College of Information Studies

University of Maryland Hornbake Library Building College Park, MD 20742-4345

Storage and Preservation

Week 3

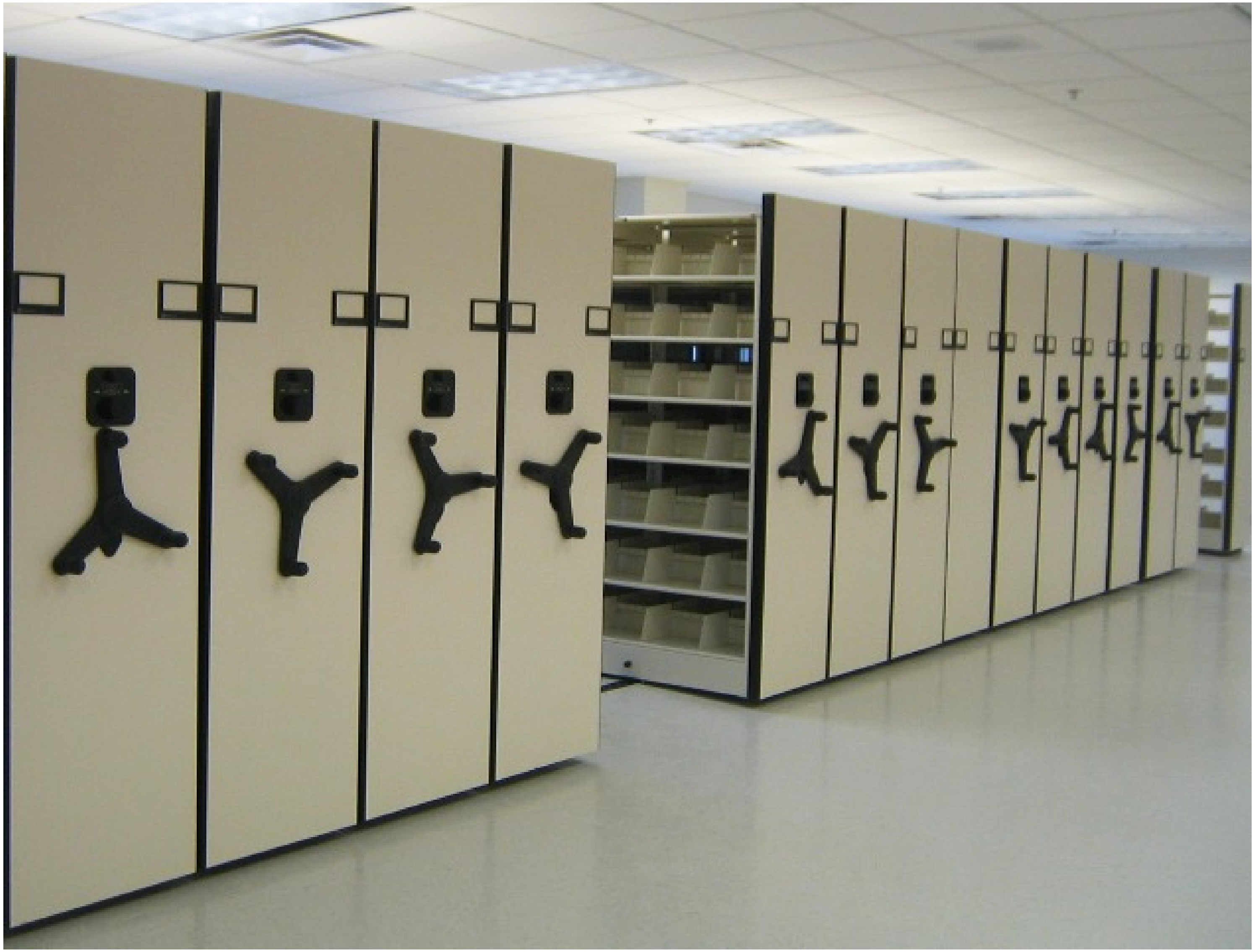
LBSC 671

Creating Information Infrastructures

Physical Storage

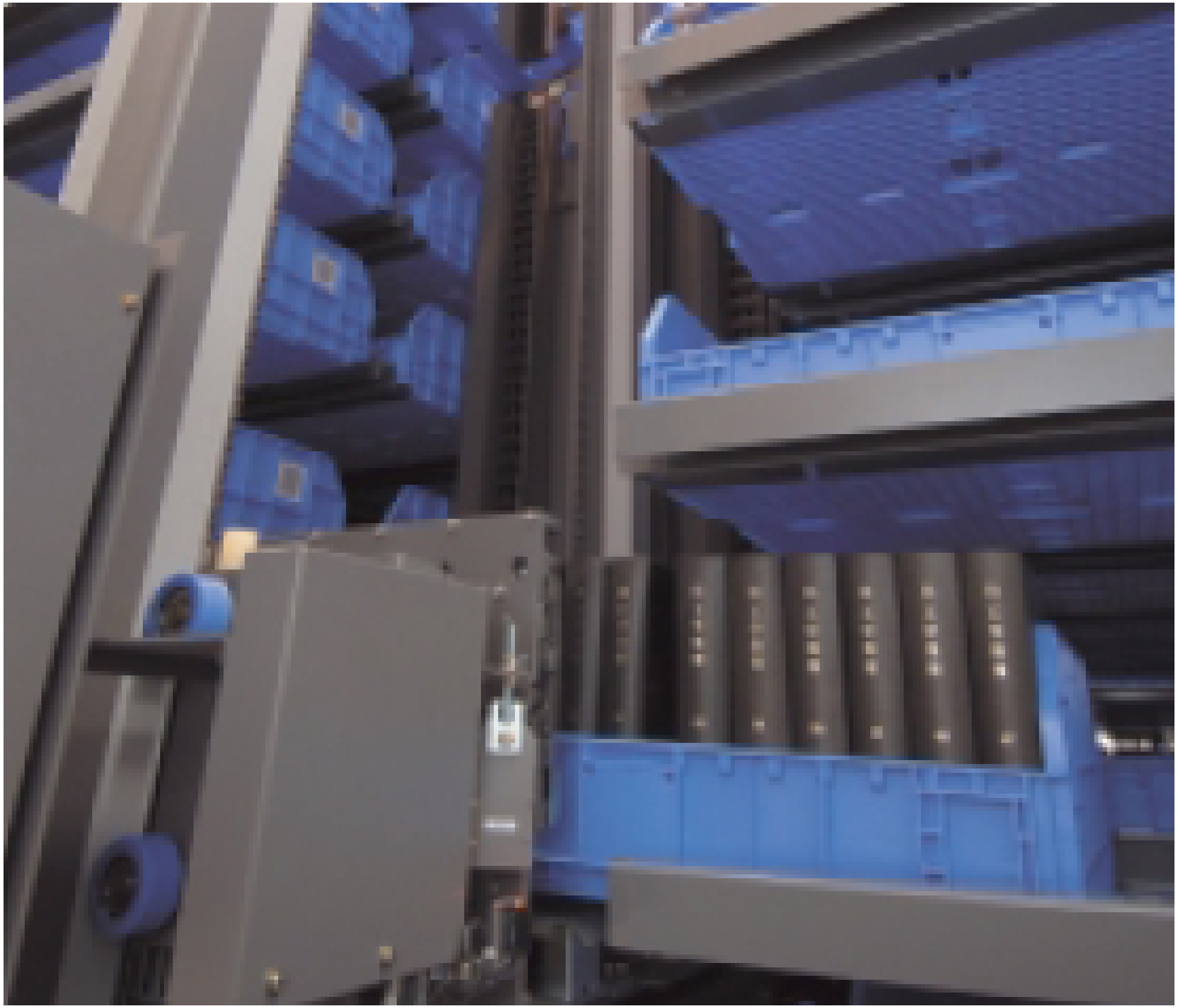
- Segregate by:
  - Users (e.g., Chemistry library)
  - Type (e.g., audiovisual materials)
  - Usage frequency (e.g., offsite storage)
  - Size (e.g., folios)
- Arrange in a way that facilitates access
  - Topical shelf order (e.g., Dewey Decimal System)
- Foster preservation
  - Environment (temperature, humidity, light)
  - Access controls (closed stacks, gloves, …)

High-Density Shelving



http://www.kmhsystems.com/high-density-storage.html

Compact Storage Robot



Kyushu University, Japan

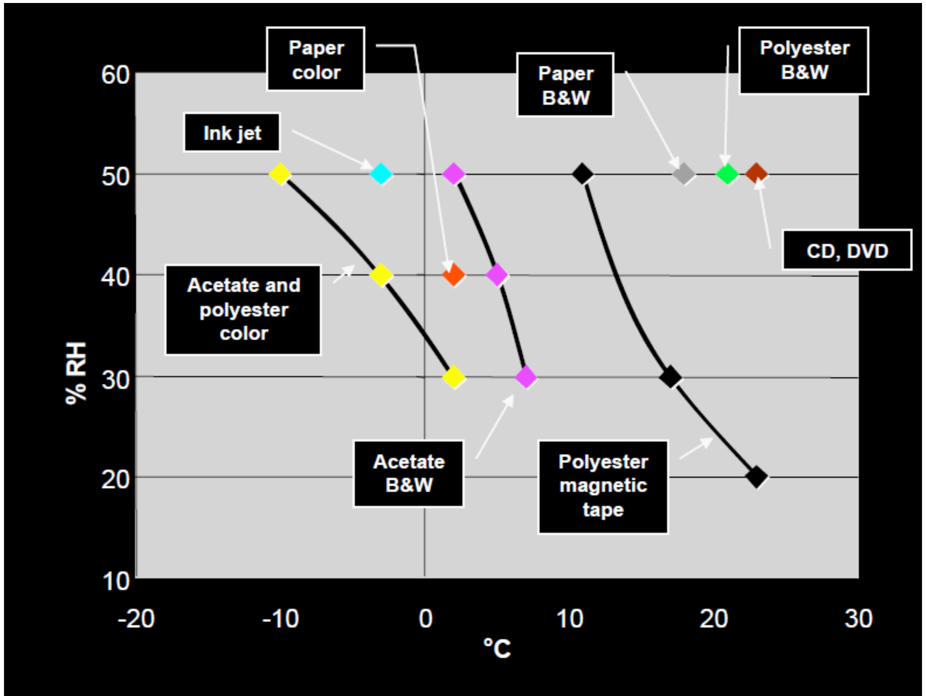
Closed Stacks

Preservation

c. 3000 BCE

Organic Decay

- Rag paper: 300-2,000 years
- Acidic paper: 25-50 years
- Acetate film: 40 years
- Nitrate film: 40-1-00 years



