SNIA DEVELOPER CONFERENCE
SDC 25
By Developers FOR Developers

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War Stories from the Storage Trenches

Moving Data Across NFS, SMB, and S3

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SDC 25

Overview

1. File and Object Storage
2. Why Copy Data?
3. How to Copy Data
4. Scenarios
5. War Stories
6. Lessons Learnt

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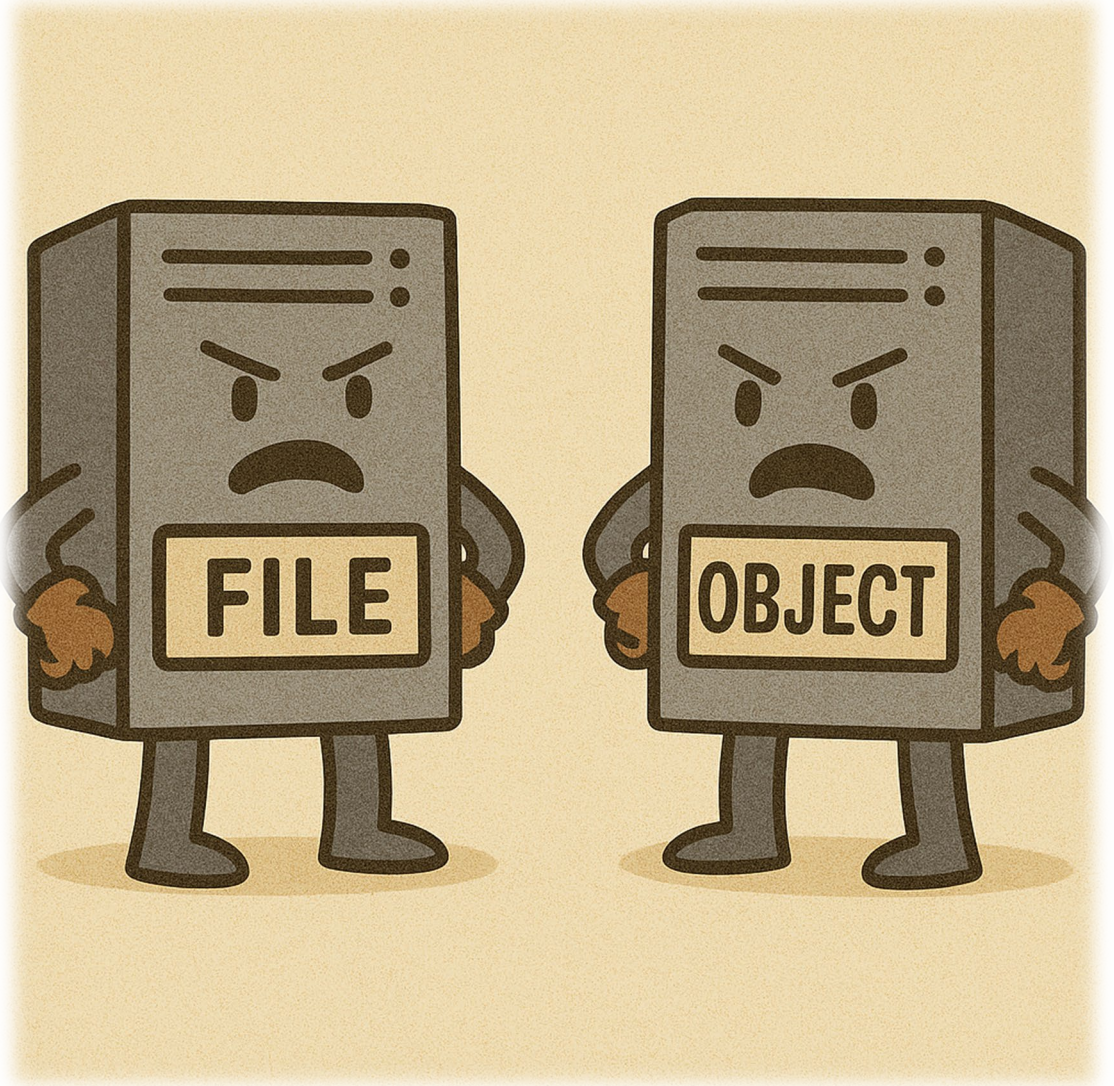

File and Object Storage

File Storage (~1980)

- File sharing, collaboration
  - High performance, often scale limitations
  - Scale getting better
- On-prem servers + a few cloud services
- NFS / SMB (Network-Attached Storage)
  - + FUSE or specialized FS drivers

Object Storage (~2000)

- Immutable objects + metadata
  - Low cost, low performance, large scale
  - But also "fast object"
- Cloud services + on-prem servers
- S3 emerged as a 'de facto standard'
  - + AzureBlob, GCS, …

There is more unstructured data in the enterprise:

- Specialized rich file services (OneDrive, Gdrive, Dropbox, Box, Sharepoint, ...)
- Application-captured unstructured data (e.g. Salesforce, Slack, Email, …)

