronted to a difficulty in reading and understanding an item of data, it will eventually declare a read/write error.



Please note: good signal transmission between the tape and the drive head depends as much on the quality of the tape as on the quality of the head.

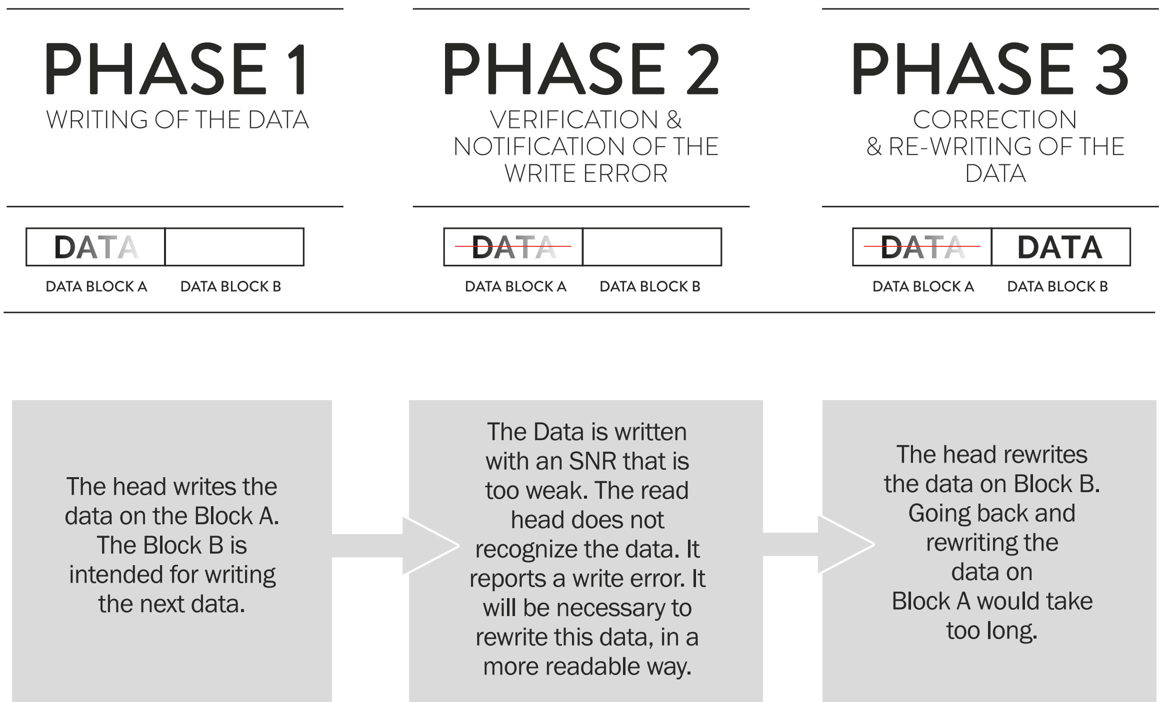
→ In other words, it can be said that, for two people to come to an understanding, the person speaking must talk with a strong voice (the tape) but also, the listener must be in possession of excellent hearing (the drive head).

→ For example, a faulty or ageing head may encounter more difficulties in capturing signals and, thus, more difficulty in reading data. This phenomenon is to be found in the theme of the lifespan of the drive (this will be covered on page 47).

→ It is therefore vital for manufacturers to produce tapes that offer performance above the minimum requirement in terms of magnetic output. It is essential to take the eventual erosion and obsolescence of a read head into account.

→ Finally, on this point we can add that the drive manufacturer can play a decisive role in the quality of the SNR. The new Terzetto head from IBM represents a real revolution in the field of data storage (you will find further information on pages 24-26).

D. Weak SNR = tape cartridge capacity loss. The process is as follows:

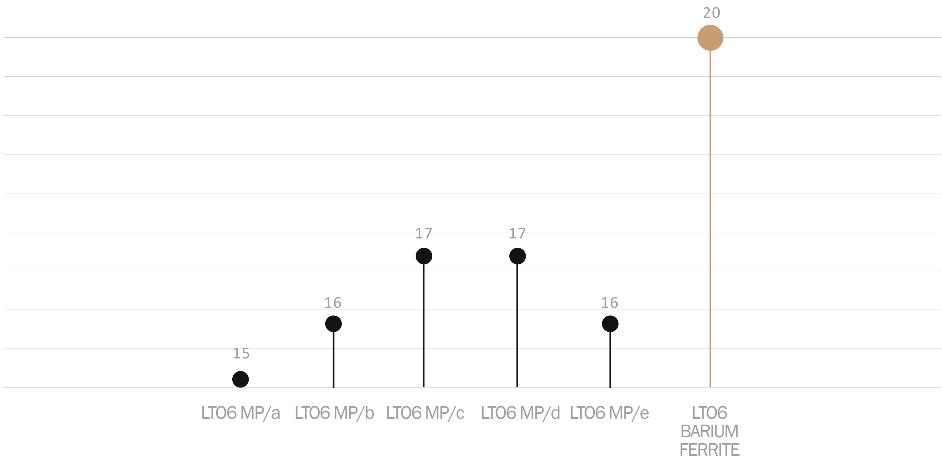


To conclude this point, we can say that too low a level of SNR will result in a greater number of write **errors, which will cause, among other things, a loss of storage capacity on the tape cartridge.**

3. The SNR of Barium Ferrite tapes is higher than the SNR of MP tapes

A. LTO6 BaFe Tapes SNR compared to LTO6 MP tapes

We have tested the SNRs of six LTO6 tapes. Five of them are made from MP (Metal Particle), with the last one being a tape made out of Barium Ferrite. You can find the result of this test below:

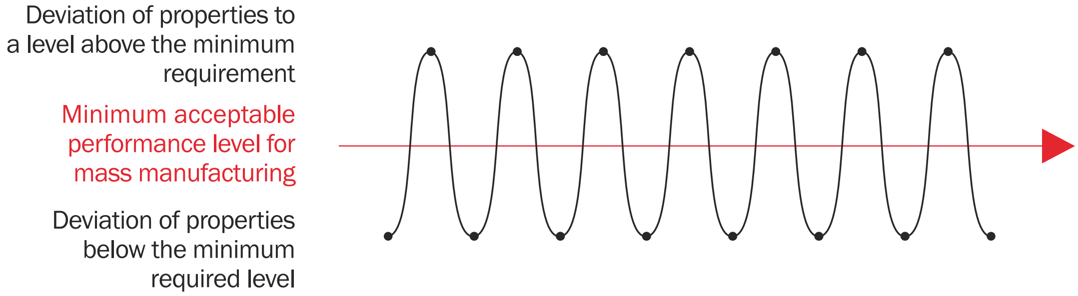


This measurement of SNR is a second way to calculate the contribution of a tape cartridge to data integrity. On page 21 in Chapter 4 about the DUDBL, you will find there is a third way to measure the data integrity of a storage technology.

B. What is the risk when using an MP (Metal Particle) LTO6 tape?

When a tape coating technology barely meets the qualification criteria for mass manufacturing of its cartridges, the risk is that the average quality of some of these cartridges will fall below the minimum level required.

It is, in fact, impossible to prevent a deviation of the electromagnetic properties of a tape cartridge during its manufacture. You can even see this qualitative deviance from one block of data to another. We can roughly summarize the manufacturing issue as follows:



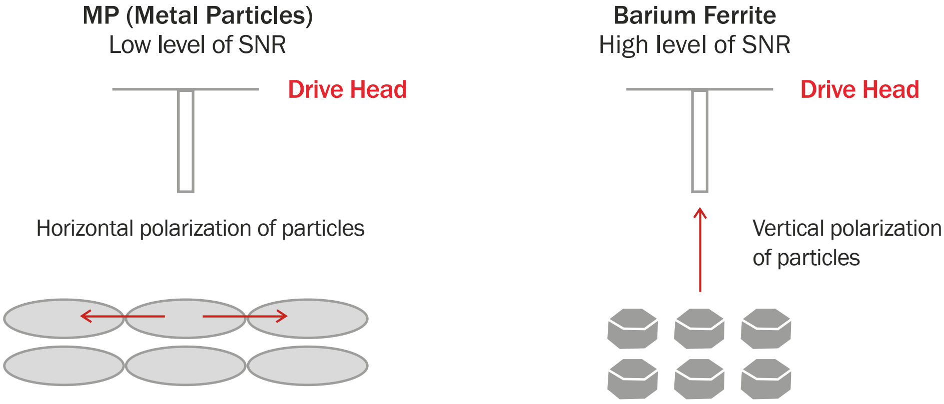
The aim of the above scheme is to demonstrate that, ultimately, and taking into account the requirements related to data storage on tapes (critical importance of the data, the need to be able to access it at any moment, and even within a more distant time), it is not enough for an LTO tape to just work. It must also be able to provide evidence of the durability of the data over time. We know these criteria, which are those specifically mentioned in this chapter on data integrity.

Fujifilm was already the world's No. 1 manufacturer for MP tapes, especially for LTO5 tapes.
The Research and Development at Fujifilm found that MP technology could at best only qualify for the minimum level of quality required by the Consortium. It was, therefore, considered that an LTO6 MP tape could not offer the guarantees of performance and durability that tape users required, hence the development and use of a new technology, Barium Ferrite.

C. Why is the SNR of LTO6 BaFe tapes higher than that of the MP tapes?

There is more than one property in Barium Ferrite which defines it as a technology superior to MP, SNR being one of them. If we had to retain two decisive advantages of BaFe over MP, it would be, on the one hand, the polarization of the Barium Ferrite particles and, on the other hand, the improved dispersion of the particles on the surface of the tape.

1. Barium Ferrite offers a **higher output power than MP, thanks to its vertical polarization.** Please see the diagram below:



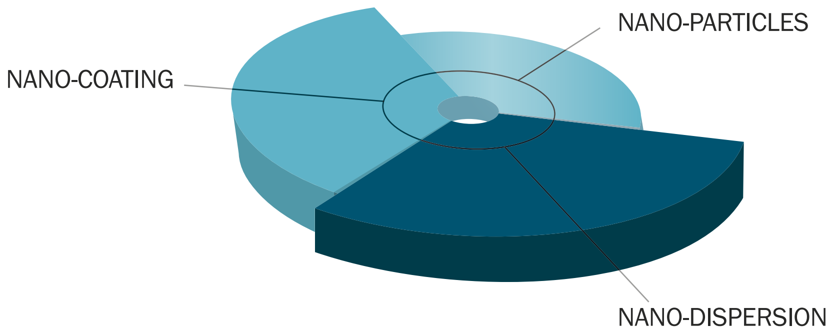
• The signals are not emitted in the direction of the drive head.
• The direction of signal emission generates opposite magnetic forces which create a chaotic sound.
• This is called noise pollution: it is the negative factor of the SNR. That which prevents the head from perceiving the signals emitted by the tape.

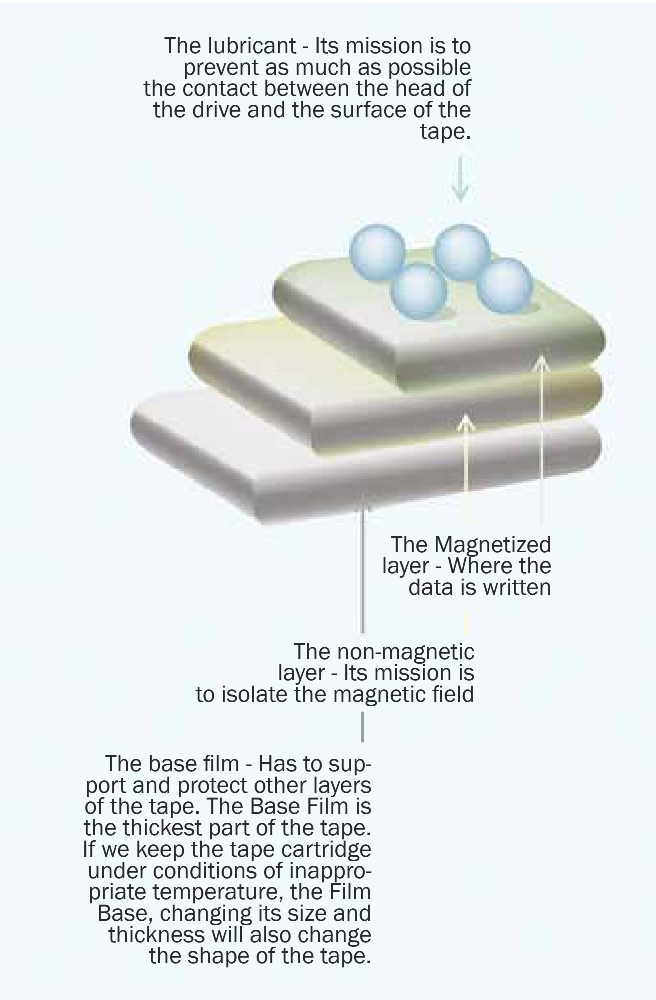
⟶ In the SNR ratio calculation:
- The "positive" sound, i.e. the output power is limited due to the polarization being too far from the drive head.
- The "Negative" sound or noise pollution is too high, due to the opposition of the magnetic forces.

