Efficient Digital Media Workflows using the Linear Tape File System (LTFS)

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Overview

- **LTFS Introduction and Overview**

  - The Digital Dilemma

  - The junction between Video and Data tapes

  - LTFS Single Drive and Library

- File-based Media Workflow Using LTFS

- Logical Copy and Physical Copy

- Future work

2011 Engineering Emmy® Award, by the Academy Of Motion Pictures, Arts and Sciences

IBM LTFS Product Debut, NAB 2010, Las Vegas

Hollywood Post Alliance Award® 2011

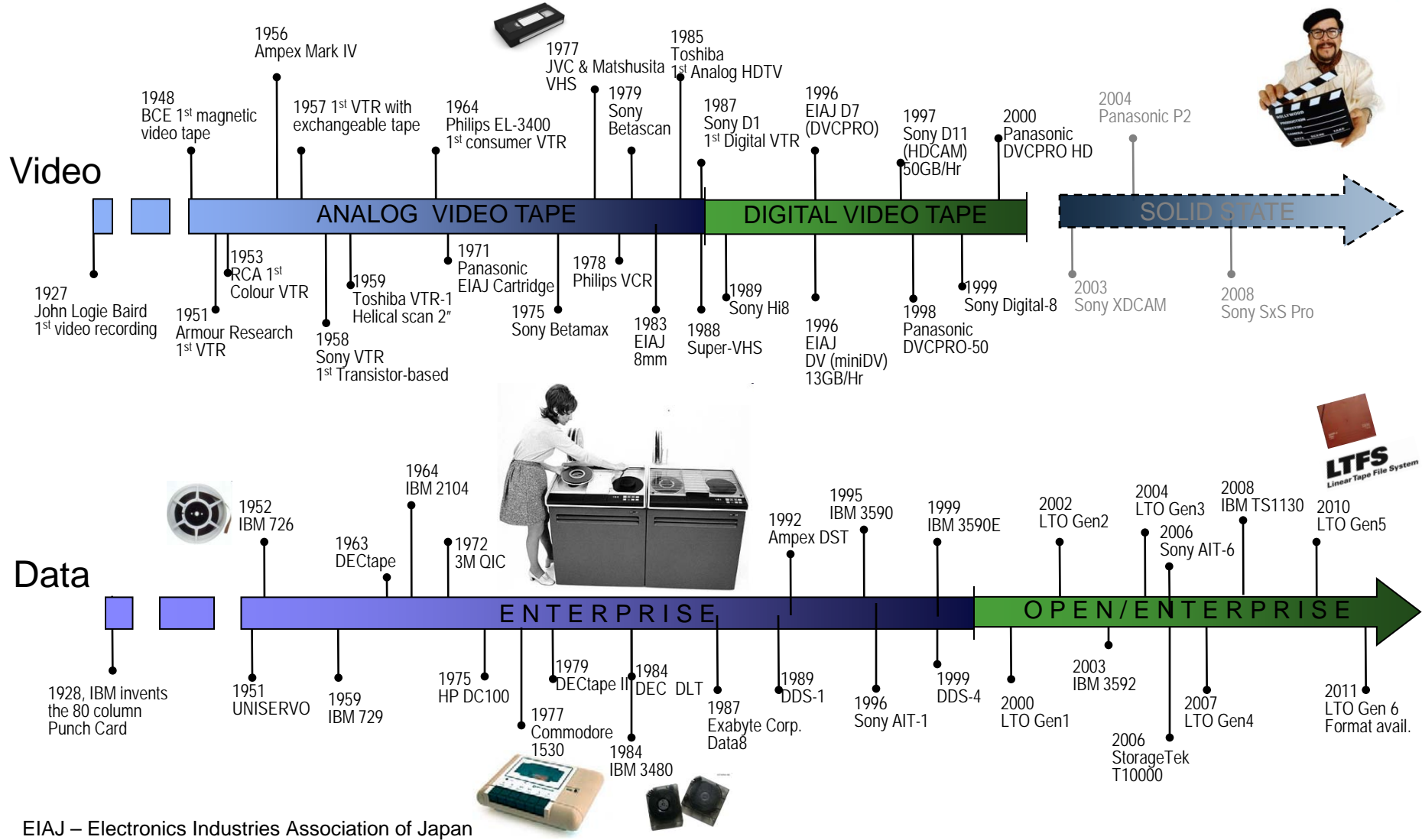PICK HIT Award®, NAB 2011, Las Vegas

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First IBM 726 Tape Unit (May 21, 1952)

➜ At 7,500 cps it was 56 times faster than punch cards

➜ Capacity in excess of 2 million digits a tape.

➜ With 100 bpi it could store the equivalent of 35,000 punch cards on a single, 1200 foot reel.

➜ 100% of the tapes were inspected with a microscope and knife…defects would be cut out and sent back to the manufacturer

60+ Years of Magnetic Data and Video Tapes
(partial list)

Video

ANALOG VIDEO TAPE | DIGITAL VIDEO TAPE | SOLID STATE

Data

ENTERPRISE | OPEN/ENTERPRISE

1956
Ampex Mark IV

1948
BCE 1st magnetic
video tape

1957 1st VTR with
exchangeable tape

1964
Philips EL-3400
1st consumer VTR

1977
JVC & Matshusita
VHS

1979
Sony
Betascan

1985
Toshiba
1st Analog HDTV

1987
Sony D1
1st Digital VTR

1996
EIAJ D7
(DVCPRO)

1997
Sony D11
(HDCAM)
50GB/Hr

2000
Panasonic
DVCPRO HD

2004
Panasonic P2

1927
John Logie Baird
1st video recording

1953
RCA 1st
Colour VTR

1951
Armour Research
1st VTR

1959
Toshiba VTR-1
Helical scan 2″

1958
Sony VTR
1st Transistor-based

1971
Panasonic
EIAJ Cartridge

1975
Sony Betamax

1978
Philips VCR

1983
EIAJ
8mm

1988
Super-VHS

1989
Sony Hi8

1996
EIAJ
DV (miniDV)
13GB/Hr

1998
Panasonic
DVCPRO-50

1999
Sony Digital-8

2003
Sony XDCAM

2008
Sony SxS Pro

1964
IBM 2104

1952
IBM 726

1963
DECtape

1972
3M QIC

1992
Ampex DST

1995
IBM 3590

1999
IBM 3590E

2002
LTO Gen2

2004
LTO Gen3

2008
IBM TS1130

2010
LTO Gen5

2006
Sony AIT-6

LTFS
Linear Tape File System

1928, IBM invents
the 80 column
Punch Card

1951
UNISERVO

1959
IBM 729

1975
HP DC100

1979
DECtape II

1984
DEC DLT

1989
DDS-1

1996
Sony AIT-1

1999
DDS-4

2000
LTO Gen1

2003
IBM 3592

2007
LTO Gen4

2011
LTO Gen 6
Format avail.

1977
Commodore
1530

1984
IBM 3480

1987
Exabyte Corp.
Data8

2006
StorageTek
T10000

EIAJ – Electronics Industries Association of Japan

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The Digital Dilemma [The S&T Council of the Academy (AMPAS), 2008]

The Digital Workflow Transformation: The Broadcast and Cinema industries change from video-tape to file-based workflows.