ISO 11799:2003

Image Permanence Institute, 2012

Threats to Physical Collections

- Organic decay
- Intentional actions
  - Pilferage and vandalism
  - Official acts
- Disasters
  - Natural disasters
    - Flood, tornado, earthquake, …
  - Accidents
    - Fire, sprinkler malfunction, …
  - Armed conflict

Disaster Mitigation Examples

- Flood:
  - Know where you can vacuum freeze dry
    - Decide quickly what to freeze
    - Air dry or dehumidify the rest
  - Immerse wet or muddy tape or film in water
    - Then air dry or dehumidify
  - Replace wet archival boxes immediately
- Fire:
  - Handle as fragile, wrap in clean paper
  - Pack between cardboard to stiffen

http://matrix.msu.edu/~disaster/balcplan.php

Digital Preservation

- Preservation of born-digital materials
  - Preserving appearance and interpretability
  - Preserving behavior
- Digitization for preservation
  - Scanning (of paper, of microfilm)
  - Audio digitization
  - Video digitization
  - Volumetric imaging
    - Digital holography, computational tomography

Binary Data Representation

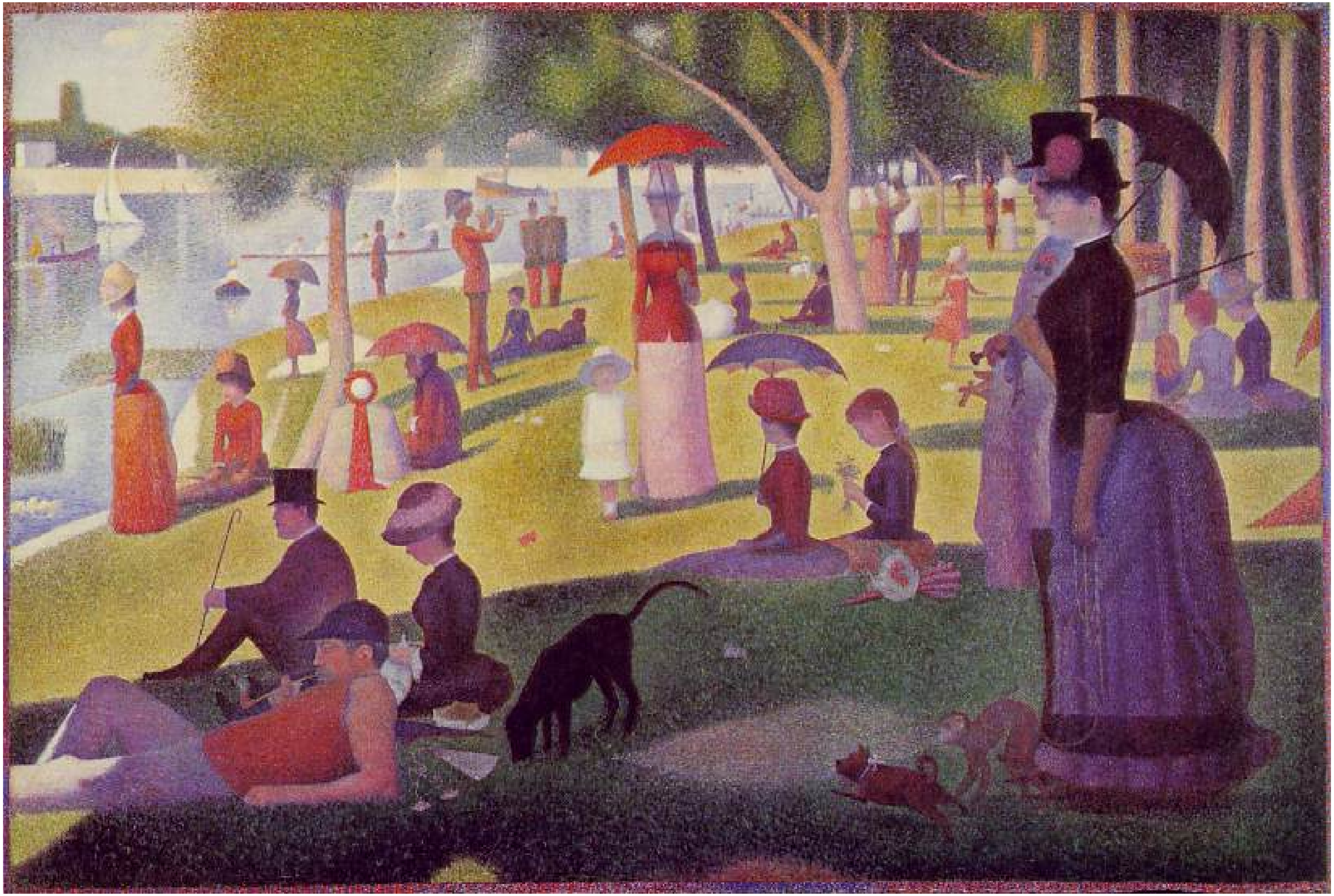
Example: American Standard Code for Information Interchange (ASCII)

01000001	= A	01100001	= a
01000010	= B	01100010	= b
01000011	= C	01100011	= c
01000100	= D	01100100	= d
01000101	= E	01100101	= e
01000110	= F	01100110	= f
01000111	= G	01100111	= g
01001000	= H	01101000	= h
01001001	= I	01101001	= i
01001010	= J	01101010	= j
01001011	= K	01101011	= k
01001100	= L	01101100	= l
01001101	= M	01101101	= m
01001110	= N	01101110	= n
01001111	= O	01101111	= o
01010000	= P	01110000	= p
01010001	= Q	01110001	= q
…		…	

Units of Size

Unit	**Abbreviation**	**Size (bytes)**
bit	b	1/8
byte	B	1
kilobyte	KB	2^{10} = 1024
megabyte	MB	2^{20} = 1,048,576
gigabyte	GB	2^{30} = 1,073,741,824
terabyte	TB	2^{40} = 1,099,511,627,776
petabyte	PB	2^{50} = 1,125,899,906,842,624

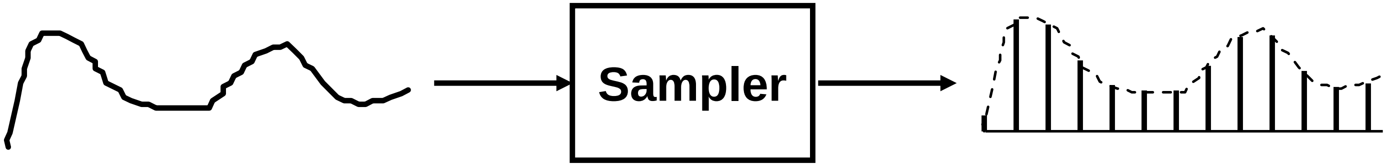
Nothing new…



Georges Seurat, A Sunday Afternoon on the Island of La Grande Jatte

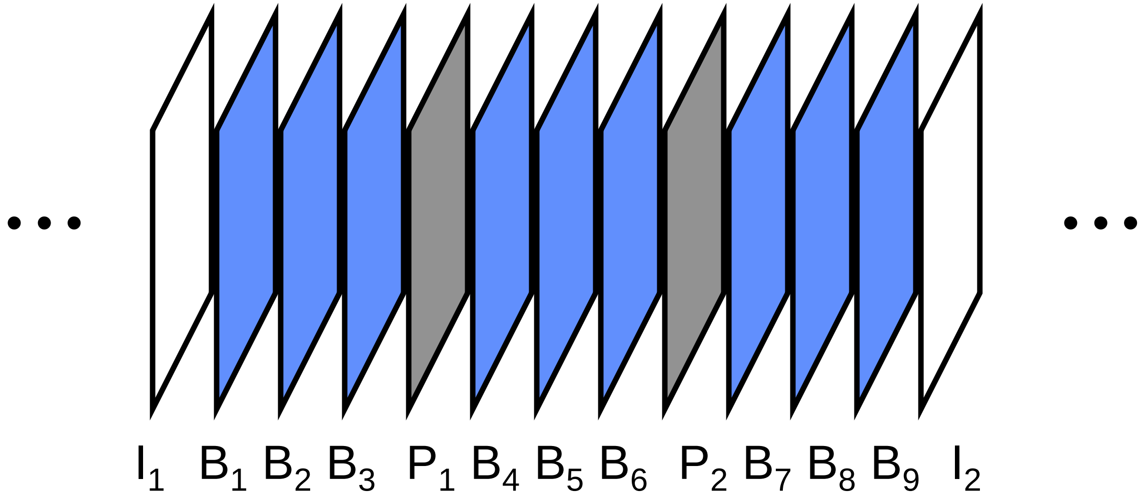
Basic Audio Coding

- Sample at twice the highest frequency
  - 8 bits or 16 bits per sample



- Speech (0-4 kHz) requires 8 kB/s
  - Standard telephone channel (1-byte samples)
- Music (0-22 kHz) requires 172 kB/s
  - Standard for CD-quality audio (2-byte samples)