• **The signals are emitted towards the head.**
This is a revolution in the area of SNR and the first cause of tape technology's progress in the field of Data Integrity.
• The very nature of Barium Ferrite particles means they emit less noise pollution than MP, as they do not generate opposing forces.
• This vertical polarization is paradigm shifting in the manufacturing of data tapes since, for years, the tradition was to believe that the output power of a particle was dependent only on its size.

4. Barium Ferrite technology provides a better dispersion, a better alignment and a better orientation of particles on the surface of the tape.

If we were being totally correct, the true name of Barium Ferrite technology should actually be Fujifilm's Barium Ferrite Nanocubic technology. The Nanocubic technology was used by Fujifilm to manufacture LTO4 and LTO5 tapes, along with MP particles. It was based on three major advances that Fujifilm wanted to achieve on tape technology:





• Nano-coating, with the aim of considerably reducing the thickness of the layers of the magnetic tape
• Nano-particles, a program for reducing the size of the particles
• And Nano-dispersion, in order to improve the distribution and alignment of particles on the tape surface.

Here we see that the Nanocubic program is the annunciation of Barium Ferrite. It should be noted that the research on Barium Ferrite dates back to the early 1990s.

With regards to the SNR issue, we can see the innovations brought in by Nanocubic technology regarding the thickness of the tape, as well as on the dispersion of the particles.

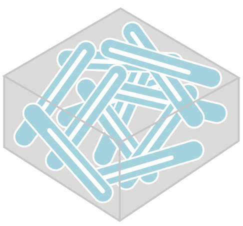
• Thickness of the tape

Nano-coating is an innovation that makes it possible to obtain an ultra-thin magnetic layer. It therefore makes it possible to reduce the demagnetization effects of the tape. In fact, we saw earlier that the polarization of the MP particles is horizontal, so that reverse magnetic forces can be created which will tend to oppose and create some negative effects. These negative effects grow when the number of layers of particles increases. It is in order to prevent this phenomenon that Fujifilm has undertaken to minimize the thickness of the magnetic layer, particularly by applying a non-magnetic lower layer, which reduces the demagnetization effects. This will reinforce the signals emitted by the magnetic layer. The signals will be stronger and more easily picked up by the read head. The demagnetization effect can go so far as producing a self-erase process of the data. Therefore, it is important to minimize them.

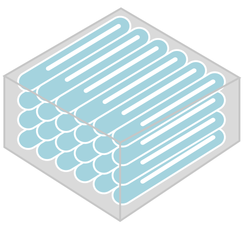
• The Nano-Dispersion. This third parameter is complementary to the two preceding ones.
In actual fact, if it is important to have particles of a small size, it is essential that they are well “stowed” on the tape. That’s what we call Nano-dispersion. However, the smaller the particles, the more they tend to remain grouped. It’s just like we’ve all experienced at the beach when it’s more difficult to get rid of a fine sand where the grains remain stuck to the skin than a thicker sand that disperses more easily.
The Nano-dispersion is realized in two stages:

- In order to achieve the coating of the particles, Fujifilm uses an organic polymer-based binder in the coated substance, which homogeneously disperses the particles on the tape.
- Once the particles are coated on the tape, they are subjected to a magnetic field in order to perfect their orientation.

A diagram allowing you to easily visualize what this Nano dispersion of the magnetic particles consists of.



Natural positioning of MP



Aligned positioning of MP particles for the Nanocubic LTO5, thanks to the Nanodispersion

The dispersion and orientation of the particles produce advantages on various fields, such as:

- **Capacity:** it is clear that a homogeneous dispersion of the particles makes it possible to achieve a higher recording density, since there are a larger number of them on the same tape surface. Although all LTO5 tapes have the same 1,5TB capacity, the orientation of the particles makes it easier to achieve the required capacity over the tape length specified by the consortium, i.e. 846m.

- **The clarity of the signal:** the homogeneous dispersion of the particles, as well as their orientation, contribute to obtaining a thinner magnetic layer and, therefore, to the reduction of the demagnetization effects as we have previously seen. These two elements also contribute to the production of a stronger signal. To give you an example, nano-dispersion makes it possible to coat a layer so thin that a litre of liquid coated with this technique would cover four football fields!

- **Recording stability:** the regular dispersion of the particles enables the head to always be able interact with the same amount of particles in the write or read process, improving the stability of the signal and, consequently, the data recording.

- **More importantly**, Nano-dispersion makes it possible to obtain a high level of SNR: the controlled orientation and alignment of the magnetic particles which are positioned next to one another will reduce the interactions of the magnetic forces. The tape will then produce a signal that will be:

  × stronger, particularly by reducing the demagnetization effects as seen above
  × but, also clearer since the background noise inherent in the magnetic field will be reduced.

5. Another way to measure the Data Integrity of LTO tapes: DUDBL.

There are other ways to test and measure the data integrity and SNR of a tape. A particularly revealing test is the DUDBL:

• We have seen that the accumulation of write errors reduces the available storage capacity on a tape cartridge.

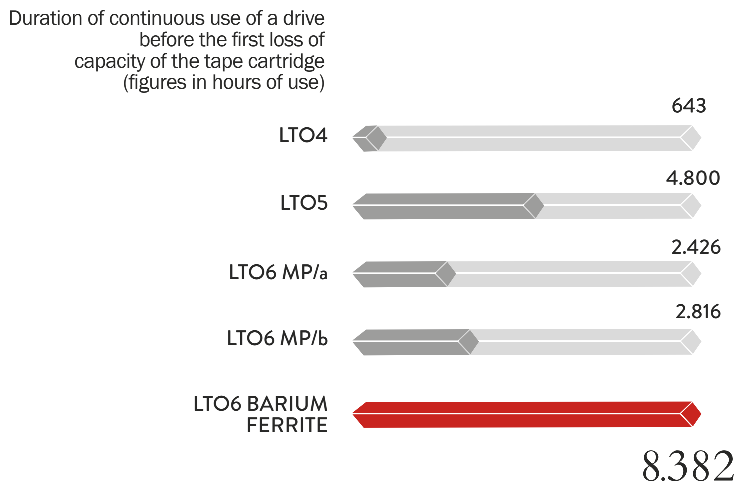
• This is why LTO tapes always offer a small delta of storage capacity greater than the official capacity. This additional delta of tape is the equivalent to 3% of the total cartridge capacity, i.e.:
- 45 GB for the LTO5 tape cartridge
- 75 GB for the LTO6 tape cartridge

This additional tape is intended to absorb possible errors in writing, in order not to penalize the user.

• It is, therefore, sufficient to operate a drive and tape in an intensive and continuous manner and to measure after how many hours the tape cartridge can no longer hold 100% of its official storage capacity. This measure is called the DUDBL in hours. The DUDBL initials stand for: "Duration of use of the drive before the first loss of capacity''.

• In other words, the DUDBL involves estimating after how many hours of intensive use an LTO6 tape will have generated more than 75 GB of write errors.

Below, you can see the DUDBLs of different LTO tapes:



Here, is evident that the data integrity of the LTO6 Barium Ferrite tapes is much higher than that of the LTO6 MP tapes.

This experiment, translated in terms of storage capacity written on the tape compared to the number of write errors, even shows that the writing error rate of the LTO6 MP is higher than that of the LTO5!

In addition, we can see that a tape coating technology, which is not renewed or improved, will degrade the performance of a format as its capacity and speed improve. Two fairly significant examples are as follows:

A. Increasing the capacity of a tape cartridge can hurt its SNR: On page 32, we will see that there are several ways to increase a tape's capacity.

• One way, which was used to produce LTO6, is to increase the number of tracks that a tape can contain. This implies reducing the width of each track.

• However, reducing the width of a track will weaken the overall magnetic field that this track will contain.

• A lower magnetic field, therefore, represents a risk of loss of SNR.

B. Increasing the writing speed also represents a significant risk of loss of SNR. This seems logical: it is, in fact, easier to make yourself understood by someone who walks past you, than by someone who runs by. To be heard or understood by a fast moving individual, you would have to speak much louder.

It is evident here, that the development of tapes of higher capacity and performance can really hurt the read and write quality of a technology. **It is unthinkable to increase the capacity of tapes indefinitely without increasing the SNR,** ideally by improving the transmission quality of the tapes, as much as the reception quality of the drives.

To put it into data storage terms, the output power of the Barium Ferrite particle is greater than that of MP, due to the vertical polarization of the particles. In a simple way, we can say that a Barium Ferrite particle “speaks louder” than an MP particle. The increase of the write speed between the LTO5 and the LTO6, even a tiny one, was therefore a new factor in degrading the SNR of the LTO6 MP.

To conclude on this DUDBL test, and to return to the original Bit-Error-Rate question, we can assume that if the BER of LTO6, as communicated by the Consortium, is $1X10^{17}$, it is truly that of the LTO6 MP and in other words, the minimum level of BER. It can also be deduced that the true BER of LTO6 Barium Ferrite, in view of the tests of DUDBL, is superior to the official BER of LTO6 tapes.

- It remains for us to guess which could be the true operational BER of the LTO6 BaFe.
⟶ In other words, is it possible to say that the BER and thus the data integrity of LTO6 technology with Barium Ferrite tapes is equivalent to that of the LTO7, namely, $1X10^{19}$?

To answer such a question, it is necessary to analyze the differences between the LTO6 and LTO7 technologies on both of their major components - the tape and the drive.

- With regards to the tape cartridge itself, there may be no significant difference between the organic SNR produced by LTO6 Barium Ferrite tapes and LTO7 Barium Ferrite tapes. Both tapes are made with the same particles. We do not find any difference here on the output power segment - both tape generations emit signals of a fairly equivalent power.

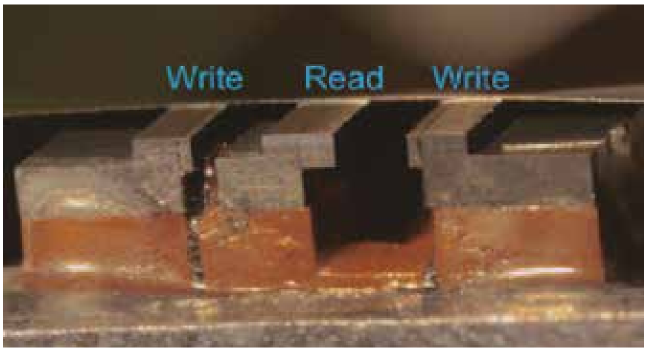
- On the other hand, when we address the question of the contribution of the drive to the SNR, we see a huge difference. LTO7 drives are more capable of capturing signals from the tape than LTO6 drives. This is due to what is probably the major innovation in tape drive technology of the past 15 years, the IBM Terzetto head.

6. Mechanism of the IBM Terzetto write and read head.

LTO7 tape drives are the first LTO drives to use the new IBM Terzetto write/read head. This technology represents a real breakthrough in the development of tape technology and is largely responsible for the dramatic advances made on tapes across all of the fundamental criteria of judgement of the performance of a storage solution: capacity, speed, archive life, durability of the drive, and, of course, data integrity.