There are many benefits to file-based workflows.

However: "… a totally committed, binding switch to digital has one major drawback: the absence of guaranteed, long-term access to created moving image and sound content."

Requirement: Archive for 100 years with no loss.

- ❑ Manage future costs
- ❑ Minimize #migrations and disruption
- ❑ Minimize risk (e.g., single-vendor)

A Media Archive at NHK, Japan

LTO Tape & Roadmap

❑Open standard by LTO Consortium: IBM, HP, Quantum.

❑Dominates data tape market

❑Gen-5 innovation of Dual Partitions enables LTFS.

❑Backward compatibility
(Read: 2 Gen-s back, Write: 1 Gen. back)

❑Forward Roadmap

ULTRIUM LTO **Eight-Generation Roadmap**

	Generation 1	Generation 2	Generation 3	Generation 4	Generation 5	Generation 6	Generation 7	Generation 8
					Partitioning	Partitioning	Partitioning	Partitioning
					Encryption	Encryption	Encryption	Encryption
			WORM	WORM	WORM	WORM	WORM	WORM
Compressed Capacity	200 GB	400 GB	800 GB	1.6 TB	3 TB	8 TB	16 TB	32 TB
Native Capacity	100 GB	200 GB	400 GB	800 GB	1.5 TB	3.2 TB	6.4 TB	12.8 TB
Compressed Data Rate	up to 40 MB/s	up to 80 MB/s	up to 160 MB/s	up to 240 MB/s	up to 280 MB/s	up to 525 MB/s	up to 788 MB/s	up to 1180 MB/s
Native Data Rate	up to 20 MB/s	up to 40 MB/s	up to 80 MB/s	up to 120 MB/s	up to 140 MB/s	up to 210 MB/s	up to 315 MB/s	up to 472 MB/s

Note: Compressed capacities for generations 1-5 assume 2:1 compression. Compressed capacities for generations 6-8 assume 2.5:1 compression (achieved with larger compression history buffer).
Source: The LTO Program. The LTO Ultrium roadmap is subject to change without notice and represents goals and objectives only.
Linear Tape-Open, LTO, the LTO logo, Ultrium, and the Ultrium logo are registered trademarks of HP, IBM and Quantum in the US and other countries.

Dual-Partition Tape – A logical view

BOT ←   EOT →

Partition 0

Guard Wraps

Partition 1

LP2   LP3   LP4
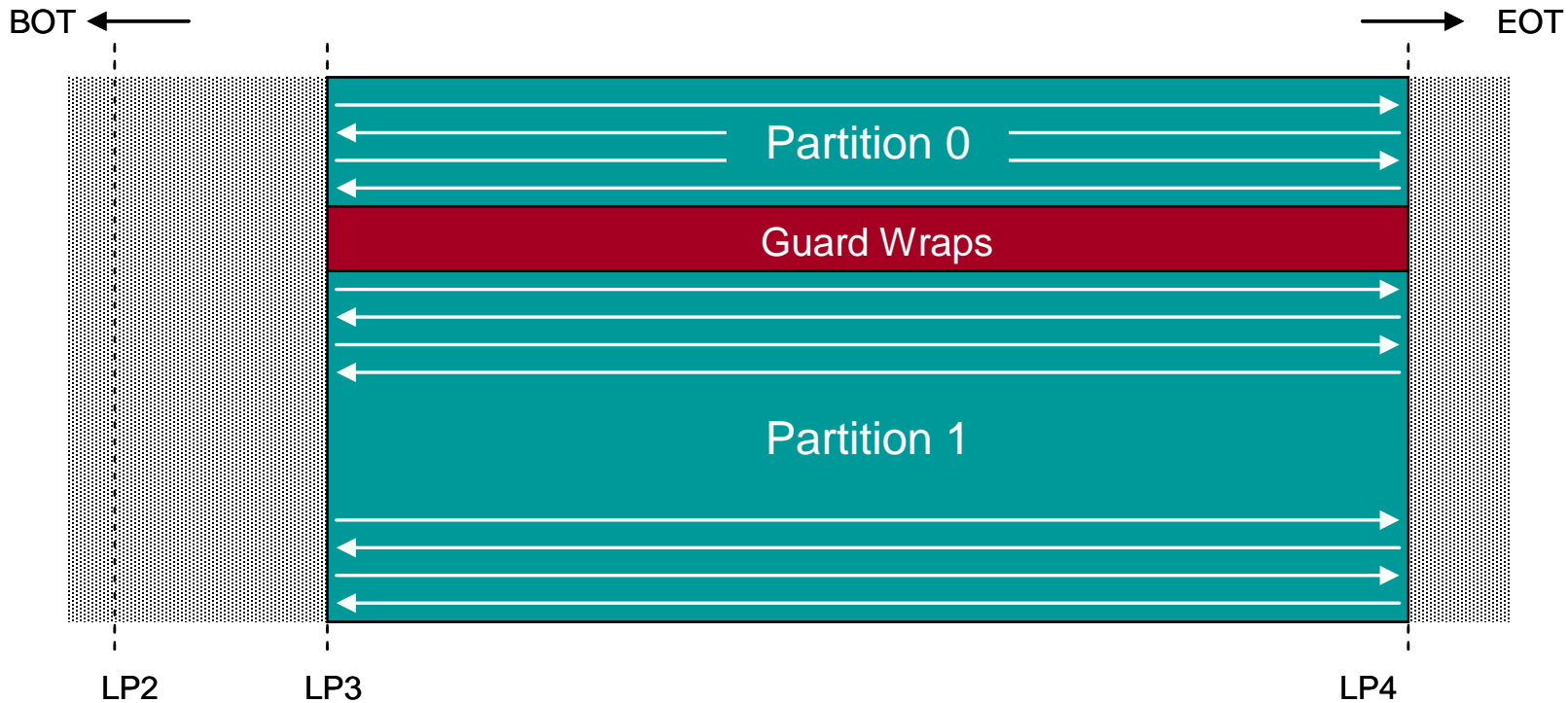
❑ Index partition: 2 wraps (about 37 GB)

❑ Data partition: 76 wraps (95% of 1.5 TB)