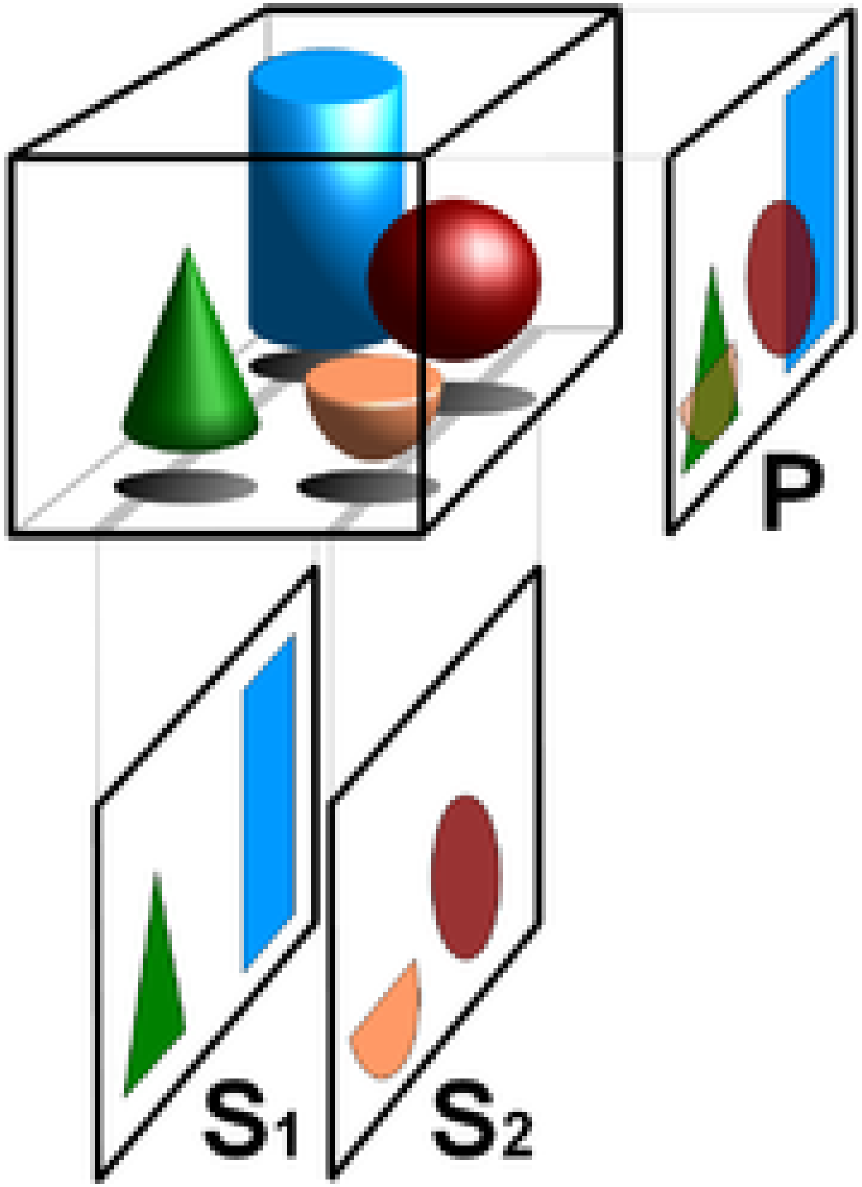
MPEG Encoding



Frame Types

I	Intra	Encode complete image, similar to JPEG
P	Forward Predicted	Motion relative to previous I and P’s
B	Backward Predicted	Motion relative to previous & future I’s & P’s

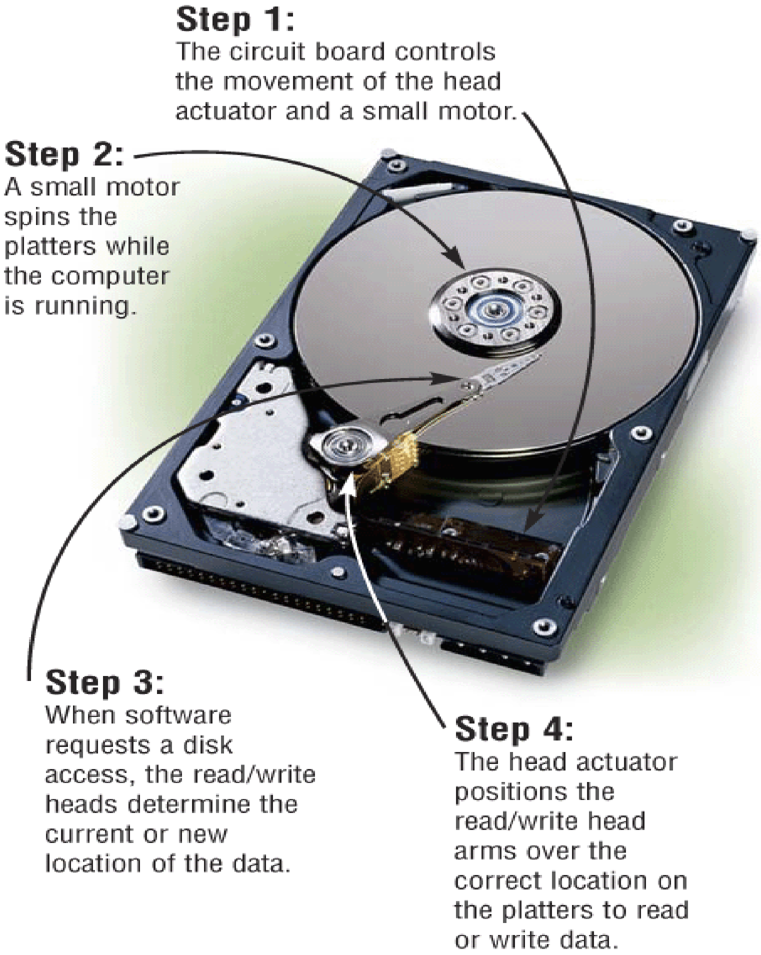
Volumetric Imaging



Rotating Storage Media

- Fixed magnetic disk
  - Hard drives
- Removable magnetic disk
  - Floppy disk
- Removable optical disc
  - CD, DVD, Blu-ray

Magnetic Disk (Hard Drive)

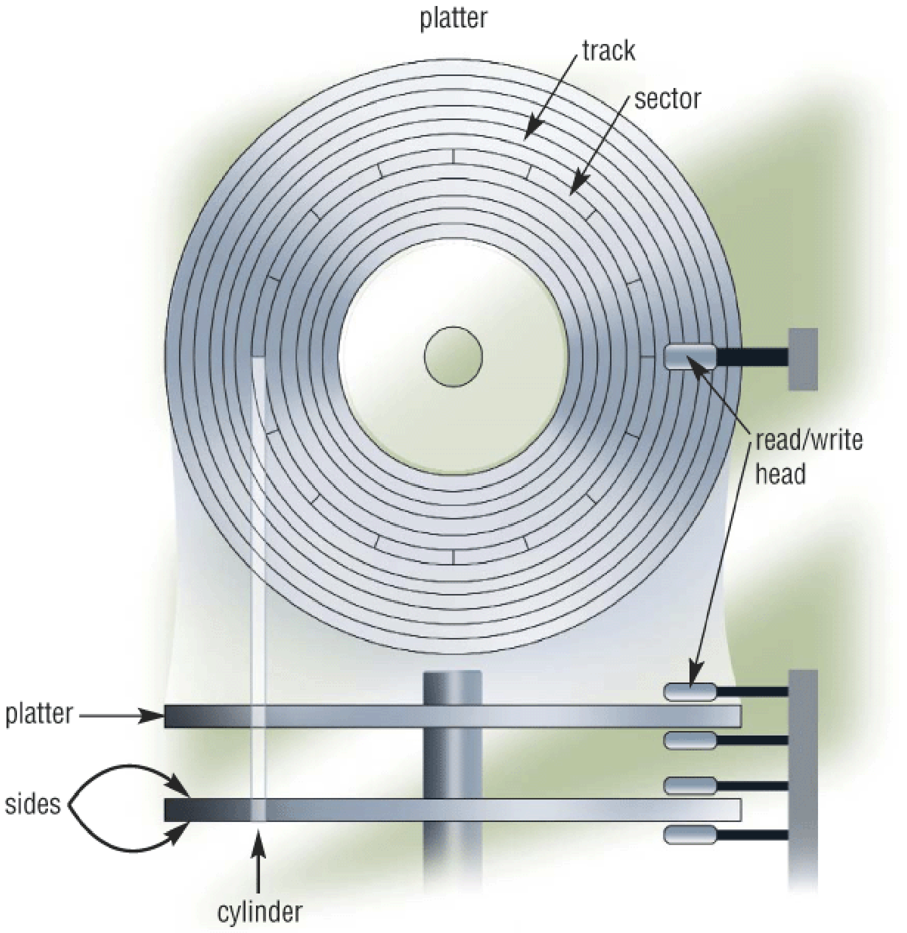


Step 1: The circuit board controls the movement of the head actuator and a small motor.

Step 2: A small motor spins the platters while the computer is running.

