Digital Magnetic Storage on Flexible Media -

Magnetic Tape as the Archival Media

FujiFilm IT Executive Summit
Houston, Texas October, 2013

Dr. Richard Bradshaw
Tape Technology Consulting
Tucson, Arizona USA
Total bits generated worldwide in 2007
\[ \sim 2.25 \times 10^{21} \text{ bits} \ (281 \text{ exabytes}) \]
growing ten fold every five years from 2004-2007, now growing even faster

in 5 years the worldwide collection of bits will exceed \[ 6.02 \times 10^{23} \text{ bits} \]
(Avogadro's Number)

* INSIC Tape Storage Roadmap 2012
The Digital Universe *

- total data generated exceeds available storage for all formats

- more than half the digital information will not have permanent storage and will be lost!

- by 2020 there will be at least 40 quadrillion storage "containers" needed to store the active information
Archival Storage of Tape

Where does Tape Fit in?

Why is Tape the Best Media for long term storage?
Archival Storage of Tape

• Tape is the ONLY media with proven, truly long term data storage and recovery.

• Tape Data Recovery & Failure Analysis
   a little history to prove the point!
IBM 726 Tape - 1952

single data bit

human hair
What's the Point?

- a fifty year old recording still retains the written data signal

- the tape could be unspooled and read

- But it couldn't be made human readable because neither the application program or a drive to read the data with were available.
IBM 726 Tape - 1952

& IBM TS1120 - 2006

726 Tape Data Bits

Human Hair
Archival Storage of Tape

So how do tapes fail & what is the risk for very long term storage?

- Tapes fail due to improper design
  - Chemical degradation
  - Unstable particles
  - Poor mechanical properties

- Tapes can wear out

- Tapes can be damaged or erased
What is the Expected Life of Current Tape?

- current particles & binders are chemically stable
- current substrates mechanically stronger & more stable than those used even ten years ago
- current tapes are less sensitive to environmental induced degradation
Archival Storage of Tape

- most tapes brought in for data recovery were over written or damaged and not at risk due to tape degradation

- this is true for even 20+ year old 3480/3490 media which used the very reactive chromium dioxide particles for the magnetic layer
Archival Storage of Tape

What has experience taught us?

- correct chemical and mechanical formulation can produce tapes that will retain the recorded signal for more than 30 years - demonstrated!
- most data loss is due to transport or handling
- robotic libraries provide the best storage, handling and data integrity checking solutions
Archival Storage - The Real Issues

- obsolescence of formats, play back devices and application software occurs faster than signal decay or data loss on tape

- management of the metadata describing the data and its origin and history is likely more important than the data

- the sheer size of almost any collection of data makes migration and management seem a very daunting if not impossible task.
The Future of Tape

What's Next?

- >60 TB capacity/cartridge by 2020
- increased virtualization and format migration management, transparent to user
- media reuse and investment protection
- improved (easier) data management
- encryption without a performance hit
- cost effective "at rest" remote storage
- tape creation & migration without physical shipment of tapes
One Final Thought ..... 

Remember this ... 
There is NO Backup for Tape!
January 28, 1986 - the Space Shuttle *Challenger* carrying what would have been the first civilians into Earth Orbit was destroyed shortly after lift off.
Seal Failure during Lift-Off
The Flight Recorders from the Shuttle were recovered after six weeks exposure to salt water at a depth of 90 feet.

Tapes from all three of the shuttle recorders were recovered:

Payload (cargo), Ops-1 (engines) and Ops-2 (voice and crew function)
Reel to Reel Recorders

Magnesium alloy reels

gamma iron oxide Ampex media

Reels mechanically damaged and corroded

NASA unwinding unsuccessful
Recovery of the Space Shuttle "Challenger" Flight Recorder Tapes

A Team Effort of IBM Corporation, Tucson, Arizona
June 1986
Chemical Analysis

- Magnesium hydroxide salt encrusted
- Calcium salts and biological deposits
- Organic crystalline deposits (substrate and binder degradation products)