If we were to summarize the contribution of Terzetto with a simple image, we could say that Terzetto = SNR.

The IBM Terzetto-GMR head.
GMR stands for “Giant Magnetoresistive’’, so it uses this famous technology invented by IBM and which has deeply marked the history of data storage, as much on tape as on disk.



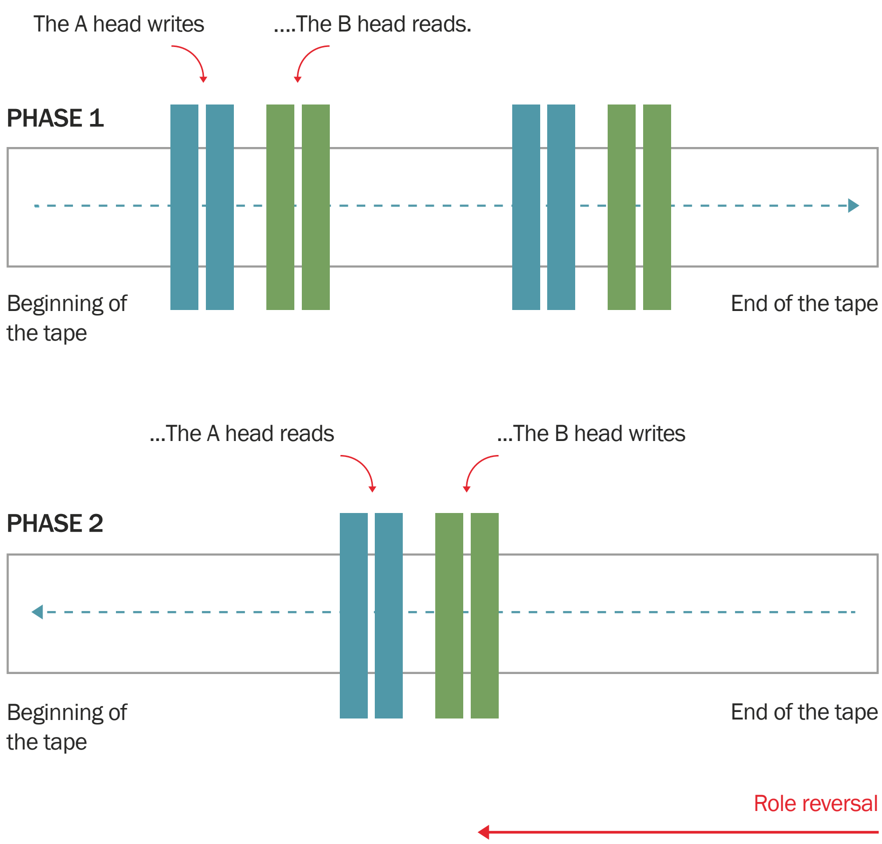
A. Drive heads up to the LTO6:

During the writing process, the head writes on tracks, from the beginning to the end of the tape, and then continues to write data on that same track from the end of the tape to its beginning.
This is the very principle of linear recording. Up to and including the LTO6 generation, drives use a two-headed system. The first head writes the data, and the second head reads the data and performs a verification of the data recorded by the write head. This system involves a reversal of roles according to the writing direction. The consequence of a dual head system is that both heads must be capable of writing and reading data, whereas these two functions do not share any technical characteristic:

- The writing process involves injecting magnetic force onto the tape. If we were to use a familiar image, we would say that the writing is carried out in the manner of a volcanic eruption - with the lava representing the magnetic field that will constitute a data on the tape, just as ink would.
- Whilst reading data consists of capturing signals from the tape.

Injecting magnetic force vs. signal sensors: in this instance, we see that the dual function of a head implies that two very different tools are produced on a tiny space. The logical consequence of this accumulation of tasks for a tape drive head is that each head is found with limited electromagnetic properties.

Operating mechanism with a double head system



IBM concluded that the dual head system was sufficiently powerful to operate a 2,5TB LTO6 drive with a write speed of 160MB/s and a $1X10^{17}$ BER.

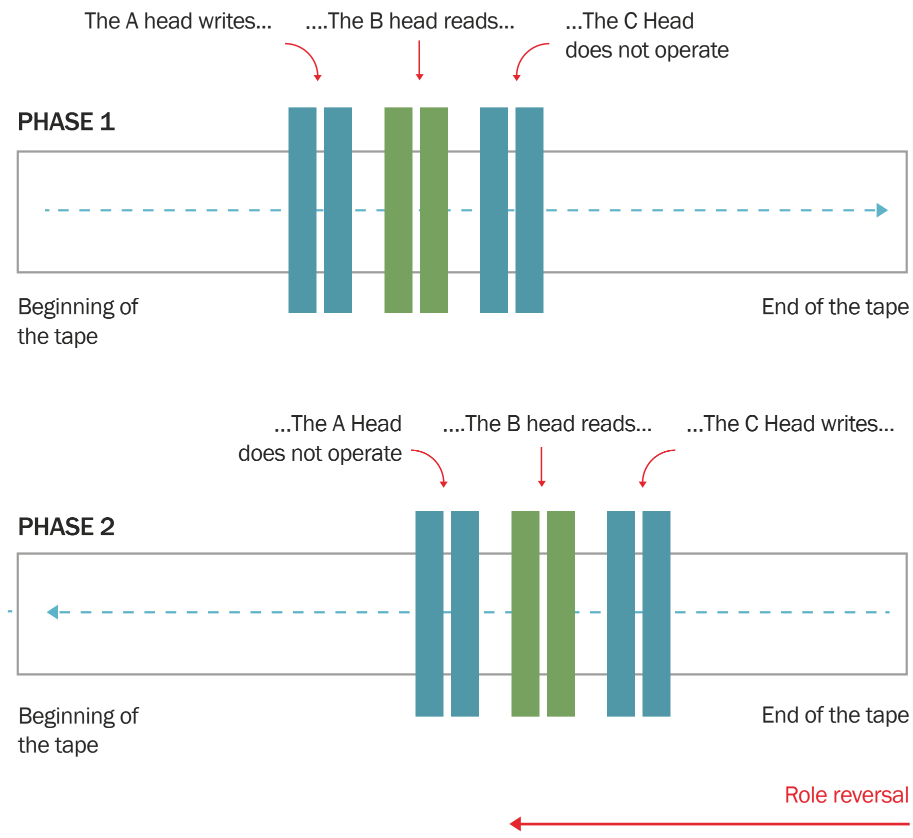
They also deduced that for an LTO7 tape drive with 6TB capacity, 300MB/s speed and 100 times greater data integrity, a new write/read head would need to be developed, which would provide more important electro-magnetic properties.

B. LTO7 drives Terzetto head:

The Terzetto Head contains three heads: two write heads which have only one function, writing, and one read head which can only read. The principle of the Terzetto system is that it allows each head to proceed with only one function. This specialization allows each head to operate with higher electromagnetic properties and this improves the level of SNR during the write and read operations.

Please see below:

Operating mechanism with a three-headed Terzetto system



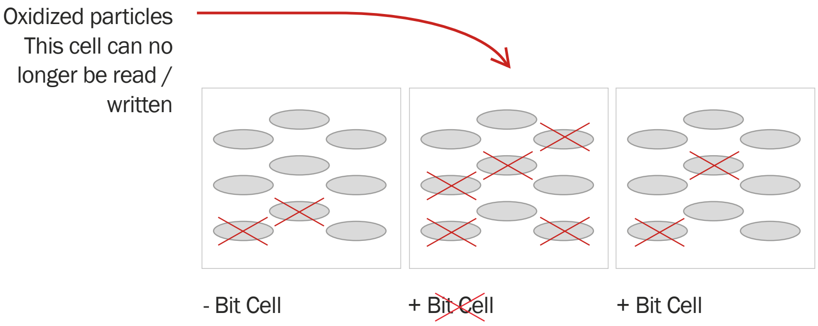
In conclusion to this point, we can say that the Research and Development on tape technology depends on the innovations of two distinct and complementary families: the drive manufacturer and the tape manufacturer. We note that it is the combined contributions of the two families, which have generated the spectacular advances made within tape technology. This case will be covered again in the conclusion of this document.

7. MP Particles oxidation: another factor that affects data integrity.

Certainly, the question of the oxidation of the particles shows that BaFe tapes offer a longer archive life than MP tapes. **This oxidation phenomenon also plays an important role in that MP tapes are less reliable than BaFe tapes.**

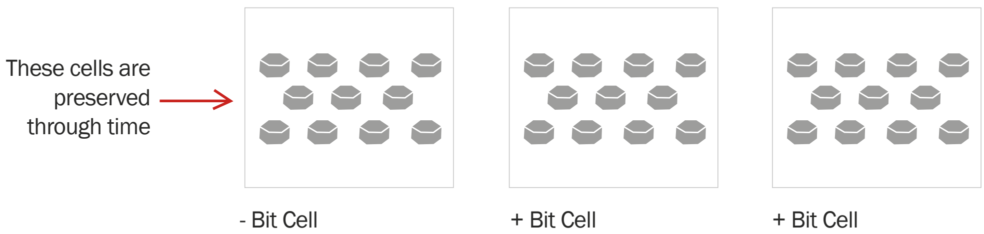
A. Metal Particles (MP) are made from Iron (Fe).

They will, therefore, naturally oxidize over time. The cells they are composed of will no longer be able to generate read/write processes. There will be a drop in performance as these cells will become invalid. More importantly, this oxidation of MP particles is a source of data loss. Please see the diagram below:



B. Since Barium Ferrite is already an oxide,

there is no phenomenon of deterioration due to the oxidation. Consequently, the LTO tape can maintain its initial performance level. As illustrated on the diagram below:

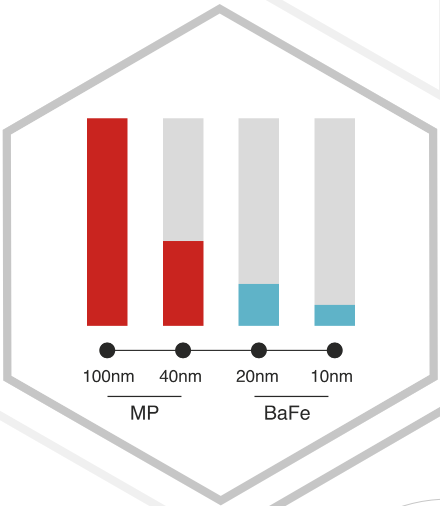


Data loss over time is a key factor in measuring data integrity. Thus, the nature of the particles (Oxide for Barium Ferrite or Iron for MP) plays a decisive role in the calculation of the BER.

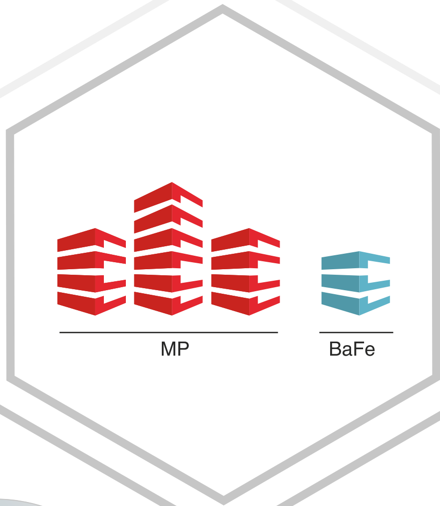
Important: we will also see this phenomenon of oxidation of particles on page 45, under the "archive life" chapter. This analysis of the nature of the particles that we are discussing, will also define that we can keep data longer over time when it is recorded on a BaFe tape, rather than an MP tape.