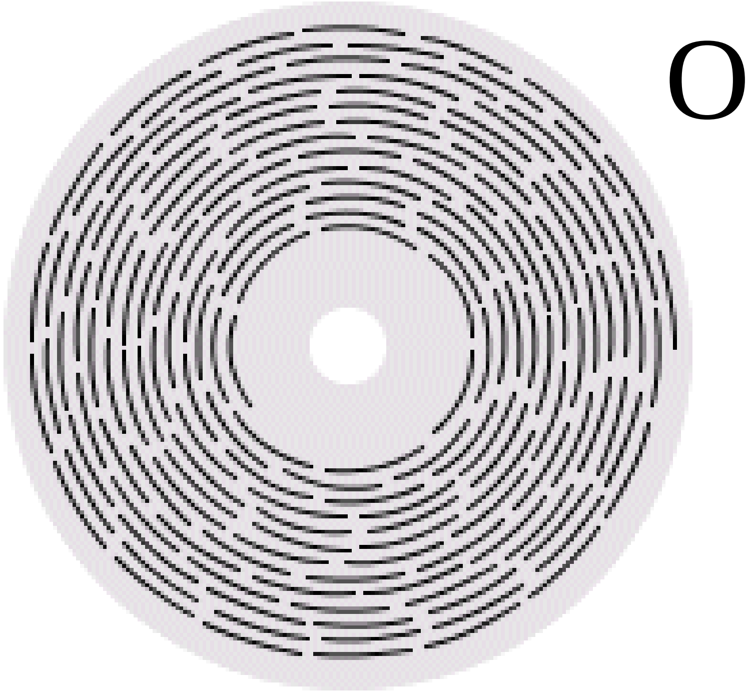
Step 3: When software requests a disk access, the read/write heads determine the current or new location of the data.

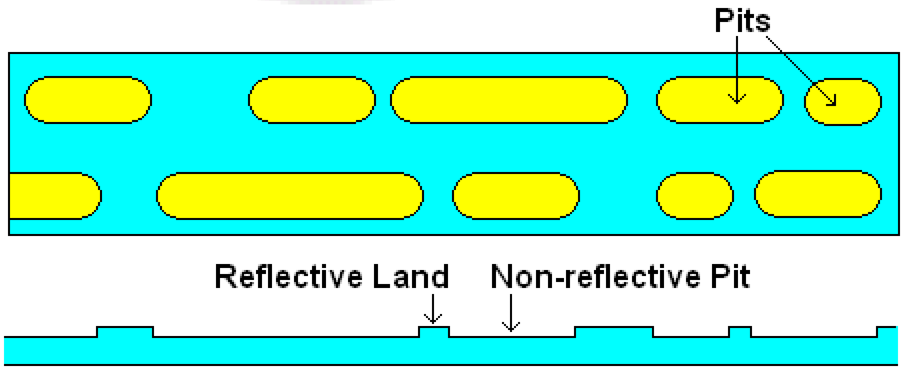
Step 4: The head actuator positions the read/write head arms over the correct location on the platters to read or write data.

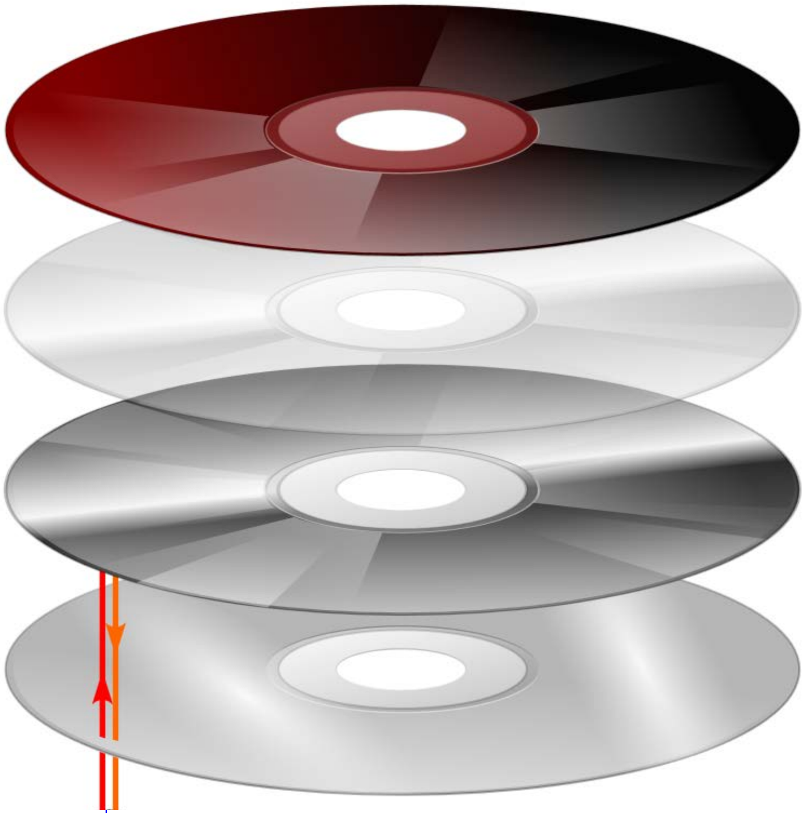


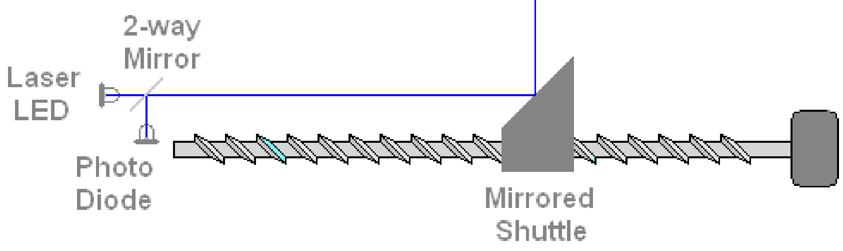
Shelly, Cashman and Vermatt, *Discovering Computers*, 2004

Optical Disc

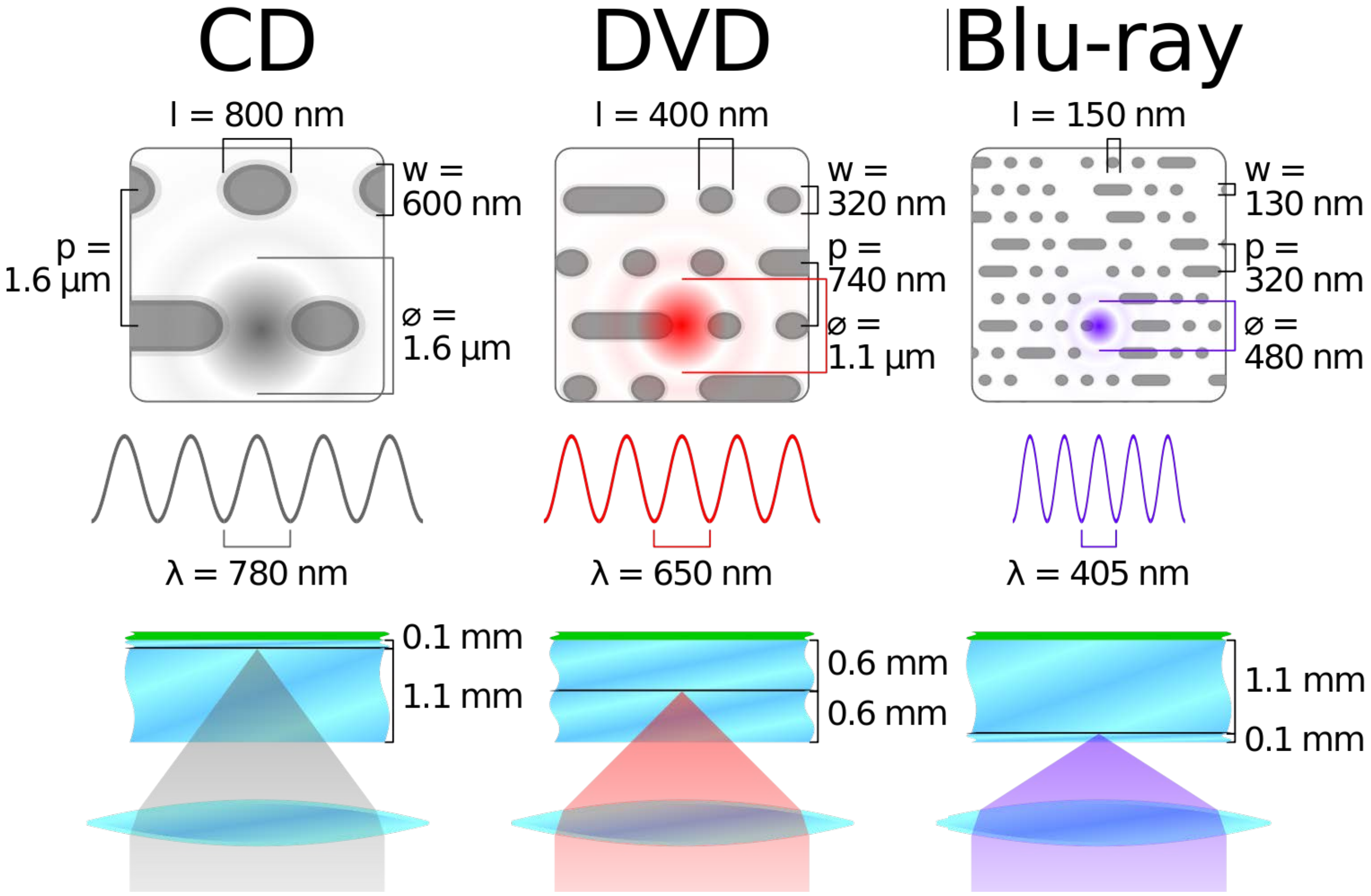








Optical Disk Technologies



near infared red violet

Magnetic Tape

- Tapes store data sequentially
  - Fast transfer, but no practical “random access”
- Used only for low-use storage
  - Disaster recovery, offline storage