❑ Guard Wraps: 2 wraps (unused)

Index Arrangement on LTFS Tape

Index Partition

LA BE L	HE AD ER	f4	f5	INDEX	

Data Partition

LA BE L	HE AD ER	INDEX	F1	F2	F3	INDEX	F3(Modify)	INDEX	F6 F7	F8	INDEX	
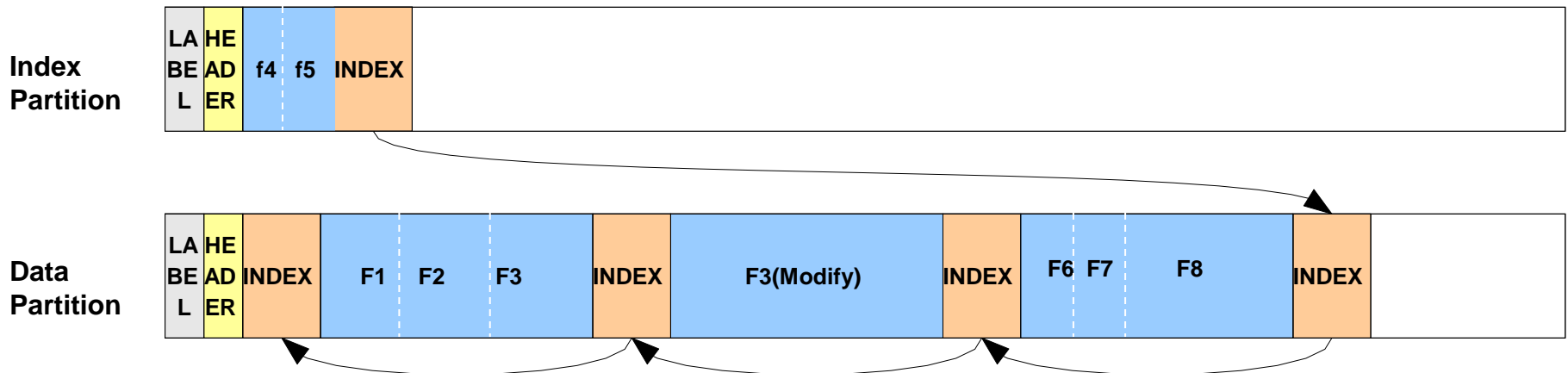
Tape contains File/Directory Index in Index Partition

Index kept as a human-readable XML schema

Keeps multiple "generations" (older versions of XML schema)

Links back to previous index tables. Supports rollback (at mount)

Automated detection and recovery from un-mount (*ltfsck*)

Supports user metadata as Extended Attributes (EAs)

LTFS Open format: http://www.trustlto.com/LTFS_Format_To%20Print.pdf

LTFS Implementation Architecture (Linux)

Application or Utility

open/close
read/write/seek
create/delete
etc.

LTFS

Directory operations

In-memory Directory

I/O operations

mount

User Space

Kernel Space

VFS Layer

Ext3   XFS   GPFS

FUSE

Device Driver

Host Bus Adapter

LTO

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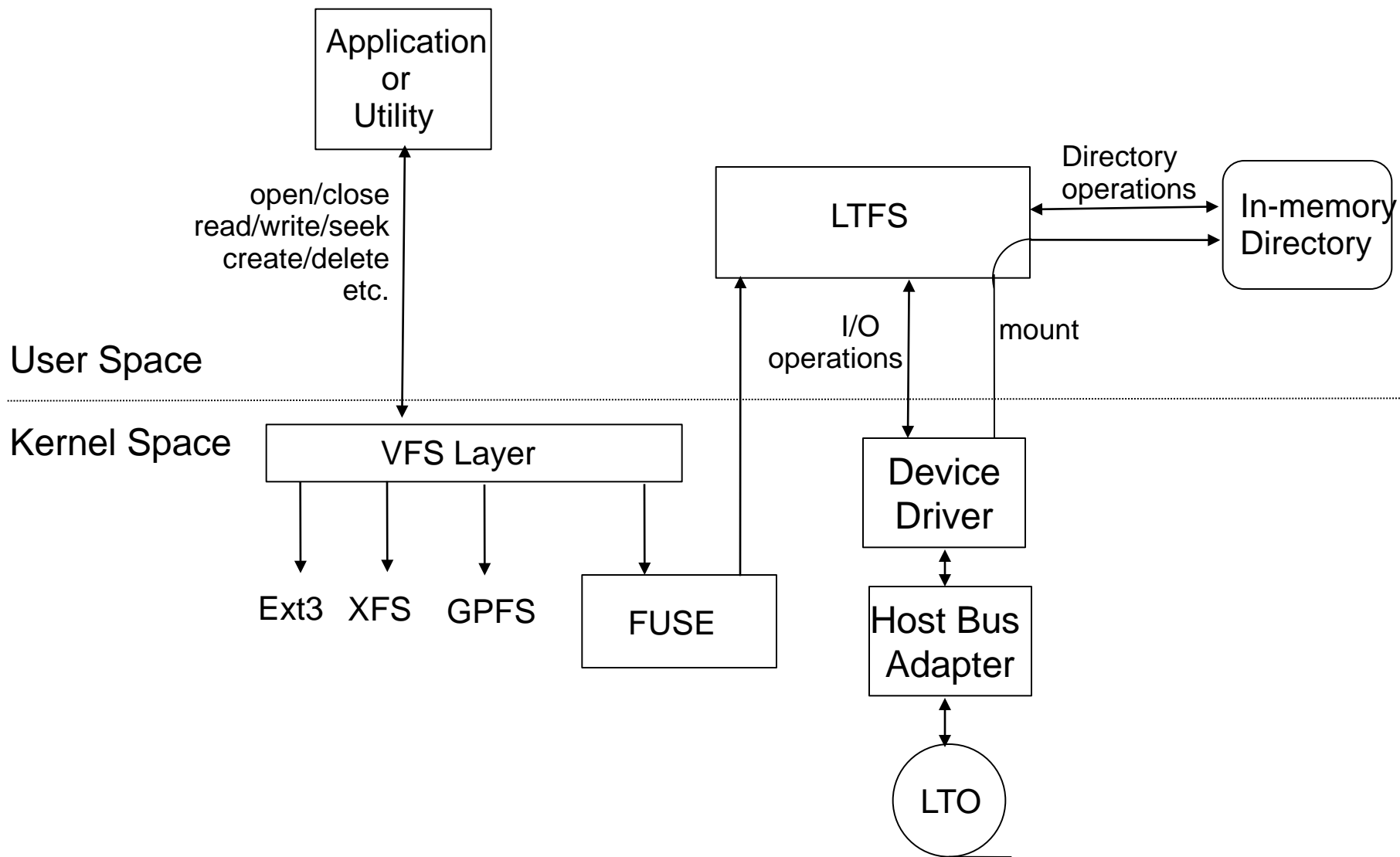
LTFS Overview