Data storage capacity

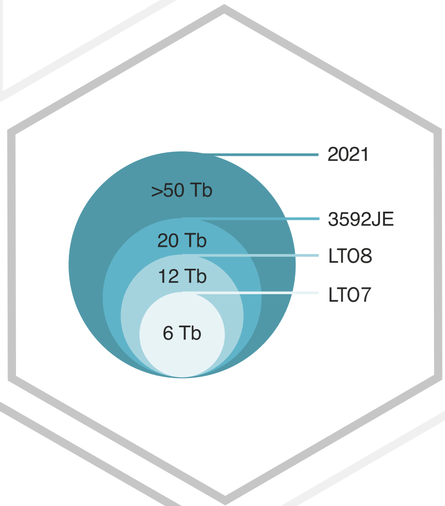
Higher Magnetic output allows the production of smaller particles

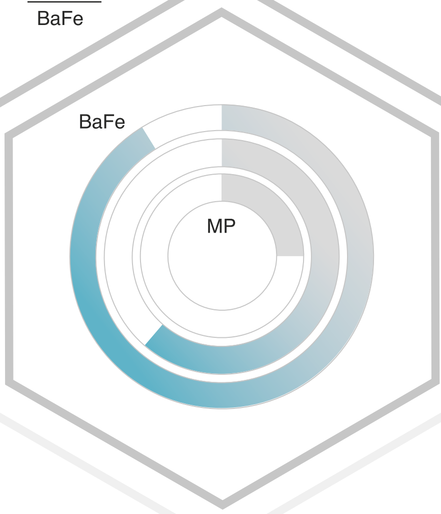


BaFe tapes = floor space reduction

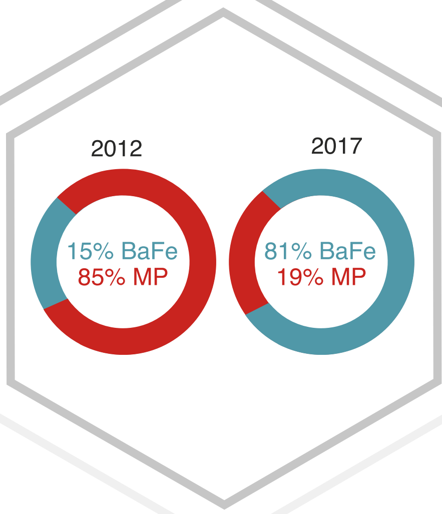


What tape capacities will companies use tomorrow?





Growing market demand in capacity

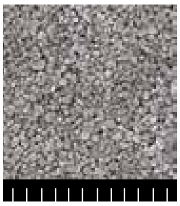


Barium Ferrite, is the winning format

Data storage capacity

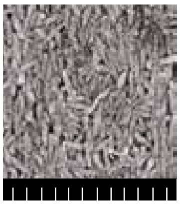
1. Barium Ferrite = greater storage capacity

The primary characteristic of Barium Ferrite particles is that they are much smaller than MP particles. The graph below shows the maximum development potential of MP and Barium Ferrite particles (all figures in nm):



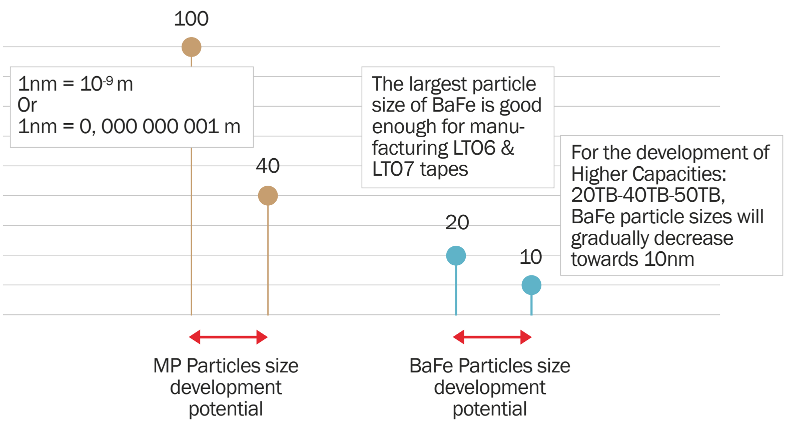
500nm

Barium Ferrite particles (BaFe)



500nm

Metal Particles



The chart below indicates that Barium Ferrite technology can produce tapes of higher capacity than MP technology. In fact, there is a limit to the development of MP technology in terms of capacity and performance:

- Fundamentally: LTO6 is the first generation of LTO tape manufactured with Barium Ferrite.

- LTO6 is also the latest generation of LTO tape manufactured with MP technology.

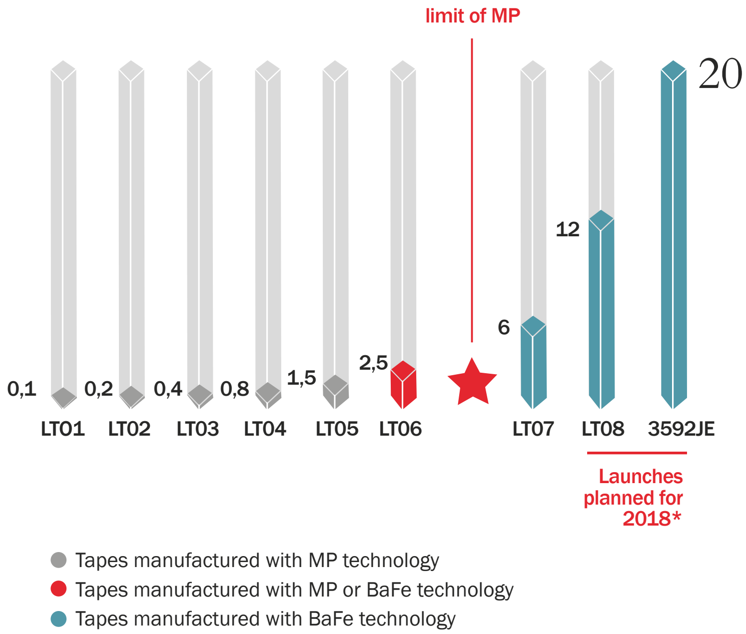
Any LTO6 tape user is, thus, subject to a choice between these two technologies. In the 'data integrity' chapter we saw that there is a difference in approach between two schools:

- The first is supporting MP technology and says that, although the tape performance is lower, and, despite the fact that MP can not produce LTO7 tapes, from the moment a manufacturer manages to coat 2,5TB of data on one LTO tape, a user may take the risk of using an LTO6 MP tape cartridge.

- the other supporting Barium Ferrite, explains that taking the risk of archiving data on an LTO6 MP tape is equivalent to playing Russian roulette with data over time.

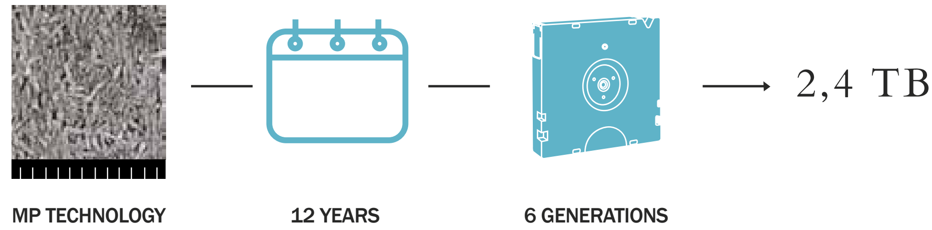
The break in terms of storage capacity between Barium Ferrite and MP can be schematically illustrated by developing a history of different LTO tape formats and compared with the upcoming formats planned for launch in 2018. On the table below the native storage capacities in TB of different tape generations are shown:

* Storage capacity and transfer rates will be confirmed by the owners of the technology by the end of 2017



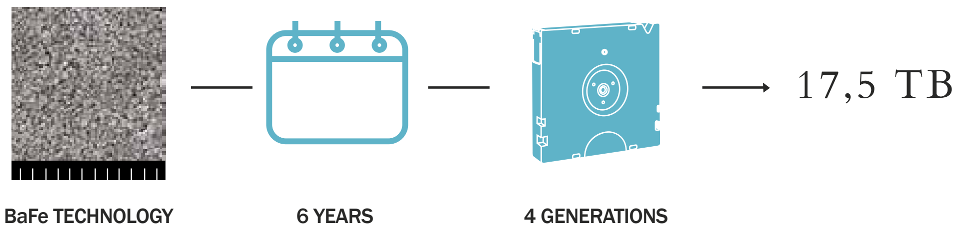
Finally, the simplest way to summarize the difference in the margin of development between both tape coating technologies, would be to look at the evolution accomplished in storage capacity on magnetic tapes for each of these technologies:

WITH MP



It took 12 years, between 2000 and 2012, and 6 generations of tapes to move from 0,1TB to 2,5TB of storage capacity (between LTO1 and LTO6). **That is an average gain of storage capacity of 0,2TB per year.**

WITH BaFe



It took under 6 years between late 2012 and summer 2018 and four generations of tapes (LTO6, LTO7, LTO8 and 3592JE) to go from 2,5TB to 20TB capacity on a magnetic tape. **So, an average gain in storage capacity of 2,9TB per year.**

IMPORTANT: In the description of the mechanism of increase in storage capacity we will see that, although it plays an important role, particle size is not necessarily the only key factor when it comes to increasing the storage capacity of a tape cartridge. We could summarize the main difficulty by saying that, even if a manufacturer is able to put a lot of particles on a tape cartridge, it still has to work. Once again, the notion of SNR is a key element of this reflection.

2. How to increase the capacity of tape cartridges?

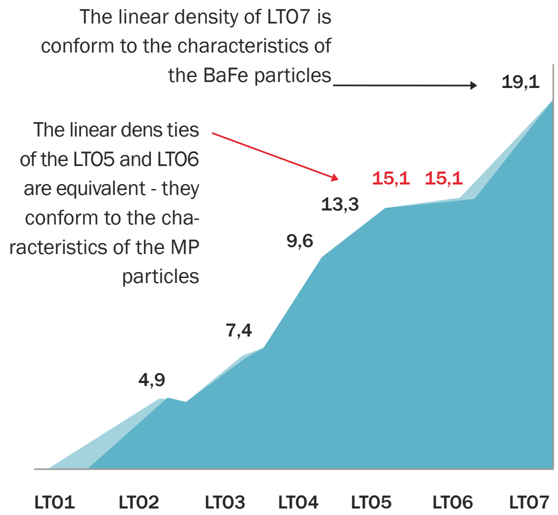
There are several ways to increase the storage capacity of a tape. Three particularly significant methods are as follows. We can:

- Increase the linear density of a write/read track, in other words, increase the number of particles, thus the storage capacity of a single track.

- Increase the number of tracks on a tape.

- Increase the length of the tape.

A. Linear density is the amount of particles that can be coated on a single write track. Below is the evolution of the linear densities of LTO tapes (all figures in kbits/mm):



Looking at the graph above, it is evident that the linear densities of LTO5 and LTO6 tapes are equivalent, whereas the linear density of LTO7 is 26% higher than that of the LTO6:

- We know that LTO6 tapes are made, either with BaFe particles or with MP particles, whereas MP cannot produce LTO7 tapes.

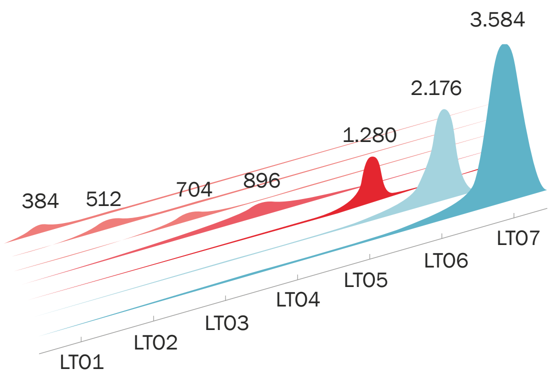
- We have also seen (page 29) that Barium Ferrite particles are smaller than MP particles. We should logically be able to put more Barium Ferrite particles on a single track. This is, indeed, the case.

- Finally, we know that BaFe particles used to produce LTO6 and LTO7 tapes are of the same size (page 29). This will no longer be the case for LTO8 (12TB) tapes, nor for the 3592JE (20TB) tapes, which will be produced with smaller size particles.

We can, therefore, conclude with the following points:

- The Linear density required for LTO6 tapes was adapted to the capabilities of MP technology.

- The linear density of LTO6 could have been much higher and closer to that of LTO7.
As a result, the capacity of LTO6 tape cartridges could have also been much higher.



• The condition for obtaining a higher LTO6 tape capacity would have been to consider the actual development capacity of Barium Ferrite.

