VXA: A Virtual Architecture for Durable Compressed Archives

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http://pdos.csail.mit.edu/~baford/vxa/

The Ubiquity of Data Compression

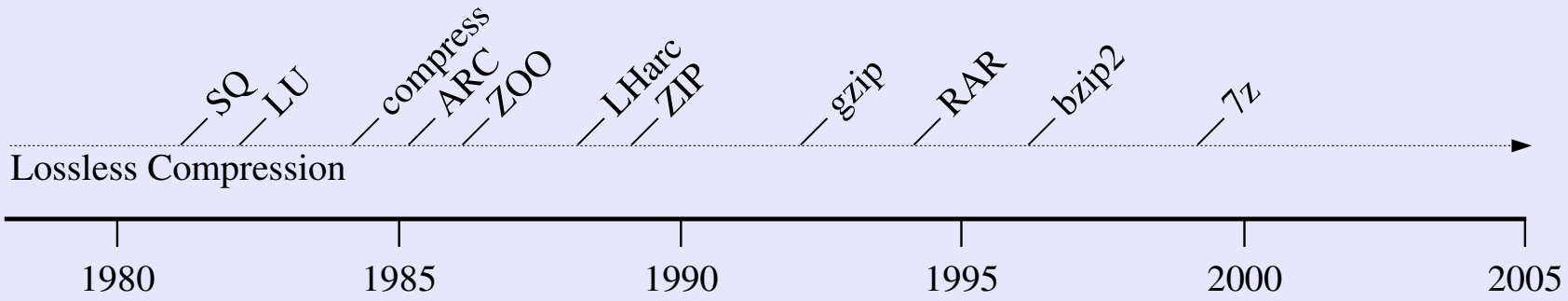
Everything is compressed these days

- **Archive/Backup/Distribution:** ZIP, tar.gz, ...
- **Multimedia streams:** mp3, ogg, wmv, ...
- **Office documents:** XML-in-ZIP
- **Digital cameras:** JPEG, proprietary RAW, ...
- **Video camcorders:** DV, MPEG-2, ...

Compressed Data Formats

Observation #1:

Data compression formats evolve rapidly



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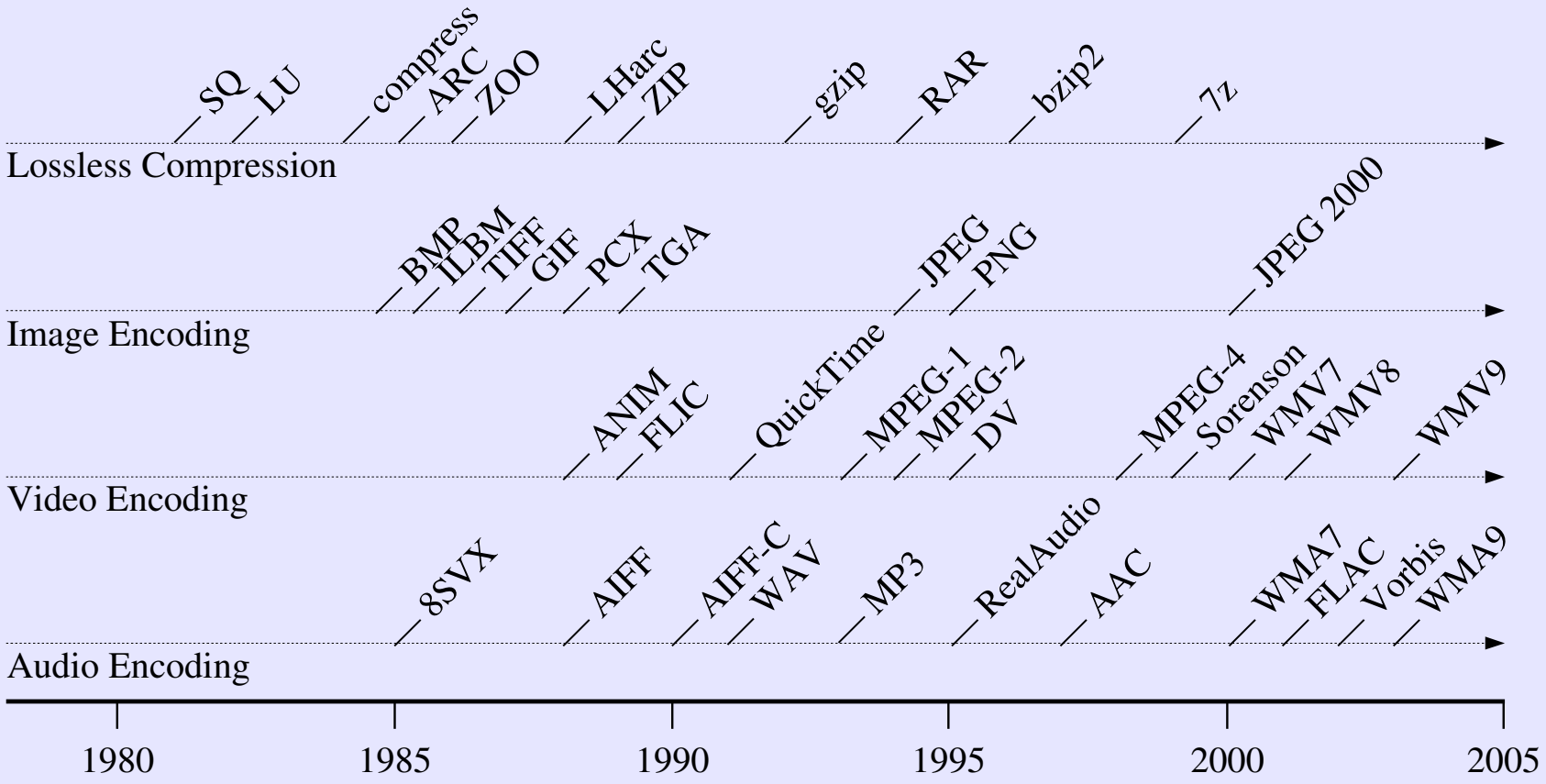

Compressed Data Formats

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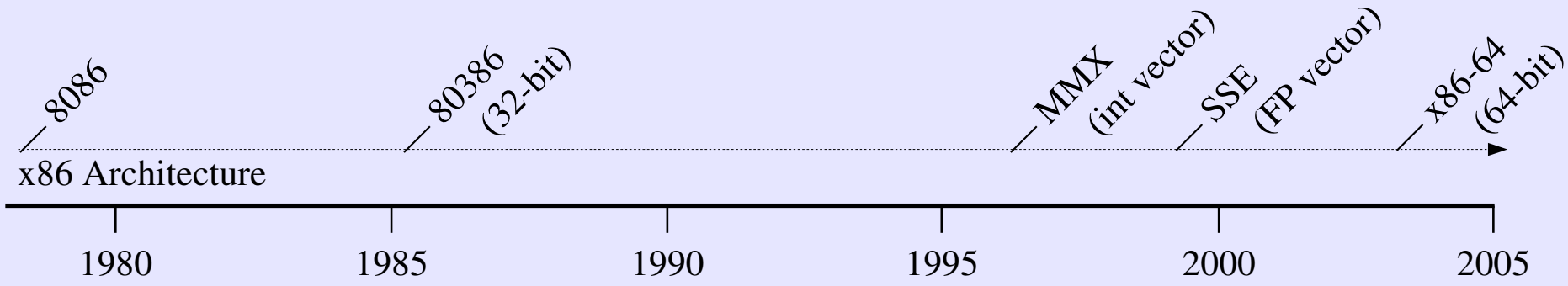
Problems:

- *Inconvenient:*
  each new algorithm requires decoder install/upgrade
- *Impedes data portability:*
  data unusable on systems without supported decoder
- *Threatens long-term data usability:*
  old decoders may not run on new operating systems

Archiving Compressed Data

Observation #2:

Processor architectures evolve more conservatively



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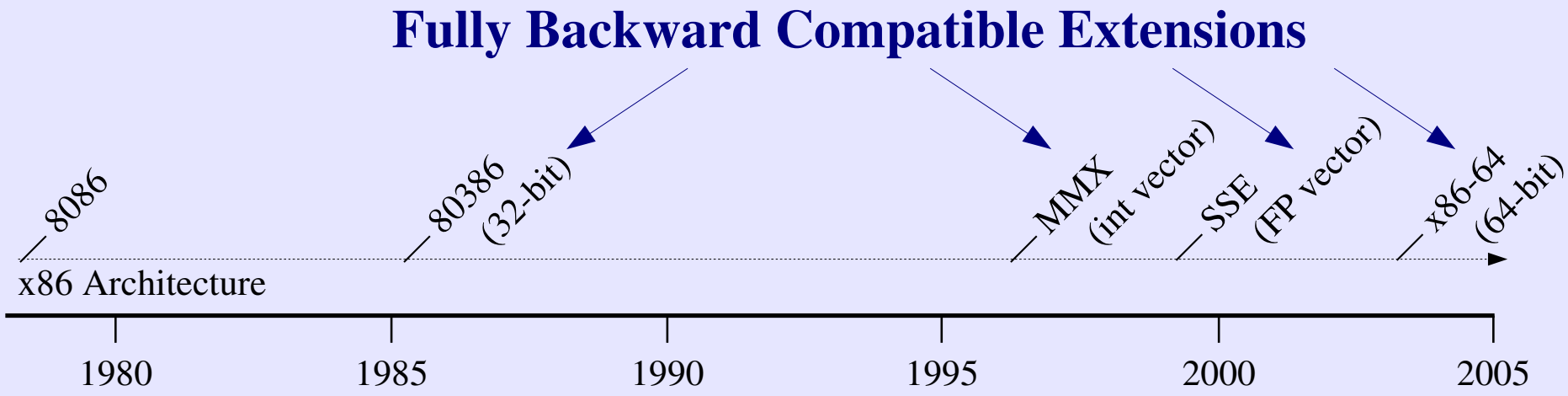

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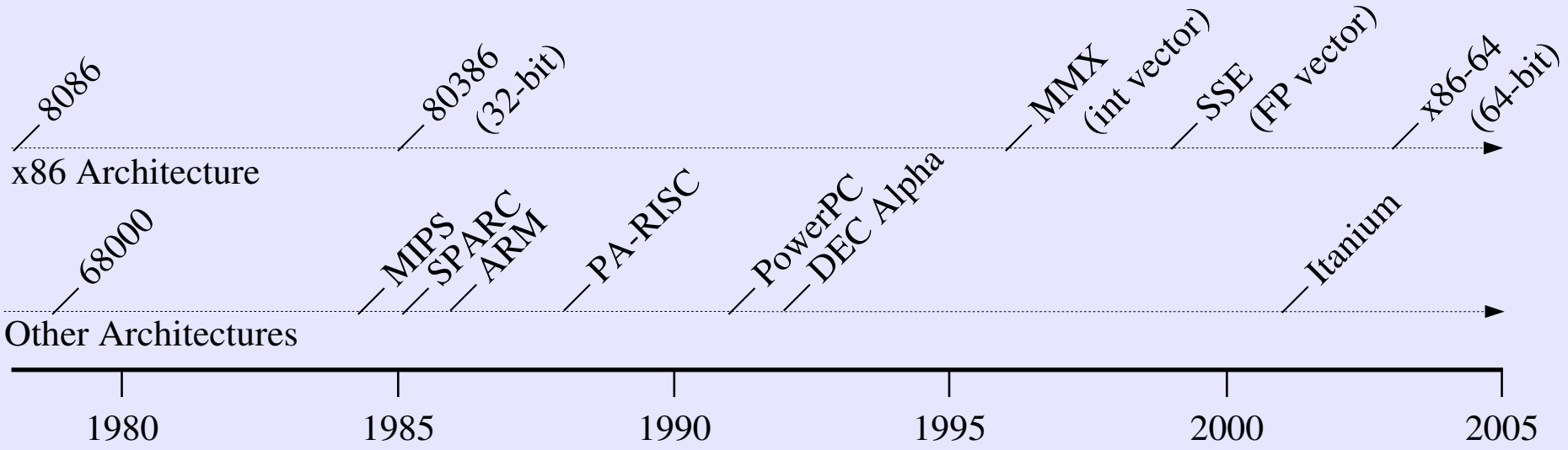

