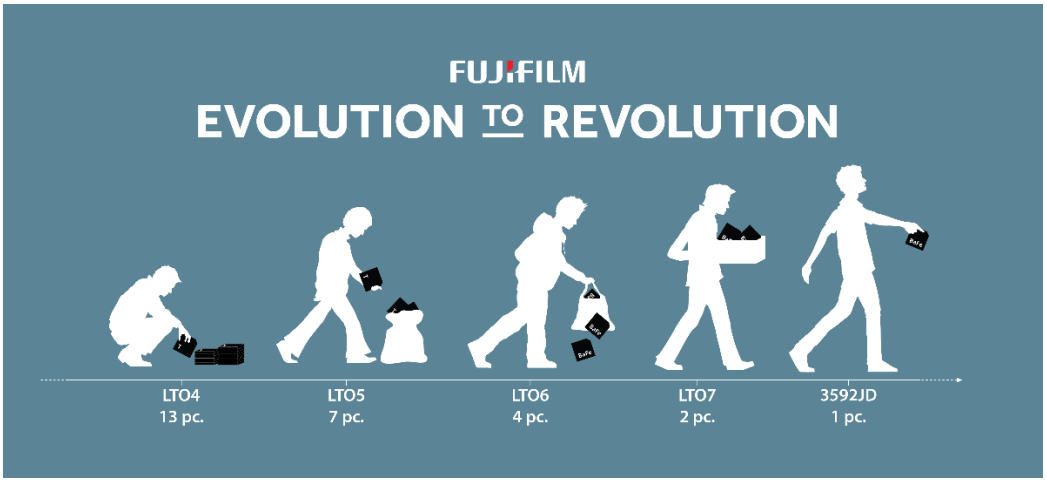
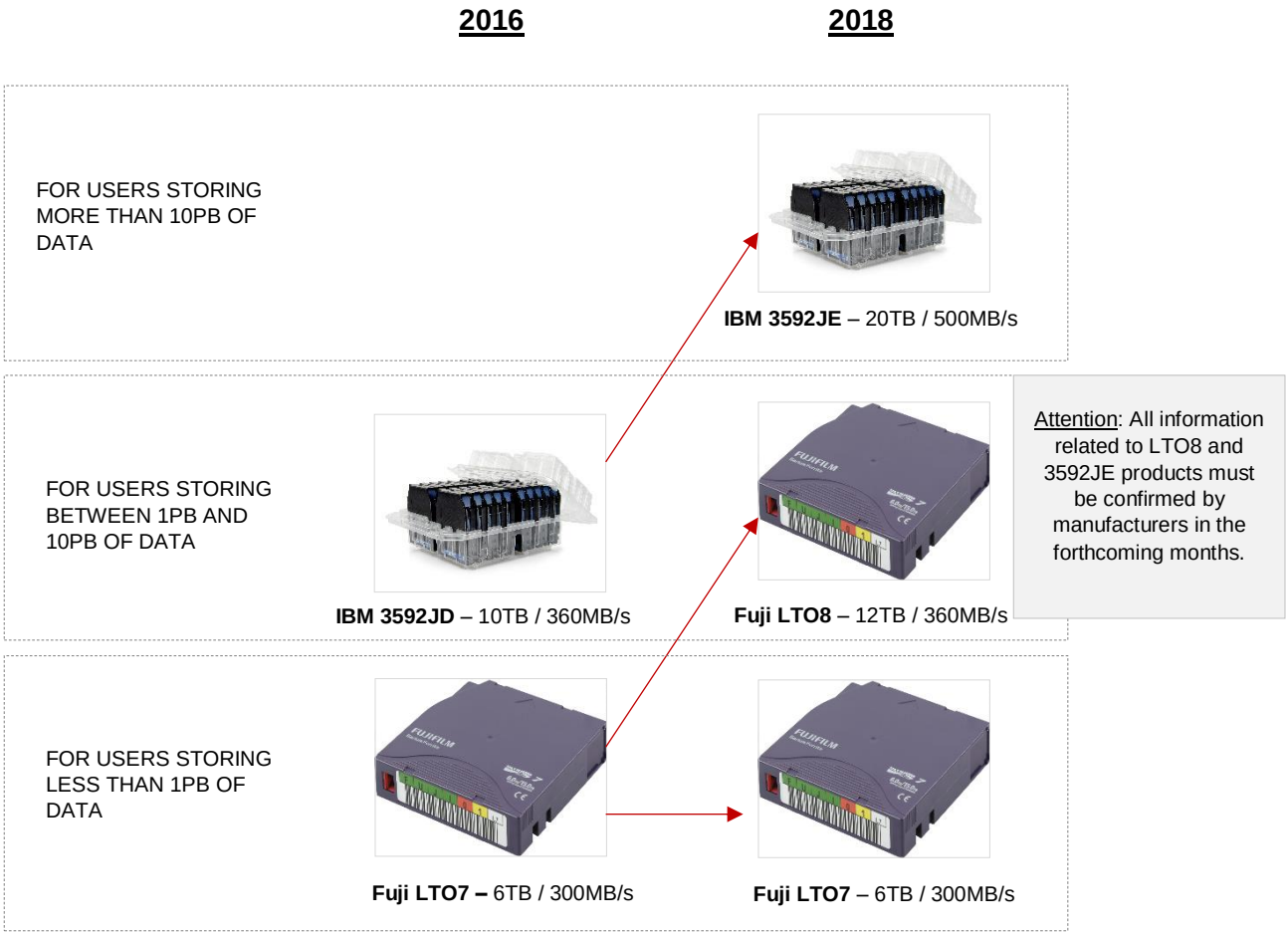