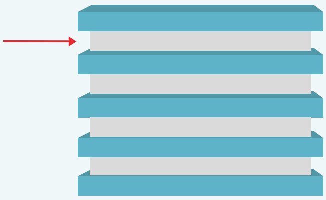
• It should be noted that a large majority of users explain that the LTO7 tape is more fitting to their actual needs than the LTO6 tape, due to the large growth of digital data.
As a result, a higher-capacity LTO6 tape would have been better perceived by IT users.

B. The number of tracks.

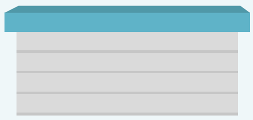
Taking the former point into account, we can deduce that since the storage capacity of a single write track could not be increased, there was no other choice than to increase the number of tracks on a single tape, in order to generate a difference of capacity between LTO5 (1,5TB) and LTO6 (2,5TB) tapes. The evolution of the number of tracks per tape generation is shown at the bottom of page 32.

From the Data Band to the particle: the composition of the tape in six steps.

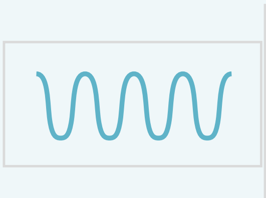
1. An LTO Tape contains 4 Data Bands. Four segments of the tape separated by the Servo track.



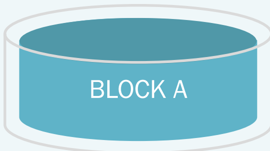
2. Each Data Band contains a certain number of wraps (34 for LTO6 / 28 for LTO7)



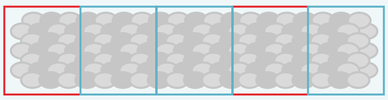
3. Each Wrap contains a certain number of Tracks (a total of 2.176 tracks for an LTO6 cartridge /3584 for LTO7)



4. A track is divided into data blocks (64kb/256kb)



5. A Data is composed of bit cells – One bit cell = one Data (1 or 0)



6. A bit cell is a cell that is made up of particles

It is evident that the increase in the number of tracks explains the higher capacity of LTO6 vs. LTO5 and contributes to the increase in capacity between LTO6 and LTO7 tapes.

- The risks associated with the increase in the number of tracks.
Increasing the number of tracks on the same tape surface as the one used for the previous LTO tape generations implies a reduction in the size of the tracks.

- For this purpose, drive manufacturers need to develop thinner heads that can write and read on smaller tracks.

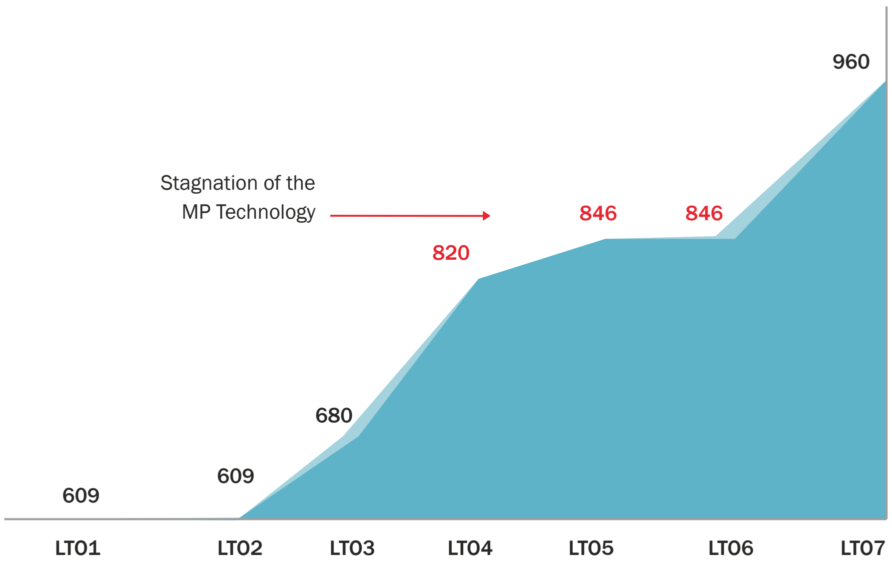
- **Another very critical point in this process is that, reducing the width of a write track will also reduce the overall level of the magnetic field, thus reducing the level of the SNR.**

Once again, this is an aspect where the advantages of both of the innovative technologies of tape make the difference:

- When it comes to the SNR, on LTO6, the vertical polarization and improved dispersion of Barium Ferrite provide greater recording stability and significantly reduces data loss.

- When it comes to the SNR, on LTO7, IBM's Terzetto technology increases the number of tracks by 64% compared to the LTO6, while increasing tape performance.

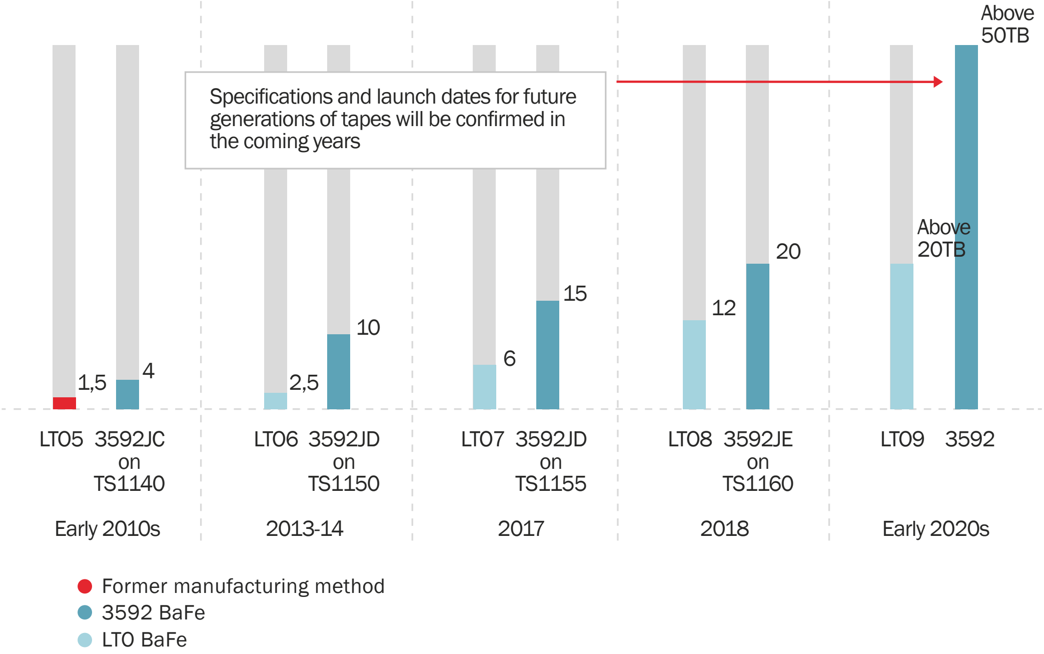
C. Increase the length of the tape. Shown below is the length of the tape (in m) for each LTO tape generation:

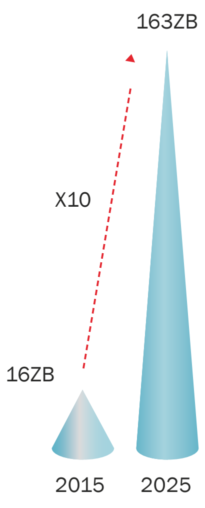


Increasing the length of a tape requires its thickness to be reduced, as the tape is wrapped around a core. The challenge is, therefore, to manufacture thinner layers of tapes, whilst preserving or improving the performance. The particle size and perfect dispersion of the particles on the tape surface contribute to increasing the length of a tape.

3. Current situation and roadmap

A. Tape technology's roadmap. The graph below illustrates the evolution of magnetic tapes since 2010:



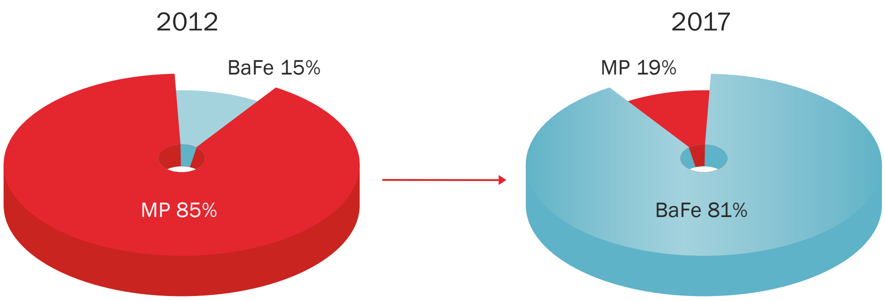


A recent IDC study indicates that the global storage capacity needed to contain digital data will increase tenfold between 2016 and 2025 (from 16 ZB of data to 163 ZB)

This rapid growth in the supply of storage capacity meets the demand of end users who are either confronted to a significant growth of digital data, or are affected by the development of new legislation on the long term retention of data.

B. Barium Ferrite is the winning format.

Another consequence of this rapid growth in the native capacity of storage tapes **is the gradual disappearance of MP technology from the tape storage market.** In fact, a quick comparison of the storage capacity delivered on magnetic tapes demonstrates the inversion of market shares between BaFe and MP technologies. Below, you can see the % shares of storage capacity delivered on the worldwide tape technology market in 2012 compared to 2017:



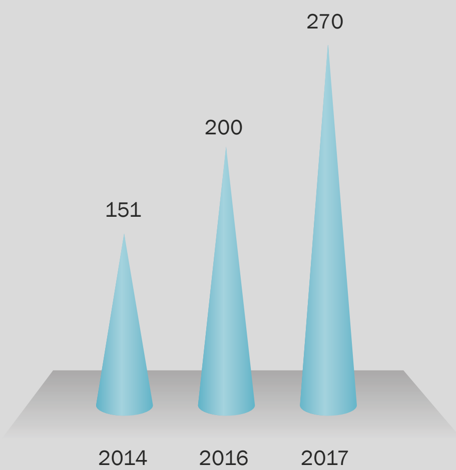
The explanation of such a phenomenon is quite logical:

- All high capacity and performance tapes, i.e. IBM 3592 and Oracle T10000, are made from Barium Ferrite. Very logically, the demand is up sharply on these high-end tapes.

- MP technology cannot be used for the production of tapes with a capacity greater than 2,5 TB. As a result it leans, of course, to obsolescence. The natural migration from older tape generations (LTO3, LTO4, LTO5 and LTO6) to new formats (LTO7 and 3592) naturally leads to a rapid decline in the number of MP tapes delivered to the global market.

Tape demand is growing fast

Tape technology, as a whole, has grown very strongly over the past two years. On the graph opposite, you can see the evolution of storage capacity delivered on the worldwide tape market since 2012 and the launch of the Barium Ferrite. (All figures = index of evolution compared to a base index of 100 in 2012).



4. Tape market segmentation update.

Please see the table below:

	2016	2018
For users who store more than 10PB of data		 IBM 3592JE – 20TB / 500MB/s
For users who store between 1PB and 10PB of data	 IBM 3592JD – 10TB / 360MB/s	 LTO8 – 12TB / 360MB/s
For users who store less than 1PB of data	 LTO7 – 6TB / 300MB/s	 LTO7 – 6TB / 300MB/s

Attention: the launch of LTO8 is planned for the first quarter of 2018 and that of 3592JE is planned for the summer of 2018. The specifications and launch dates of these two products can still be changed by the manufacturers.

A few additional remarks on the table above:

A. Large companies that store between 1PB and 10PB of data, or those that store 0.8PB of data today but are faced with such growth that within five ye-ars they will find themselves with 4-5PB of data. These users require a higher storage capacity tape than LTO7, in order to reduce the floor space and cost of storage of the tape cartridges.

In addition, there are a number of these companies that do not have the urgency to improve the writing speed compared to the LTO7.

In other words, what these companies are asking for is an LTO7 tape with double the capacity, whilst maintaining the same write speed. Hence, the specifications of the LTO8 tape that will launch with a capacity of 12TB and write speeds ranging from 300MB/s to 360MB/s, depending on the drive model used (HH or FH).

