Threats to Preservation

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Optimism vs. Pessimism

- Two kinds of engineering
  - Optimistic – making good things happen
    - e.g turbochargers
  - Pessimistic – preventing bad things happening
    - e.g air-bags
- Preservation is 100% pessimistic
  - Goal is that nothing bad happen to content
- Pessimistic engineering = applied paranoia

Overview

- No system is perfect
  - How good does preservation need to be?
  - How good is preservation?
- What are the threats to preserved content?
  - How can we model & address them?
  - How can we measure how well we're doing?
- How can we set performance goals?
  - And improve cost-performance through trade-offs
- Preservation service level agreements?
  - Can they actually transfer responsibility?

CSTB Report (2005)

- “It is essential that ERA design proposals be analyzed against a threat model in order to gain an understanding of the degree to which alternative designs are vulnerable to attack. ...This initial threat modeling would be only the first step of a larger, iterative threat-countering process that involved designing against expected threats, observing failures that occur, and designing new countermeasures.”

Threats Not Isolated

- “Close examination of 6 case studies ... indicate that latent rather than active failures now pose the greatest threat to the safety of high-technology systems.” Reason *Human Error* (1990)
- Errors are correlated – for example:
  - Between drives in storage array (Talagala 1999)
  - Human error & hardware failure (e.g. TMI)
- Correlations make threat modeling difficult

A Start on Modeling

- Baker *et al*., Eurosys '06
- Archive data are infrequently accessed
  - Can't depend on user access to detect errors
  - Must audit or *scrub* replicas against each other
  - Errors at any time, some *latent* until next audit
- Errors have correlation parameter > 0
- We ask: “How likely is a double failure?”
  - Second failure *after* first occurs
  - *Before* first failure detected and repaired

Using Our Model

- Model 2 replicas of part of Internet Archive
  - Using IA data on hashes of files over time
  - 30K hrs, 1.5M 50MB files, 1336 hash changes
- Auditing improves Mean Time To Data Loss
  - No audit, MTTDL 64 days
  - 4 month audit, MTTDL 3.4 years
  - 2 week audit, MTTDL 12.3 years
- Key is not to let latent errors fester
  - But auditing can be costly – IA turned it off

Well, Duh!

- Getting analytic model this far is hard
  - Need more replicas, threats, correlation
  - Thus need simulation not analytic model
- Getting good data to drive models is hard
  - IA data set noisy, short, old.
  - Others (NetApp, MSFT, ...) unavailable
- Better models could answer basic questions
  - For target reliability, *how much replication*?
    - Answer controls economics, thus sustainability
  - For target replication, *how to arrange replicas*?
    - Answer controls system architecture

Our Threat Model

- Media failure
- Hardware failure
- Software failure
- Network failure
- Obsolescence
- Natural Disaster
- Operator error
- Internal Attack
- External Attack
- Organization Failure
- Economic Failure

Media Failure

- No affordable media reliable enough
  - Both bit rot and catastrophic failure inevitable
- Need many *independent* replicas
  - Geographically, administratively, technologically
- Replicas must be *audited* frequently
  - Otherwise latent errors fester
- *Routine* access to, migration of replicas
  - Otherwise they likely won't work when needed

Hardware Failure

- Useful life of hardware < useful life of media
- Hardware must *flow through* the system
  - Rolling, desynchronized upgrade of replicas
  - Encourage diverse (=independent) hardware
- Better to add and delete replicas separately
  - Upgrade in place likely to synchronize errors

Software Failure

- Diversity & Randomization are keys
- Replicas with diverse implementations
  - down to operating systems => very expensive
  - protocols not software – replica interoperability
  - don't rule it out for the future
- Version skew is a start on diversity
  - Replicas spread across 3 versions
- Randomization is a form of diversity

Network Failure

- Both communication & services can fail
- 10^{-7} packets have undetected errors
  - End-to-end closed-loop checks essential
- Preservation systems use network services
  - Routing? DNS? NTP? Resolvers? ...
  - All have temporary or permanent failures
- High correlation with other failures
  - e.g. natural disaster, economic failure

Obsolescence

- Obsolescence isn't just for formats, software
  - although that's what's had all the attention
  - see our Nov 2005 D-Lib paper
- Format obsolescence is like prostate cancer
  - It's a serious, potentially fatal problem
  - If you live long enough you *will* suffer from it
  - No certain cure, no effective prophylactics
  - Odds are something else will kill you first
  - Watchful waiting is normally the best Rx

Natural Disaster

- Geographic distribution with fail-over
- Recovery should be automatic
  - The people will have better things to do
- Load-sharing much better than fail-over
  - Nothing special happens in a disaster
  - No-one needs to do anything
  - Much more likely to work (Patterson 2002)

Operator Error, Internal Attack

- High prevalence, massive under-reporting
  - http://www.secretservice.gov/ntac/its_report_050516.pdf
- Administrative independence essential
  - Replicas must be *peers* not masters & slaves
  - No central control => cooperating organizations
- Dual-key administration ineffective
  - Group-think, social engineering, ... => not independent
- Logs must be *tamper-proof*
  - Hard to ensure this

External Attack

- Diversity
  - of administration – social engineering
  - of jurisdiction – legal attacks
  - of software - vulnerabilities
- Paranoia
  - Constant security review – learn from OpenBSD
- Isolation
  - Dedicated hardware, aggressive packet filters
  - Off-line replicas? They can't be kept off-line ...