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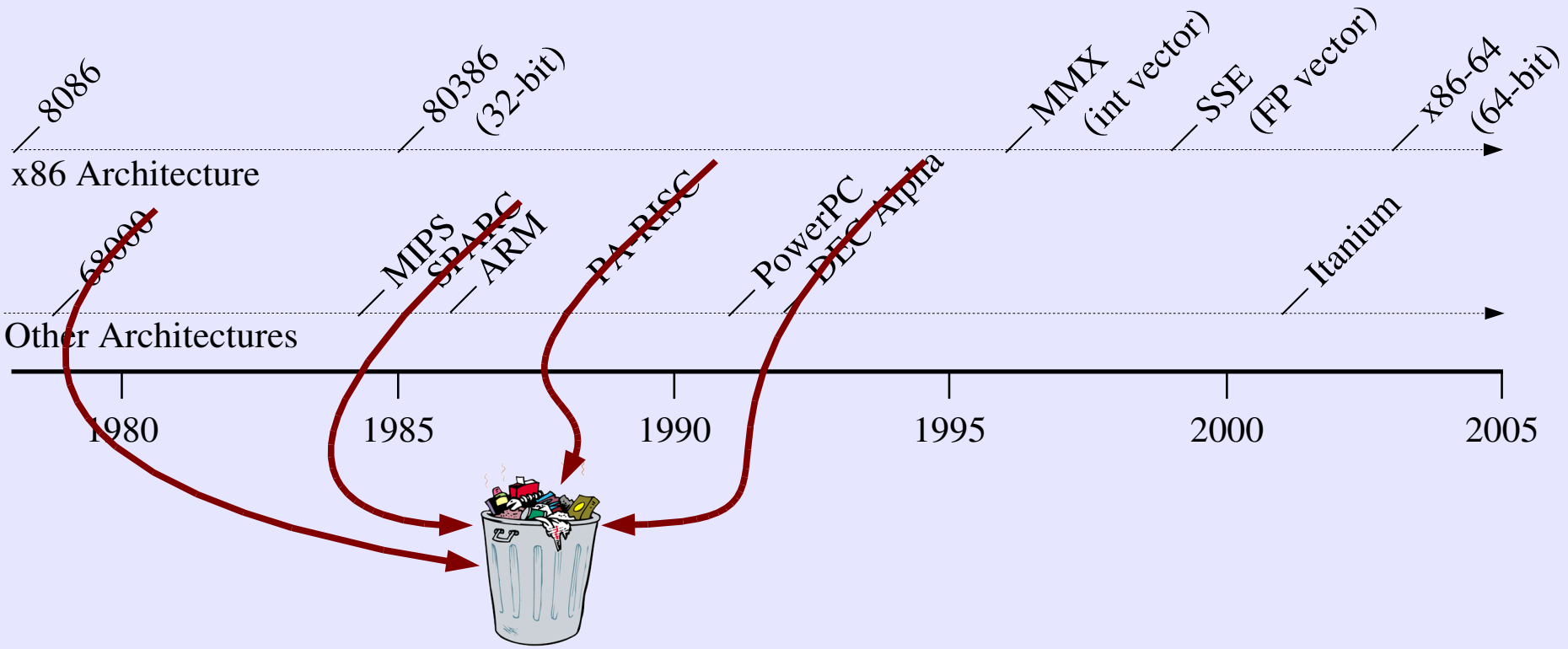

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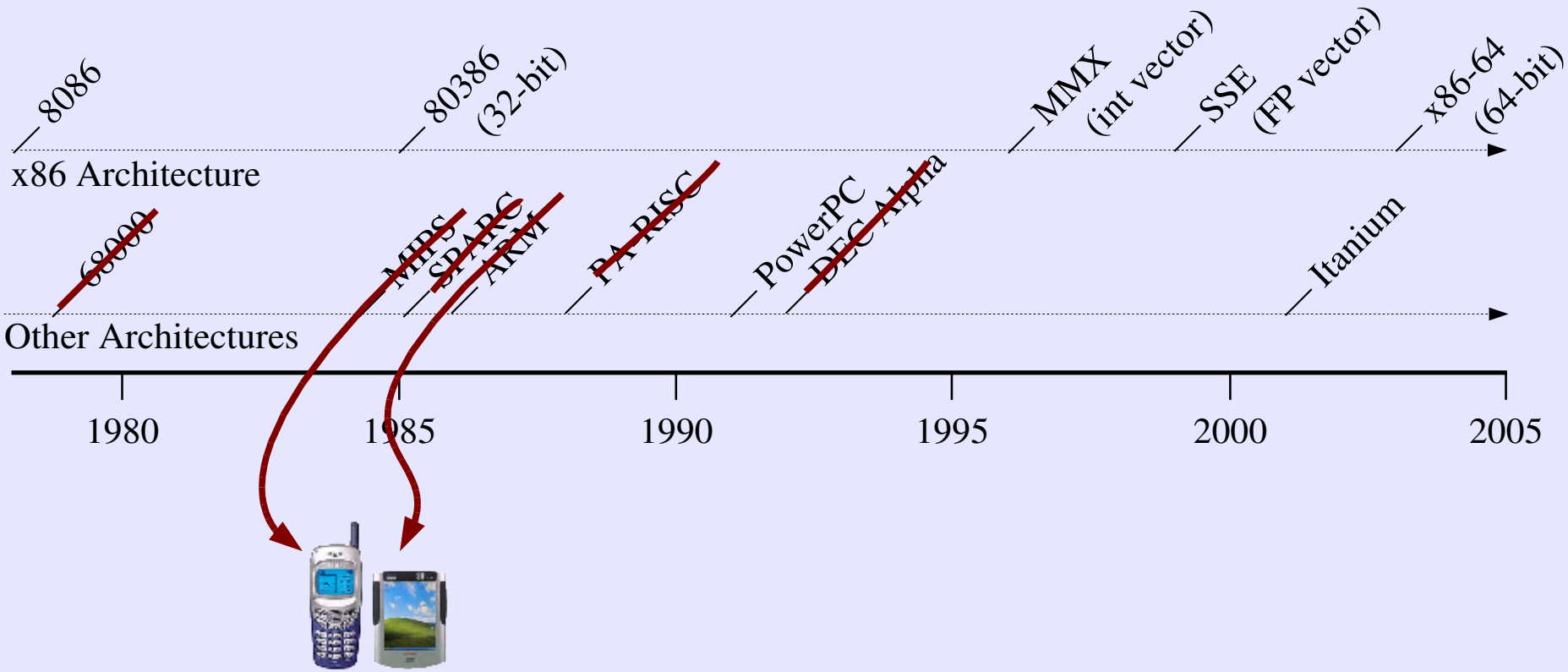

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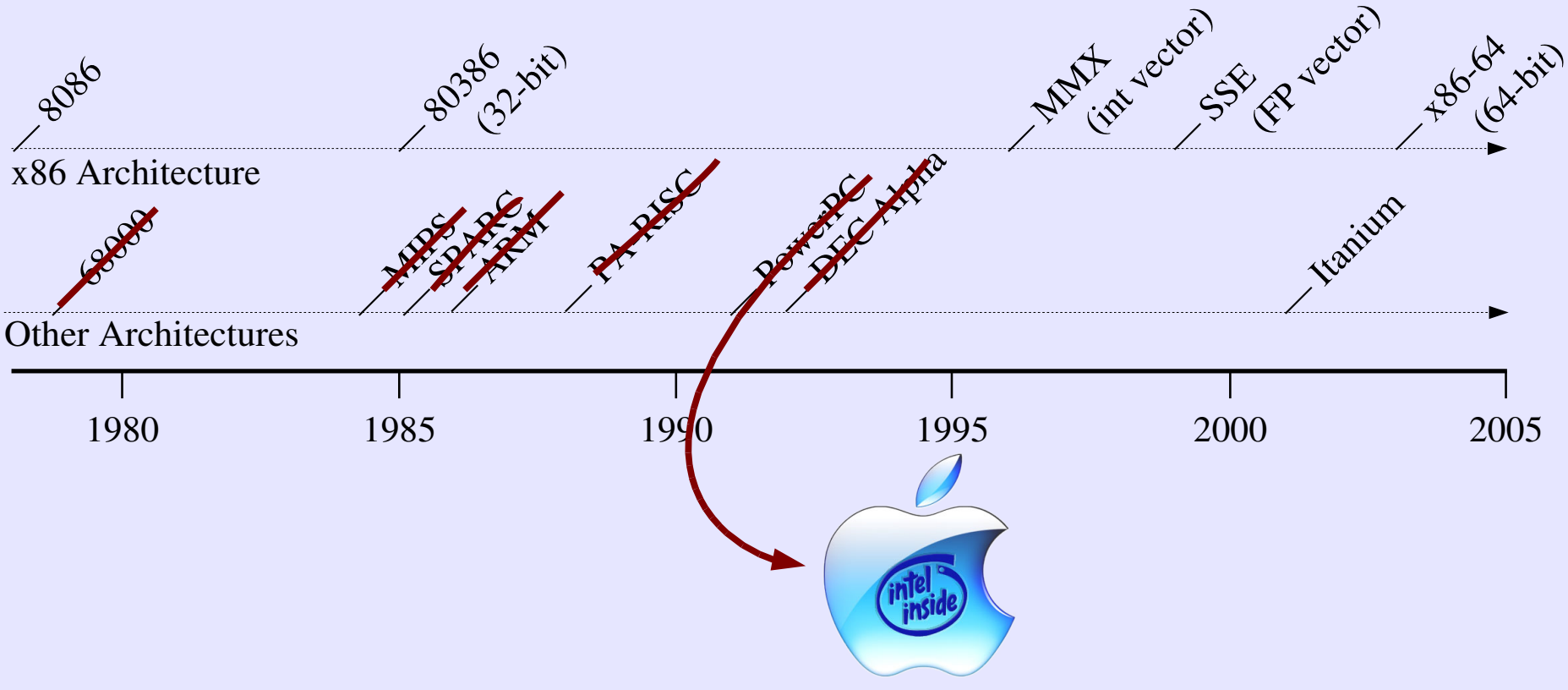

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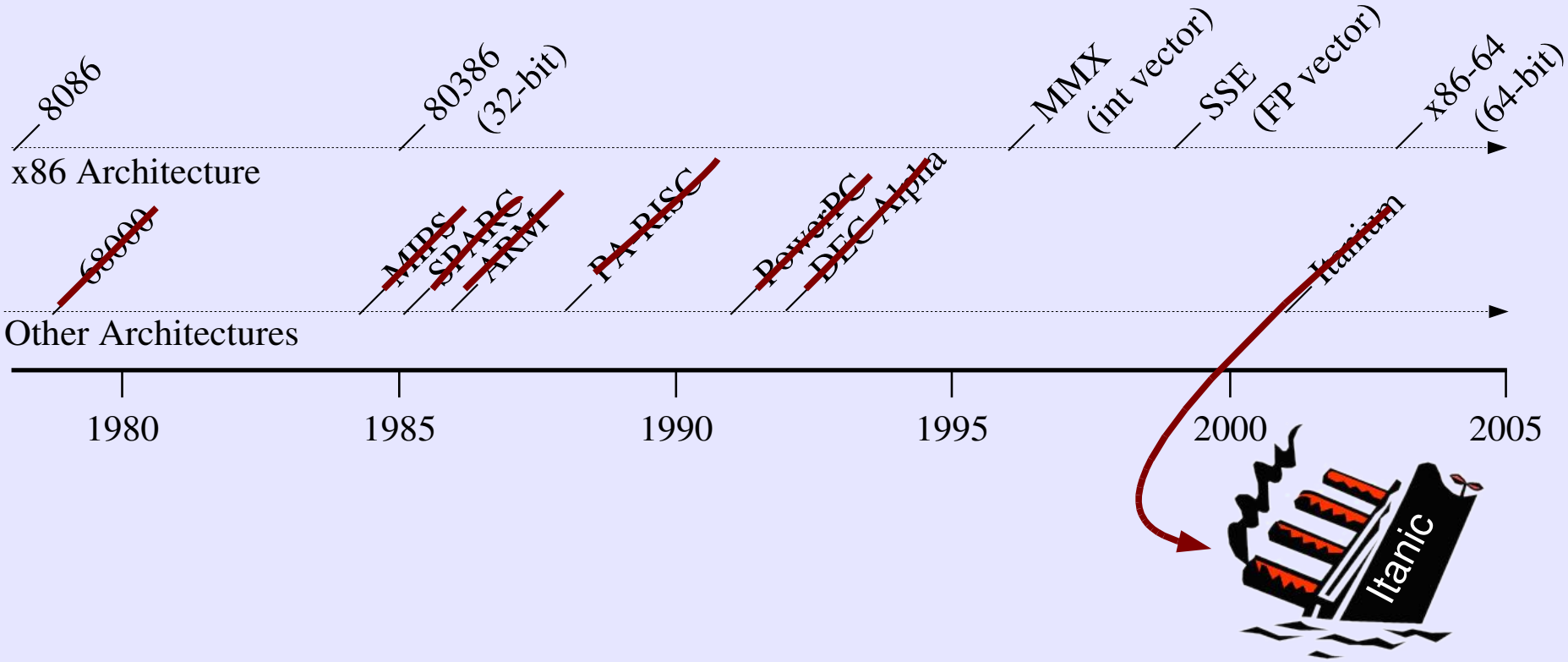
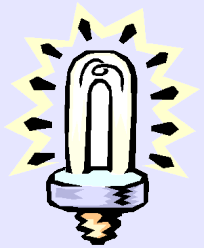