B. Large companies that store capacities greater than 10PB.

The number of companies whose storage needs exceeds 10PB of data is growing rapidly due to the explosion in the creation of digital data.

An important point is that the creation of new data generates a demand, not only for more storage capacity, but also for greater write speed. Achieving a write speed of 500MB/s on a storage medium for long-term data retention is the outcome of the analysis of the demands that European companies have provided to manufacturers.
We are talking about industry segments such as Scientific Research, Television or Cinema, Banks, Remote Sensing, Universities, Ministries, Large Industries, Hospitals, or companies that rely on more vertical use such as areas like Video Surveillance, Big Data, Artificial Intelligence or IoT. IBM's 3592JE will offer 20TB capacity and 500MB/s transfer rate.

C. SMBs: LTO7 is designed to last and is the ideal choice for small and medium sized companies. LTO7 already accounts for a quarter of the storage capacity delivered each month on LTO tapes in Europe and is expected to exceed 60% by the summer of 2018.

Why is LTO7 the ideal storage solution for small and medium-sized businesses?

LTO7	RELIABILITY	SPEED	FLOOR SPACE	LONGEVITY
	↓	↓	↓	↓
	The data integrity of LTO7 is 100 times greater than that of LTO6	The LTO7 drive is nearly 2X faster than competing products (LTO6 drive or HDD)	An LTO7 tape contains the equivalent of 2,4 pcs of LTO6 tapes and four LTO5 tapes	Almost all LTO7 tapes are made from BaFe

5. The fundamental question of floor space

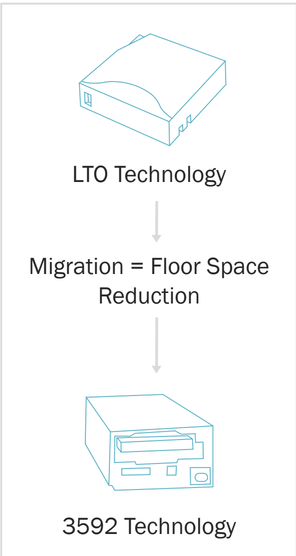
A. Large companies - the primary consequence of the development of Barium Ferrite technology on the world of data storage is that manufacturers are able to meet the demands of large companies who're facing two major challenges.

These European companies must:

0,13 €

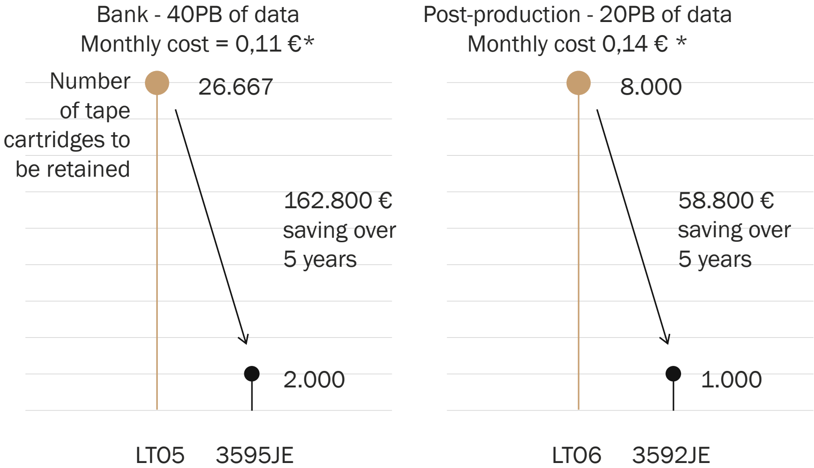
- on the one hand, absorb the large growth of digital data
- on the other hand, comply with legal requirements in terms of the long-term retention of data.

The growth of digital data involves a drastic increase in the number of cartridges that are retained. Plus, the new regulations, contribute to the increase in the cost of the storage of tape cartridges by limiting the possibility of erasing old critical data.

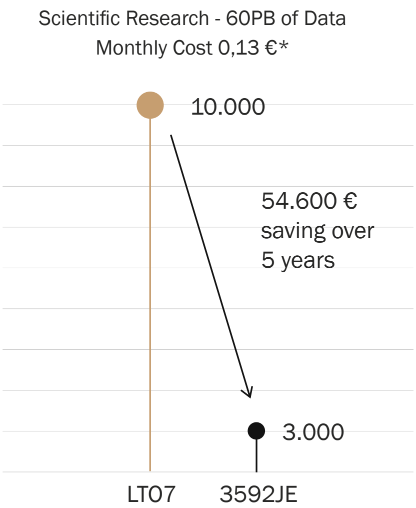


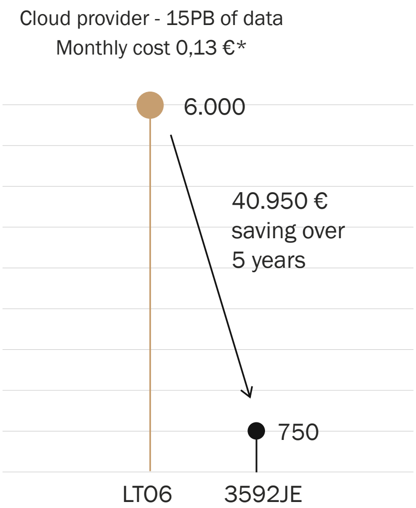
0,13 € per cartridge per month → We conducted a survey of more than 1.000 IT users who store, at a minimum, over 800TB of data. The result is that, for more than 85% of the companies we contacted, the average monthly cost of storing a tape cartridge is at best 0,13 € per tape cartridge per month.

Thus, we can give four examples of companies using LTO tapes, for whom the use of a higher capacity tape, namely IBM's 3592JE, will generate significant saving in the cost of conservation of the cartridges over the long term.



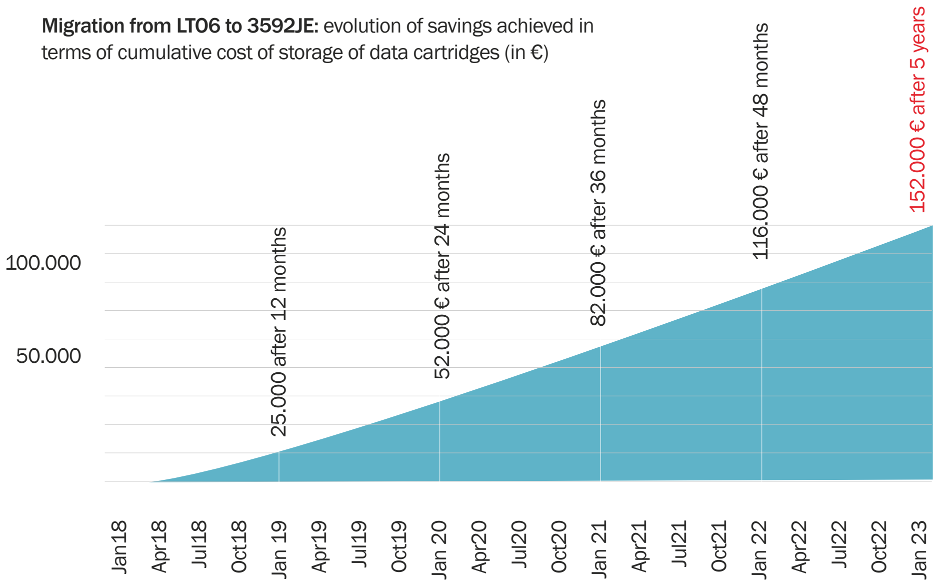
* Monthly cost means: average monthly cost of storing one tape cartridge





Some notes on the tables above: we took into account, the theoretical fact that none of the companies described above is experiencing data growth. On the other hand, these figures do not factor in another important aspect in the calculation of the cost of floor space - the size and volume of the storage system within the IT room (see page 41 in the chapter on SMB).We can also use the example below, which is the case of a company in the field of movie production.
The storage capacity used by this company will grow from 40PB to 70PB in the space of five years. As far as the cost of storing the cartridges is concerned, by migrating from LTO6 tapes to the new 3592JE tapes, this company will attain almost 150.000 € of savings in five years.

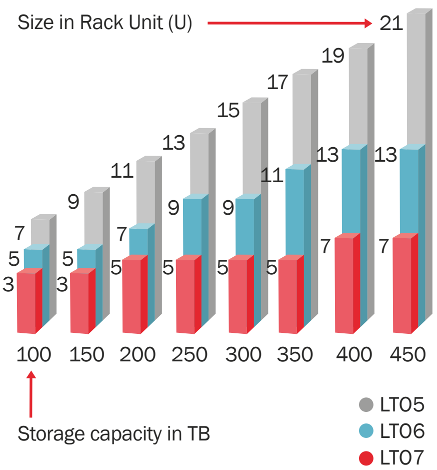
Migration from LTO6 to 3592JE: evolution of savings achieved in terms of cumulative cost of storage of data cartridges (in €)



B. What about SMBs?

The size of the library is the other component that greatly influences the cost of floor space. For companies located in the city centre, where the cost of renting space can be a substantial figure, data growth is an indication of additional real estate costs. It is, therefore, also beneficial for SMBs to migrate to higher-capacity solutions, namely the LTO7.

What size in Rack Unit (U) do we need to store data on LTO7 tapes?



The Oracle SL-150 tape library consists of modules.
Each module can hold 30 cartridges and two drives. The "rack-mountable" size of any module is 2U except for the first module, the base module, which is 3U in size.

For instance:
- a 60-slot library requires 5U (3U + 2U) of Rack unit.
- a library of 90 slots requires 7U (3U + 2U + 2U) of Rack unit.

From the table above, it is evident that storing 350TB of data on LTO7 tapes would require a library that is half the size of an LTO6 tape/drive library and three times smaller than what would be required for LTO5 tapes. We can support this study with a user case.

- Example with a full backup mode.

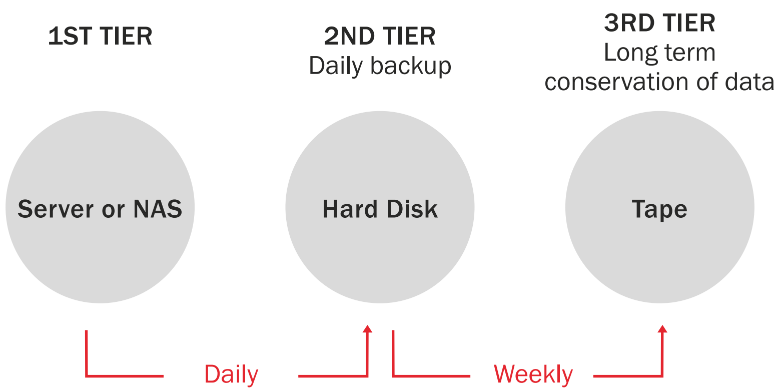
- A hospital that stores 50TB of data, will meet a storage capacity growth of 15% per year and reach 87TB of data stored on the fifth year.

- This hospital used to save all of their data on Hard Disk. A significant loss of data due to the fragility of the hard drive technology convinced the user to switch to tape.

- We can estimate the size of the library and the floor space required for this user.

*** What is a Full Backup?**

The full backup mode consists of copying, on a regular basis, all the data a company owns, on a tape solution. It is generally saved over the weekend. For medium sized companies, which store more than 50-60TB, a majority of them operate in the following mode:



The user performs a daily backup on hard disk, after office hours (often at night at 2-3 am). This data is not secure over the long term since the lifetime of a hard disk does not exceed 3-4 years.

The user practices a copy of the data on a set of LTO tapes in order to secure them in the long term. This copy is made over the weekend.