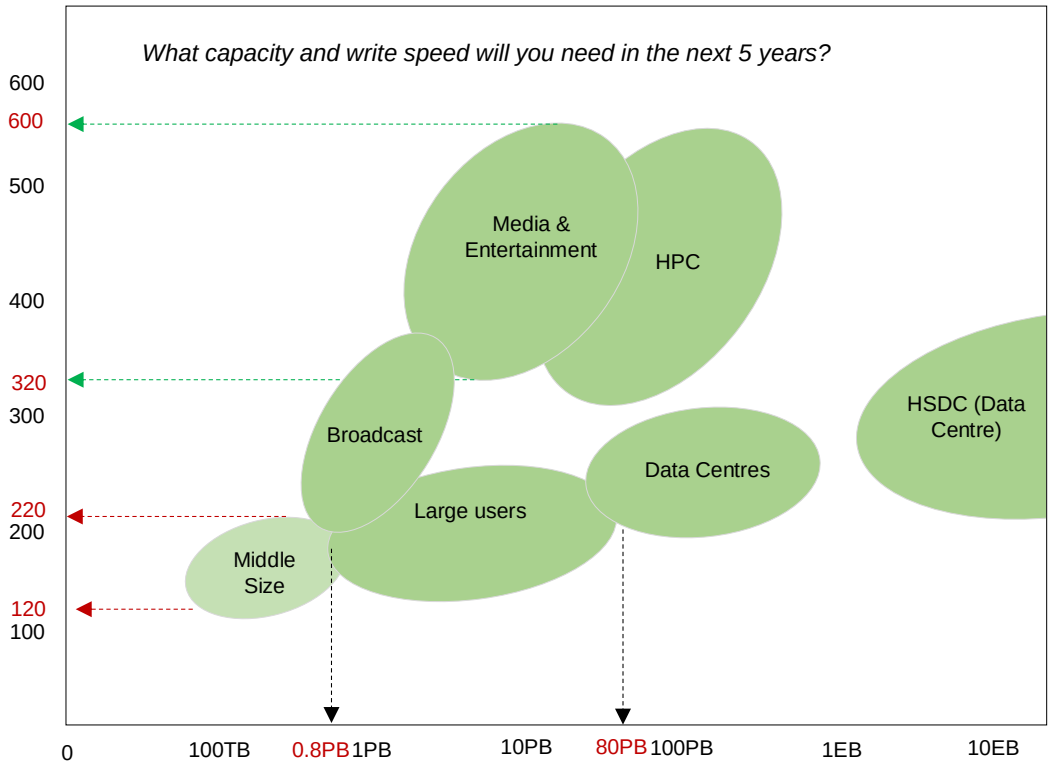
WHAT IS THE FUTURE OF TAPE TECHNOLOGY FOR DATA STORAGE AND MANAGEMENT?

There is news in the field of tape storage: two new products will be launched in 2018 which will change tape technology's offer in the field of data storage. Planned for summer of next year is what we can call the IBM revolution; the new 3592JE drive with a 20TB capacity data tape and with 500MB/s transfer rate. Prior to this, the start of the year will see the launch of the new LTO8 with a capacity of 12TB and close to 350MB/s transfer rate (information to be confirmed by the LTO Consortium). Below you will see an image showing the future possible segmentation of the tape market:



Genesis of the creation of the two new products and explanations:

The launch of these two new tapes is a consequence of user demand. The significant growth in the creation of new digital data has considerably accelerated the development of new solutions to help resolve the challenges faced by digital data users. However, the needs of users vary according to their own individual situations. To address these needs, IBM and Fujifilm have listed the desires and projections of thousands of users to determine the future needs of each segment. Below is a summary of the data that we have collected around the world:



Note, for example, in the table above that:

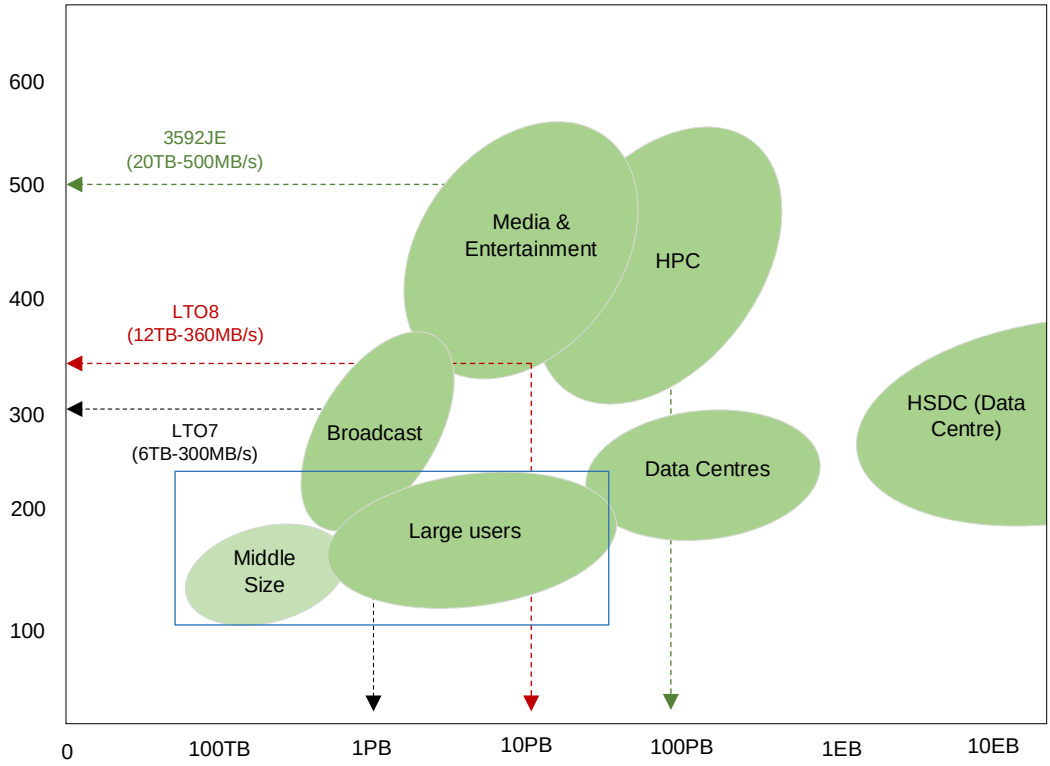
- Most storage capacity requirements for medium-sized companies range from 80TB to 1PB. The same companies have explained that transfer rates between 120MB/s and 220MB/s will still be suitable for them within the next 3-4 years. (See red lines)