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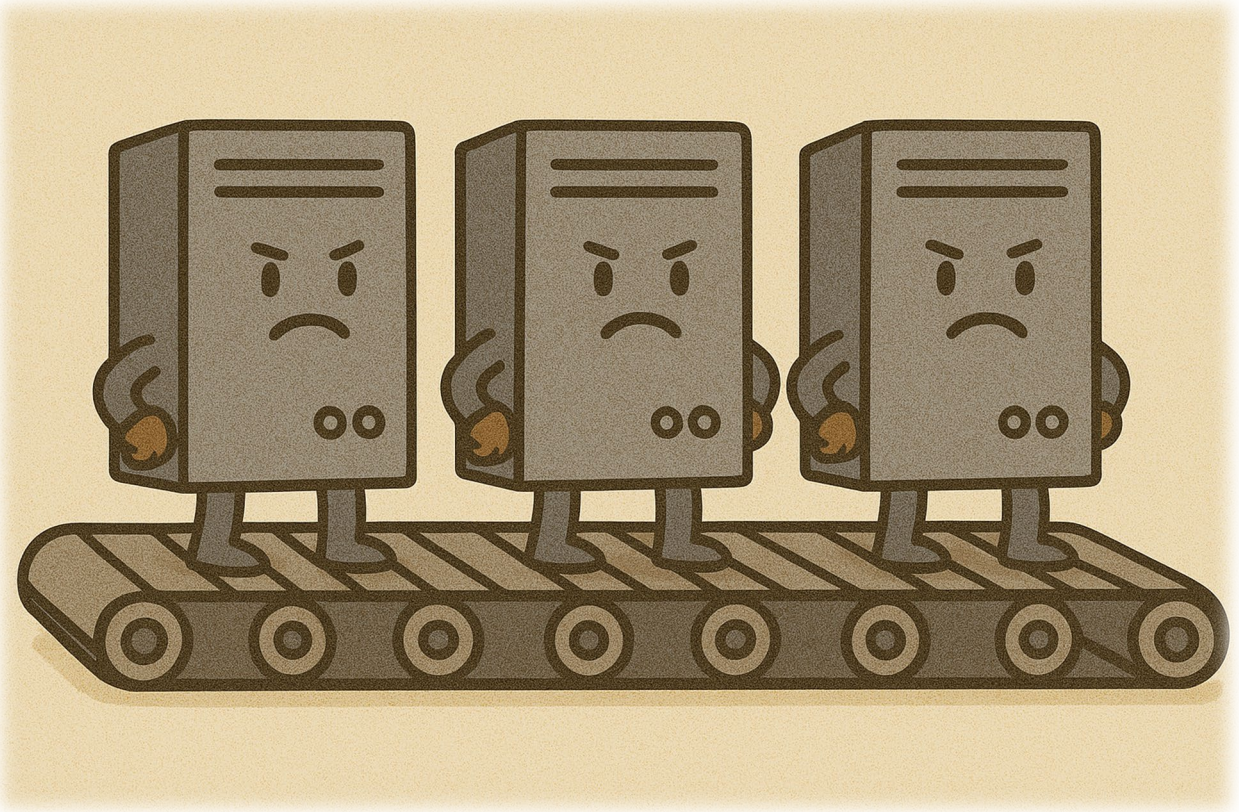

Why Copy Data?

- Data Move / Migrate
  - Vendor Swap
  - Technology Refresh
  - Datacenter Consolidation
  - Server/AD Consolidation
  - Cloud Adoption
  - Cloud Repatriation
  - Geopatriation
  - Free up primary storage
  - Data Relocation
  - Cleanup
- Data Replication
  - Often cross-vendor
  - Hybrid cloud
  - 3rd copy
- Data Archival
  - Often to tape-based object
- Data Copy
- AI Pipeline
- Data Backup
- Data Tiering

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Goal of Making a Data Copy

Copy files and objects between source and target storage.

Naive goal: “Target must be 100% identical to source”.

- ✓ File / object content
- ✓ Path, name
- ✓ Basic metadata (timestamps, ownership, permissions, S3 user-metadata)
- ✗ Other S3 metadata

  ETag, last modification time, version-id, history, storage class, retention, …
- ✗ Other file metadata

  change time, inode number, snapshots, SACL, stubs, tiering, size on disk, hard links, …

How to Copy/Migrate Data (1)

```
1. cp -r *.*
2. Point clients to target
```


How to Copy/Migrate Data (2)

```
1. cp -p -r *.*
2. Point clients to target
```


How to Copy/Migrate Data (3)

1. Make source read-only
2. cp -p -r *.*
3. Point clients to target

How to Copy/Migrate Data (4)

1. Do full copy (cp -r -p *.*)
2. Repeat [Do incremental copy]
3. Cutover:
   - Make source read-only
   - Final incremental copy
4. Point clients to target

How to Copy/Migrate Data (5)

1. Do full copy skipping recent changes
2. Repeat [Do incremental copy skipping recent changes]
3. Cutover:
   - Make source read-only
   - Final incremental copy (no skipping)
4. Point clients to target

How to Copy/Migrate Data (6)

1. Do full copy skipping recent changes
2. Repeat [Do incremental copy skipping recent changes]
3. Dry-run: Incremental copy (no skipping) + report
4. Plan Cutover
5. Execute Cutover:
   - Make source read-only
   - Final incremental copy (no skipping)
6. Point clients to target

How to Copy/Migrate Data (7)

1. Do full copy skipping recent changes
2. Repeat [Do incremental copy skipping recent changes]
3. (optional) Small test at target. Goto 2
4. Dry-run: Incremental copy (no skipping) + report
5. Plan Cutover
6. Execute Cutover:
   - Make source read-only
   - Final incremental copy (no skipping)
7. Point clients to target
8. Panic! Problems on target during production usage!
   - Copy-back changes from target to source
   - Point clients back to source
   - Goto 2

Data Copy/Migration - Summary

- And much more:
  - Pre-migration assessment & sizing
  - Filtering out unwanted files & objects
  - Selectively retrying specific failures
  - Parallelization & throttling
  - Copy data retention dates & legal holds
  - Mapping identities
  - “Chain of Custody” report
  - Resuming half-failed migrations
  - …

➔ Migration is a non-trivial non-linear non-fully-plannable process!