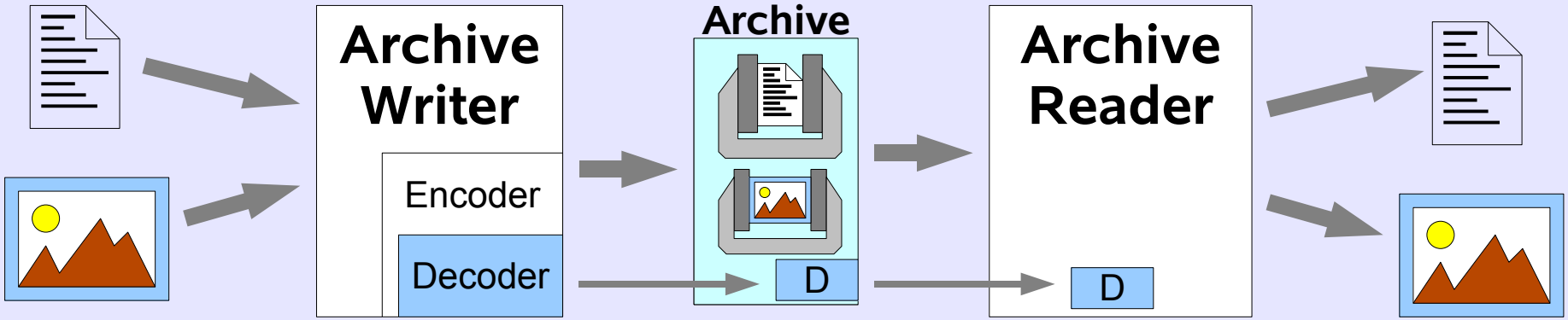
VXA: Virtual Executable Archives

Observation 1+2: Instruction formats are historically more durable than compressed data formats



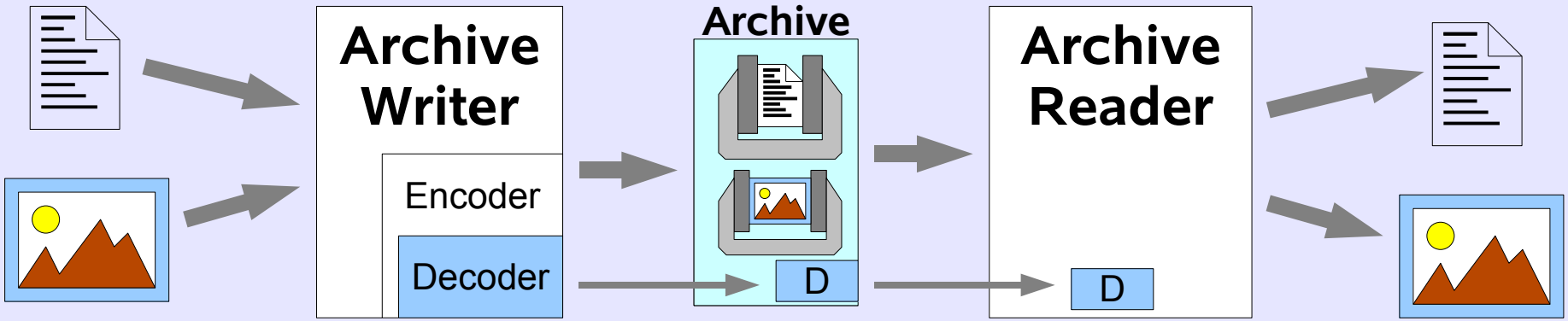
Make archive *self-extracting* (data + executable decoder)

To extract data, archive reader runs embedded decoder



Goals of VXA

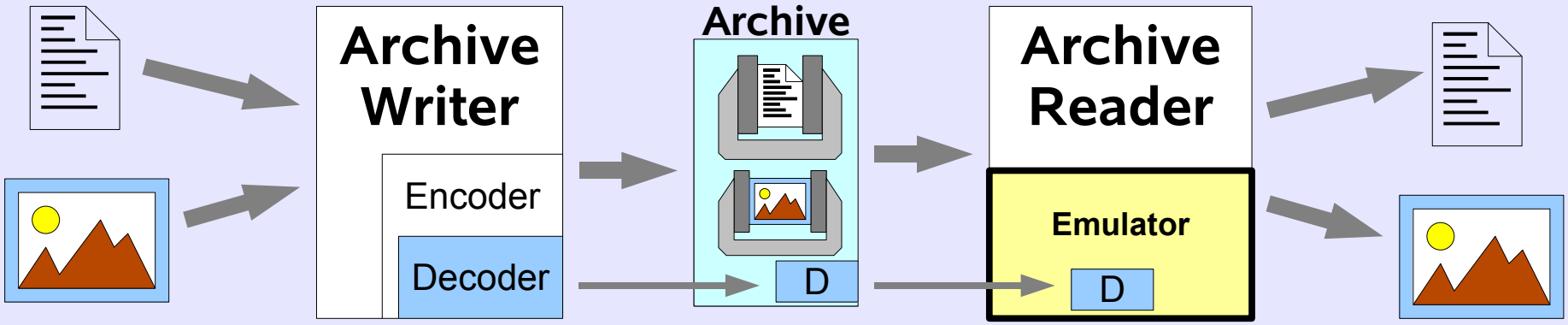
Make self-extracting archives...



Goals of VXA

Make self-extracting archives...

1. **Safe:** malicious decoders can't compromise host
2. **Future-proof:** simple, well-defined architecture [Lorie]



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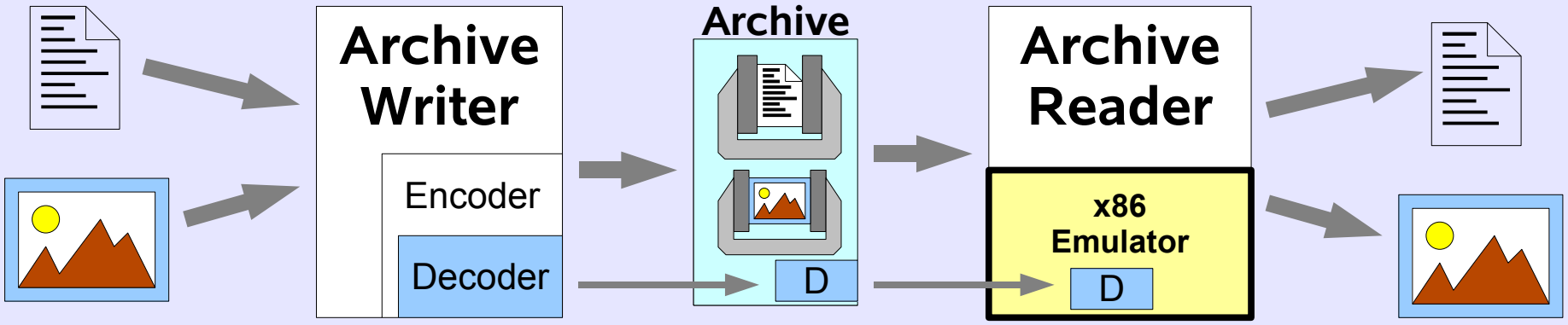
Make self-extracting archives...

1. **Safe:** malicious decoders can't compromise host
2. **Future-proof:** simple, well-defined architecture [Lorie]
3. **Easy:** allow reuse of existing code, languages, tools



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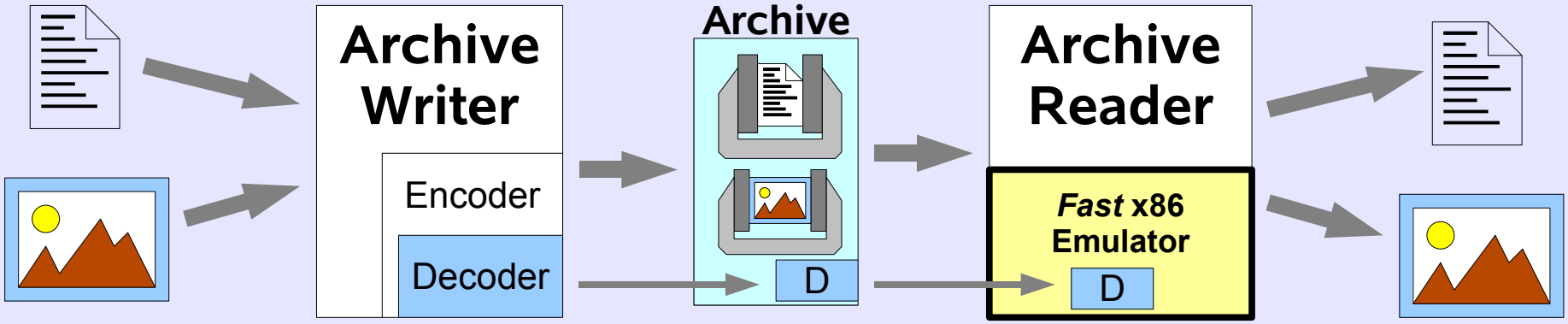
Make self-extracting archives...