- An open, non-proprietary tape format
  - Open source code and specification
  - Invented by IBM Almaden Research Center
- File system support for:
  - MAC, Linux, Windows.
- Multi-vendor support
  - Supported by the LTO Consortium
  - Media by 5 manufacturers
- Self-describing
  - Each cartridge has index of files on tape
- Mount and export as other file systems

Enabling file based digital workflows and unlocking the digital tape value proposition for all phases of the media production, distribution, and archive life cycle

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LTFS in Standalone Drive Mode
(Open Source: www.ibm.com/systems/storage/tape/ltfs)

❑ Support at OS level for file commands (POSIX) – open, read, write, seek,…

   ❑ Enables standard applications to write/read LTFS tapes

   ❑ Directories, Files, command-line and GUI file explorers

❑ Makes tape self-describing, portable, interchangeable, and long-term archive-able storage media

❑ For M&E:

   ❑ One storage format for all video & multimedia data types

   ❑ Self-describing: separate storage format from OS & storage system
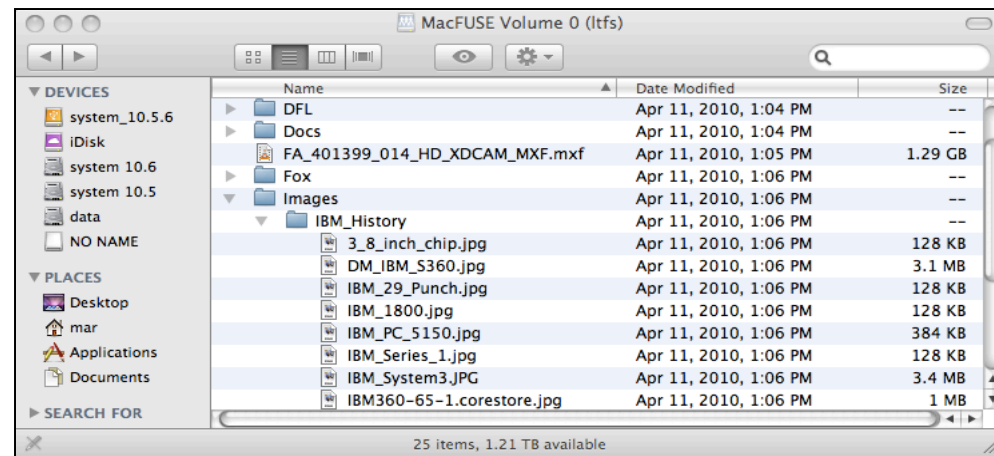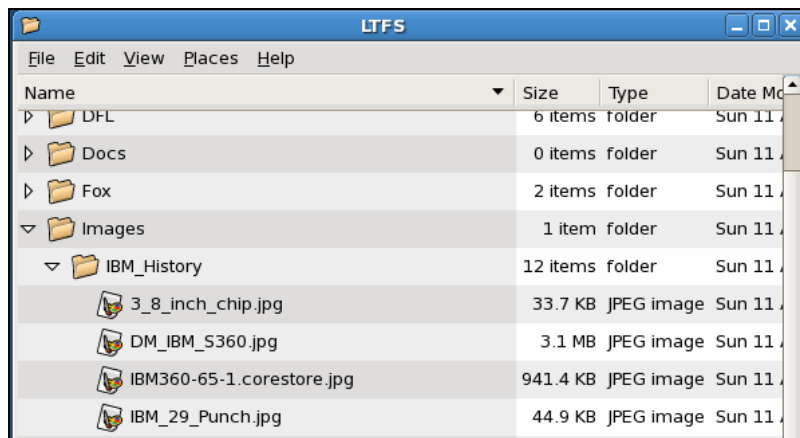
LTFS in Library Mode

❑ Mount Library, not Drive

❑ LTFS presents directory structure of entire library

   ❑ Each volume shows as separate file system directory

   ❑ LTFS Caches Index in memory of each tape read/written

❑ After mount, all tape directories are viewable, searchable without mounting any tape

   ❑ Meta-data operations (browse directory, filename search) do not require tape movement

   ❑ LTFS drives automation to mount tape on file read/write on request

❑ Supported across entire automation platform

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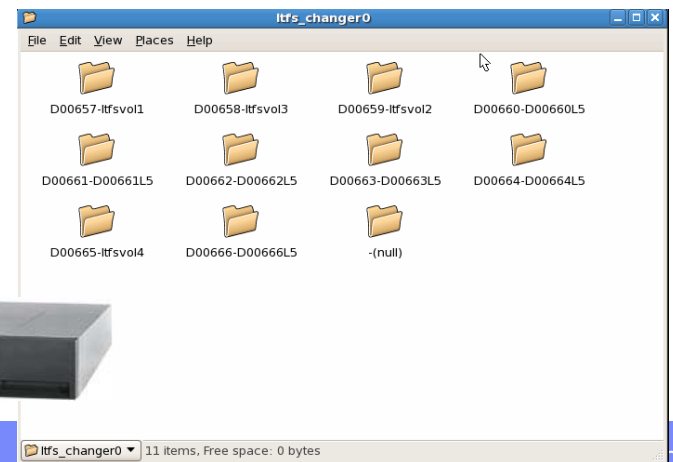
What LTO/LTFS is not …

❑ The file system looks, to both users and applications, as if it's a Hard Drive. However seek time is still of a tape

   ❑ Some applications might time-out while waiting for seek

   ❑ For efficient use, user must be educated of the tape media

❑ LTO is an append only tape format.