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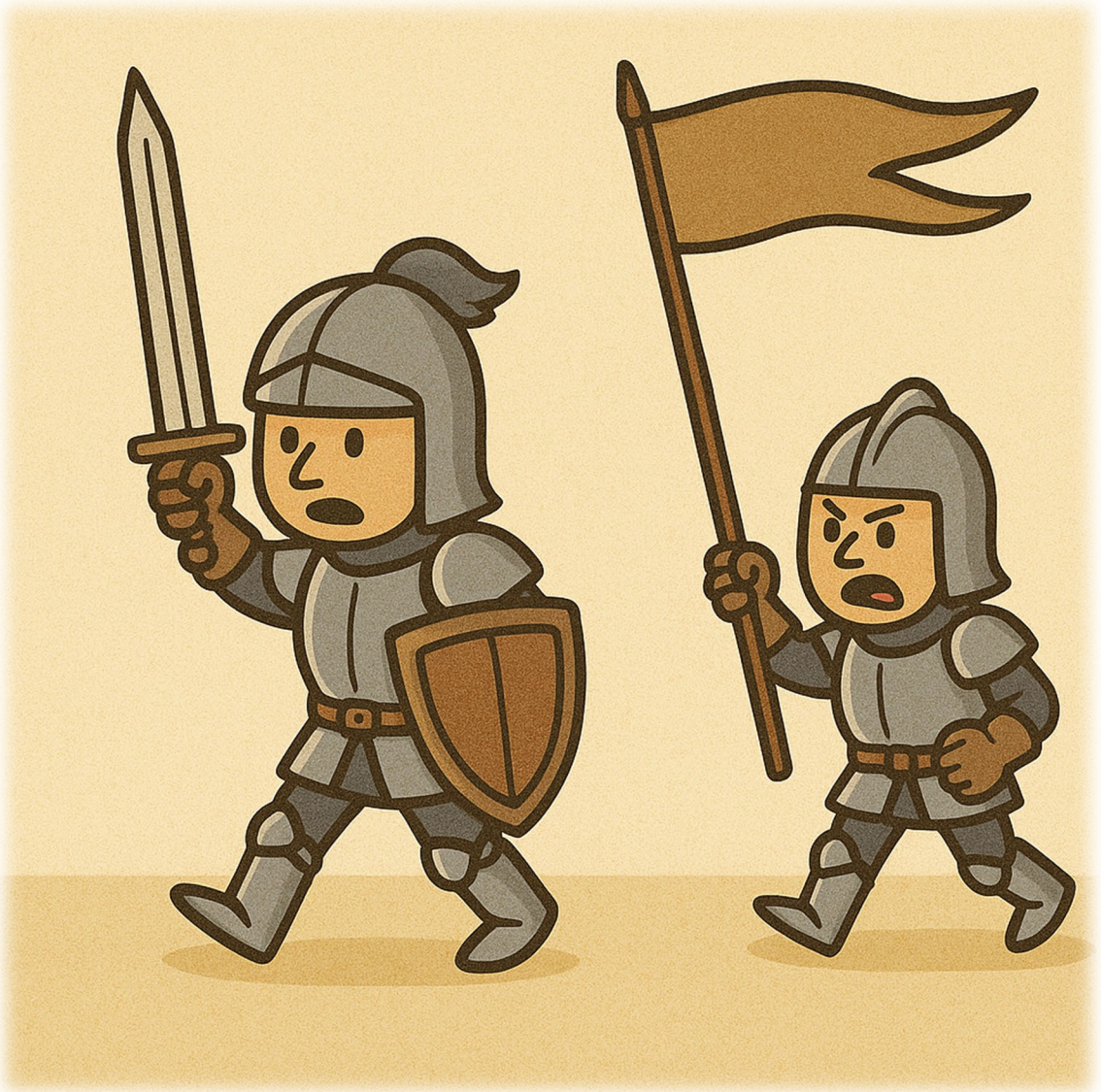

Basic Scenarios

- Full server copy
- Cross-vendor
- Same-protocol
  - SMB → SMB
  - NFS → NFS
  - S3 → S3

Advanced Scenarios

- SMB+NFS → SMB+NFS
  - *"multi-protocol NAS"*
- File gateways
- Locked data: retention & legal hold
- Granular data reorganization
- Protocol change
  - File → Object → File
  - (S3 → AzureBlob → S3)