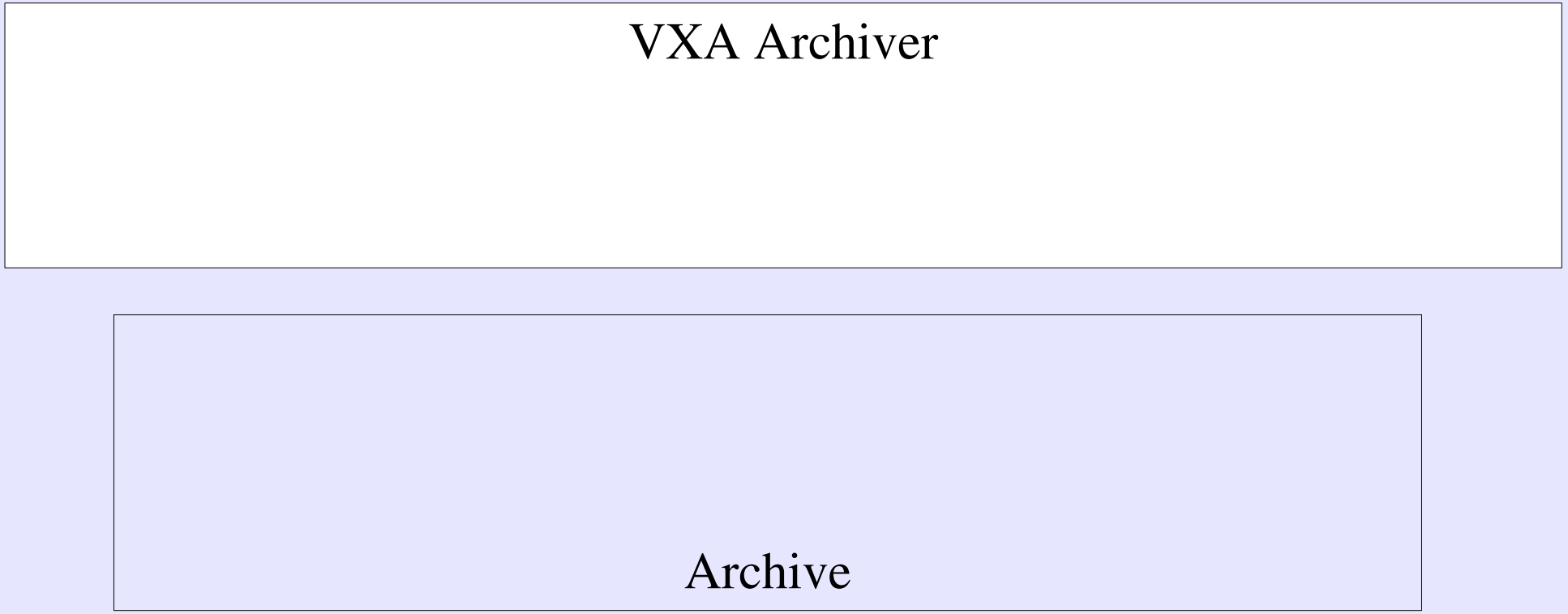
1. **Safe:** malicious decoders can't compromise host
2. **Future-proof:** simple, well-defined architecture [Lorie]
3. **Easy:** allow reuse of existing code, languages, tools
4. **Efficient:** practical for *short term* data packaging too



Outline

- Archiver Operation
- vxZIP Archive Format
- Decoder Architecture
- Emulator Design & Implementation
- Evaluation (performance, storage overhead)
- Conclusion

Archive Writer Operation



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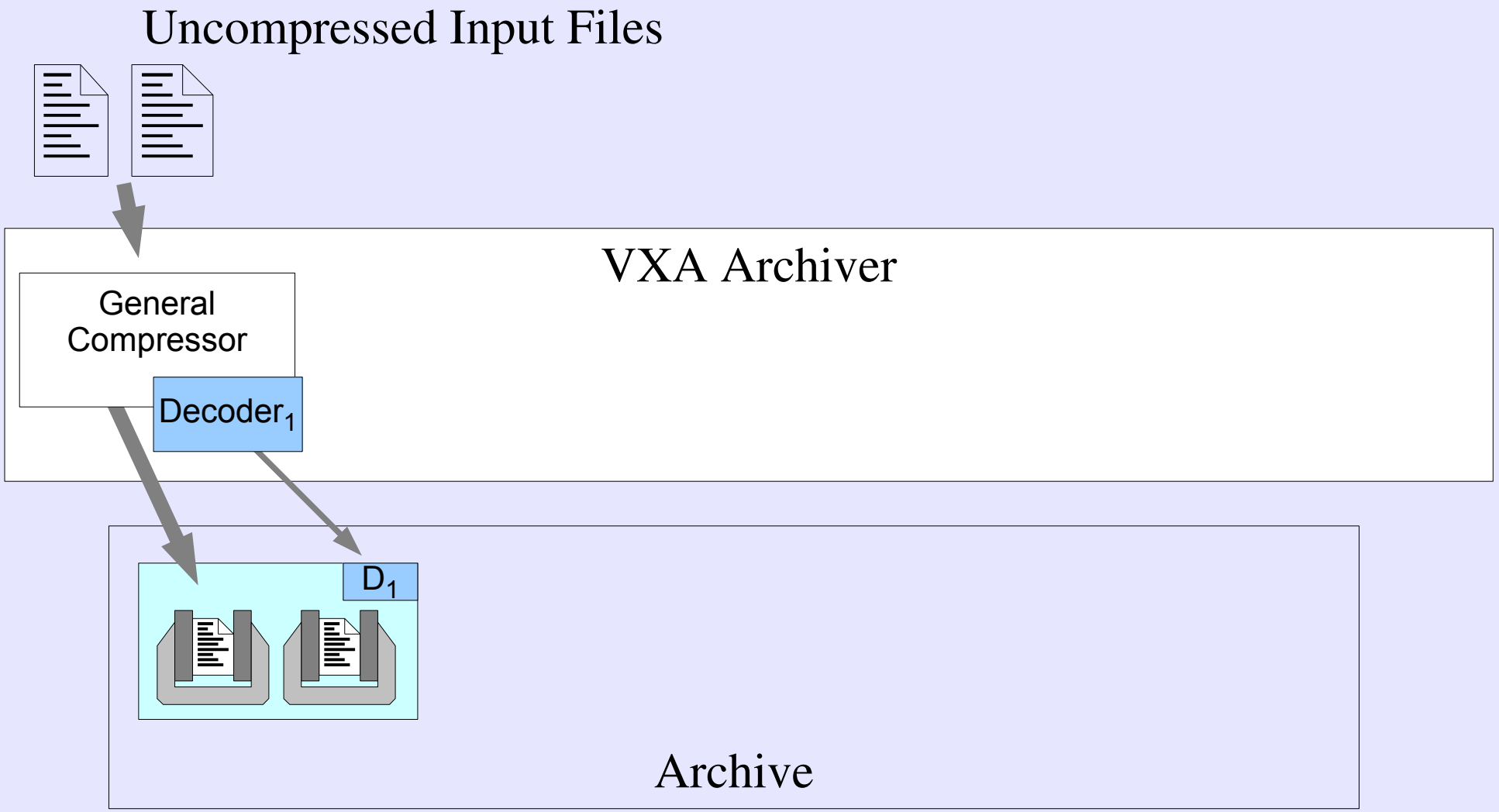

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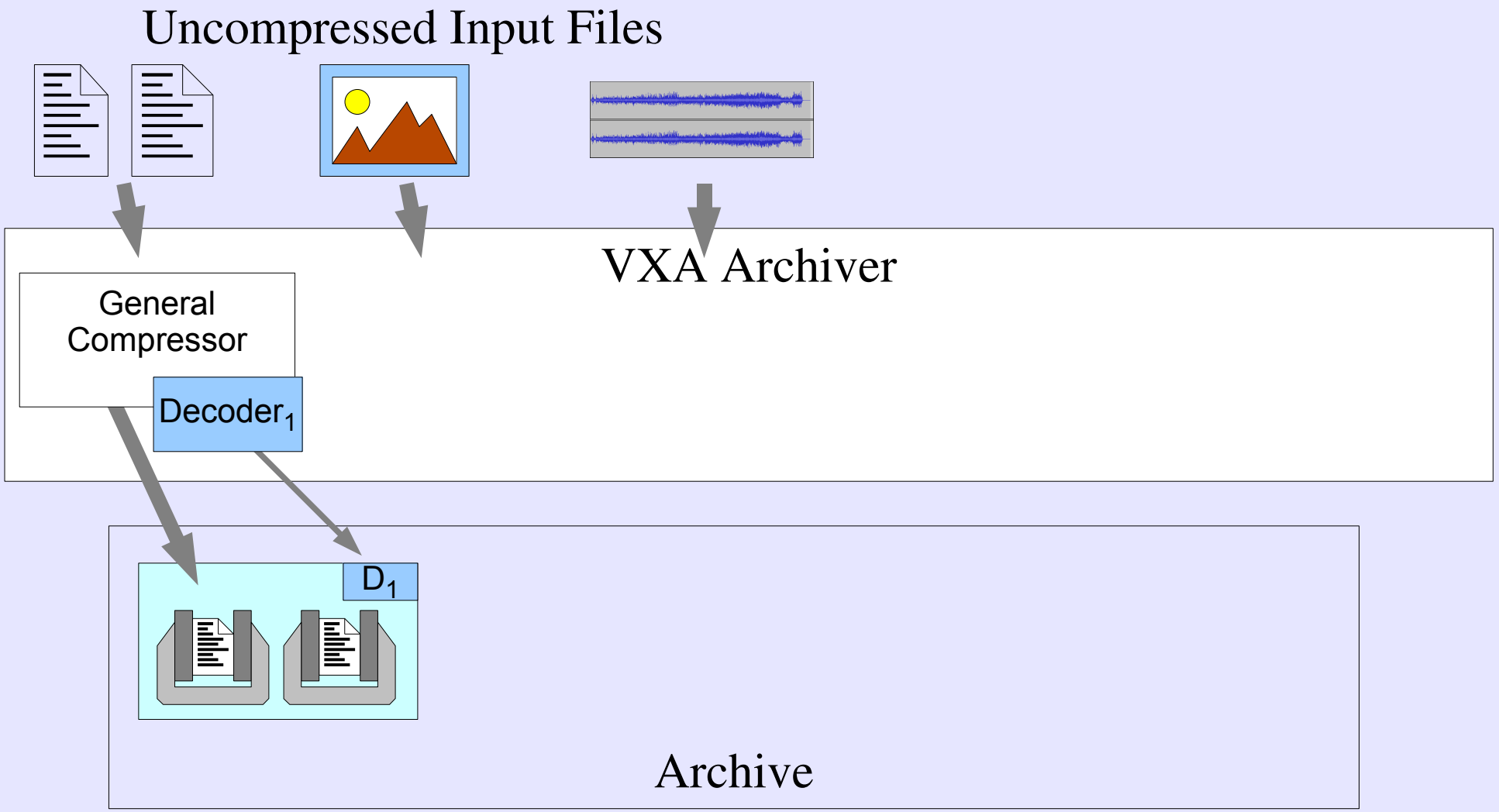

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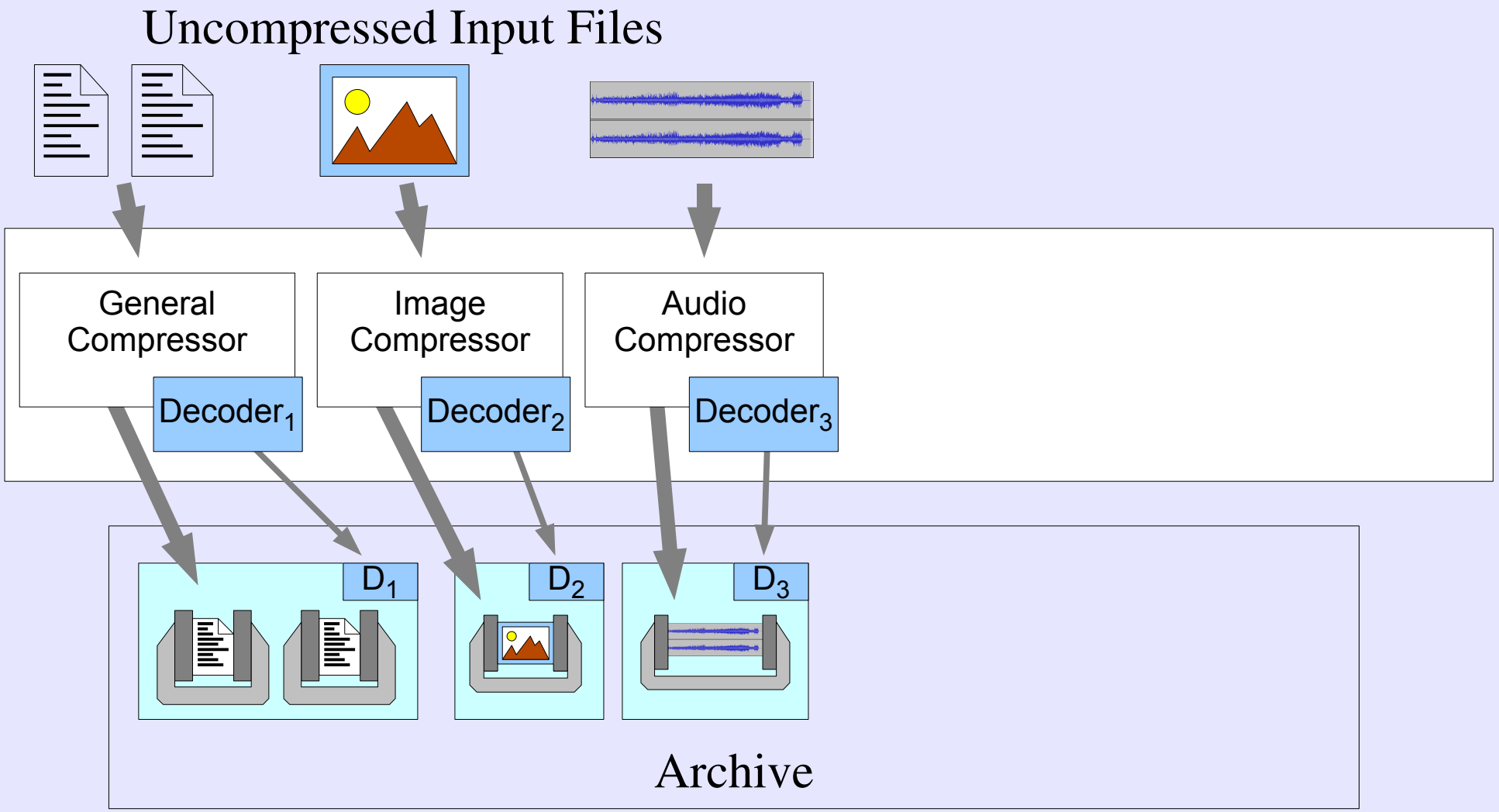