   ❑ LTFS allow to modify files by replacing, splitting and adding extents

   ❑ To reclaim released space, entire tape need to be erased (active set copied)

❑ Better read one file at a time (can write multiple) otherwise might observe a lot of tape seeking…

❑ Beware of any indexing applications "peeking" at files (e.g., file search indexers, thumbnails generators, …)

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Enables File Based Digital Workflows

Today

Capture

Ingest

Reader 1
Reader 2
Reader 3
.
.
.
Reader n

Video Tape Formats, XDCAM, Flash, Removable Hard Drives

Media Asset Management System

File copy or physical

NLE Storage

LTO Proprietary #1

NLE System

Disk Storage

File copy or physical

Import/ Export

Process

2nd Archive Management System Vendor A

LTO Proprietary #2

2nd Archive Management System Vendor B

LTO Proprietary #3

Archive Management System Vendor A

LTO Proprietary #2

With **LTFS** Linear Tape File System

Capture

Ingest

Media Asset Management System

File copy or LTFS

LTFS Linear Tape File System

LTO5 (50 hours/cartridge) D2M cassette (1.5 hours/cassette) LTO Uses 1/200th vault space

File copy

NLE System

Working Disk Storage

File copy

Archive Management System LTFS Vendor A

2nd Archive Management System LTFS Vendor A or B

LTFS Linear Tape File System

LTFS Linear Tape File System

LTFS Linear Tape File System

Video Capture to LTO/LTFS

Access any file, directly on tape, by any application

FOR-A LTR100-HS

FOR-A LTR120-HS

BroadcastEngineering PICK HIT 2010

Ingest, workflow

Work with files & tapes

Put content on tapes

Transport tapes

Servers

LTO-5 / LTFS

Put tape into archive

Portable

1-Beyond Wrangler FlexVTR

Archive-able

IBM TS3500
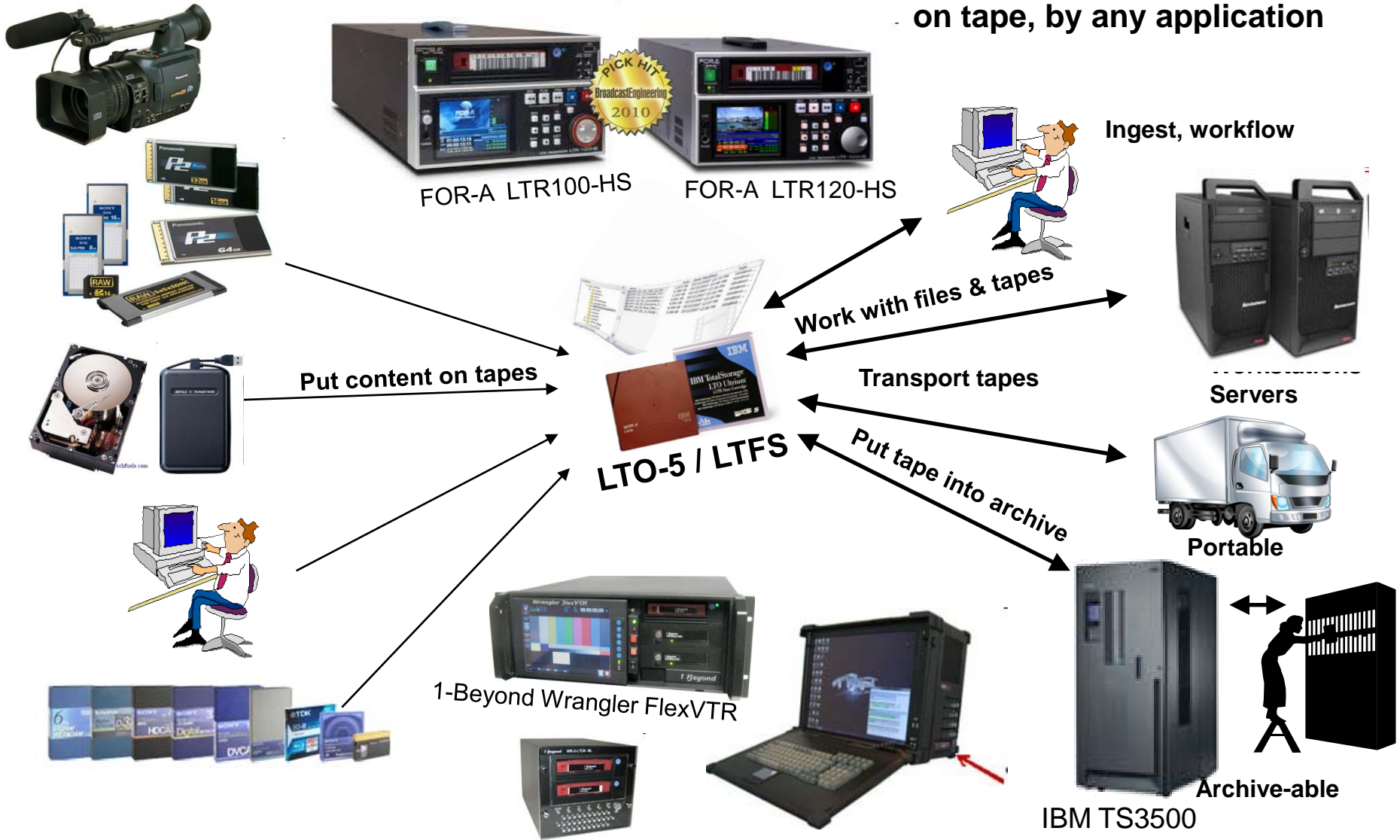
Media Workflow: From Cassette to File-Based

Before: Digital Video Cassette workflow

Pros: portable AND long term archive-able storage media

Cons: proprietary storage, single video format, very expensive, slow access, metadata on separate media.
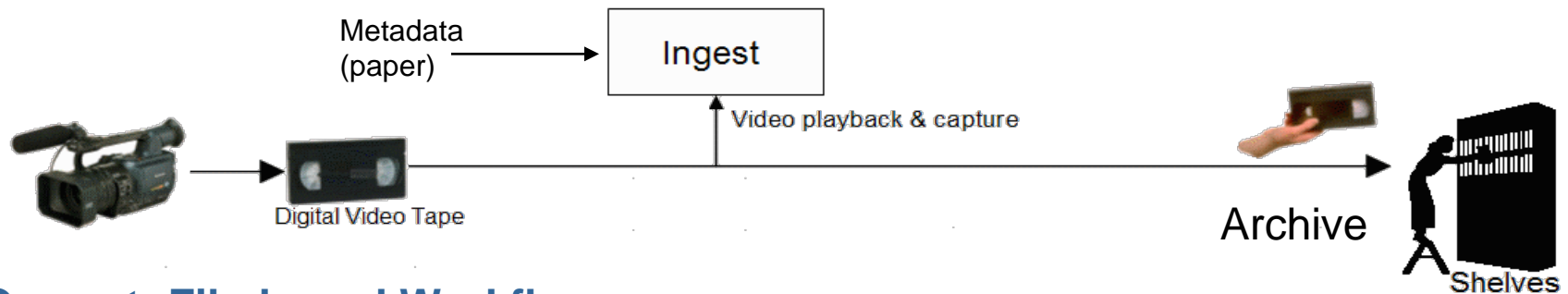
Current: File-based Workflow

Pros: any FS storage, any video format, portable, easy access, metadata.