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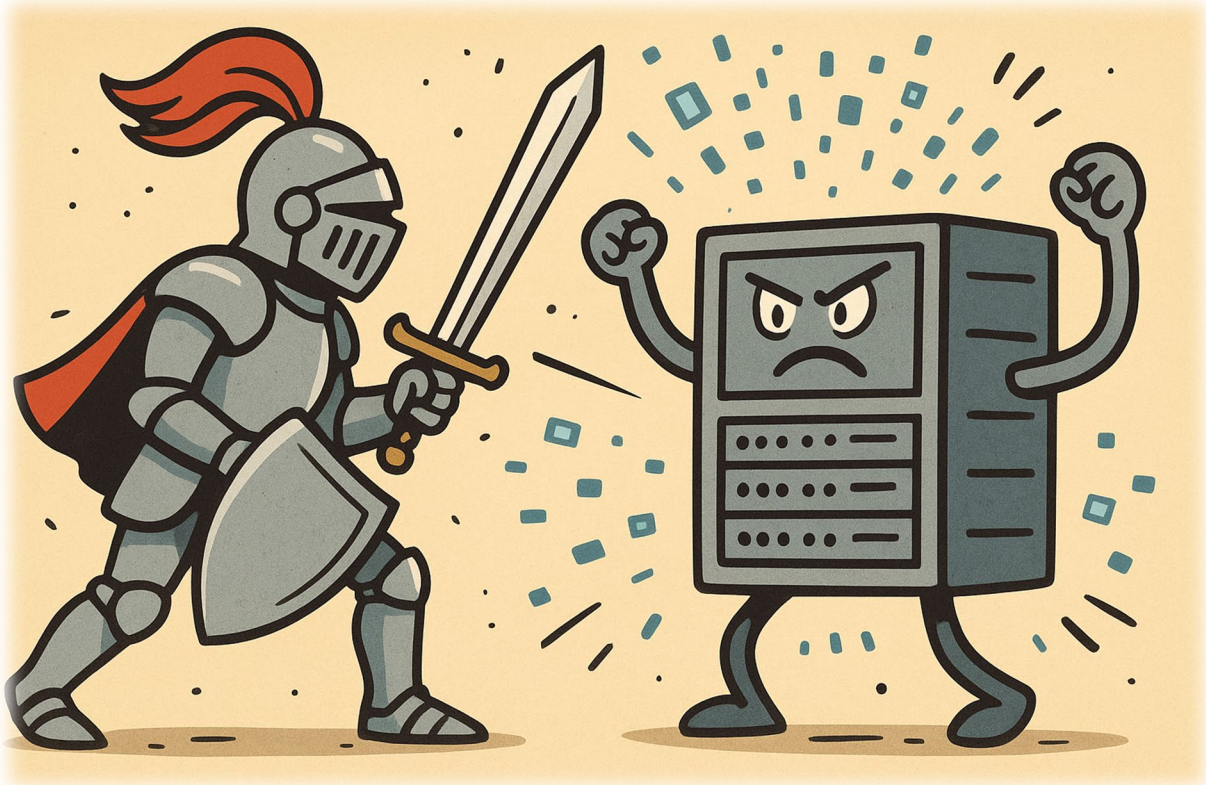


War Stories – Protecting Customers Against Themselves

- Sanity checks before you start
  - Non-empty target
  - "Automatic" retention (lock) on target
- Why do you need a formal cutover?
  - A "quick" write test against target: can screw up synchronization
  - Applications or users pointing at target before formal cutover is finished
  - Data loss…
  - Split brain…

War Stories - Configuration

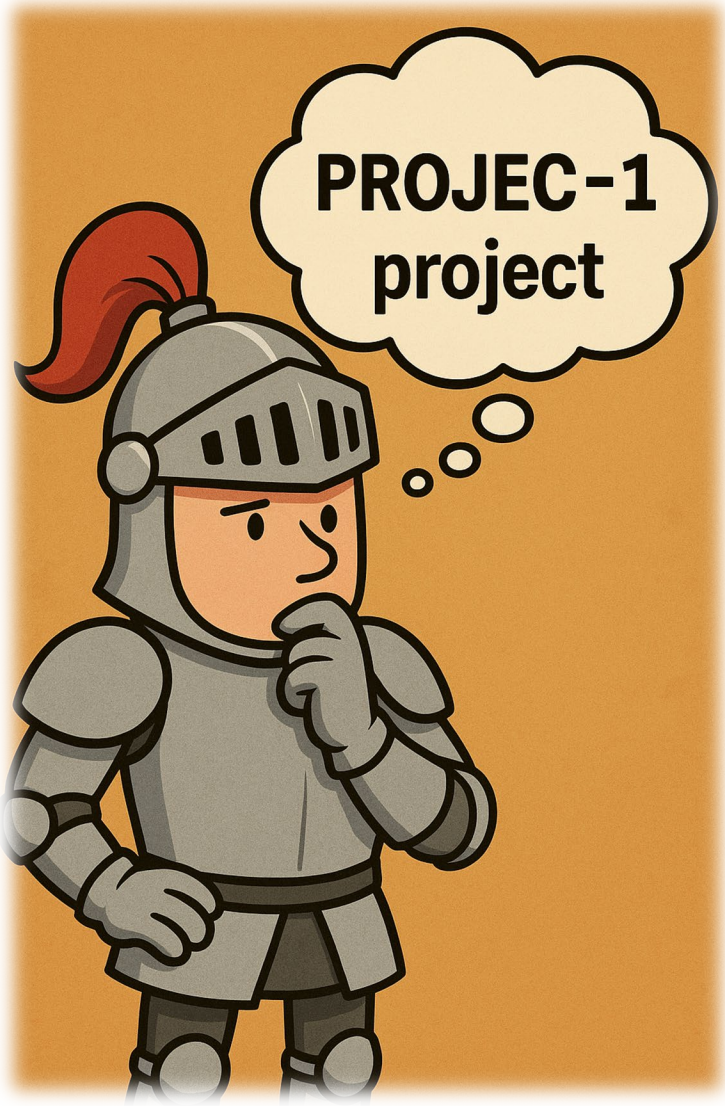
- Accessing the wrong server…
  - Source and target
  - Misconfigured proxies
  - DNS fun
    `https://s3.company.net/bucket/`
    `https://bucket.s3.company.net/`
- Insufficient Access rights
  - E.g. cannot access subdir
- Credentials
  - Mistyped passwords and access keys
  - App team not willing to share credentials