*** How to calculate the needs of a company in terms of library size or number of slots?**

The question of constitution and configuration of the hardware depends on the wishes of the user and can vary on a case-by-case basis. **This is, moreover, an advantage of tape technology over disk: the tape is a system that adapts to the needs of users.** In the area of full backup, we note, however, quite recurring backup modes. One of the most common is the following :

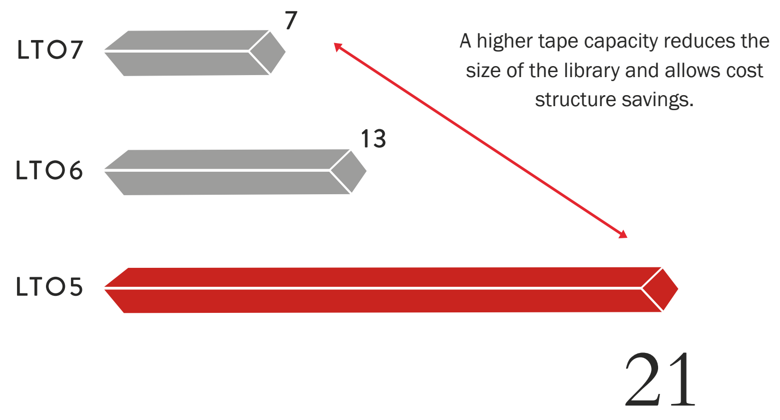
- The user copies all of their data on a set of tape every weekend. It generates a second copy that they leave at another location, for security purposes.

- They renew this copy of the data from disk to tape every weekend. For this, they will reuse the same set of tape every weekend, will overwrite the data and generate a new copy.

- We generally recommend that users do not rewrite more than 50-52 times on the same tape cartridge. In this case, the user will continue their copies on a new set of tape each year.

- Finally, the current trend in the IT market is that data storage users prefer to reduce the frequency of physical intervention on the library: in other words, they prefer the first copy to remain in the library over a long period of time (generally five years).

We can see below that the higher capacity of the LTO7 tapes greatly reduces the space occupancy for this user. Also below in Rack Size (U), are the comparative sizes of tape libraries that this user could purchase:



Other Benefits of Barium Ferrite. Focus On Speed

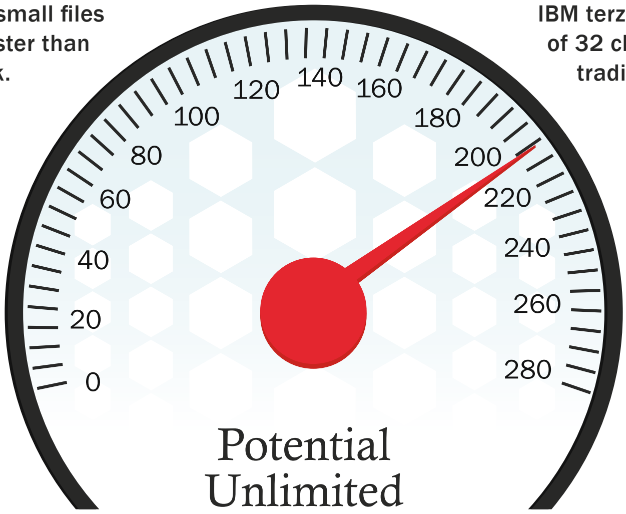
Higher speed = combination of the BaFe tape and the IBM Terzetto head.

LTO7 drives write small files more than 3X faster than Hard Disk.

IBM terzetto head is comprised of 32 channels instead of the traditional 16 channels.

LTO8 drives write data more than twice as fast as LTO5 & LTO6 drives.

High SNR leads to high writing speed and high Data integrity.



Other Benefits of Barium Ferrite

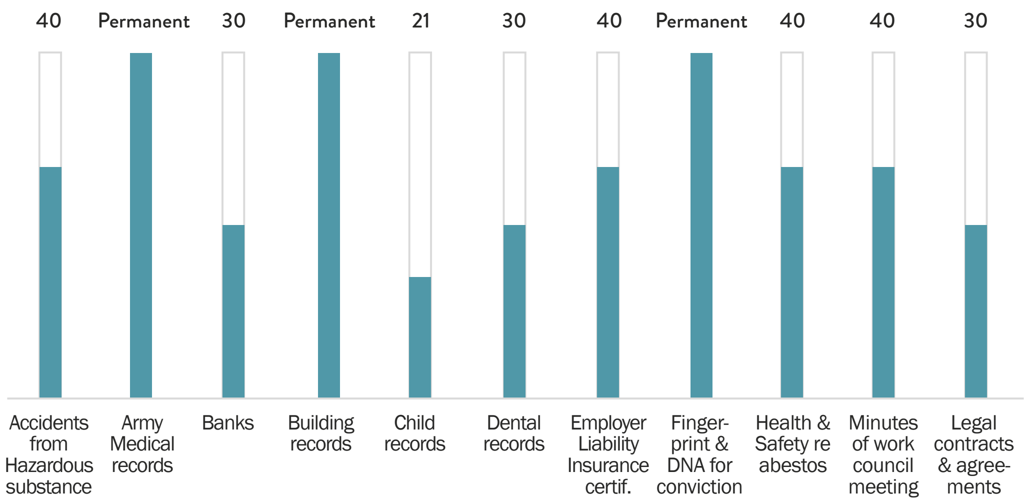
1. The Archive Life or lifetime of data recorded on magnetic tape.

We saw earlier in the chapter entitled '' MP Particles oxidation" on page 27 that the lifetime of Barium Ferrite particles is greater than that of MP particles. The reason why we discuss the lifetime of a particle in chapter three, after having discussed at length the questions of data integrity and storage capacity, is that even if Barium Ferrite particles can retain data beyond 30 years, traditional MP particles still manage to exceed 20 years of data retention.

On this particular point, the most spectacular difference is not really between the BaFe and MP particles, but between tape technology and Hard Disk.

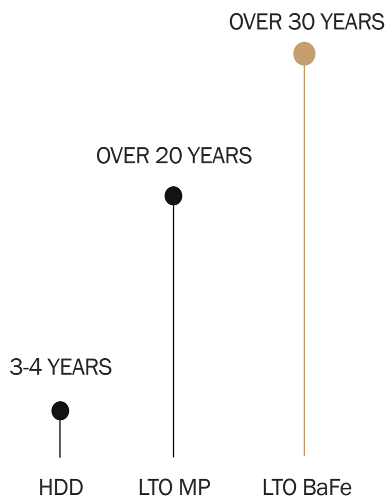
We can begin with looking some guidelines and legal obligations regarding the retention of data over the long term in the EU. A few examples are highlighted below:

According to the law, for how many years are we required to retain data in UK?



We can compare these obligations with the long term retention capacity provided by tape technology and Hard Disk:

How long can we keep data on the following storage device?



* We can see here that archive life is not the main weakness of MP technology.

* However, we also saw on the previous page that legislation requires some users to keep their data for 30 years, and sometimes even longer.

* In this case, it is recommended to use BaFe.

* Finally, Hard Disk cannot compete with tape on long-term data retention because of its extreme fragility.

2. The lifespan of the drive

The higher SNR of Barium Ferrite also has the advantage of extending the life of the tape drive. In reality, when the tape drive reaches the end of its life, the write/read head tends to become "deaf". It is more difficult to pick up signals from the tape.

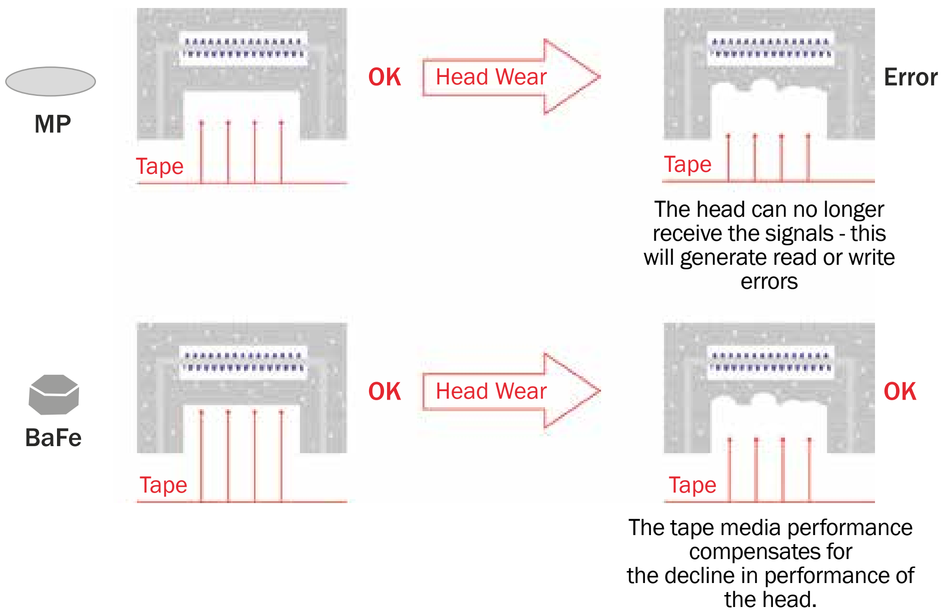
As a result, the drive has more trouble reading the data.

The Barium Ferrite SNR gives the tape a much higher output power than the MP tape. Roughly speaking, it can be said that the “voice” of the BaFe tape is more powerful than that of the MP tape.

As a result, the stronger ‘’voice’’ of BaFe compensates for the progressive deafness of the drive: the drive’s head thus continues to function more in time with a BaFe tape than with an MP tape.

Please see the diagram below:

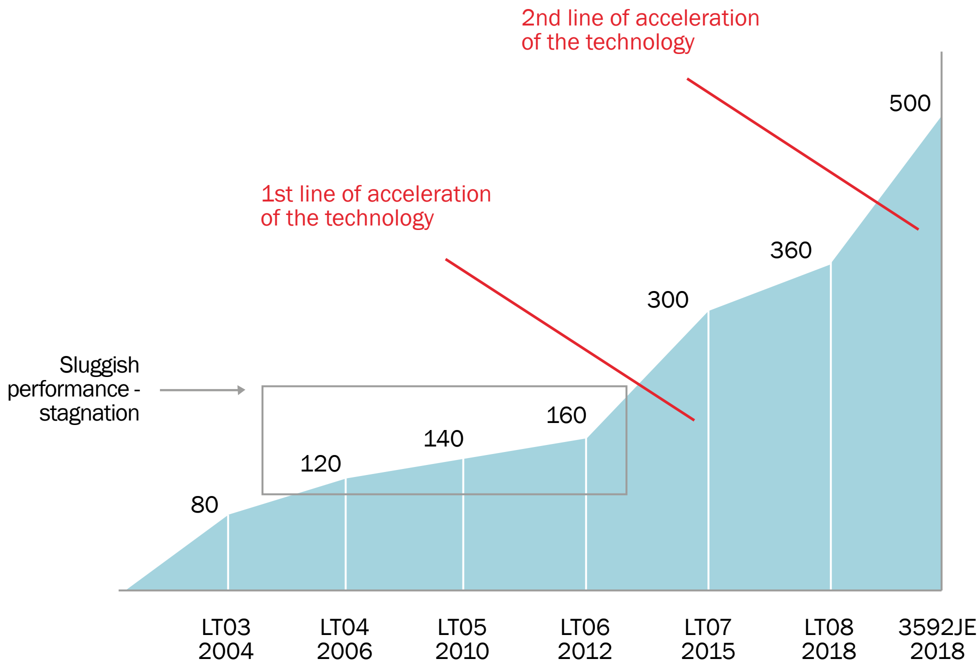
Recording stability – Barium Ferrite tapes can be read/written correctly even when the drive head is worn after multiple uses



3. Writing Speed

A. The major role of IBM

The writing speed is a fundamental criterion when judging any aspect of the different storage technologies, such as when looking at its importance compared to data integrity, floor space reduction, archive life, the ecological footprint or the total cost of ownership. In recent years, tape technology has achieved a real leap forward in terms of read or write speed. Below, you will see the evolution of the transfer rates of different tape generations:



It is impossible to mention the progress made in writing speed between LTO6 and LTO7 without mentioning the instrumental role played by IBM. In fact, two major innovations are largely responsible for this sudden acceleration of the performance of LTO tapes after a dozen years of stagnation (see chart above). These two innovations are:

- **The use of a 32-channel head** - Up to LTO6, the write head was composed, at most, of 16 writing channels. These writing channels can be compared to 16 pens grafted onto the head and which write concomitantly on the tape:

  • The significant increase (+ 64%) in the number of tracks on LTO7 tapes compared to LTO6 (3.584 vs. 2.176), required greater write and read capacity than what 16 channels could provide.