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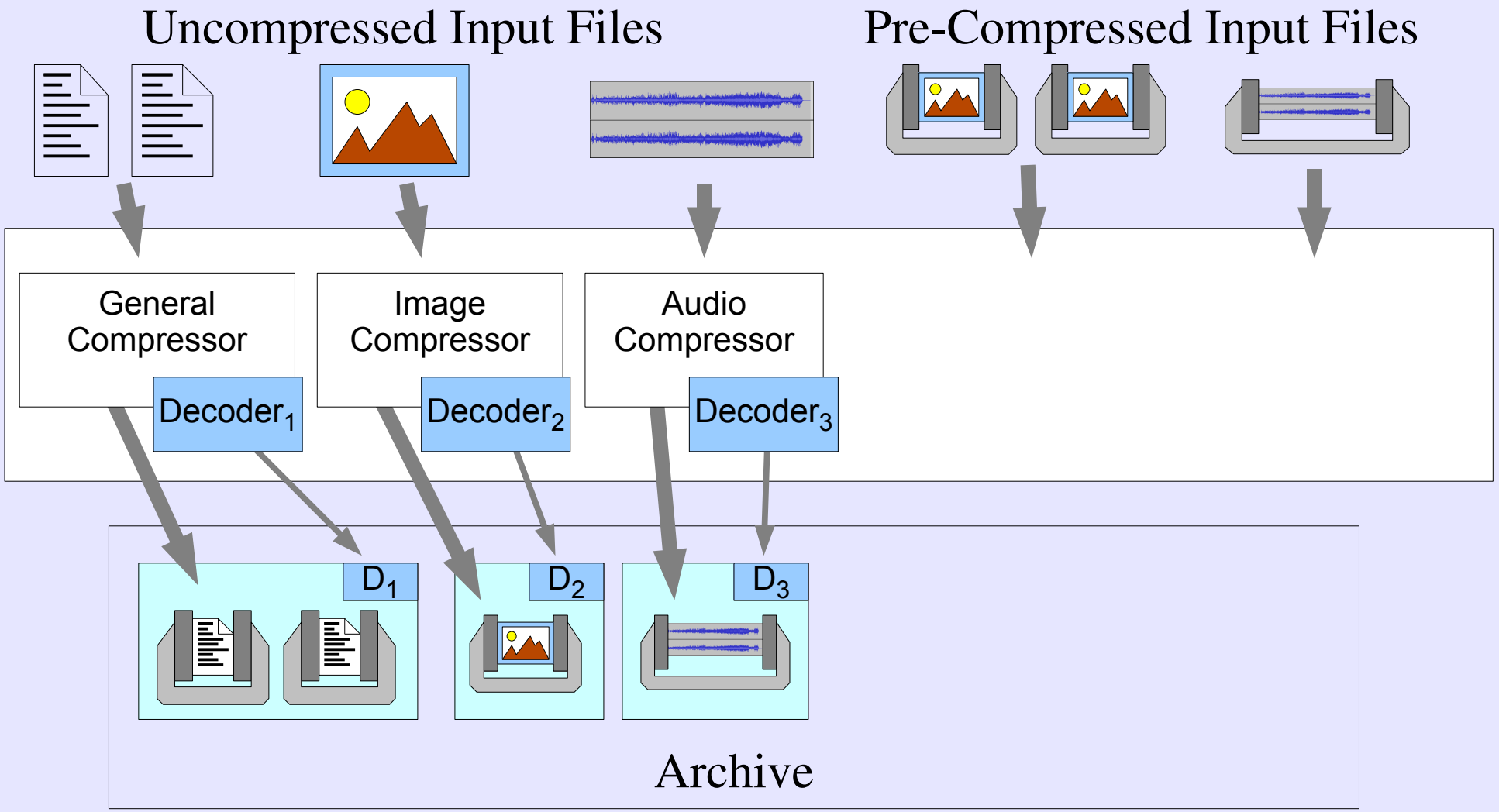

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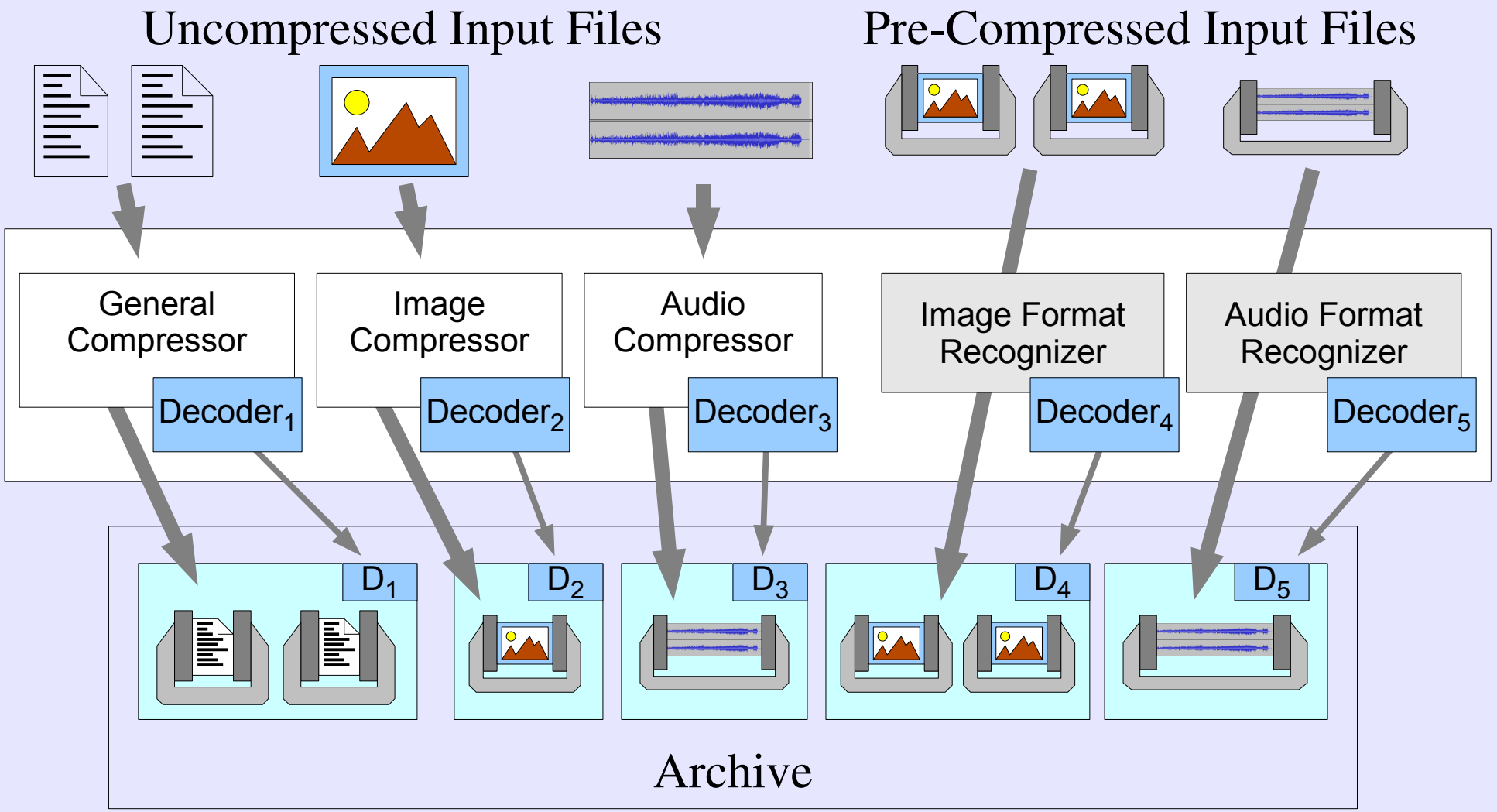

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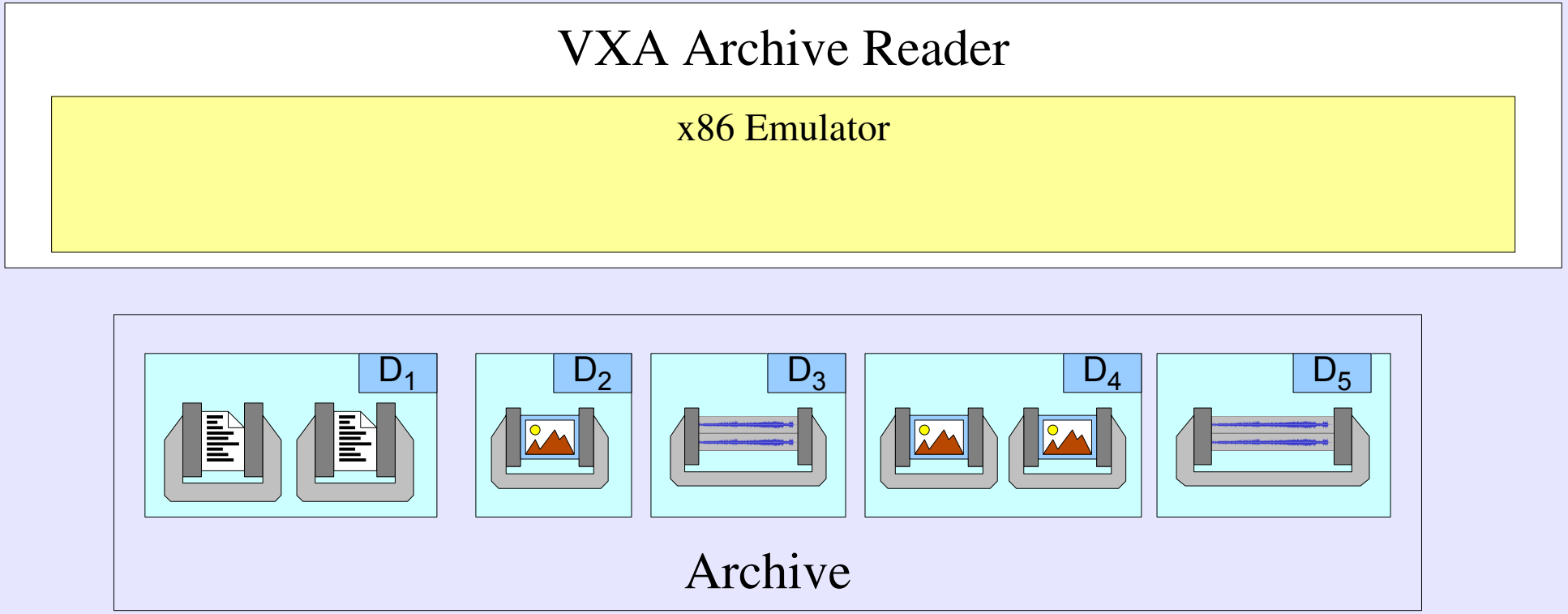