Cons: many FS storage media, portable is not archive-able, copy everything several times, proprietary archive format

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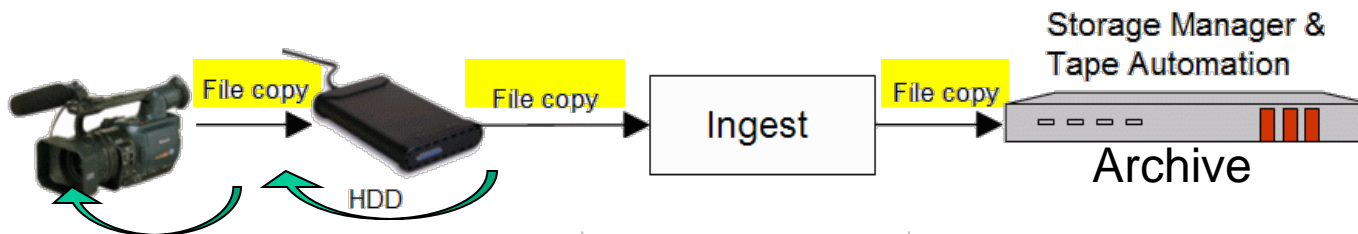
File Based Workflow With LTFS:

Pros: open storage media, any video format, portable, metadata, archive-able,
   cost-effective (enjoy large-scale economy of data storage)
Cons: more IT-savvy than video tape, might cause long file-seek times (naïve use).

Ingest to Archive:
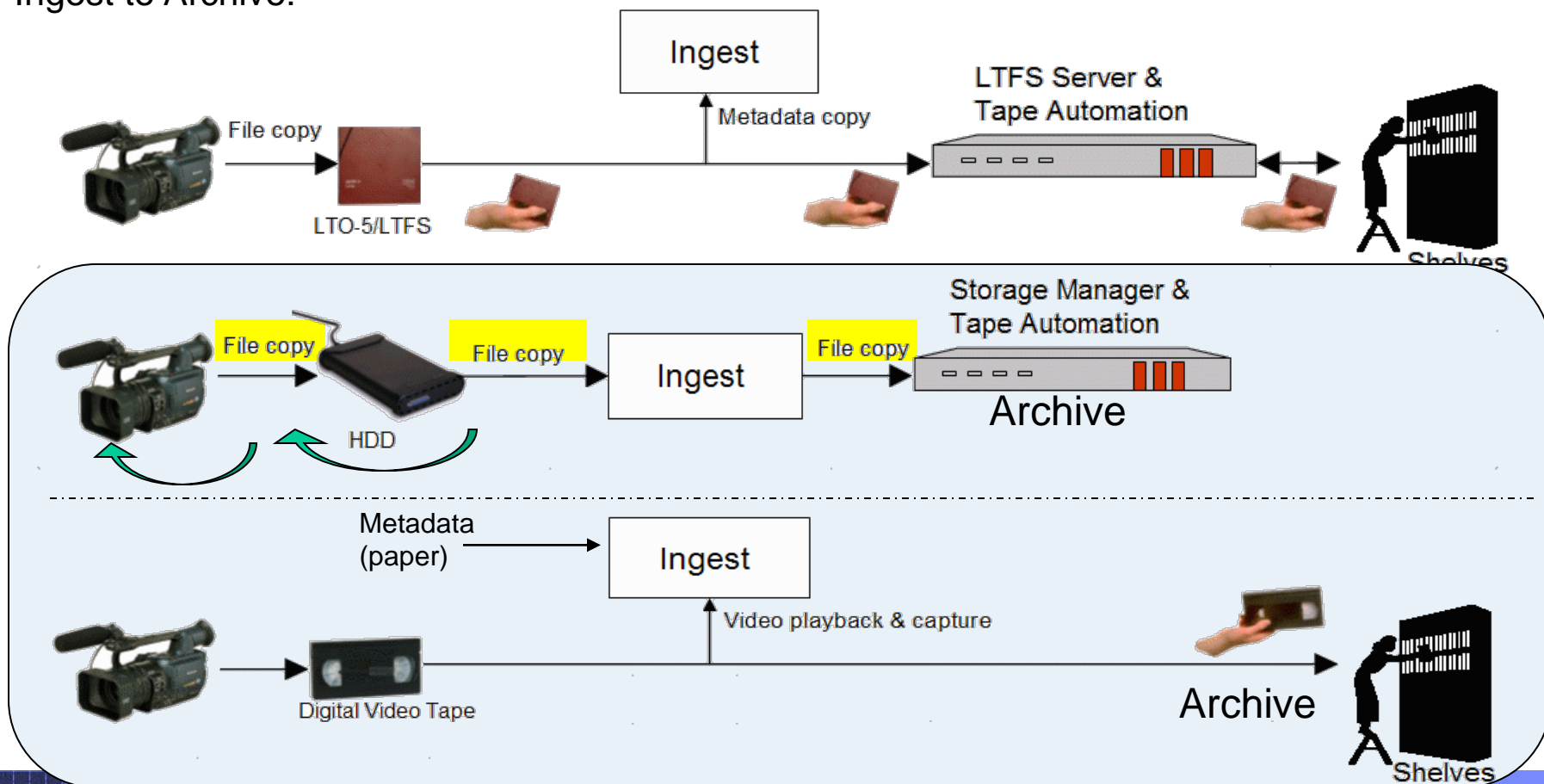
File Based Workflow With LTFS: MXF Metadata

Pros: open storage media, any video format, portable, metadata, archive-able, cost-effective (enjoy large-scale economy of data storage)

Cons: more IT-savvy than video tape, might cause long file-seek times (naïve use).

Ingest to Archive:

Ingest

Metadata copy

File copy

LTO-5/LTFS

LTFS Server & Tape Automation

Shelves
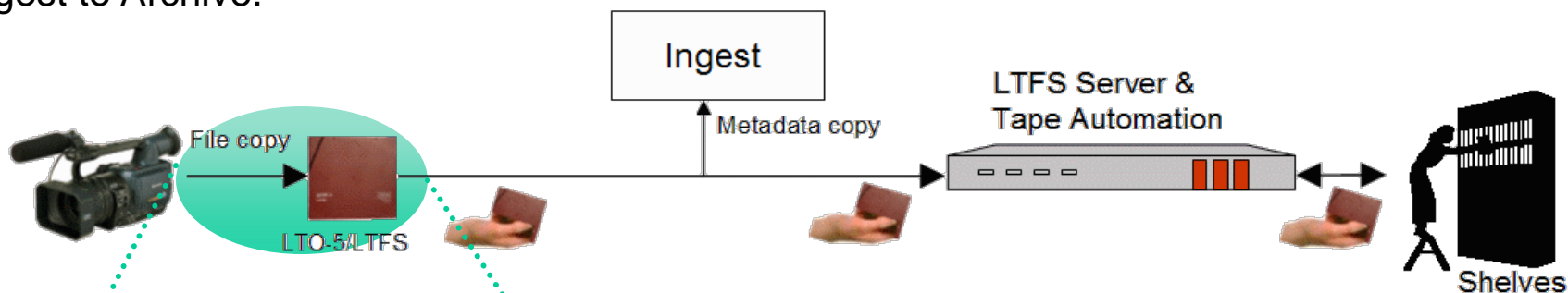
MXF Metadata
(Material Exchange Format)