- The category ''Large users'' brings together all companies that use capacities greater than 1PB, besides key segments such as Broadcast, Scientific or Remote Sensing. This segment includes large companies such as banks, government organizations and large industries. We can see from the table above that the ''Large user'' segment is more concerned with the issue of floor space reduction than the increase in the transfer rate. The majority of them are satisfied with the LTO7 transfer rate (shown on the table above) but are experiencing a large growth in the creation of new digital data. A growing number of examples of users in this category whose capacity requirements will reach 80PB in the coming years. (See black line).

- Finally, large Datacentres are not necessarily those that require the highest write speed. High write speed is a specific demand that originates from two segments which, for various reasons, would not reject the idea of working with transfer rates well in excess of 400MB/s: the Scientific environment and the Broadcast market.

What we at FUJIFILM are preparing for the next 5 years!

Below you can see the new segmentation of the storage tape range, as envisaged for the different user segments:



A few points about this table:

Why is the transfer rate of LTO8 so close to that of LTO7? The collection of user desires as listed in the "Large users" category reinforced the idea that we should, as a priority, develop a kind of LTO7 tape that would have a capacity which would be twice as large.

- During our discussions with users in this ‘’Large users’’ category, FUJIFILM did not receive any real request to increase the current speed of tape technology. Most companies that store between 1PB and 10PB explained us that they are satisfied with the current speed of the LTO7. Only those with capacity requirements beyond 10PB were looking forward to new possible developments in writing speed. Naturally, a good number of them already uses Enterprise tapes (IBM 3592 or Oracle T10000) or plans to migrate to 3592JE once it will be launched.

- In addition, write speed is one of the criteria on which tape far surpasses Hard Disk since we can see that LTO7’s real operational speed is more than 2X faster than the new generations of Hard Disk and 3.5X faster than the majority of HDD used on the European market.

- On the other hand, large users state an urgent need for higher capacity tapes in order to reduce the use of floor space and, therefore, the cost of conservation of data cartridges.

- Our survey amongst hundreds of large users in Europe shows that the vast majority of them estimate the cost of conservation of their tape media at an average £0.11 per cartridge per month (2016).

- Many users have accumulated large quantities of LTO tape cartridges over the past 15 years. These users simply ask us to reduce the number of data cartridges that they must keep.

- The explosion of new regulations regarding the long-term retention of data implies that they cannot afford to erase their old data.

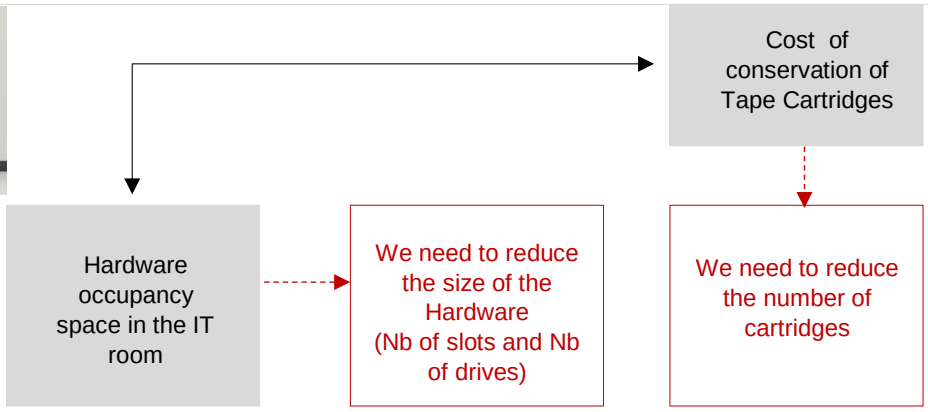
- In addition, Hard Disk is not an option due to its three main weaknesses: extremely low security level, very low performance and a TCO that is sometimes close to 20X more expensive than tape technology.

⇨ Therefore, we had to produce a new LTO tape that would offer double the capacity of the LTO7 tape… it's called LTO8!

1) <u>Greater storage capacity = reduction of floor space = cost reduction.</u>

We can define the issue of floor space and storage capacity through the combination of two major challenges. Please see the table below:

CHALLENGES IN THE FIELD OF FLOOR SPACE REDUCTION



a. Conservation of Data: an issue affecting nearly all users.