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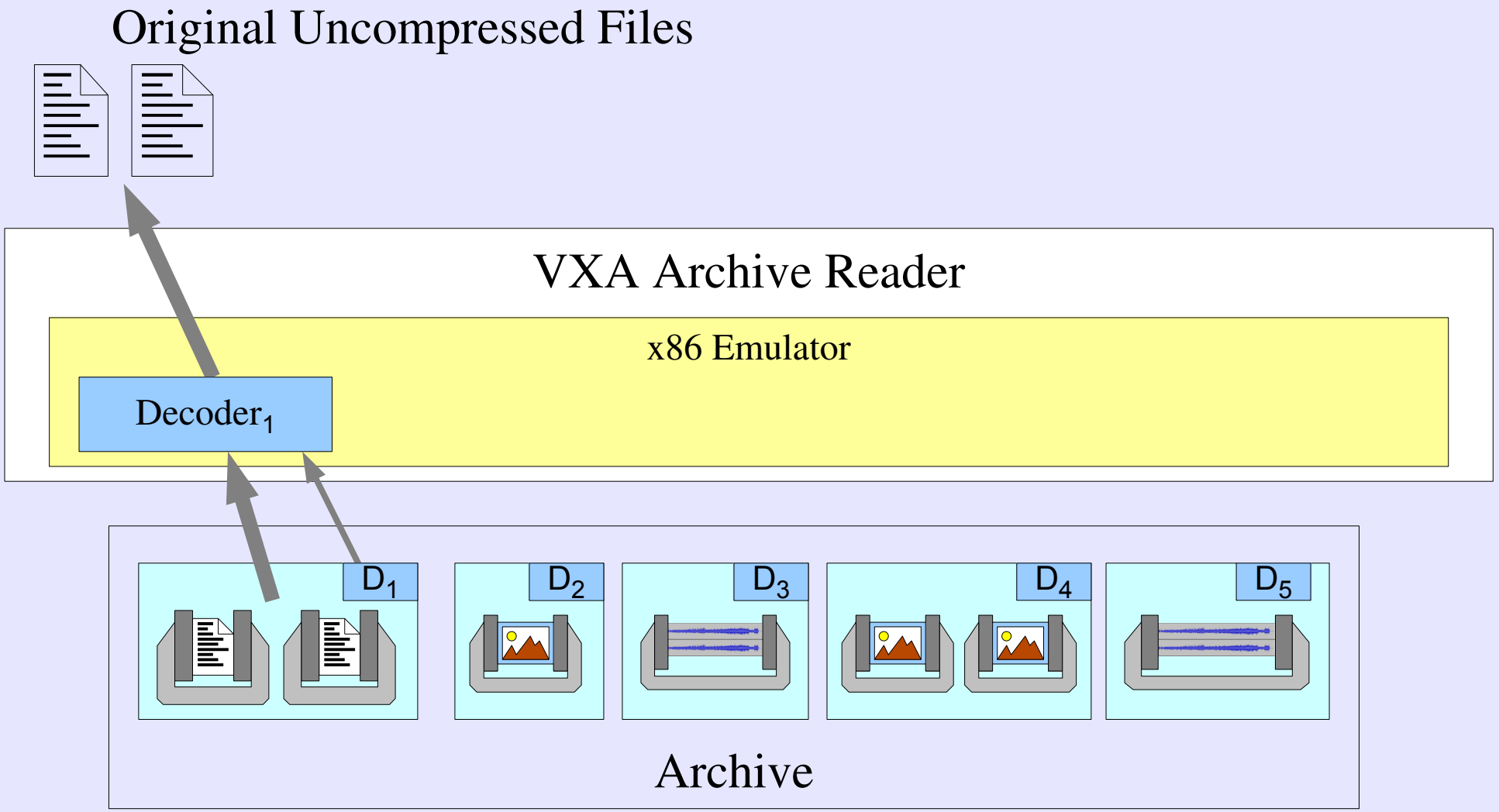

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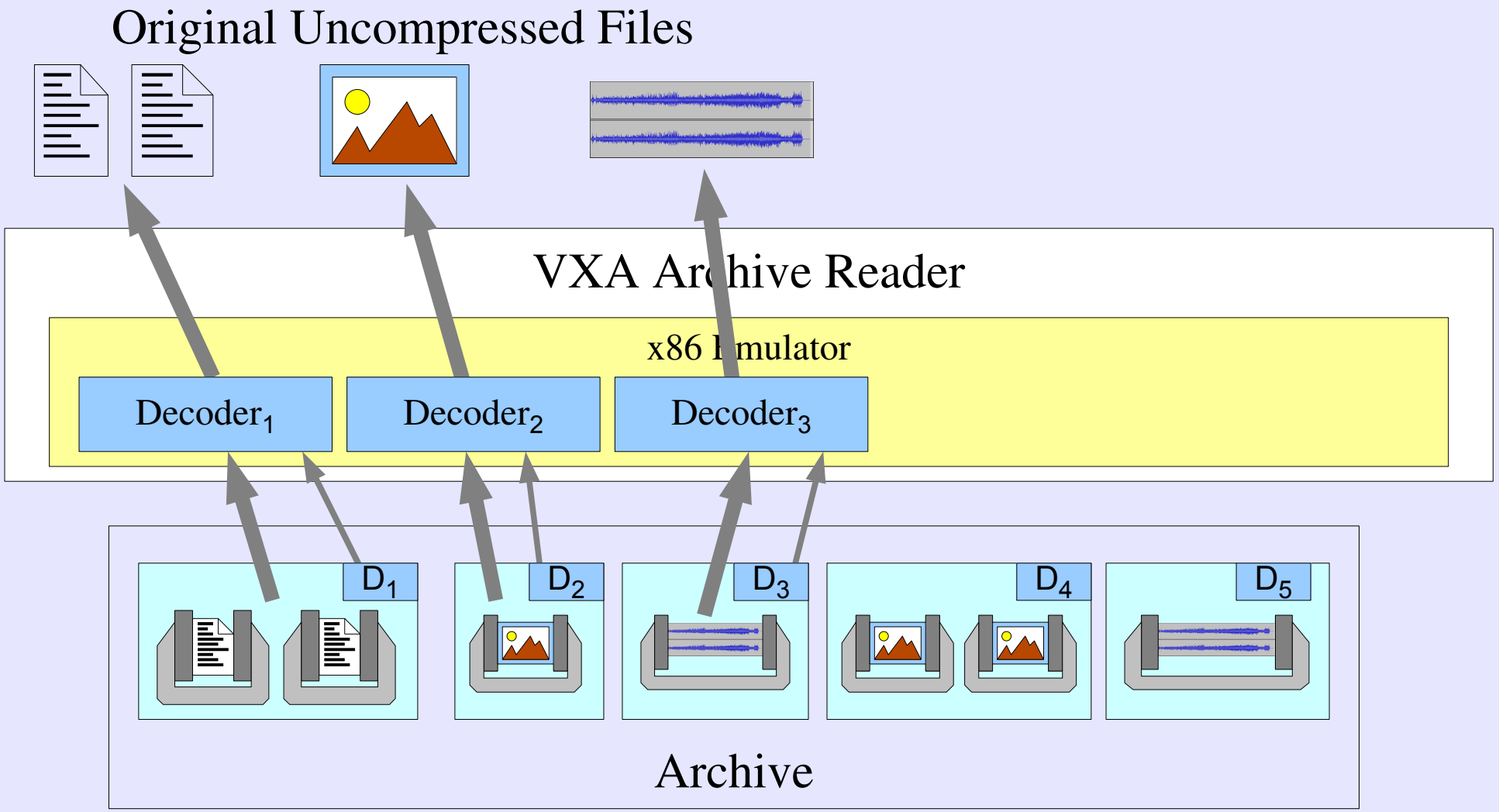

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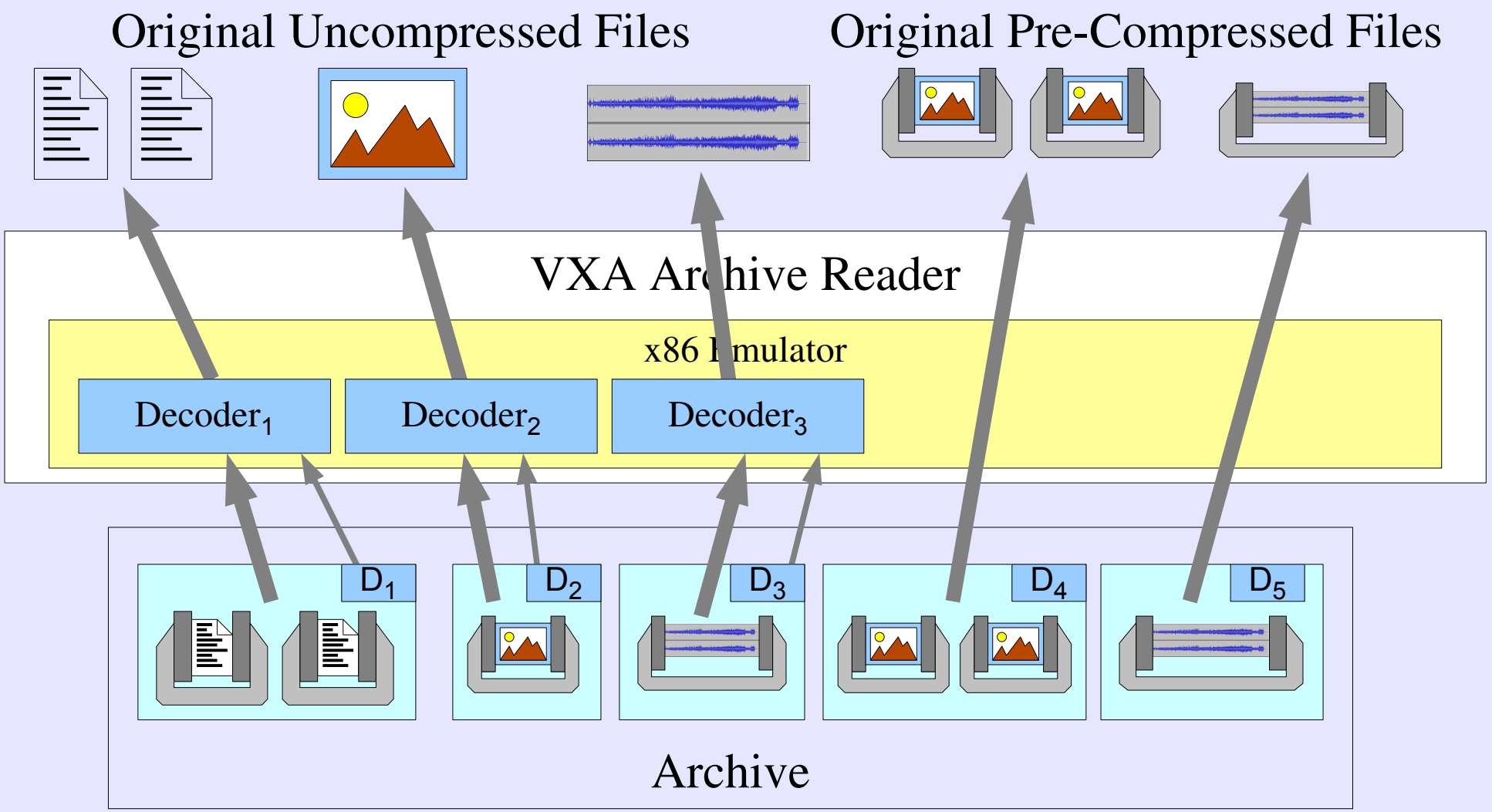