Metadata Generation

Source Material

(MPEG-2, H.264, …)

MXF file wrapper

Video Preview

LTO-5 / LTFS

Video Storyboard

MXF partial video restore

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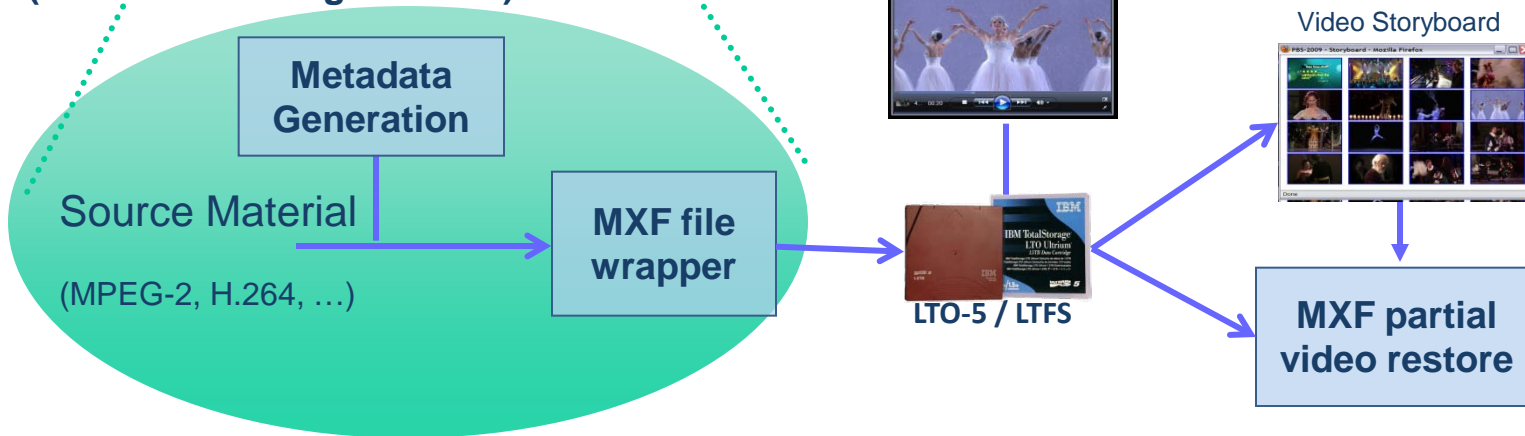
Logical Copy and Physical Copy

Logical Copy (IBM LTFS Copy Tool)	Physical Copy (IBM ITDT v6.1)
Copy files and directories (like cp) (tape->tape, disk->tape, tape->disk)	Duplicate tapes (like dd for LTFS) (tape->tape, image->tape, tape->image)
Optimal copy by files' order on tape	Copy blocks by sequential order
Preserve directories, metadata, EAs	Preserve partition, location
Copy all/selected files (console/batch)	Copy entire tape content
Copy current files, defrag	Preserve multiple extents
Reclaim tape space	Preserve deleted files & rollback

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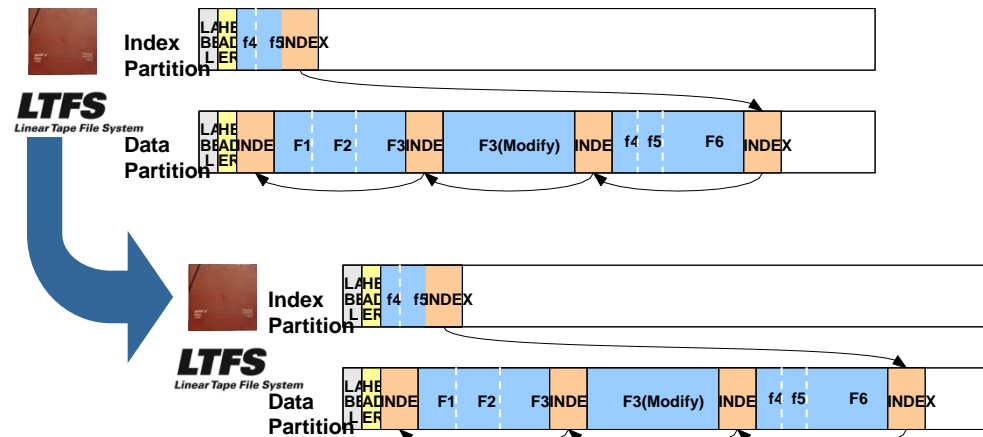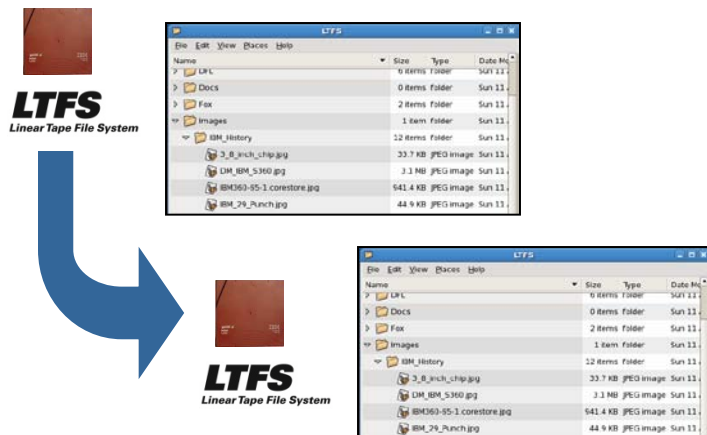
Logical Copy

❑ Operates at files level on LTFS-mounted tape/s

❑ Interactive mode: Files specified by regexp, for example:

```
ltfscp -srcpath=/mnt/LTFS/proj1 -dstpath=~/proj1 -srcspec=*.dpx
```

❑ BATCH mode: Files (and options) specified by an XML script:

```
ltfscp -batchfile=~/proj1/batch21.xml
```

❑ Optimize copy performance:
Reorder files list using files' order on tape to minimize total seek time

❑ Preserve file attributes, dates, and extended attributes

❑ Space reclamation (copy only current files), file de-fragmentation

❑ Multi-buffer, multi-file, multi-threaded copy (maximize tape streaming)

❑ Use cases:

❑ high performance batch jobs for archive and restore; tape reclamation, data migration