War Stories - Timestamps

- Make target identical to source?
  - Target timestamp changes post-write (antivirus?)
  - Lifecycle acting on target object
  - Listing items vs getting item metadata (stat, HEAD)
  - Timestamp granularity
    - `12:12:01.332` vs `12:12:02`
  - Cannot set S3 modification time, or file `ctime`
- Heisenberg Observer Effect: source `atime`
- Can we trust `mtime`
  - Open an MS Word doc but do not make any changes.
  - File content is modified but `mtime` is reset to its original value

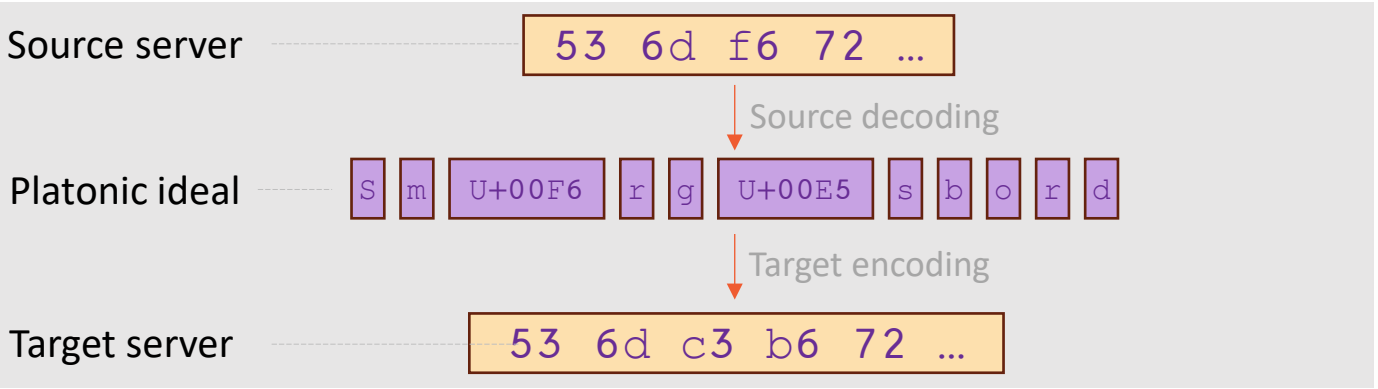
War Stories – Names

- Inconsistent length limits
  - Files: NAME_MAX, PATH_MAX, MAX_PATH
  - S3: 1024 UTF-8 BYTES
  - Azure Blob: 254 (or 63) "path segments"
- Illegal characters
  - \ / : * ? " < > | 0x00
- Illegal names
  - SMB
    - CON, PRN, NUL, NUL.txt, AUX, CLOCK$, COM1…9, LTP1…9
    - "file.", "file ", ".", ".."
  - S3
    - too/many/../../../dotdot/segments
    - object_key_ending_in_slash/
    - soap
- SMB Case sensitivity & "8.3 names"
    - project, PROJECT, Project/
    - PROJEC~1, PROJEC~2, … depends on creation order



War Stories – Name Encoding

- Seen this before?
  - Smörgåsbord - SmörgÍsbord
  - Résultat_élève.xls - Rщsultat щlшve.xls
  - Müller - M?ller - MÃ¼ller - M�ller



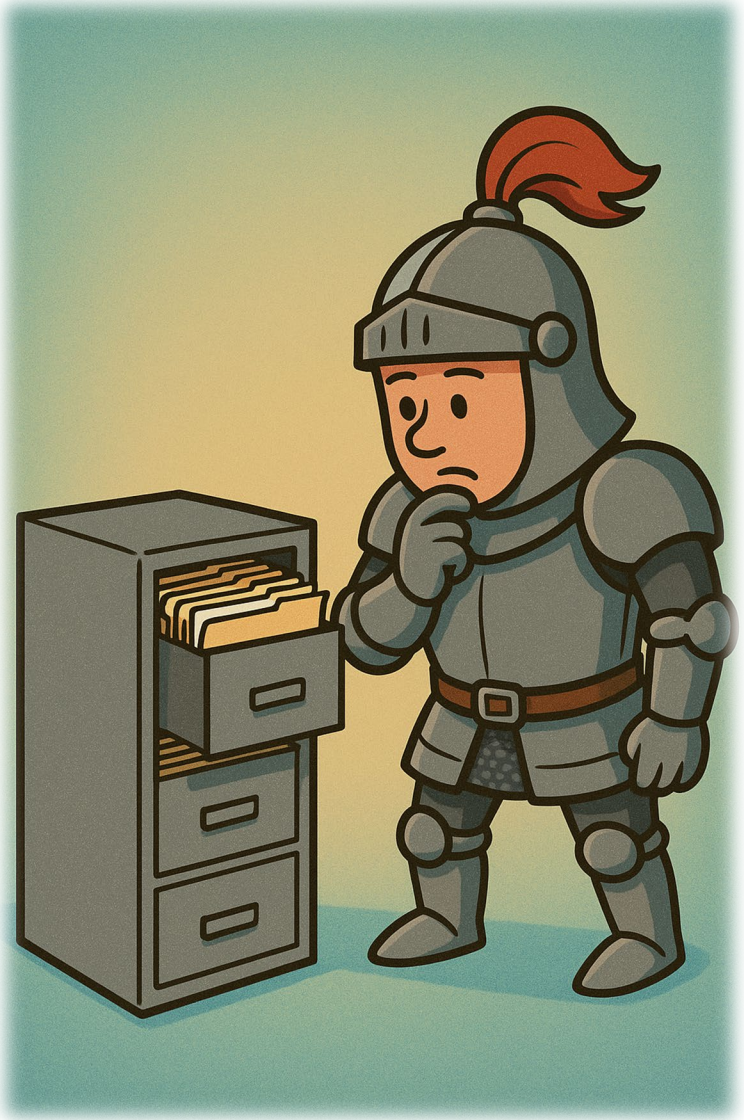
- Encoding ISO-8859-1, UTF-16, UTF-8, …

  "UTF-16 is a dumb useless hack. UTF-8 is a brilliant useful hack."