The question of the quantity of data to be archived and the length of time this data has to be protected affects a very large majority of Companies. The need to create tape cartridges of greater capacity arises for three major reasons!

- Reason 1 is the explosion in the creation of new digital data - we can also divide this aspect into two categories. On one hand, we have trades, which are, organically, in strong growth. The demand for production towards these new players generates a sharp increase in storage capacity requirements: data centres, remote sensing, social networks, etc. In the case of these companies, the growth in the creation of new digital data is proportional to the growth of their business. On the other hand, we have companies whose creation of new digital data increases dramatically without necessarily being linked to the growth of their activity. These are the use of new applications, new software or new work tools that generate more digital data to enable the company to progress in its own activity. Of course, Media & Entertainment industry, for whom the switch to 4K format can represent up to 7 times more GB of data to keep than before. We also have the case of industries that multiply digital use in order to measure and calculate the performance of the machines that they create (railway, military & air transport industry). Strong growth in digital data among medium-sized users where the increasing use of 3D-type formats has generated data growth rates in excess of 50% within a year. Finally, the digitization of formats of analogue or paper type is another sector of strong growth of storage capacity.

- The second event is the increase in new regulations concerning the long-term retention of data. The internet is full of studies and analysis on the various costs associated with poor data retention over time. We also have cases of users who cannot delete data that was saved in the 1990s, due to the new regulations and also possible financial penalties to which these companies may need to pay.

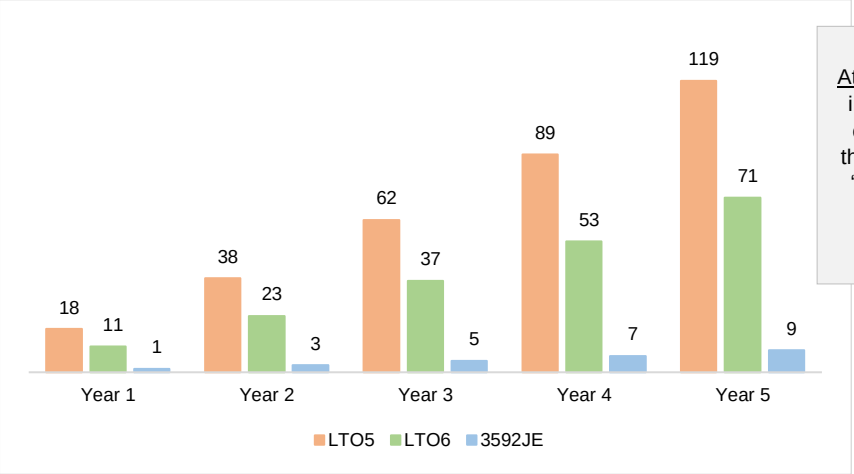
- The third major event is the fact that a number of companies have succeeded in generating technological innovations to solve the aforementioned issues. IBM's new read / write head, the Terzetto head, is part of these technological innovations. Fujifilm's tape coating technology, Barium Ferrite, is another breakthrough. These innovations open up new perspectives in terms of the evolution of data storage and backup technologies and offer dramatic advances over previous generations of tapes in terms of storage capacity, write speed or Data integrity. At a time when Hard Disk is at its limit in all of the key criteria: linear density, write speed, and data integrity. It seems that the only two current technologies to offer durable solutions are SSD for specific applications and Data Tapes.

b. Reducing the number of Tape cartridges that you will need to use:

If we keep to the estimations that we have collected from the market and go with the idea that the average cost of storing tape cartridges is £0.11 per cartridge per month. We can give two examples on this subject:

Example 1

A European bank that currently stores 20PB of data on LTO5 tape cartridges. This bank will experience a data growth of 3.5PB per year, and reaches 34PB of data within 5 years. The estimated accumulated cost of retaining the data of this bank will change as follows, depending on the tape generation on which the user will choose to keep data (all figures in k £ - thousands of £) :



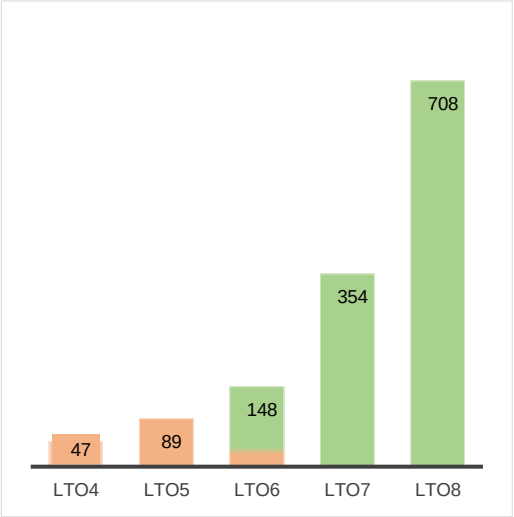
Attention: The figures quoted in this table are cumulative expenditures. This means that year 2 = expenditure for ''Year 1'' + expenditure for ''Year 2''.

Migration from LTO5 to the new 3592JE in 2018 would allow the bank to save £ 110,000 cost of conservation of the tape cartridges over 5 years.