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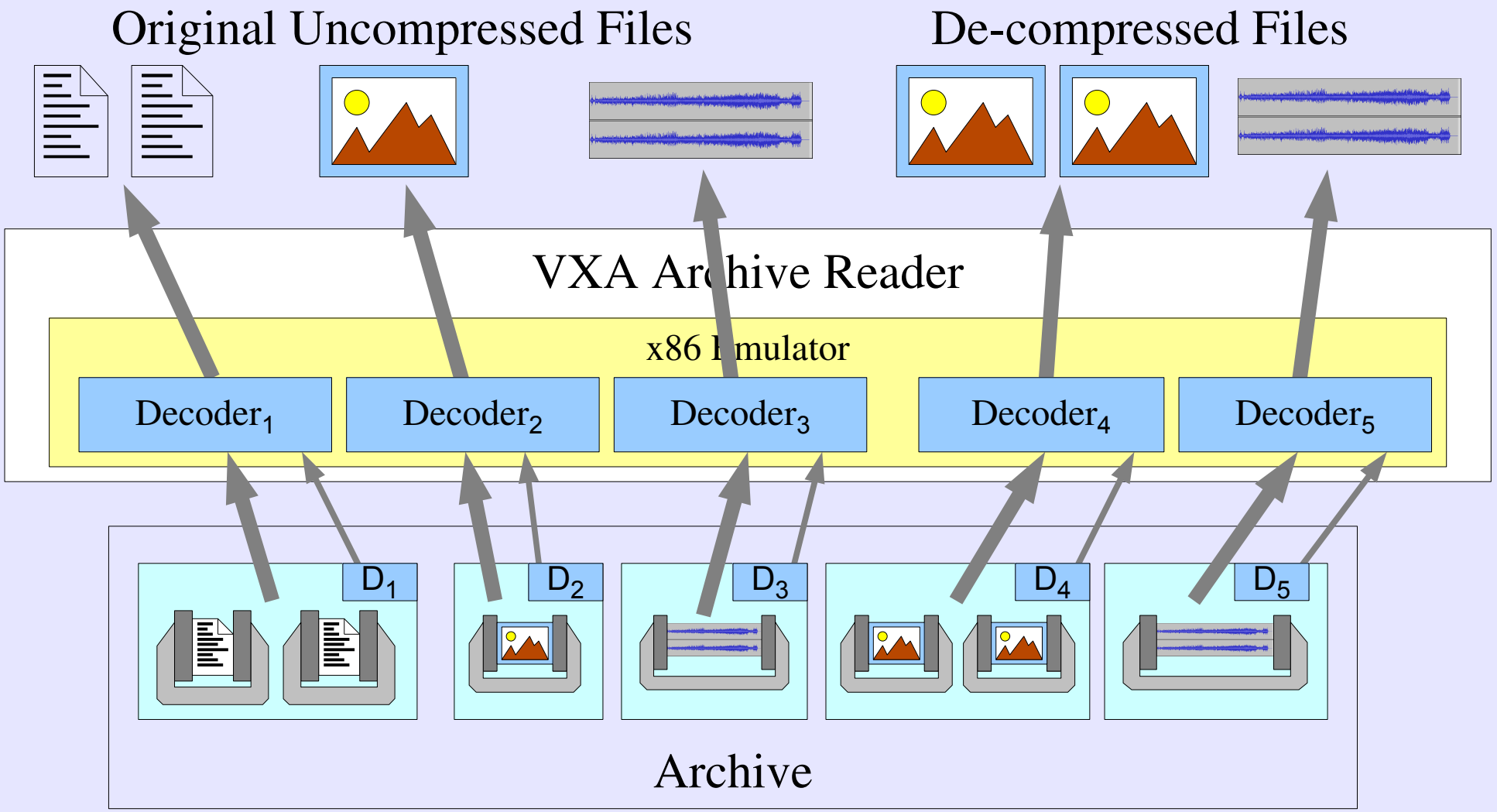
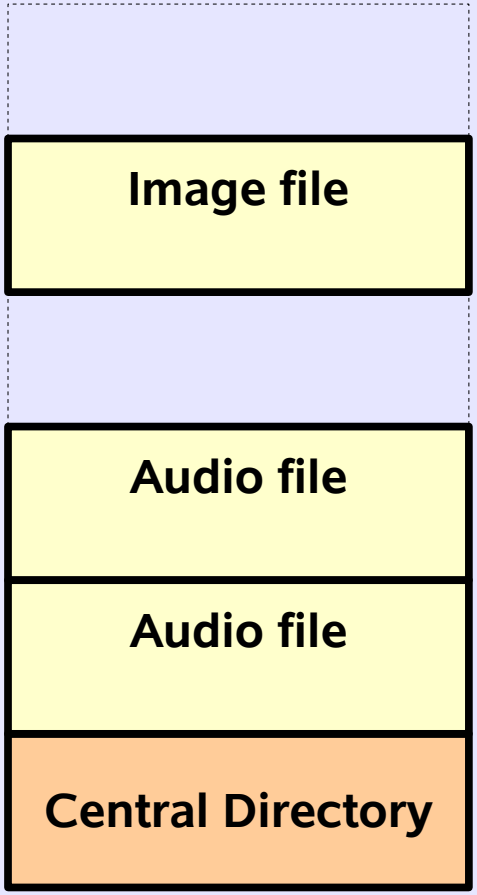


vxZIP Archive Format

- Backward compatible with legacy ZIP format



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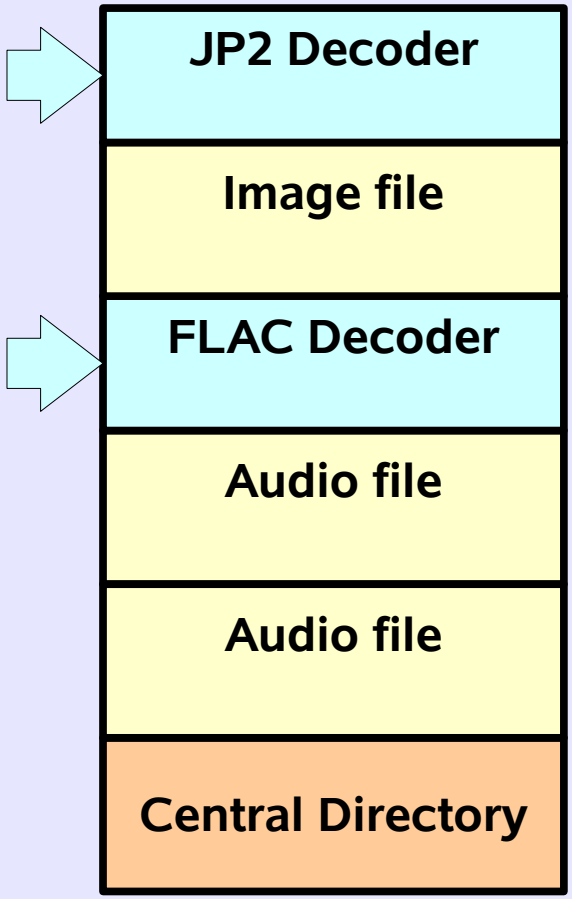

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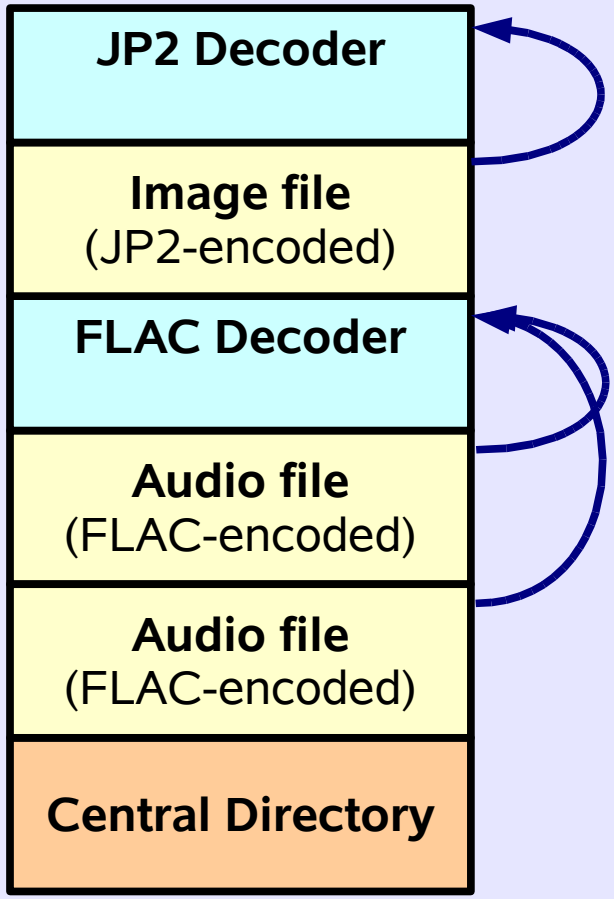

vxZIP Archive

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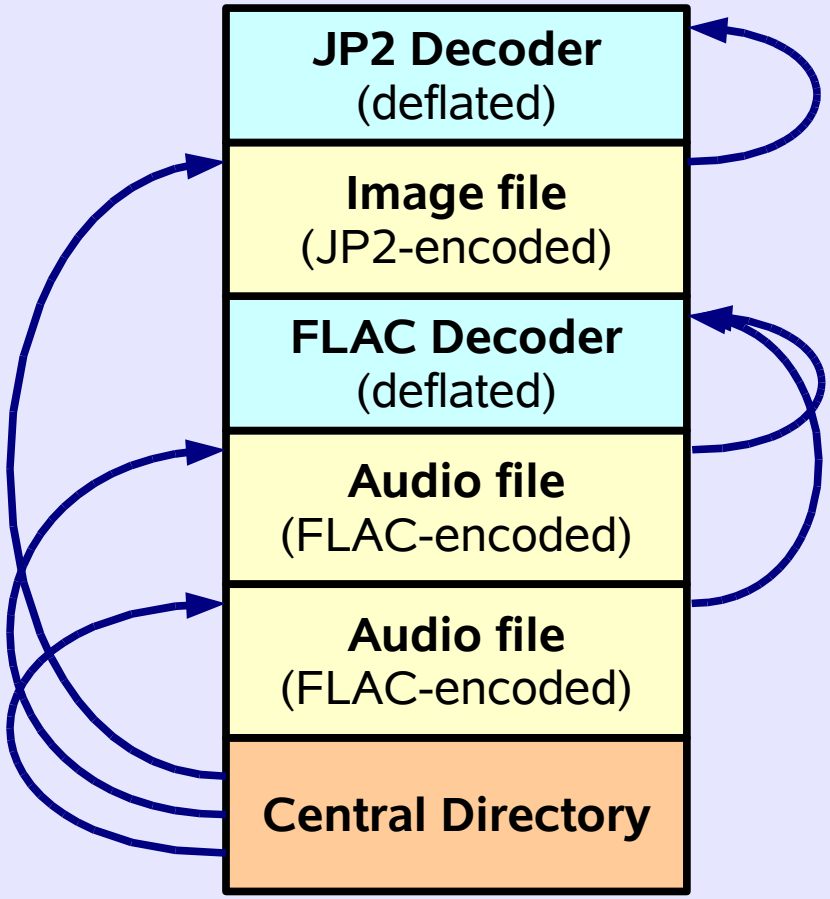
- Archived files have new extension header pointing to decoder
- Decoders are hidden, “deflated” (gzip)



vxZIP Archive

vxZIP Decoder Architecture

- Decoders are ELF executables for x86-32
  - Can be written in any language, safe or unsafe
  - Compiled using ordinary tools (GCC)
- Decoders have access to five “system calls”:
  - *read stdin, write stdout, malloc, next file, exit*
- Decoders **cannot**:
  - open files, windows, devices, network connections, ...
  - get system info: user name, current time, OS type, ...