Organization Failure

- Succession planning
  - Fall-back sustainability?
  - Accepting custody of content is never free
- Open Source software, open formats are key
  - Without them, transfer may be too expensive
- SIP=DIP capability
  - Get out *exactly* what you put in

Economic Failure

- Sustainability is the fundamental problem
  - Bits vulnerable to interruptions in money supply
- Economic triage is inevitable
  - No-one has budget to keep all they want to keep
- Cost-performance trade-offs minimize triage
  - No-one has cost or performance data or models
- Cost-insensitive design is all too common
  - E.g. metadata quality vs. cost of acquisition vs. benefit

Measuring Performance

- Long-term storage is a big market
  - Without a performance benchmark!
  - Benchmarks drive mature tech markets
- My suggested benchmark: bit half-life
  - Look at a bit in a storage system
  - How long until 50% chance it has flipped?
- Technology cost/performance axes
  - Cost: $/bit/yr
  - Performance: bit half-life

A Reasonable Goal?

- How long do we need to keep data?
  - Libraries routinely keep paper for 100 years
  - Copyright is life + 70 years
  - SNIA “100-year Archive Task Force”
- 1PB, 100 years, 50% probability no damage
  - 1PB is a lot of data now ...
  - But in 100 years it will be 10^{-9} of a hard drive

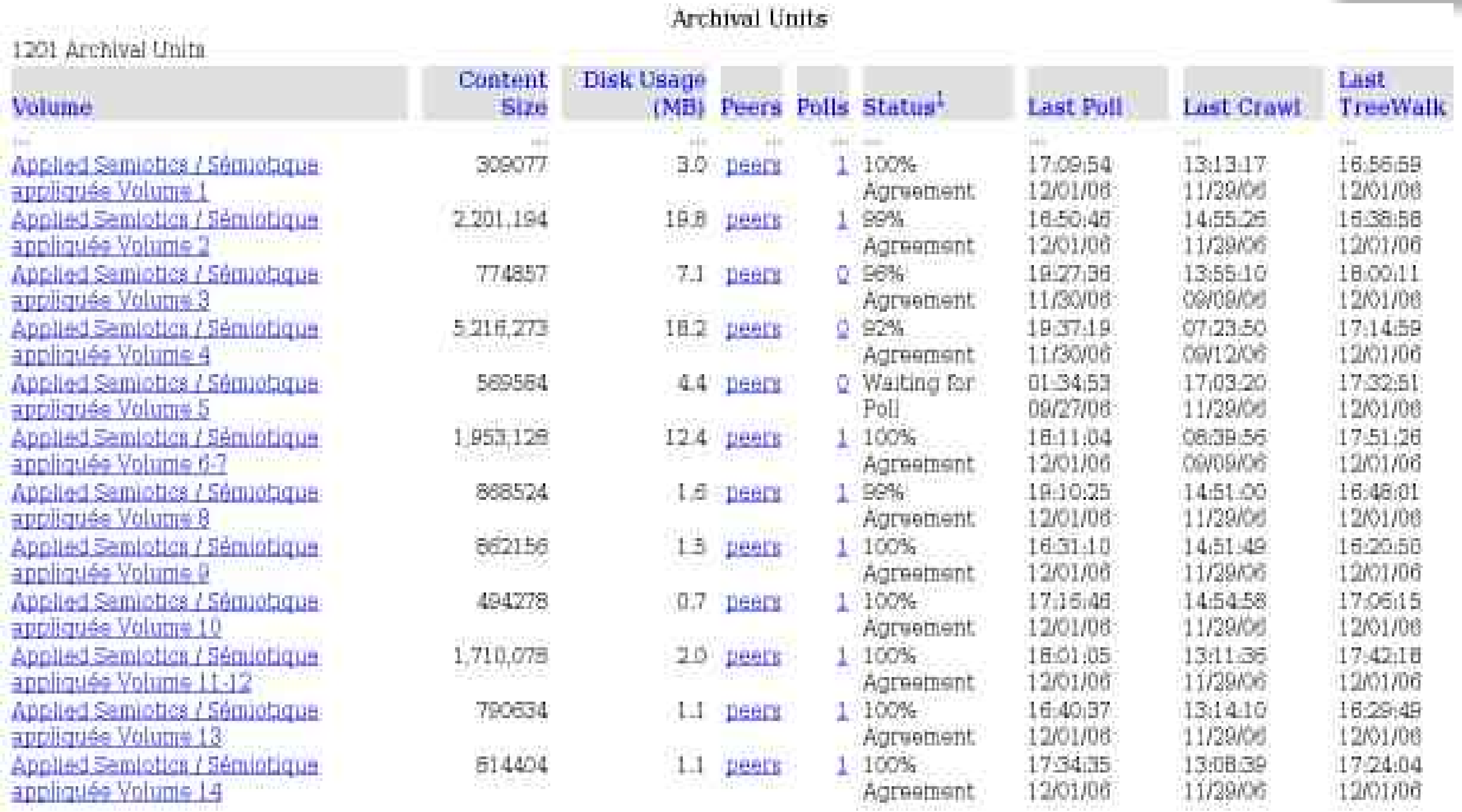
How Hard Can It Be?