Example 2

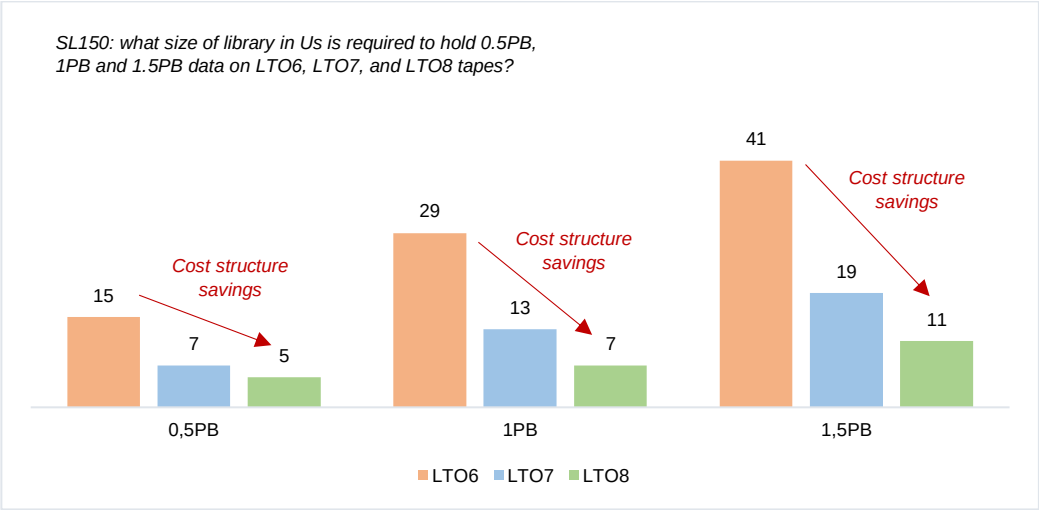
A larger capacity data cartridge is also a way to reduce the size of the hardware within the IT room and avoid additional expenses related to data growth. Advances in tape technology are also of interest to small and medium sized users. In the case of a user whose available space in their Rack system is a maximum of 5U. If we take the example of the Oracle SL-150 library, which is an ideal product for SMBs because of its scalability, a 5U space can contain 60 tape cartridges spread over two modules of 30 slots each. Since a slot must be reserved for the cleaning cartridge, the available capacity for saving data is 59 slots. Below, you can see the maximum native capacity that the SL150 can save in a 5U (3U +2U) physical space (all figures in TB):

See Information on LTO4, LTO5, LTO6, LTO7 & LTO8.



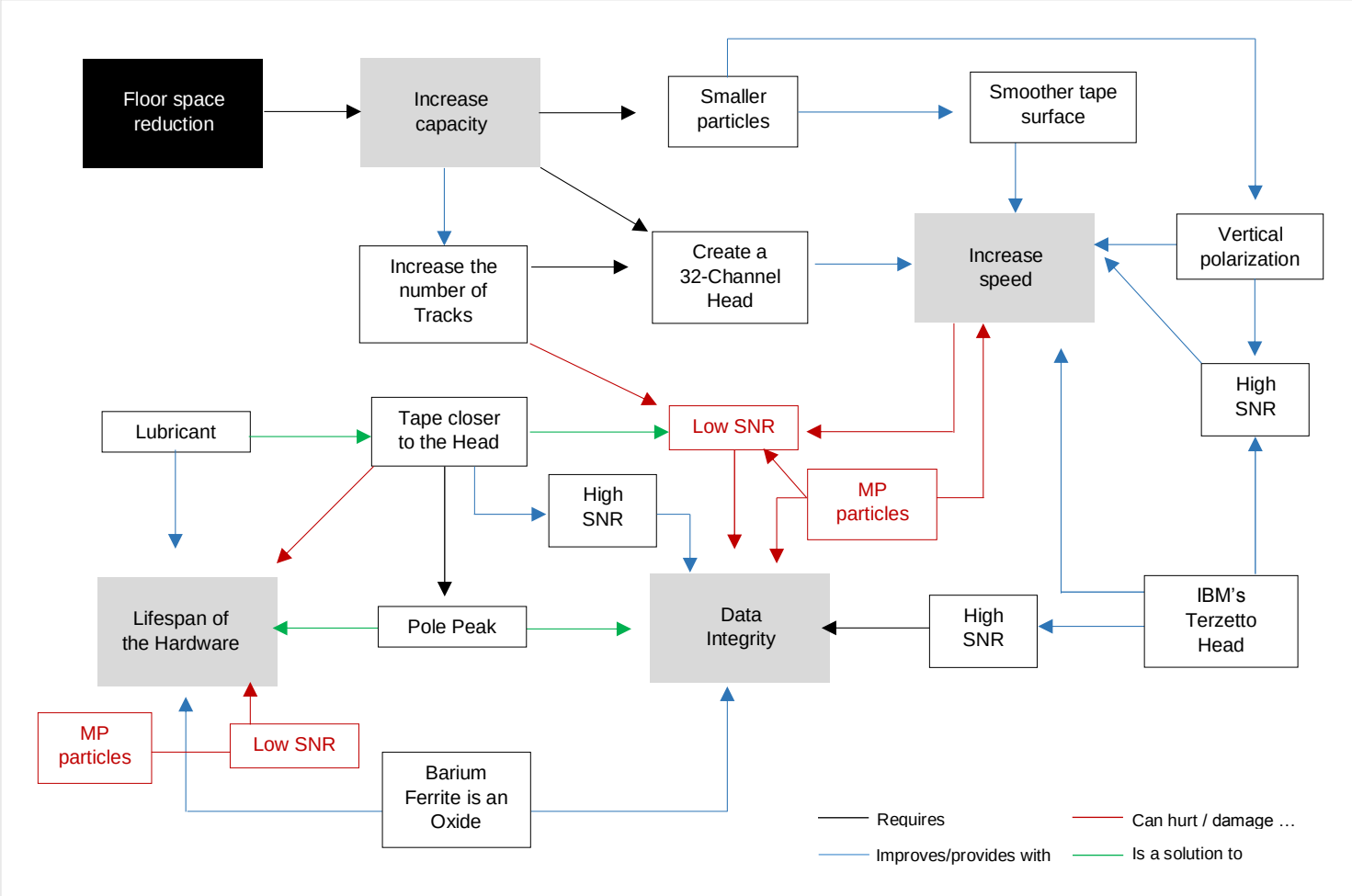
- *One SL-150 module can hold 30 tape cartridges and two drives.*
- *The first module is of 3U Form Factor (size)*
- *Any other module is of 2U Form Factor (size).*
- *Each module is easy to insert into the Rack system, in the same way as a server or a NAS.*