Logical Copy – batch mode

- Can specify any list of files
- Different levels of logs/reports
- Most suitable for system-generated batch jobs

In this example:

- Traverse directories recursively
- Allow use of sparse files
- Copy two groups of files, one *.dpx and the second contains two specified files
- All warnings are logged in a log file

```xml
<?xml version="1.0" encoding="UTF-8"?>
<ltfscpspec version="1.0">
  <params>
    <loglevel>WARNING</loglevel>
    <recursive>enable</recursive>
    <sparse>enable</sparse>
  </params>
  <data>
    <file>
      <srcpath>/data/proj1</srcpath>
      <dstpath>/mnt/ltfs/proj1</dstpath>
      <srcspec>*.dpx</srcspec>
    </file>
    <file>
      <srcpath>/data/proj1</srcpath>
      <dstpath>/mnt/ltfs/proj1/doc</dstpath>
      <sf>copyright.doc</sf>
      <sf>readme.doc</sf>
    </file>
  </data>
</ltfscpspec>
```

Physical copy

- ❑ Copy all blocks sequentially by source partition & block order
- ❑ Multi-buffers, multi-threading architecture, maximize tape streaming
- ❑ While copying, adapt index blocks to comply with target tape
- ❑ Copy verification (optional)
- ❑ Handles and adapt LTFS information in CM (Cartridge Memory)
- ❑ Can create a disk image of an LTFS tape
  - ❑ Use in a single-drive mode
  - ❑ Use to copy tapes to remote location (archive mirror)

Capture

MASTER

LTFS Linear Tape File System

Ingest station

Transfer Tape's Image File

Network

Archive System LTFS

Remote Archive Backup System

MASTER COPY

LTFS Linear Tape File System

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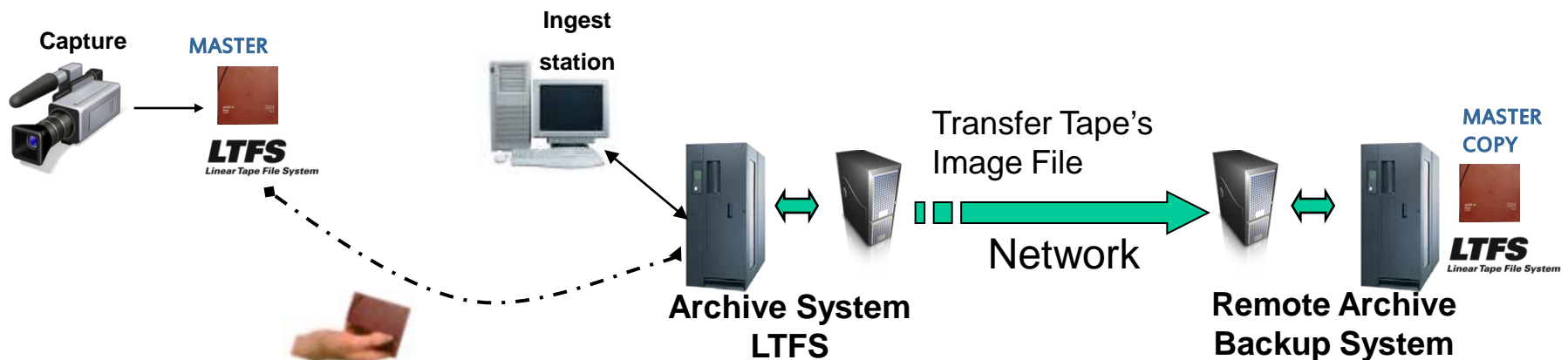
Case Study: Thought Equity Motion
Video Archiving in the Cloud

Challenges

- Needed a low cost delivery platform for enterprise scale Video Supply Chain as a Service
- Information growth of ~100 TB per month
- Easy self-serve access required by clients

Solution

- IBM Linear Tape File System at several global locations, including some client facilities
- IBM System Storage® TS3200 Tape Library, LTO®-5 tape drives

Benefits

- Opened up new business opportunities
- Enabled more predictable and transparent pricing for clients
- Portable, interoperable, scalable, cost-effective data protection and long-term storage

*'LTO 5 and LTFS significantly reduce the ancillary costs around storage. This is a **real game-changer** from IBM'*

Mark Lemmons

CTO, Thought Equity Motion

See TEM with LTFS on Youtube: http://www.youtube.com/watch?v=M7w0irkQni4

LTFS Ecosystem
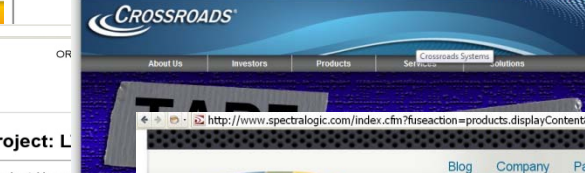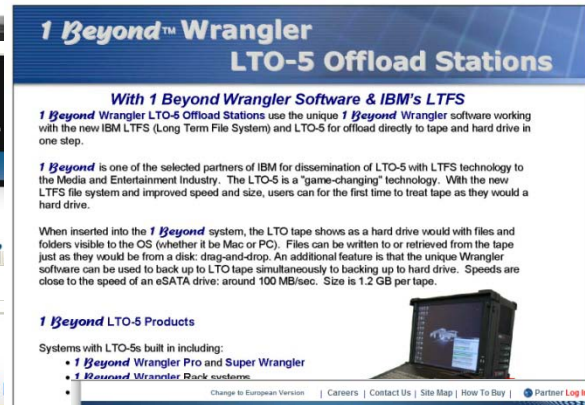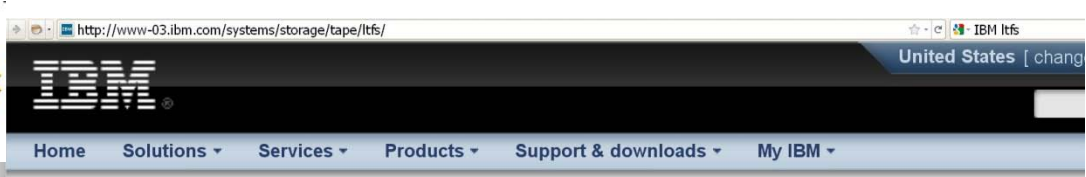
Challenges and Future Development

❑ LTFS Standardization

❑ Systems and Applications

    ❑ Ingest/migrate and catalog.

    ❑ transport, backup/restore, archive.

❑ Support large tape archives (100K-1M tapes)

    ❑ Distributed across servers, vendors, geographies

    ❑ Access via Hierarchical Storage Management (HSM)

❑ Domain-specific devices (e.g., video transcoding)

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Acknowledgements

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