- Significant binder and substrate degradation
Mechanical Analysis

- very low coating adhesion
- poor mechanical integrity

But: dynamic mechanical analysis (DMA) indicated sufficient binder integrity to make separation of the tapes possible
Initial Assessment

- magnetic layer strongly adhered to the backcoat
- magnesium hydroxide primary “glue”
Process Development/Verification

- unrecorded supply reel from payload recorder was used to develop a recovery procedure
- separated tape was written several times and returned to NASA
Data Tape Recovery – Ops-1
Data Tape Recovery – Ops-2
Recovery Process

- rinse tank and collapsible, spring-loaded hub designed and built
- method to remove damaged reel from tape perfected
- chemical rinse and re-lubrication method developed
IBM Model Shop Flange Removal
Lower Flange Removal
IBM Model Shop Hub Removal
Ops-2 Tape, Flanges Removed
Ops-2 Tape, Flange & Hub Removed
Ops-2 On Delrin Spring-load hub
Transferred to Rinse Tank
Chemical Rinse Process
Treated Tape – Ready to Unwind
Unwind Fixture
Treated Tape Unwind
Readback Transport
Signal Processing
"... the restoration by IBM engineers was a 'minor miracle.'"

CHEMICAL AND ENGINEERING NEWS
August 25, 1986

Technology

Acid baths help recover Challenger tapes

By Jim Erickson
The Arizona Daily Star

After three months of work by 16 IBM Tucson engineers, it all came down to a two-syllable exclamation by space shuttle Challenger pilot Michael J. Smith: "Uh-oh!"

Smith's remark, heard on a tape that was restored by IBM engineers at the company's General Products Division laboratory on Rita Road. A transcript of the intercom tape was released by NASA earlier this week.

"It's clear that without the IBM (restoration) process, those tapes and that information would have been lost because the tape reacted with the reel to create a

(A NASA official quoted in The Washington Post concerning IBM Tucson's restoration of the Challenger intercom tapes.)

A minor miracle

IBM engineers defy odds—help save Challenger tapes
Challenger crew alive after blast, NASA says

By Paul Recer
The Associated Press

SPACE CENTER, Houston — Space shuttle Challenger pilot Michael J. Smith exclaimed “Uh-oh!” at the moment the spacecraft exploded, and some of the crew apparently lived long enough to turn on emergency air packs, NASA said yesterday.

Smith's remark, heard on a tape of the shuttle's intercom system, was the first indication that any of the seven astronauts killed may have been aware of the Jan. 28 disaster, the worst in the history of space exploration.

The astronauts probably survived the explosion and breakup of the shuttle orbiter and could have had 6 to 15 seconds of “useful consciousness” inside the crew compartment after the blast, said Dr. Joseph Kerwin, an astronaut-physician who investigated the cause of death for the crew.

The force of the crew compartment's hitting the ocean was so destructive, however, that the precise cause of death for the crew could not be determined, he said.

The intercom tapes, which include enthusiastic chatter among the crew about the moments after liftoff, were recovered from the wreckage of the Challenger and analyzed by National Aeronautics and Space Administration and IBM engineers. (Some of the IBM work was done at the company's Tucson plant.)

The tape, a transcript of which was released by NASA yesterday, offered no evidence that any crew members other than Smith knew anything was abnormal prior to his single exclamation 73 seconds after launch — the very second that ground controllers lost communication with the craft.

Previously, the last known words from the Challenger were those heard from Commander Francis R. "Dick" Scobee to ground controllers, when he responded "Roger, go at throttle up," confirming that the shuttle's main engines had been raised to full power.

School teacher Christa McAuliffe and mission specialists Ronald McNair and Gregory B. Jarvis are not heard on the recording.

NASA said the three "could monitor all voice activity but did not make any... comments."

Admiral Richard H. Truly, associate administrator for space flight, said it was not unusual for there to be no comment from crew members.

See CHALLENGER, Page 2A
Challenger Tape Recovery Team

Ed Bartkus, SEM, tape handling
Ric Bradshaw, chemical process
Blair Finkelstein, signal capture and copying
Clem Kalthoff, vessel & support hub design

Resources & technical support of entire IBM Tucson Laboratory & Model Shop