  - But UTF-8 is not perfect
    - BOM, overlong encoding, 0x00
    - "Problematic code points" RFC-9839
    - *WTF-8 to the rescue ?*

War Stories – File Storage

- Annoying limitations
  - Number of files per dir
  - Number of inodes
- Mutable & Locked files
- NAS gateways / tiered solutions
  - Rehydration doesn't work at scale
  - ➔ Use gateway for metadata, bypass it for data



War Stories – Object Storage

- HTTP 200 is not always a success

War Stories – Object Storage

```
GET / HTTP/1.1
Host: bucket.s3.company.net
```

```
HTTP/1.1 200 OK

<?xml version="1.0" encoding="UTF-8"?>
<ListBucketResult>
<Contents>
    <Key>sample1.txt</Key>
    <LastModified>2024-11-04T19:39:04.000Z</LastModified>
    <Size>22</Size>
</Contents>
<Contents>
    <Key>sample2.txt</Key>
    <LastModified>2024-11-04T19:39:04.000Z</LastModified>
    <Size>22</Size>
</Contents>
…
</ListBucketResult>
```


War Stories – Object Storage

```
GET / HTTP/1.1
Host: bucket.s3.company.net
```

```
HTTP/1.1 200 OK

<?xml version="1.0" encoding="UTF-8"?>
<ListAllMyBucketsResult>
<Buckets>
  <Bucket>
    <Name>engineering</Name>
    <CreationDate>2025-0526T19:37:25.000Z</CreationDate>
  </Bucket>
  <Bucket>
    <Name>marketing</Name>
    <CreationDate>2024-11-09T10:20:55.000Z</CreationDate>
  </Bucket>
  ...
</ListAllMyBucketsResult>
```


War Stories – Object Storage

```
GET / HTTP/1.1
Host: bucket.s3.company.net
```

```
HTTP/1.1 200 OK

<html>
  <body>
    <h1>Welcome to Intranet</h1>
    <p>Welcome all!</p>
  </body>
</html>
```


War Stories – Object Storage

```
POST /?delete HTTP/1.1
Host: bucket.s3.company.net

<Delete>
  <Object><Key>sample1.txt</Key></Object>
  <Object><Key>sample2.txt</Key></Object>
</Delete>
```

```
HTTP/1.1 200 OK

<?xml version="1.0" encoding="UTF-8"?>
<DeleteResult xmlns="http://s3.amazonaws.com/doc/2006-03-01/">
  <Deleted>
    <Key>sample1.txt</Key>
  </Deleted>
  <Error>
    <Key>sample2.txt</Key><Code>AccessDenied</Code>
  </Error>
</DeleteResult>
```


War Stories – Object Storage

- HTTP 200 is not always a success
- Better safe than sorry

War Stories – Object Storage

Suppose AWS S3 introduces a new object “subresource” such as tagging.
Some S3 application uses that feature against an ‘old’ S3-compatible server.

```
PUT /important_doc?newfeature HTTP/1.1
Host: bucket.s3.company.net

<?xml version=”1.0” encoding=”UTF-8”?>
<NewFeature>
    <SomeConfig />
</NewFeature>
```

```
HTTP/1.1 200 OK
```

```
GET /important_doc HTTP/1.1
Host: bucket.s3.company.net
```

```
HTTP/1.1 200 OK

<?xml version=”1.0” encoding=”UTF-8”?>
<NewFeature>
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</NewFeature>
```
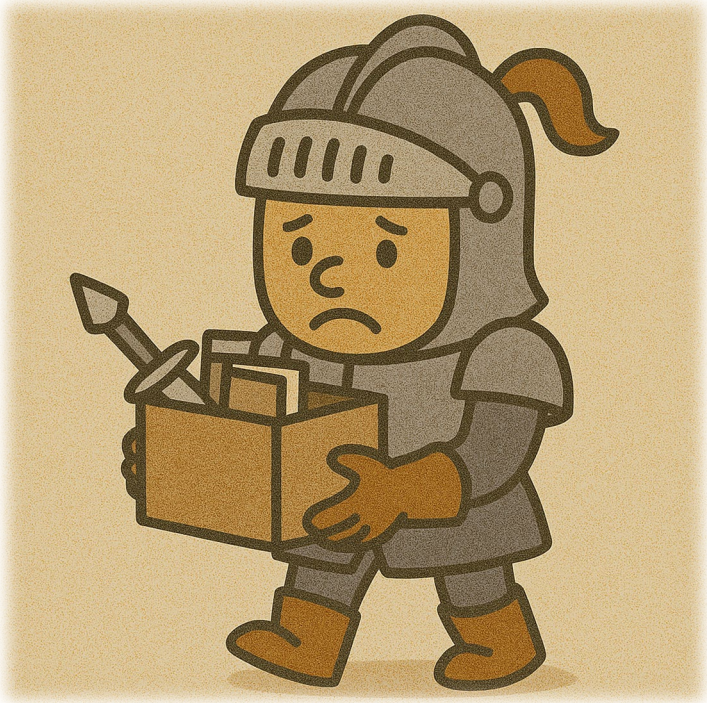