Solid-State Memory

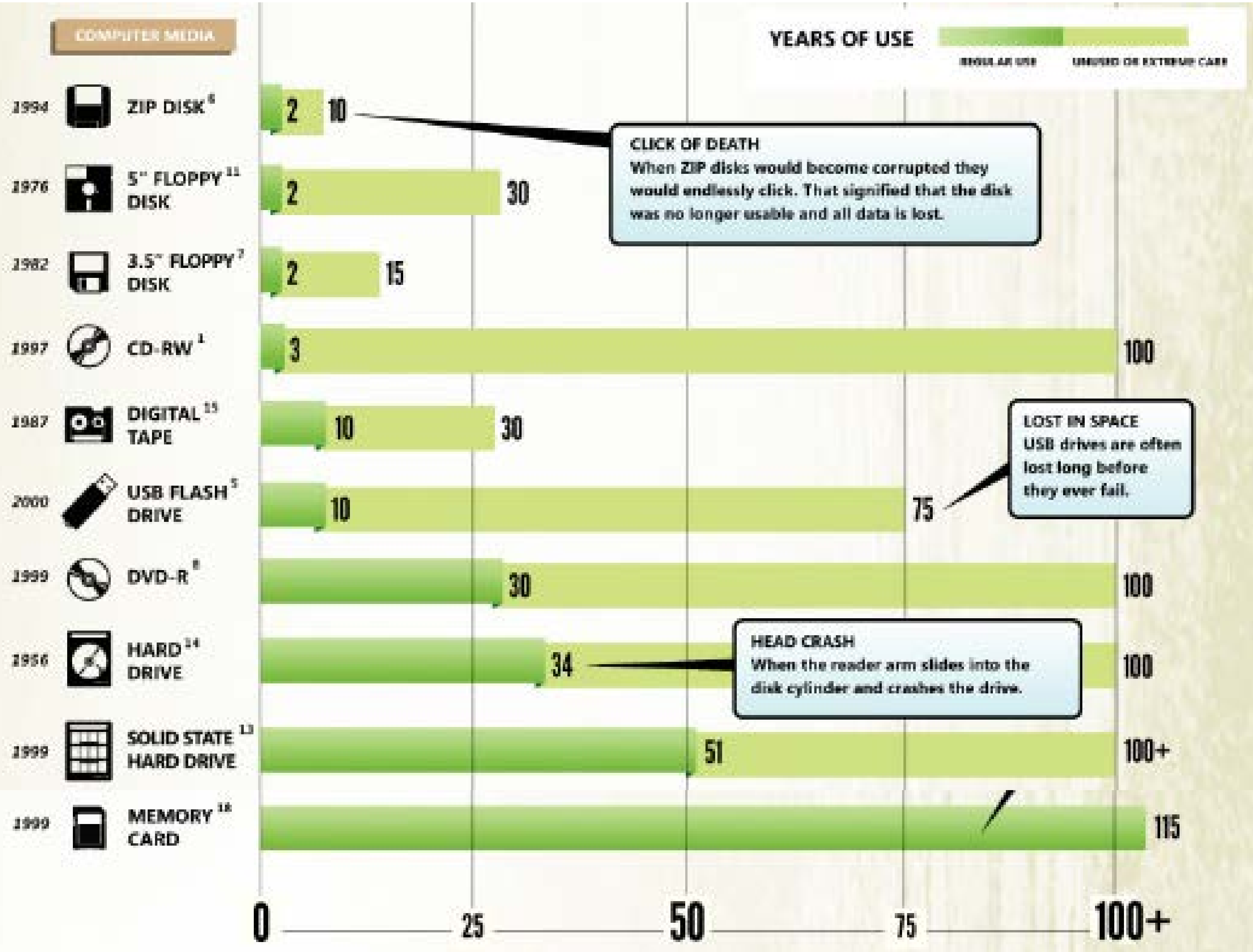
- ROM
  - Does not require power to retain content
  - Used for “Basic Input/Output System” (BIOS)

- RAM
  - Cheap and fast, but works only while power is on

- Flash memory (Solid State Disk, memory sticks)
  - Much faster “random access” than rotating disk
    - ~10,000 times faster, but ~10 times more expensive per bit
  - Limited number of lifetime write operations (~5,000)
    - But Zipf’s law permits “wear leveling”

Threats to Digital Collections

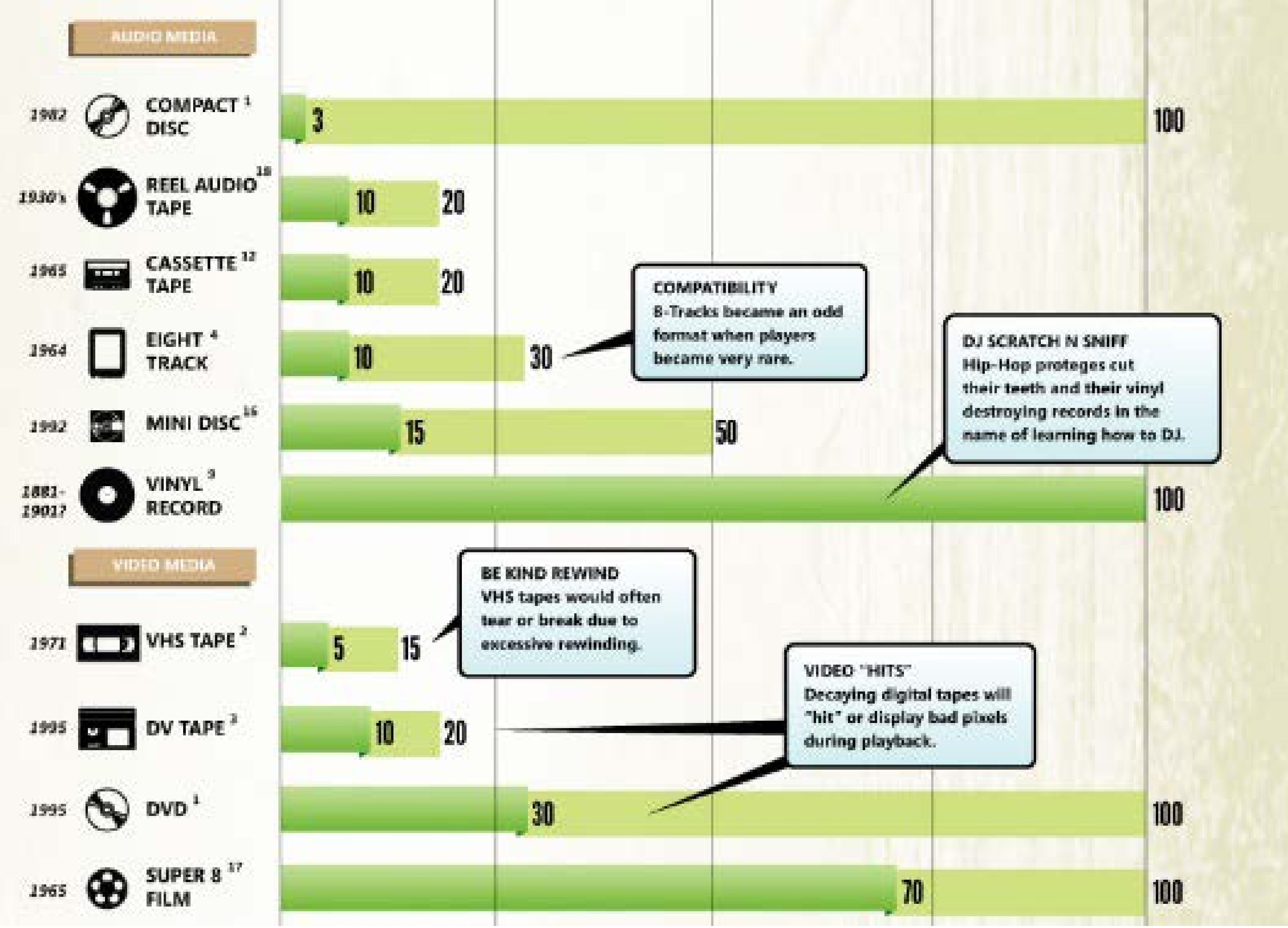
- Business decisions
  - Termination of service
  - Termination of infrastructure support
    - e.g., reading Amiga files, displaying Word Perfect
- Malfunctions
  - Hardware failure, operator error, software bugs, …
- Vandalism (hackers)
- Disasters
  - Physical risks to servers
  - Electromagnetic pulse



CLICK OF DEATH
When ZIP disks would become corrupted they would endlessly click. That signified that the disk was no longer usable and all data is lost.

LOST IN SPACE
USB drives are often lost long before they ever fail.

HEAD CRASH
When the reader arm slides into the disk cylinder and crashes the drive.



COMPATIBILITY
8-Tracks became an odd format when players became very rare.

DJ SCRATCH N SNIFF
Hip-Hop proteges cut their teeth and their vinyl destroying records in the name of learning how to DJ.

BE KIND REWIND
VHS tapes would often tear or break due to excessive rewinding.

VIDEO "HITS"
Decaying digital tapes will "hit" or display bad pixels during playback.

http://www.crashplan.com/medialifespan/

Media Migration

- What format should old tapes be converted to?
  - Newer tape
  - Rotating media
  - Solid state disks

- How often must we “refresh” these media?