Look at the question from another angle and ask how many Us of Form Factor it would take to contain 0.5PB, 1PB and 1.5PB in a modular library system, such as the Oracle SL-150. See the result below:



2) How did we manage to increase the capacity of our tapes at FUJIFILM?

The development of tapes of higher capacity and performance is difficult but possible. This ability to enhance the Tape is also what differentiates it from Hard Disk. Indeed, increasing capacity involves a number of technical challenges. To summarize what's in the mind of our FUJIFILM Engineers with the following information diagram:



We can see that each improvement made on a data storage medium implies a significant number of new innovations to be reached. Everything has to work at the same time. You cannot increase the capacity of a product without increasing its writing speed, or verify that the data integrity or the lifespan of the drive will not be diminished. Below is a non-exhaustive list of explanations of the graph above, and therefore of the development and manufacturing mechanism of the new FUJIFILM tape storage solutions:

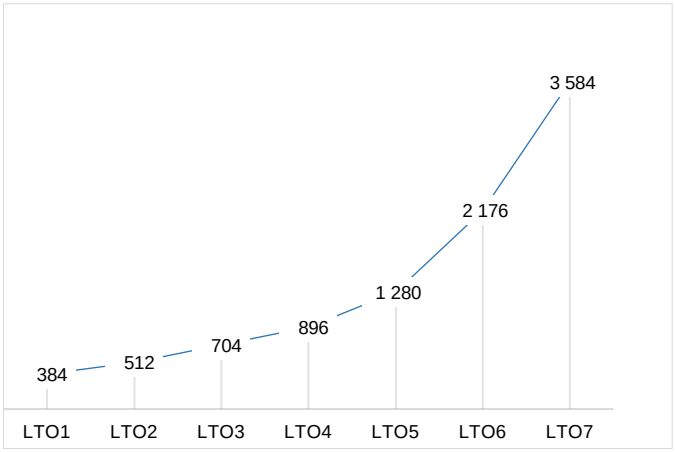
- In order to increase the Storage capacity on a tape, you must be able to increase the number of particles on it (by making them even more microscopic).

- MP particles cannot generate more capacity than the 2.5TB of LTO6. The first reason is that they are too large, and the second and most important reason, is their SNR (Signal-to-Noise Ratio) level, which is far too low for the use of higher capacity tapes (see page 9).

- Barium Ferrite particles are the only ones capable of producing higher capacity tapes. The particle sizes used to manufacture LTO7 tapes are also the ones that will be used for manufacturing LTO8 tapes. This means that we do not need to develop smaller particles for the next generation of LTO tapes. For tapes of 20TB or greater, new smaller particles, and thus, a new generation of Barium Ferrite technology will be developed by FUJIFILM.

- As the number of particles are increased on the tape surface, we must increase the number of writing tracks. See below the evolution of the number of the track density of the LTO technology:

  Track Density Graph



Write speed – Data Integrity and SNR

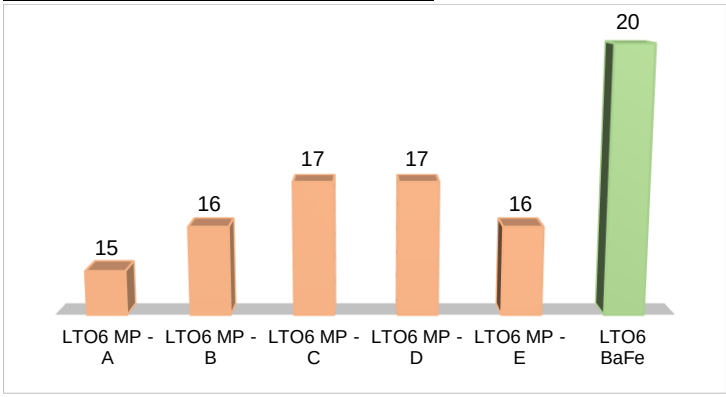
It is not enough to increase the capacity of an LTO tape, it is also necessary to increase the writing speed. It was essential to innovate. One example of innovation in the field of tape speed is the use of a **32-channel head**: LTO7 offers a write speed almost twice that of the LTO6. LTO6 used a 16 channel head.

- It was necessary to build smaller heads, that are able to write on narrower tracks since we increased its number. Moreover, with regards to the track density, it can also be noted that the use of narrower writing tracks is a risk for the SNR of the tape. The SNR is fundamental in the process of reading and writing. **The Signal-to-Noise Ratio** is the measure of the magnetic power of a tape. It is the ratio between the signal emission and the noise pollution generated by both the particles and the system. This noise pollution, if too high, can prevent the read head from picking up the signals emitted by the tape. The SNR impacts the write speed as much as the data integrity or the lifetime of a drive. In short, the SNR is the ability of a head to communicate with the tape. MP LTO6 tapes have a poorer SNR as compared to Barium Ferrite LTO6 tapes.