Data loss… Caused by ignoring unknown query string params, or request headers

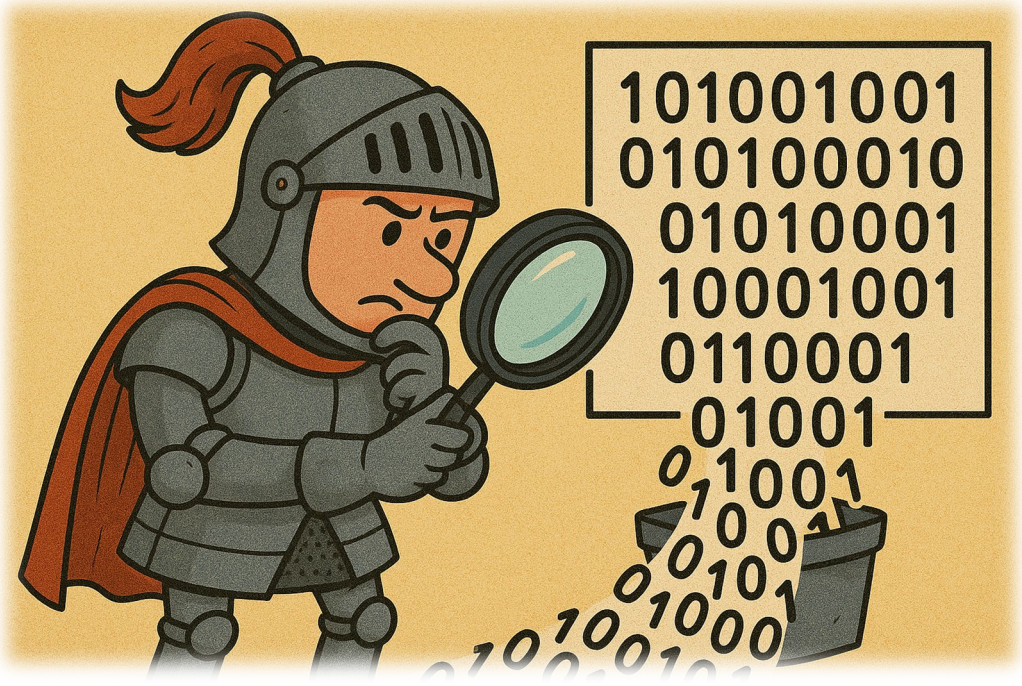


War Stories – Object Storage

- HTTP 200 is not always a success
- Better safe than sorry
- HTTP HEAD requests
  - No (error) response body
- HTTP response status code
  - Create → 200 or 201 ?
  - Delete → 200 or 204 or 404 ?
- Beware
  - ETag is not (always) the content MD5
  - S3 Version-id and timestamp not settable

War Stories – Content

- Content size limits
- Metadata size limits
- (SMB) Alternate Data Streams
- Eventual consistency
  - Not present in listing but can access
  - Present in listing but FileNotFound
  - Outdated content
- Trust but verify
  - Read back what you just wrote to target



War Stories – Multi-Protocol

- NFS/SMB multi-protocol – Case sensitivity
  - NFS: `file.txt and FILE.TXT` - SMB: read `FILE.TXT`
  - Could get worse: `DIR/ and dir/ and DIR~1/`
- Single item becomes multiple files/objects
  - `my/cool/document.txt`
- Cannot copy object back to file
  - `my/cool/project/`
  - `my/cool/project` vs `my/cool/project/file.txt`

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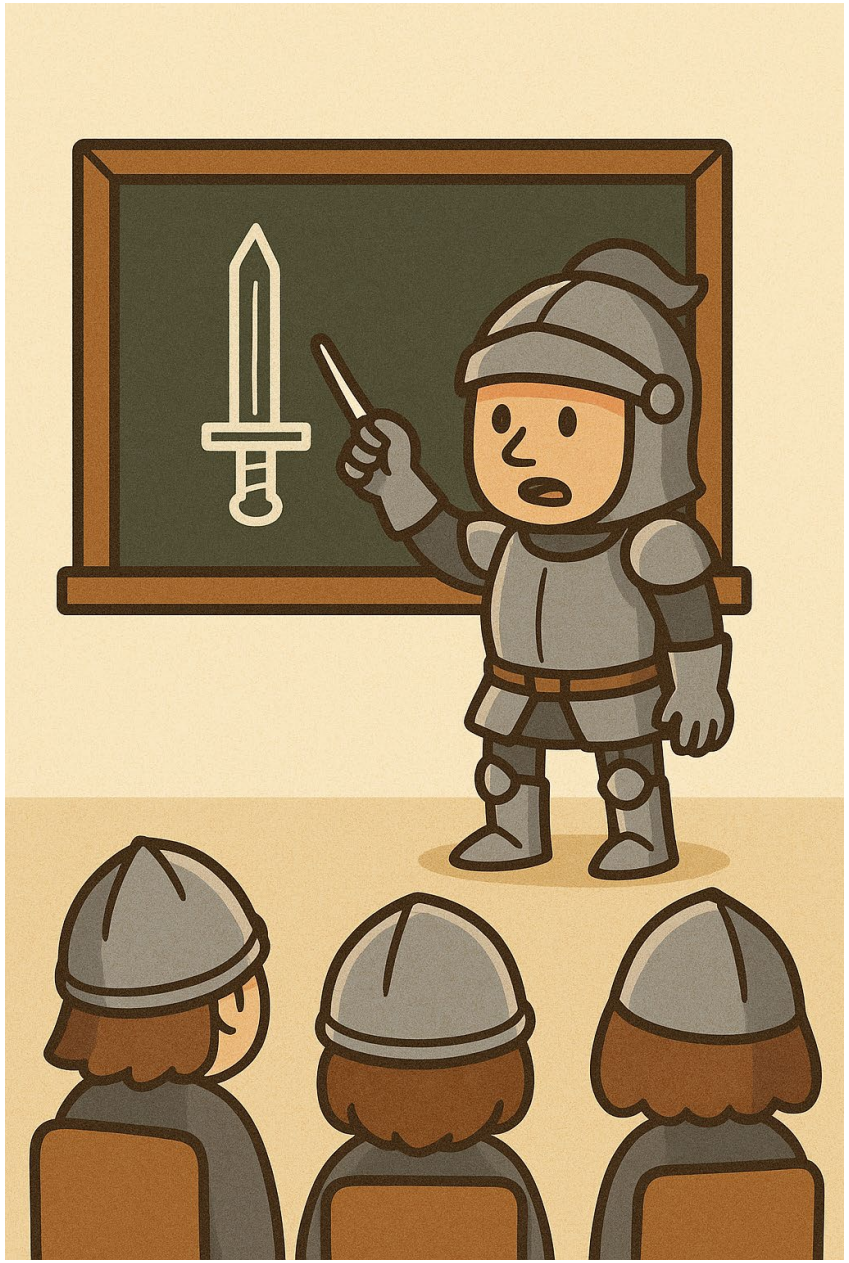