- 1PB, 100 years, 50% probability no damage
  - Sounds reasonable, doesn't it?
- That's a bit half-life of 10^{18} years
  - One hundred million times age of universe
  - Must measure really, *really* small effects
- Say the half-life of a bit on a disk is 10 years
  - That's a long service life for a drive
- Must amplify drive bit half-life by 10^{17}
  - Even improbable events will have a big effect

Read the Fine Print

- Example from Amazon S3 license:
  - "AMAZON DOES NOT WARRANT THAT AMAZON WEB SERVICES ... WILL BE ACCESSIBLE ON A PERMANENT BASIS OR WITHOUT INTERRUPTION OR THAT THE DATA YOU STORE IN ANY SERVICE ACCOUNT WILL NOT BE LOST OR DAMAGED."
- All services disclaim liability the same way
  - So do all software components of preservation systems
  - Which is why the lawyers insist on adding them
- No players have any skin in the game
  - If things go wrong, its not their problem

LOCKSS Monitoring



Archival Units

1201 Archival Units

Volume	Content Size	Disk Usage (MB)	Peers	Polls	Status[1]	Last Poll	Last Crawl	Last TreeWalk
Applied Semiotics / Sémiotique appliquée Volume 1	309077	3.0	peers	1	100% Agreement	17:09:54 12/01/06	13:13:17 11/29/06	16:56:59 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 2	2,201,194	19.8	peers	1	99% Agreement	16:50:46 12/01/06	14:55:25 11/29/06	16:38:58 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 3	774857	7.1	peers	0	96% Agreement	19:27:36 11/30/06	13:55:10 09/09/06	18:00:11 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 4	5,216,273	18.2	peers	0	92% Agreement	19:37:19 11/30/06	07:23:50 09/12/06	17:14:59 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 5	569564	4.4	peers	0	Waiting for Poll	01:34:53 09/27/06	17:03:20 11/29/06	17:32:51 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 6-7	1,953,128	12.4	peers	1	100% Agreement	18:11:04 12/01/06	08:39:56 09/09/06	17:51:26 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 8	868524	1.6	peers	1	99% Agreement	19:10:25 12/01/06	14:51:00 11/29/06	16:48:01 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 9	862156	1.3	peers	1	100% Agreement	16:31:10 12/01/06	14:51:49 11/29/06	16:20:56 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 10	494278	0.7	peers	1	100% Agreement	17:16:46 12/01/06	14:54:58 11/29/06	17:06:15 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 11-12	1,710,078	2.0	peers	1	100% Agreement	18:01:05 12/01/06	13:11:36 11/29/06	17:42:18 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 13	790634	1.1	peers	1	100% Agreement	16:40:37 12/01/06	13:14:10 11/29/06	16:29:49 12/01/06
Applied Semiotics / Sémiotique appliquée Volume 14	614404	1.1	peers	1	100% Agreement	17:34:35 12/01/06	13:08:39 11/29/06	17:24:04 12/01/06

Where Are We?

- Sustainability is the fundamental problem
  - Adequate bit half-life @ affordable $/bit/yr
  - Adequate bit half-life is a very aggressive target
- Cost & performance models unrealistic
  - Dynamic costs, multiple correlated threats, ...
  - Many hard-to-quantify threats poorly understood
  - Very hard to benchmark system performance
- Not a good place to be
  - Better models + better data is the place to start

Work Done By

- LOCKSS Research Team (since 2001)
  - Mary Baker, Mehul Shah & colleagues @ HP Labs
  - Mema Roussopoulos & students @ Harvard CS
  - Petros Maniatis & interns @ Intel Research Berkeley
  - Support: NSF, HP, Intel, Sun
- LOCKSS Engineering Team (since 1998)
  - Tom Lipkis, Tom Robertson, Seth Morabito, Thib G.
  - Special thanks to Mark Seiden
  - Support: LOCKSS Alliance, Mellon, Library of Congress