- Another improvement to tape that can cause damage is in the increased speed. The use of smaller sized particles naturally increases the speed of the system - it is faster to cover 10GB of small size particles than 10GB of large size particles. Speed is also a risk for the SNR because the read head, accelerating its movement will have more difficulty in capturing the signals emitted. There are a plethora of factors likely to decrease the SNR, hence the sound quality of the signals emitted by the tape towards the head are critical.

- There are multiple concrete consequences of a bad SNR: starting with **data integrity**. Data integrity is measured in BER (Bit-Error-Rate). More than in the writing, the actual measure of data integrity is in the ability to read previously written data, whether in a month's time or in five years. If we write with an SNR that is too low, it is exactly as if we wrote on paper using ink that was not dense enough. If, at the moment of writing, the head validates the written data and can read it, it is, however, possible that it won't be able to read it again two weeks later, due to the natural loss in magnetic property from a low SNR. In this case, it would be enough for a micro-meter of a data item to be physically changed, so that the read head would no longer recognize the written data. An " O " would become a " U " and the word wouldn't make sense at the time of reading the data and it would become unreadable for the read head. This is a case of data loss. It is also a major weakness of MP LTO6 tapes.

SNR Graph – Various LTO6 Tapes



- Another factor of data loss is the fact that the MP particle is made of iron. It will naturally **oxidize over time**. Bit Cells, (the cells that assemble several particles), will no longer be active and, therefore, will no longer be readable.

- A concrete **consequence of a bad SNR in terms of storage capacity**: it is a point that is still related to the data integrity. When the read head degrades, it has increasing difficulty perceiving the signals of a low SNR tape. A low SNR, badly captured by the drive head, will naturally generate errors in the writing. However, when an error is validated by the drive head, it does not return to the block on which the error was committed, it would take too long. The write head will directly go to the next write block and, therefore, waste writing space on a tape. This reduces its real capacity. Our Technical Hotline has received calls from MP tape users who had used only a portion of the total tape capacity due to too many write errors.

New IBM Head

- In order to address the risk of low SNR related to the track density and the system speed, IBM has developed a new head, **the Terzetto**, whose role in the development of next tape generations is so central, that we can truly speak of a major turning point in the history of tape technology. The principle of the Terzetto is simple: from now on, we will use three heads instead of two heads like the previous generations. The Terzetto is used in LTO technology, from LTO7. Traditional dual heads contained two heads: one for writing one for reading. The read head must check the writing of the first head. Moreover, the write head cannot continue writing until the read head has carried out its verification. The problem is that the head will write a track to the end of the tape and then continue to write in the opposite direction towards the beginning

of the tape. There is, therefore, a constant alternation in the properties of both Heads. By changing the writing direction, the write head will become the read head and vice versa. This implies that both heads must possess two contradictory properties: writing implies that the head injects magnetic field towards the tape, whereas reading implies that the head must pick up the magnetic fields from the tape. This double property means that these two heads can only function with a medium level of electro-magnetic properties, which is suitable for LTO5 or LTO6 technologies but not for future tape generations. The Terzetto, each head will have its specialization and will only carry out one task - the Terzetto is composed of two write heads and one read head. Each of these three heads is exclusively designed for its function and consequently has more electromagnetic properties than previous heads.

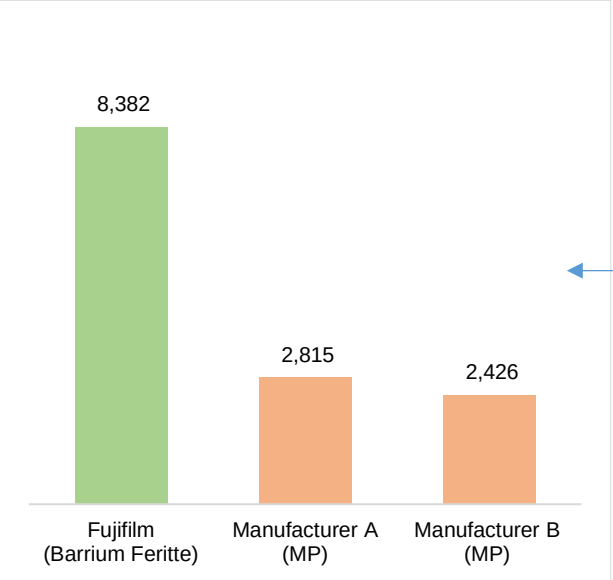
Lifespan of the Hardware

We have seen above that a higher speed can harm the SNR. Additional means which can be used to improve the capture of the signals by the head is to bring the head as close as possible to the tape. Although this solution is satisfactory, it creates a risk for the lifetime of the drive.

It is essential to avoid a contact between the head and the tape, as the head writes or reads through a magnetic field. Any contact with the tape will deposit an amount of debris and contaminants on the drive head. This debris will naturally damage the head and considerably decrease its lifespan.

We recommend the use of Barium Ferrite tapes. The greater SNR's makes it easier for the drive read to receive signals from such tapes. MP LTO tapes will be more likely to have problems in the future.

Graph to show time duration before first loss of data with LTO tapes



During an experiment, we measured how many hours we could intensively use an LTO6 drive with three different LTO6 tapes (one Barium Ferrite tape and two MPs), before noticing the first loss of capacity related to eventual read/write error corrections.