Lessons Learnt – Developers of Data Mobility Software

- Defensive coding. Trust no one. Double check everything:
  - Server bugs
  - Ill-defined protocols
  - Process mistakes, people making errors
- Support old storage systems.
  - Don’t expect vendor bug fixes.
- Support server-specific quirks
- Read specs & docs
  - Understand how things work *in theory*
- Read again specs & docs
  - Be creative, get in the mind of the server developer, prevent mistakes

Lessons Learnt – Storage System Developers

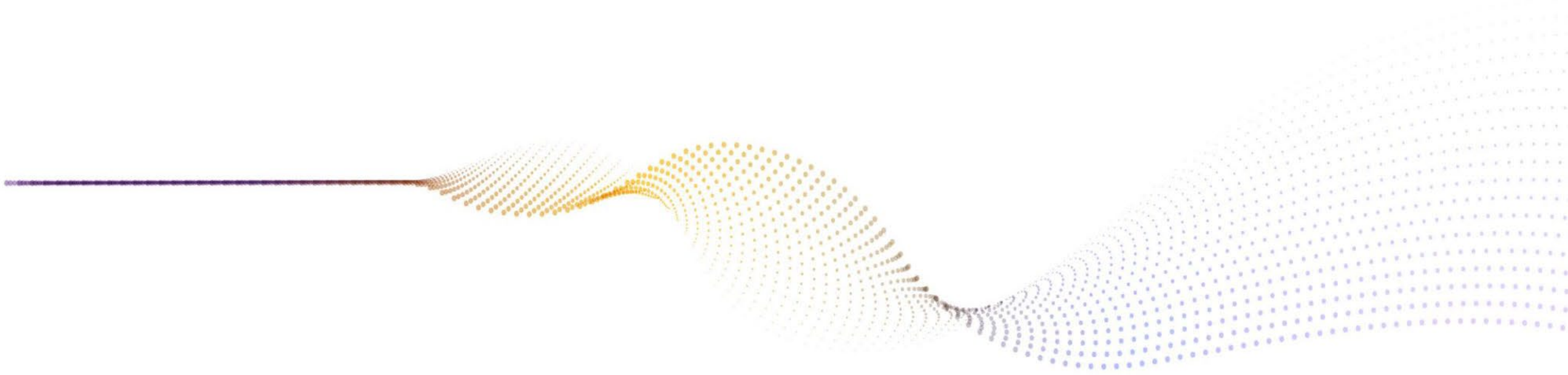
- Rich logging, rich error responses
- Sanitize your inputs
  - Refuse everything you don't support (request headers, query string params, XML request body elements, …)
  - Loosen up using whitelists
- Think of data mobility!
  - Settable S3 credentials
  - Settable S3 version-id
  - One day cutover could be as simple as a DNS change
- Fast way to get full + incremental inventory of all files/objects
  - Offer a way to detect that something DIDN'T change (changetime, version-id, LastModified)
  - Don't forget metadata changes (e.g. for S3 retention changes or object tags)
- Semantics of S3 dialects (S3-RDMA ?)
- Join SNIA collaboration efforts – SMB and S3 plugfests; compatibility test suite

Lessons Learnt - Application Developers

- Test against various storage systems
- Use safe characters, short names, compact metadata, bounded-size content
- Do not assume the server understands your requests
  - Process both error and success responses diligently
- S3
  - Do not use custom HTTP headers, query string params
  - When using shiny new features (e.g. conditional PUT), provide a fallback code path
  - Do not (only) rely on versionid or lastmodified timestamp. Make sure you can recover / rebuild.

Lessons Learnt – Storage Administrators

- Test your application with your storage system (or ask storage vendor)
- Understand your scaling and performance requirements
- Think of data mobility from day one
  - Especially if you consider gateways or tiering solutions
- Migration, replication, data copying
  - Requires careful planning
  - Requires dedicated software and methodology. It is not just “running a script”.



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