Risk Management

- Redundancy drives down uncorrelated risk
  - Let *p* be the probability of loss of one copy
  - Then *p*p*p* is the chance of loss at 3 sites
  - Example: if *p=0.01* then *p*p*p=0.000001*

- Two fundamental problems:
  - Unanticipated correlation
    - For example, an operating system bug
  - Underestimated “black swan” probabilities

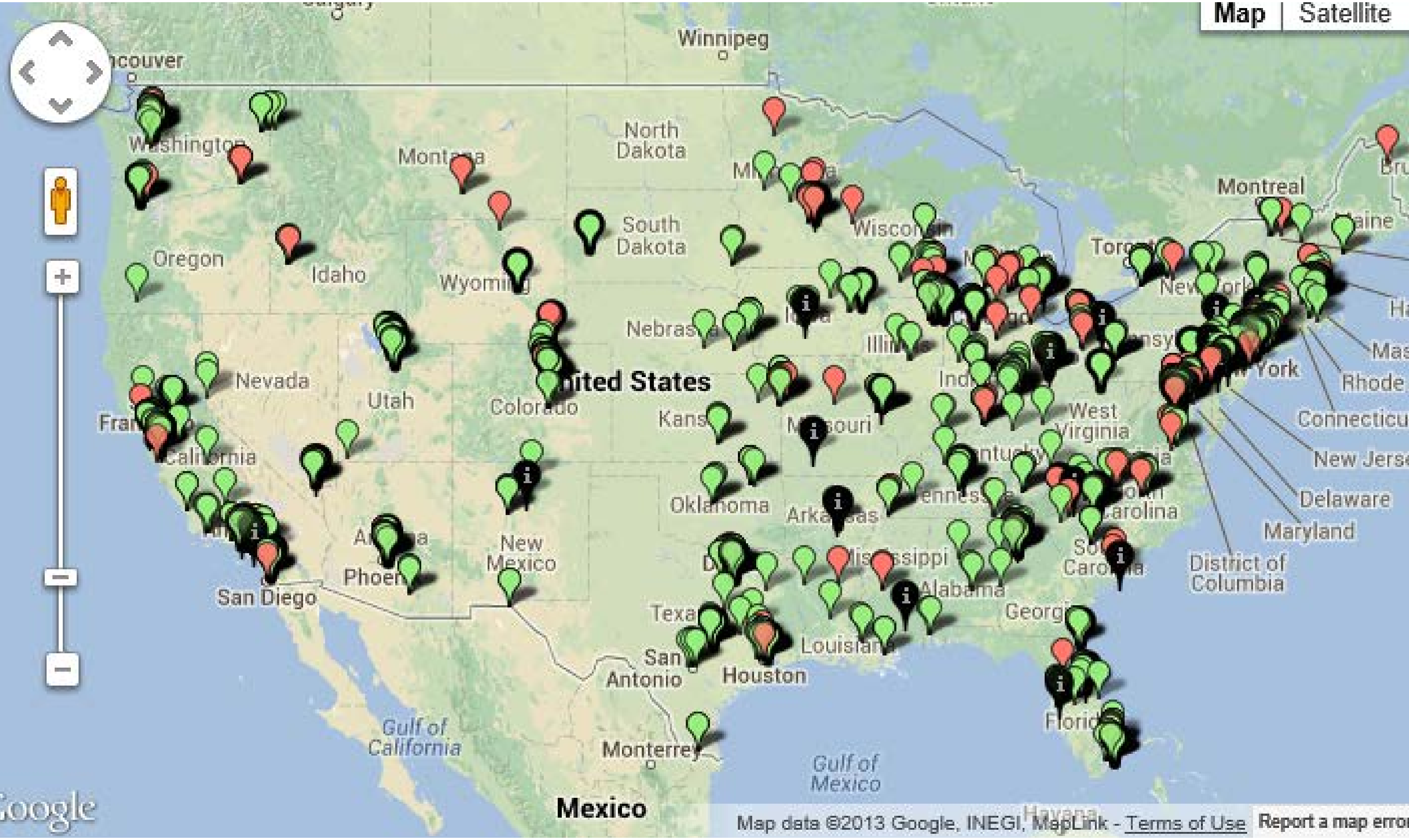
Layered Defense

- Good storage practices
  - – Offline: Media migration
  - – Online: uninterruptable power, RAID, backups
- Distributed storage
  - – Storage Resource Broker (SRB), LOCKSS, …
- Air gaps
  - – Interrupt unexpected correlation

Data Centers

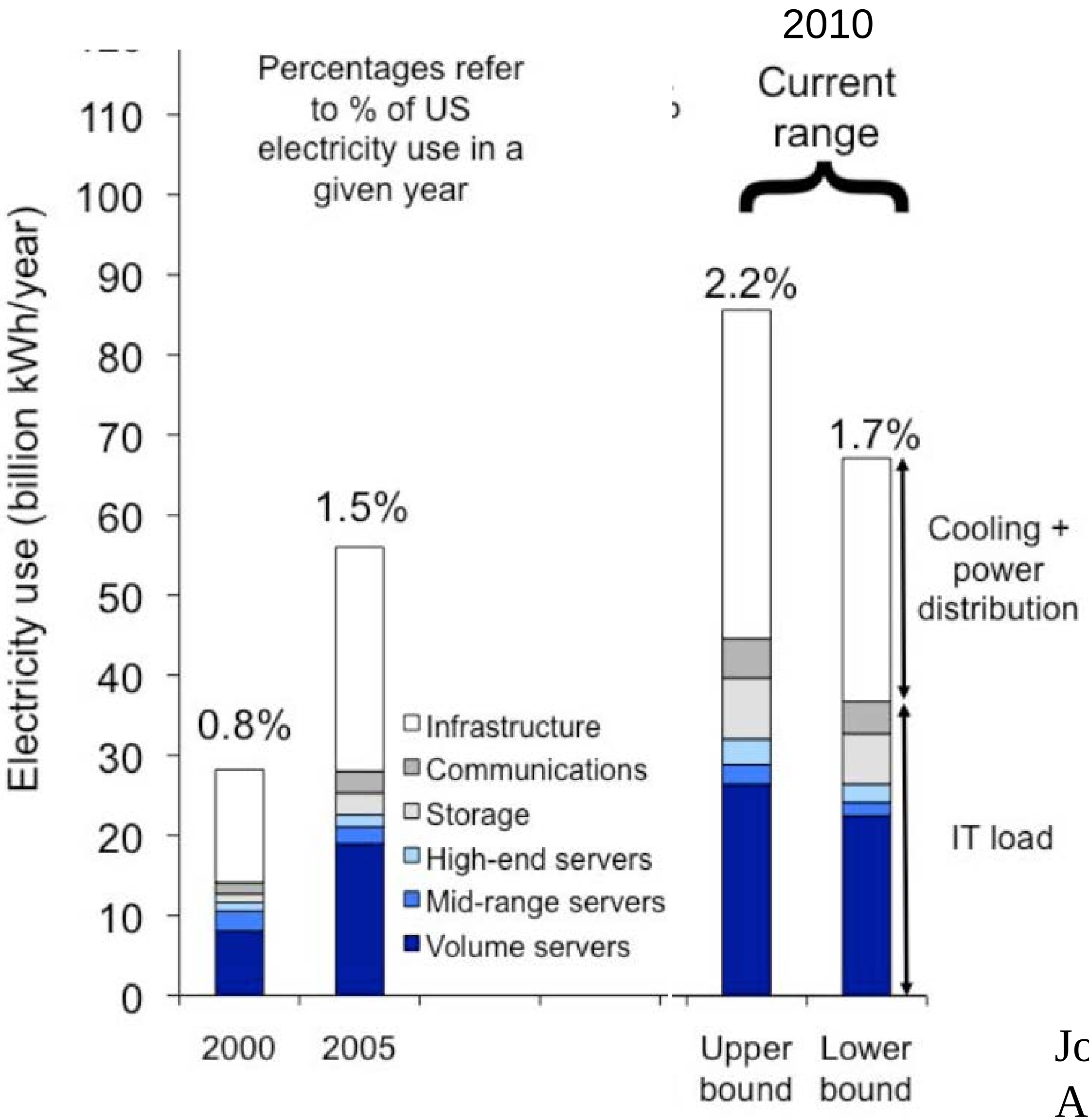
Source: Wikipedia

Shared Data Center Locations



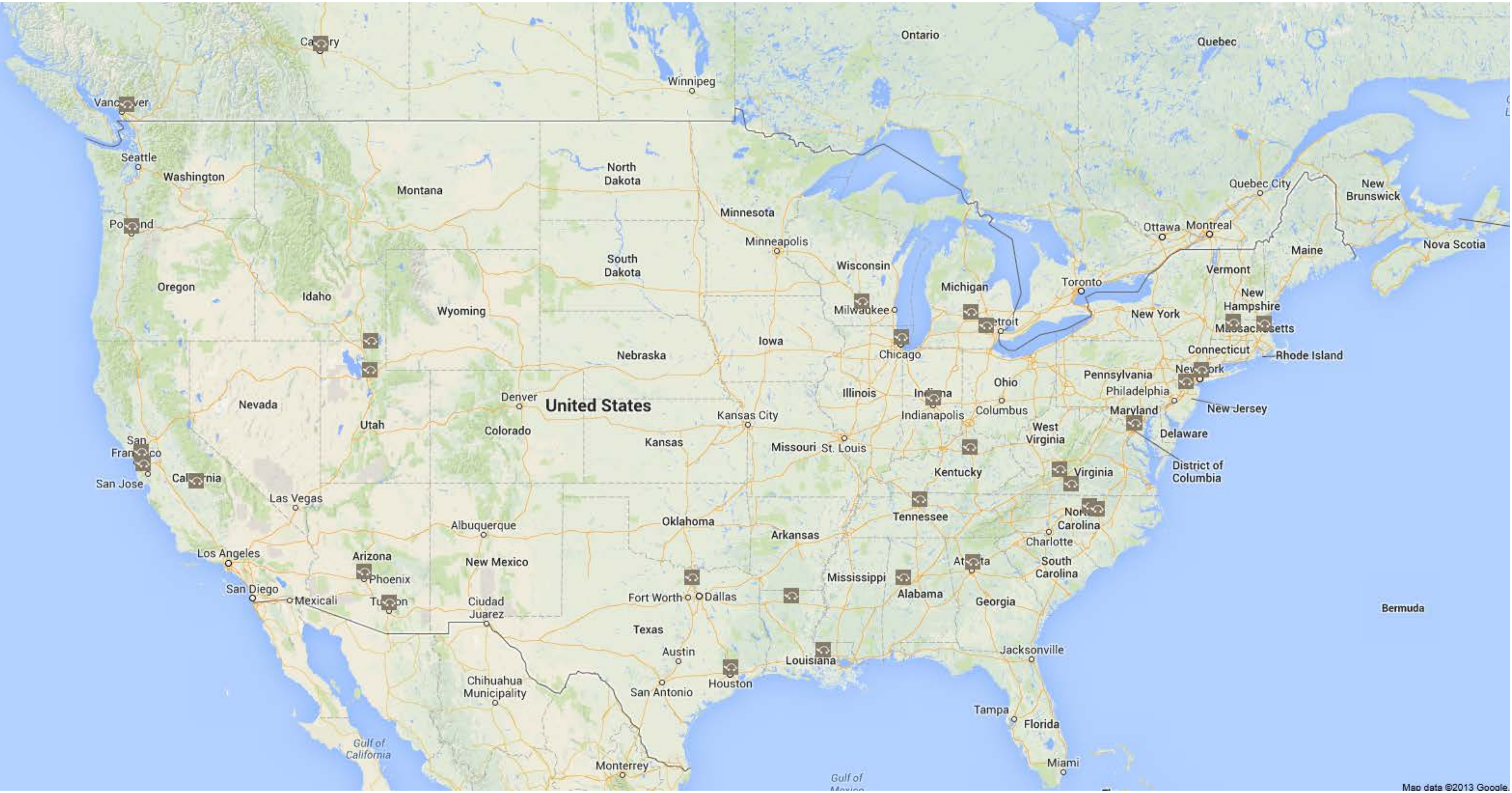
http://www.datacentermap.com/usa/datacenters.html