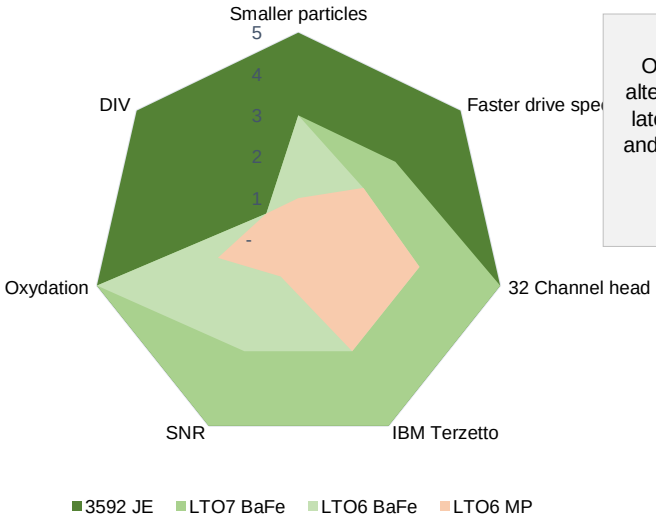
See that an LTO6 drive with BaFe cartridge can be used three times longer before encountering the same loss of performance as an LTO6 drive with MP cartridges.

Tape Protection Systems

The tape should be smooth. A tape that is too rough could cause problems for the tape head. A lubricant has been developed to serve as a buffer between tape and the head which assists in the manufacture of the latest new high capacity tapes and heads.

Summary and Conclusions

Graph to show latest history of tape technology.



On this graph, you will find an alternative way to summarize the latest history of tape technology and the technological innovations achieved by 2017.

Some explanations about the table above:

LTO6 BaFe vs LTO6 MP – Factors which differentiates these two qualities of tapes:

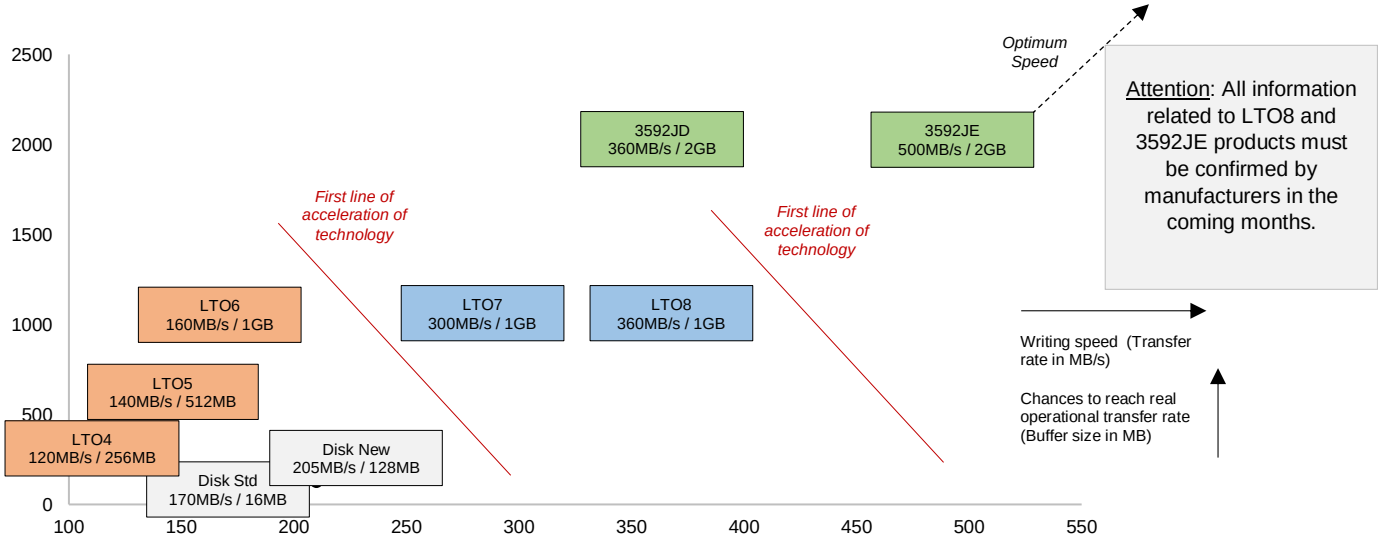
- particle size, which results in a smoother surface, contributes to better writing speed and reduces contact between the Drive Head and the tape,
- the SNR, fundamental in all (write error, recording stability, therefore real writing speed, loss of storage capacity etc ...),
- the oxidation of the PM particles, which increases the number of write errors.

LTO7 vs LTO6 – What differentiates these two tape generations:

- the Terzetto Head, of course, which improves the quality of transmission and capture of signals (better data integrity for example),
- the improvement of the SNR, thanks to the Terzetto Head,
- the use of a 32 channel head that dramatically increase the writing speed.

3592JE vs LTO:

- Smaller particles with 3592JE
- Consequence of using smaller particles is that the system will operate at a higher speed than any generation of LTO tape. See below the evolution of the writing speeds of the main data storage media:



- We can also see that a 32 channel head is capable of reaching record speeds since there is a real possibility that IBM will decide to launch the 3592JE with 500MB/s transfer rate. It is also certain that, when the time comes to produce tapes with a native capacity of 40-50TB it will be necessary to increase the writing speed and produce heads that can contain more write channels.

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