• Moreover, we can see that the writing speed of LTO tapes clearly stagnated between LTO4 and LTO6 with only 40MB/s in the space of six years, at the time when the market was experiencing an explosion in the creation of new Digital Data!

• LTO7 drives are the first LTO drives that work with 32 writing channels: the operating speed of the drive is greatly improved.
32 heads working at the same time provide a performance that is twice as impactful as 16 heads.

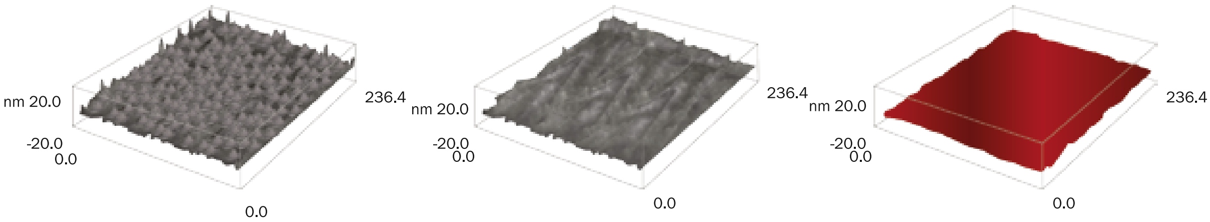
- **The Terzetto head:** SNR is an essential condition for the increase in writing speed. Terzetto being synonymous with SNR, it is obvious that it opens up new perspectives in the field of writing speed on tape.

B. The contribution of Barium Ferrite

Since SNR plays a fundamental role in writing speed, it is evident that Barium Ferrite also contributes greatly to the increase in transfer rates of new generations of tape drives and cartridges.

The vertical polarization of the BaFe particles combined with a smoother tape surface are two major strengths that enable BaFe to propose higher SNR levels than MP. Below, we can see the evolution of the tape surface.

Evolution of the roughness of the tape surface



MP (LTO5) BaFe1 Next Generation

A low level of SNR hurts the quality of communication between the head and the tape. During the write process on the tape, the system constantly measures the level of SNR. When SNR figures drop dramatically, either because the drive is declining or that the cartridge has a low level of SNR (MP), the system automatically makes the decision to operate at a speed lower than its original speed. An LTO6 MP tape can, therefore, definitely not operate with the same speed as a LTO6 Barium Ferrite.

Conclusion

The description of a Phenomenal Progression

The best way to address the progress made in tape technology by the Fujifilm-IBM duo is to draw the history, from 2012 to today, of the advances achieved on seven key technical aspects of developing a data storage medium.

If we begin with the idea that the 3592JE tape is the best tape possible in terms of performance, we could give a rating for the previous technologies, from 1 to 5. 5 being the best score, and in principle, the score of the 3592JE for each of these 7 segments.

It should be noted that giving a mark of 5 to IBM's 3592JE is a theoretical estimate in the sense that we know that tape technology will still improve. For example, you will see, on the charts below, that:

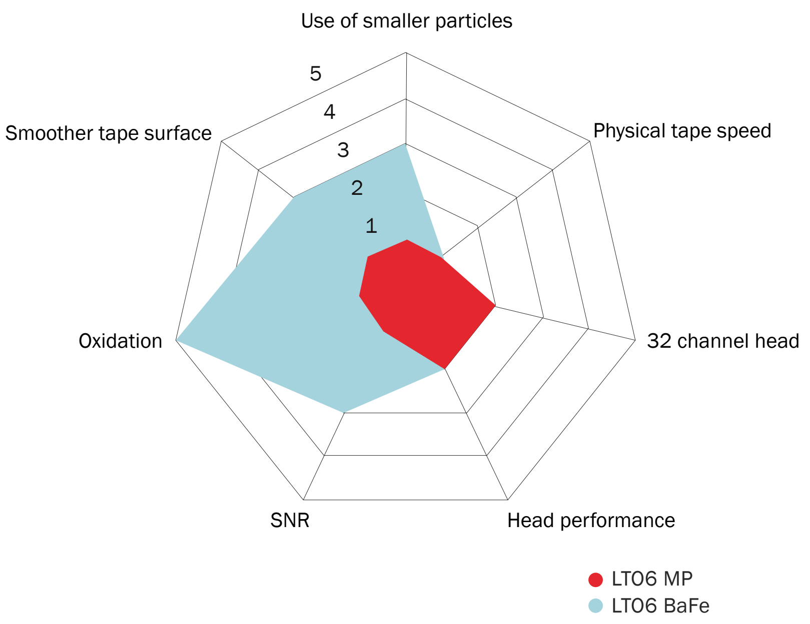
- 3592JE has a score of 5 on the ''use of smaller particles'' criteria. However, we already know that Fujifilm is actually developing tapes that exceed 50-60TB and which the launch date has not yet been decided by IBM. These tapes of 50- 60TB or more will be manufactured with particles smaller in size than those used for 3592JE.

- In addition, for tapes of capacities above 50-60TB, it will also be necessary to come up with transfer rates capable of processing a very large data capacity in a record time: it will be necessary to switch to the use of a write head that will use more than 32 writing channels.

As a result, we cannot decree that 3592JE is the end of the history of tape and that no higher generation will be produced. On the other hand, we can use 3592JE as a provisional or theoretical end of history and take a look back at where tape was in the early years of 2010, where it is today, and make a quick inventory of some technological breakthroughs that have enabled such development. The seven fields of study we have chosen are as follows:

- Use of smaller particles
- Physical tape speed
- 32-channel head
- IBM Terzetto
- SNR
- Oxidation
- Smoother tape surface

1st step - LTO6 MP and LTO6 BaFe tapes.
The marks are stated on the chart below:



We can see from the chart above that the points on which the LTO6 BaFe outperforms the LTO6 MP are based on four of the seven criteria taken into account in this study:

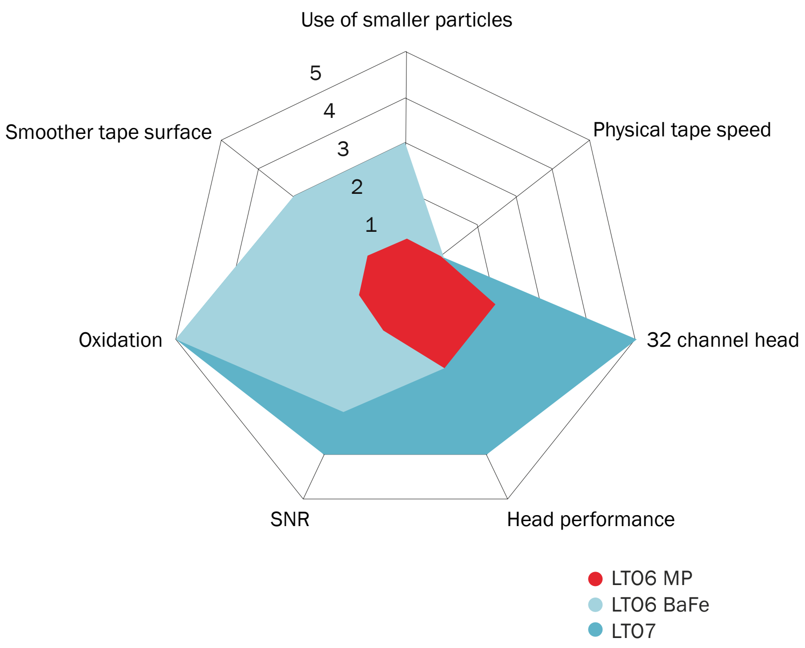
- A higher level of SNR, although we can also notice that LTO6 BaFe SNR does not obtain the maximum score. We, therefore, speak here of the difference in SNR generated by the vertical polarization and/or the quality of the dispersion of the particles on the tape. We saw, in the chapter '' SNR-data integrity '' that LTO7 will upgrade the qualities of LTO technology by using IBM's Terzetto head.

- The oxidation or absence of oxidation of the BaFe particles, which considerably prolongs the lifetime of a data.

- A smoother tape surface due to smaller particles and a better particle dispersion on the surface of the tape. This contributes to a better SNR, and, therefore, to improve data integrity, as much as the writing speed.

- Finally, of course, the size of Barium Ferrite particles that are smaller than MP particles. Size is understood to be an important criterion in the sense that it increases the capacity of the cartridges.

2nd step – LTO7. See the marks on below chart:



From the launch of LTO7, LTO technology advances on three important points, namely:

- The 32-channel head - on the chart above, we can see the limit of the 16-channel heads used for LTO6 drives. In the writing speed section of this document (page 48), we saw that the 32-channel head was the main reason why LTO7 drives were able to propose a transfer rate that is so high compared to the previous generation (140MB/s of progression between two generations!)

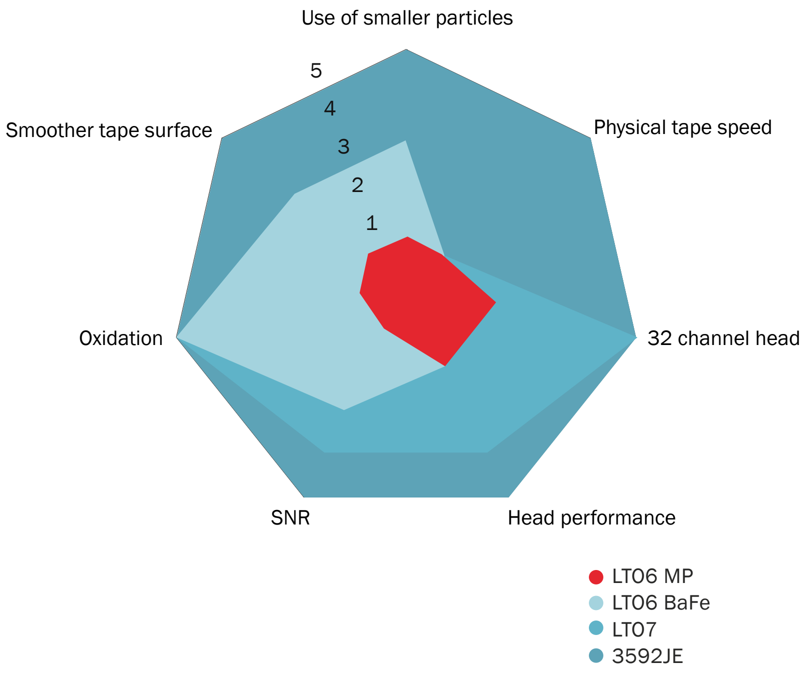
- The Terzetto head which appears in LTO from LTO7, and whose direct consequence is the improvement of the SNR.

- On the other hand, the particle size used for LTO7 tapes is the same as the one used for producing LTO6 tapes, which also explains that the tape surface is not necessarily a criterion for LTO7's improvement vs LTO6.

- To summarize, we can see on the chart above, the break points between different generations:

  - SNR, Oxidation, particle size and tape surface, when comparing LTO6 BaFe with LTO6 MP.
  - SNR still, write speed, Terzetto head, when comparing LTO7 with LTO6.

3rd step – 3592JE. The marks are stated on the chart below:



The IBM 3592JE will overturn the technical criteria for manufacturing a storage medium, as it will offer an unprecedented level of performance and reliability in the field of long-term data storage: 20TB capacity, 500MB/s speed, and greater data integrity than competing products.

We already know that we will use smaller Barium Ferrite particles than those used for LTO6 and LTO7. We also know that the surface of the tape will be smoother, that the speed of passage of the tape in the drive will be faster and that Fujifilm will further increase the SNR level of its Barium Ferrite tapes.

We know, above all, that IBM will launch a new write head (the TMR-Terzetto), which will offer properties superior to any previous tape drive head.

In the coming weeks, it will be interesting to see what IBM is preparing for the launch of 3592JE in 2018. We will discuss new projects such as Fast Sync (which optimizes the speed of writing small files), X copy (which will improve the tape-to-tape migration process),
Recommended Access Ordering (ordering files in order to access them faster). We will also discuss the Humidity Sensor (a process that measures moisture within the system in order to allow the user to react before the drive is damaged). To be continued....

Value from Innovation