Data Center Electricity Use (USA)



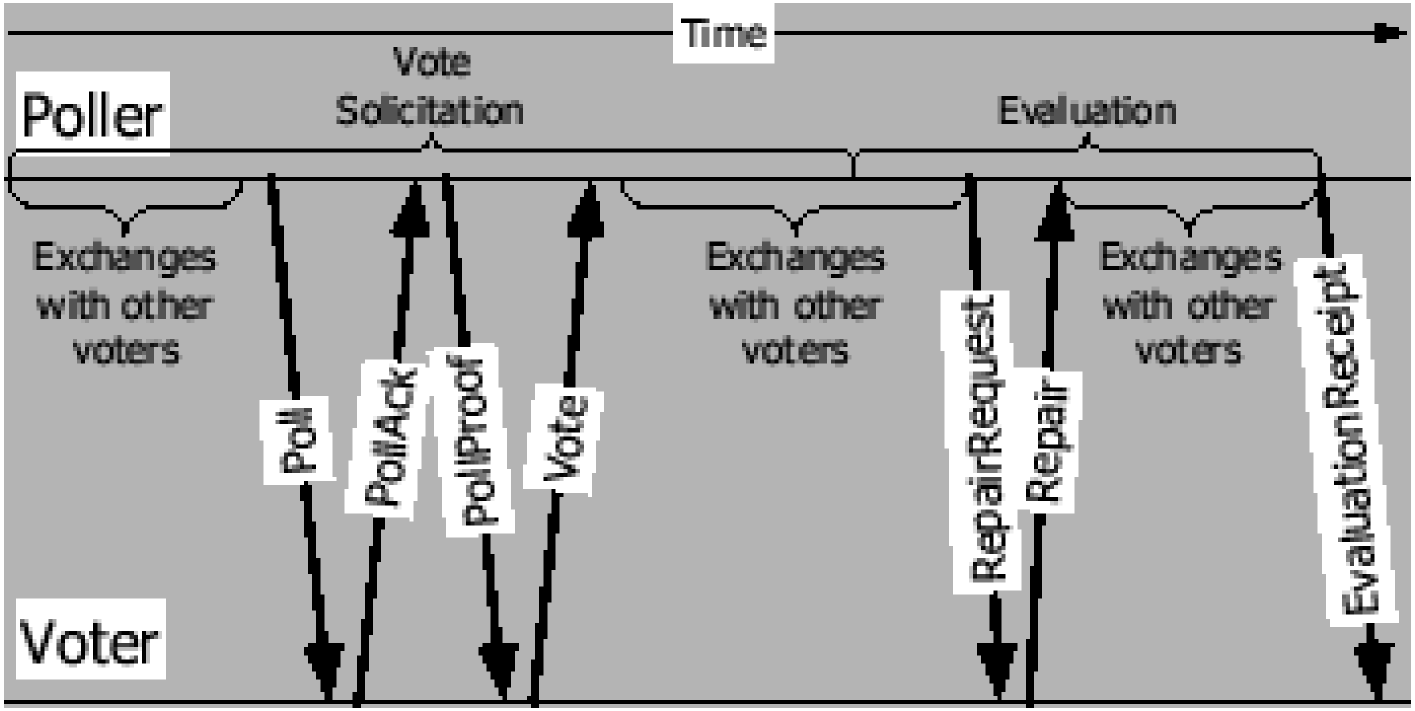
Jonathan Koomey,
Analytics Press, 2010

Digital Federal Depository Library



http://lockss-usdocs.stanford.edu

LOCKSS Distributed Repair

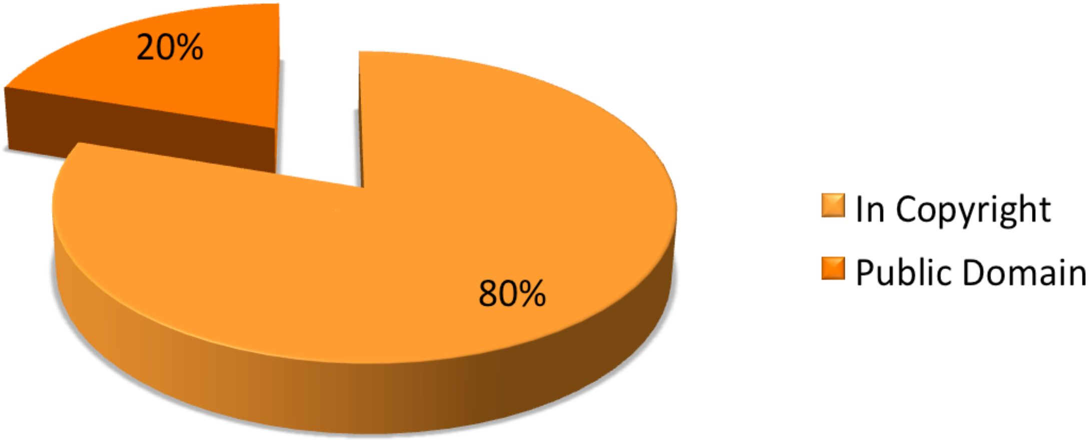


ITHAKA

- JSTOR digitization
  - Back runs of journals
  - Recently expanded to books
- Portico preservation
  - Centralized management, originally for journals
    - Release triggers: discontinuation, loss of access
  - Also service for books and datasets

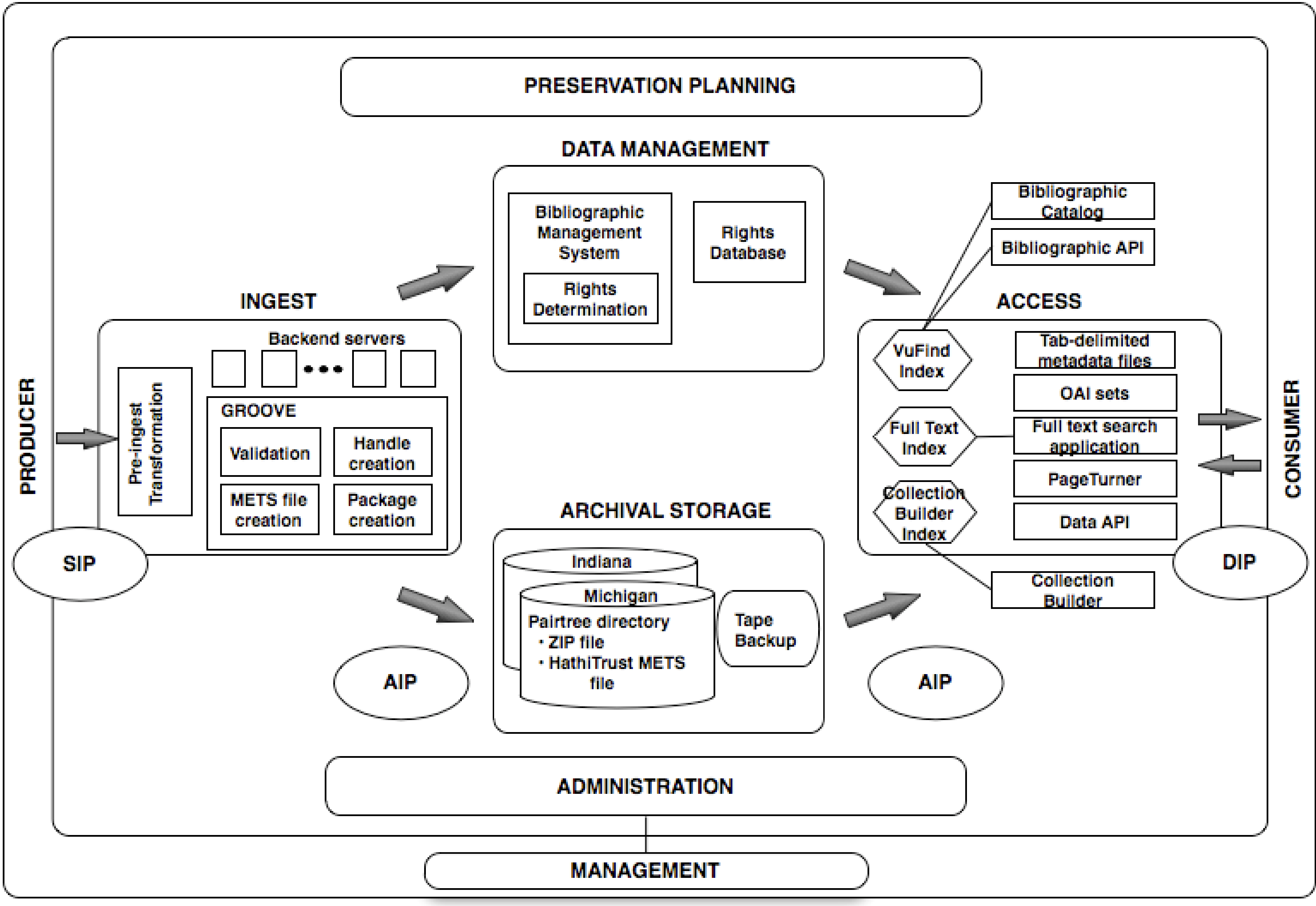
HathiTrust

- Centralized repository for digitized books
  - – Google Books digitization (via owning libraries)
  - – Microsoft book search (ran from 2006-2008)
  - – Internet Archive
    - Million book project, project Gutenberg, contributions, …
  - – Cooperative digitization



As of August 13, 2010

6,549,680 Total volumes
3,798,116 Book titles
153,311 Serial titles
1,300,896 Public Domain



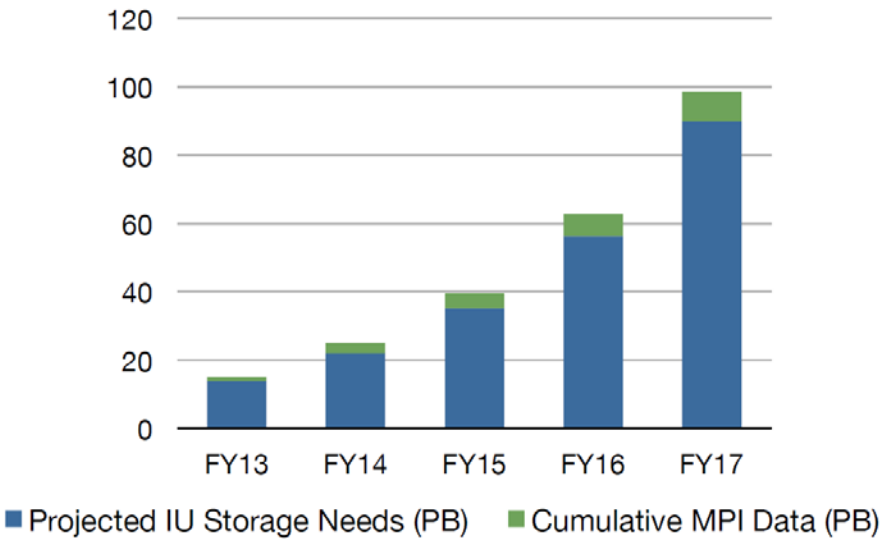
Jeremy York, IFLA 2010

Indiana University Digitization

Table 6: Media Preservation Targets, 2013-2027

Target	Hours	Objects	% of Total Holdings
15 Years— all media types	317,000	408,000	71%
Audio	207,000	284,000	82%
Video	83,000	66,000	53%*
Film (access digitization)	27,000	58,000	69%

*IU Bloomington video holdings include a large number of non-archival, commercial VHS tapes and DVDs that circulate primarily to students. These are not included here.



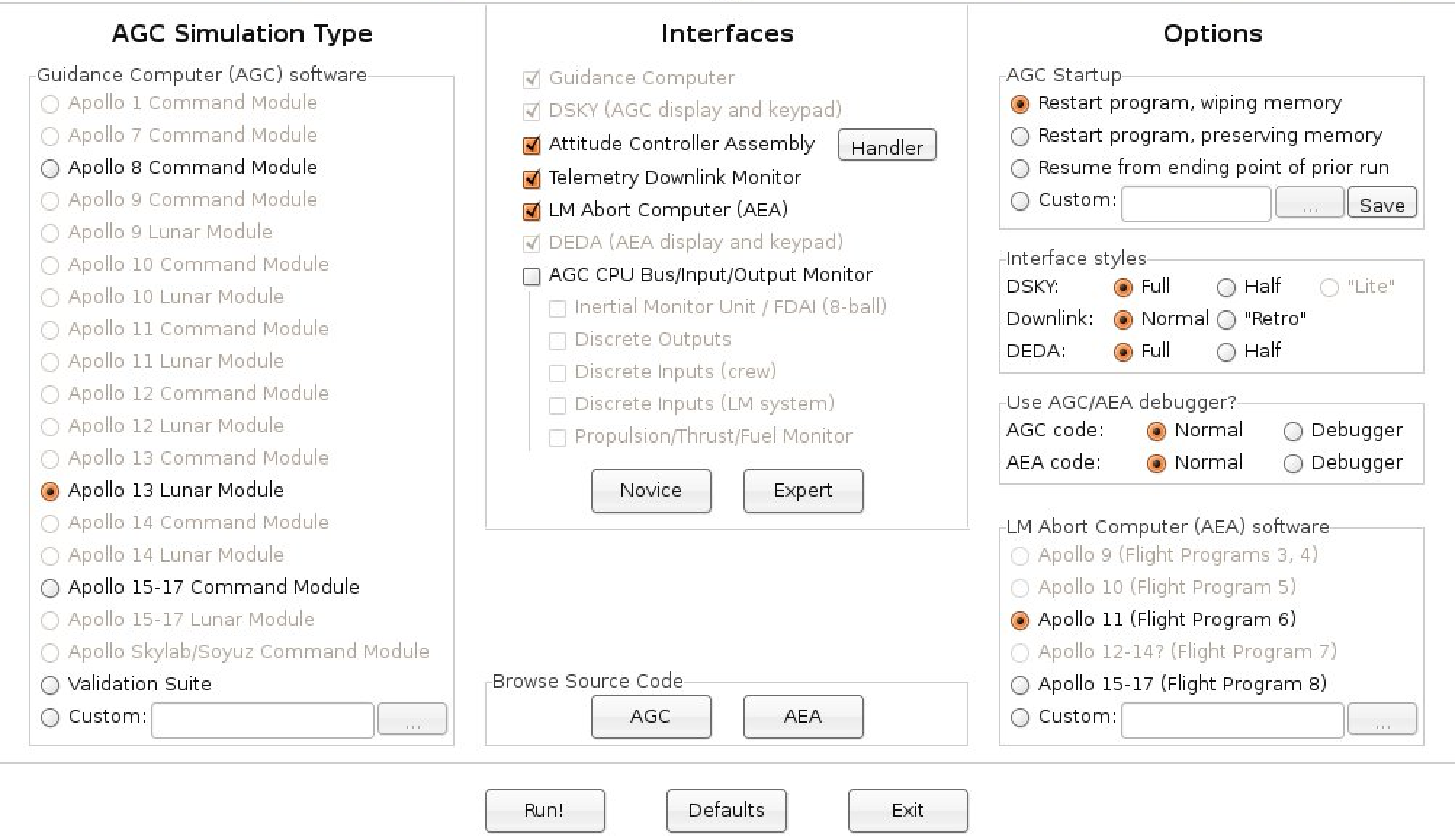
Preserving Behavior

- Word processors
  - Formatting, track changes, undo deleted text
- Spreadsheets
  - Formulas, visualizations
- Databases
  - Queries, forms, derived values
- Computer-Assisted Design (CAD)
  - Display, modification, manufacturing
- Software
  - Simulation, games, embedded systems, …

Behavior Preservation Strategies

- Format migration
  - For example, convert Word Perfect to PDF
- Emulation
  - Allows running old software on newer systems

Apollo Guidance Computer Emulation



AGC Simulation Type

Guidance Computer (AGC) software

○ Apollo 1 Command Module
○ Apollo 7 Command Module
○ Apollo 8 Command Module
○ Apollo 9 Command Module
○ Apollo 9 Lunar Module
○ Apollo 10 Command Module
○ Apollo 10 Lunar Module
○ Apollo 11 Command Module
○ Apollo 11 Lunar Module
○ Apollo 12 Command Module
○ Apollo 12 Lunar Module
○ Apollo 13 Command Module
● Apollo 13 Lunar Module
○ Apollo 14 Command Module
○ Apollo 14 Lunar Module
○ Apollo 15-17 Command Module
○ Apollo 15-17 Lunar Module
○ Apollo Skylab/Soyuz Command Module
○ Validation Suite
○ Custom: ...

Interfaces

☑ Guidance Computer
☑ DSKY (AGC display and keypad)
☑ Attitude Controller Assembly Handler
☑ Telemetry Downlink Monitor
☑ LM Abort Computer (AEA)
☑ DEDA (AEA display and keypad)
☐ AGC CPU Bus/Input/Output Monitor
☐ Inertial Monitor Unit / FDAI (8-ball)
☐ Discrete Outputs
☐ Discrete Inputs (crew)
☐ Discrete Inputs (LM system)
☐ Propulsion/Thrust/Fuel Monitor

Novice Expert

Browse Source Code

AGC AEA

Options

AGC Startup

● Restart program, wiping memory
○ Restart program, preserving memory
○ Resume from ending point of prior run
○ Custom: ... Save

Interface styles

DSKY:	● Full	○ Half	○ "Lite"
Downlink:	● Normal	○ "Retro"	
DEDA:	● Full	○ Half	

Use AGC/AEA debugger?

AGC code:	● Normal	○ Debugger
AEA code:	● Normal	○ Debugger

LM Abort Computer (AEA) software

○ Apollo 9 (Flight Programs 3, 4)
○ Apollo 10 (Flight Program 5)
● Apollo 11 (Flight Program 6)
○ Apollo 12-14? (Flight Program 7)
○ Apollo 15-17 (Flight Program 8)
○ Custom: ...

Run! Defaults Exit

http://www.ibiblio.org/apollo/

An Integrated Strategy

- Delay decay of organic materials to buy time
- Balance quality and scale
  - For future access, quantity has a quality all its own
- Rescue high-value at-risk collections
- Design diversity into the process
  - Technologies, risk exposure, institutions
- Adequately resource the process

Before You Go!

- On a sheet of paper (no names), answer the following question:

  What was the muddiest point in today’s class?