Decoders Ported So Far

(using existing implementations in C, mostly unmodified)

General-purpose (lossless):

- **zlib:** Classic gzip/deflate algorithm
- **bzip2:** Burrows-Wheeler algorithm

Still image codecs:

- **jpeg:** Classic lossy image compression scheme
- **jp2:** JPEG 2000 wavelet-based algorithm, lossy or lossless

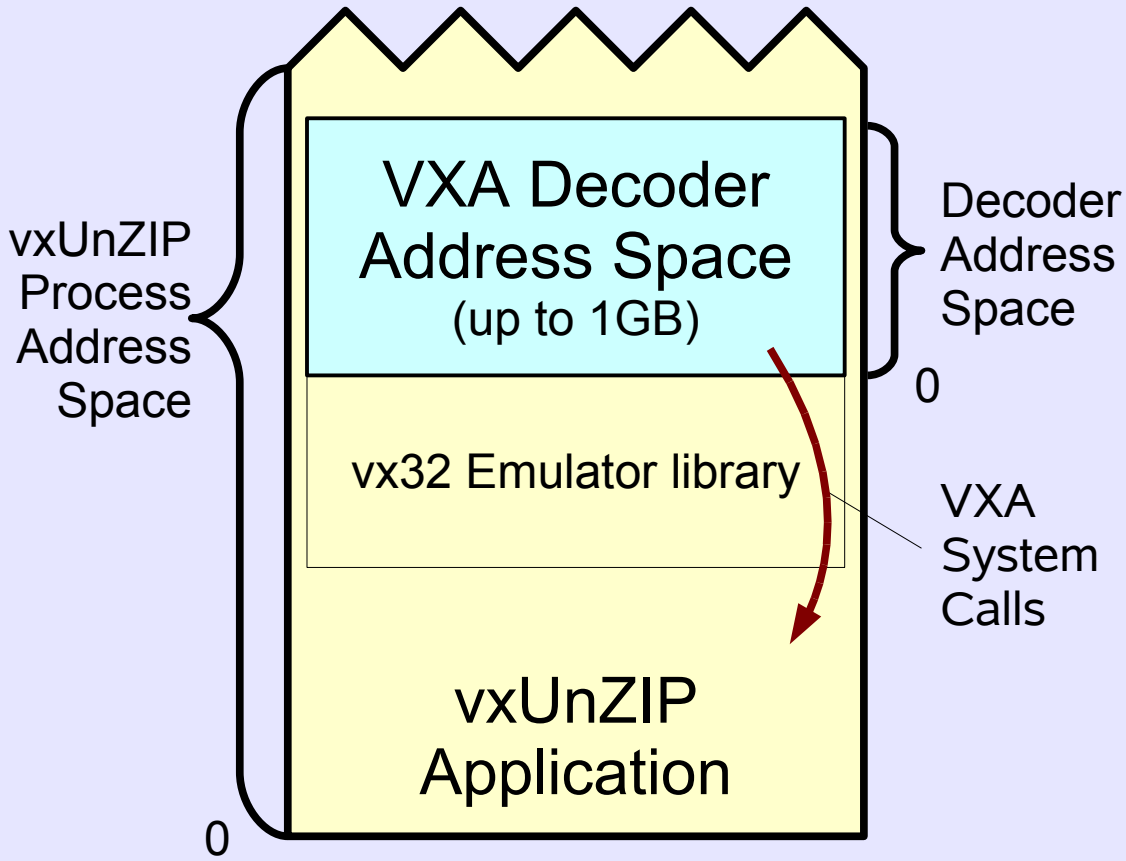
Audio codecs:

- **flac:** Free Lossless Audio Codec
- **vorbis:** Standard lossy audio codec for Ogg streams

vx32 Emulator Architecture

Runs in vxUnZIP process

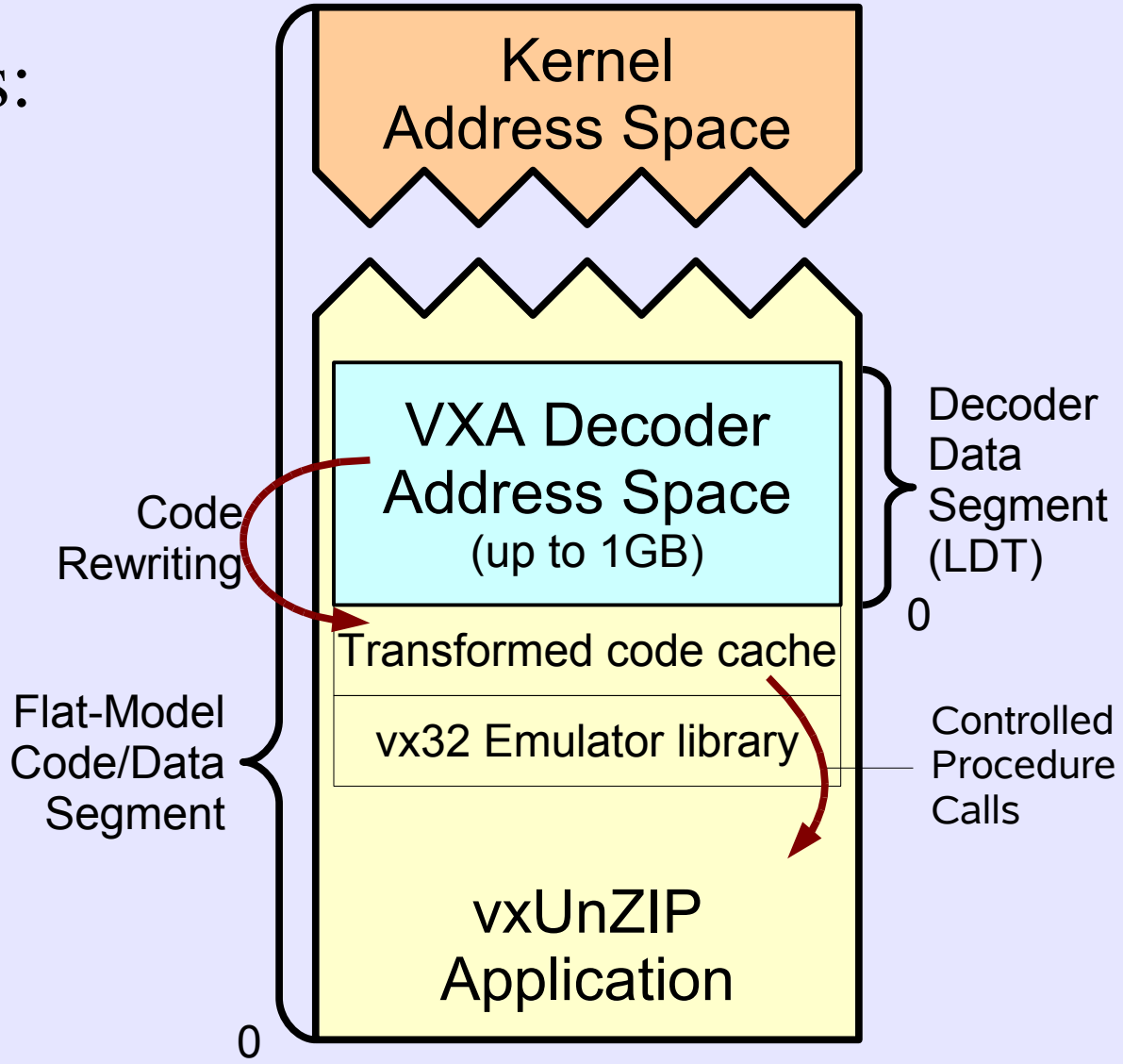
- Loads decoder into address space sandbox
- Restricts decoder's memory accesses to sandbox
- Dispatches decoder's VXA “system calls” to vxUnZIP (*not* to host OS!)



vx32 Emulator Implementation

On x86-{32/64} hosts:

- Secure fault isolation [Wahbe]
- Data sandboxing via custom LDT segments
- Code sandboxing via instruction rewriting [Sites, Nethercote]
- No privileges or kernel extensions



vx32 Emulator Implementation

On other host architectures:

- Portable but slow “fallback” instruction interpreter (mostly done)
- Fast x86-to-PowerPC binary translator (in progress)
- Hopefully more in the future

Emulator implemented as generic library

- Can be used for other sandboxing applications

Evaluation

Two issues to address:

- Performance overhead of emulated decoders
  - not important for long-term archival storage, but...
  - *very* important for common short-term uses of archives: backups, software distribution, structured documents, ...
- Storage overhead of archived decoders

Performance Test Method

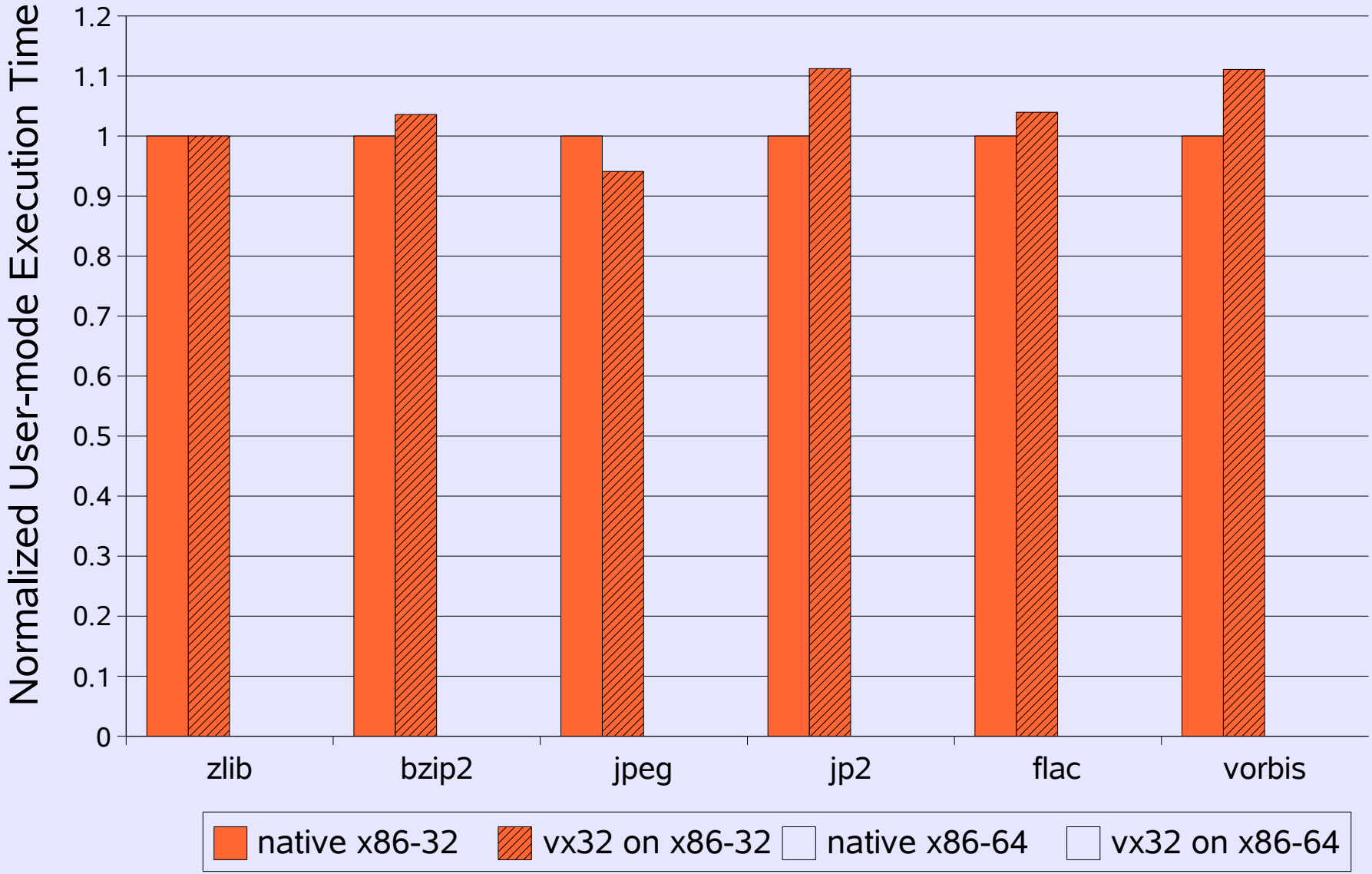
Run 6 ported decoders on appropriate data sets

- Athlon 64 3000+ PC running SuSE Linux 9.3
- Measure *user-mode CPU time* (not wall-clock time)

Compare:

- Emulated vs native execution
- Running on x86-32 vs x86-64 host environment

Performance Overhead



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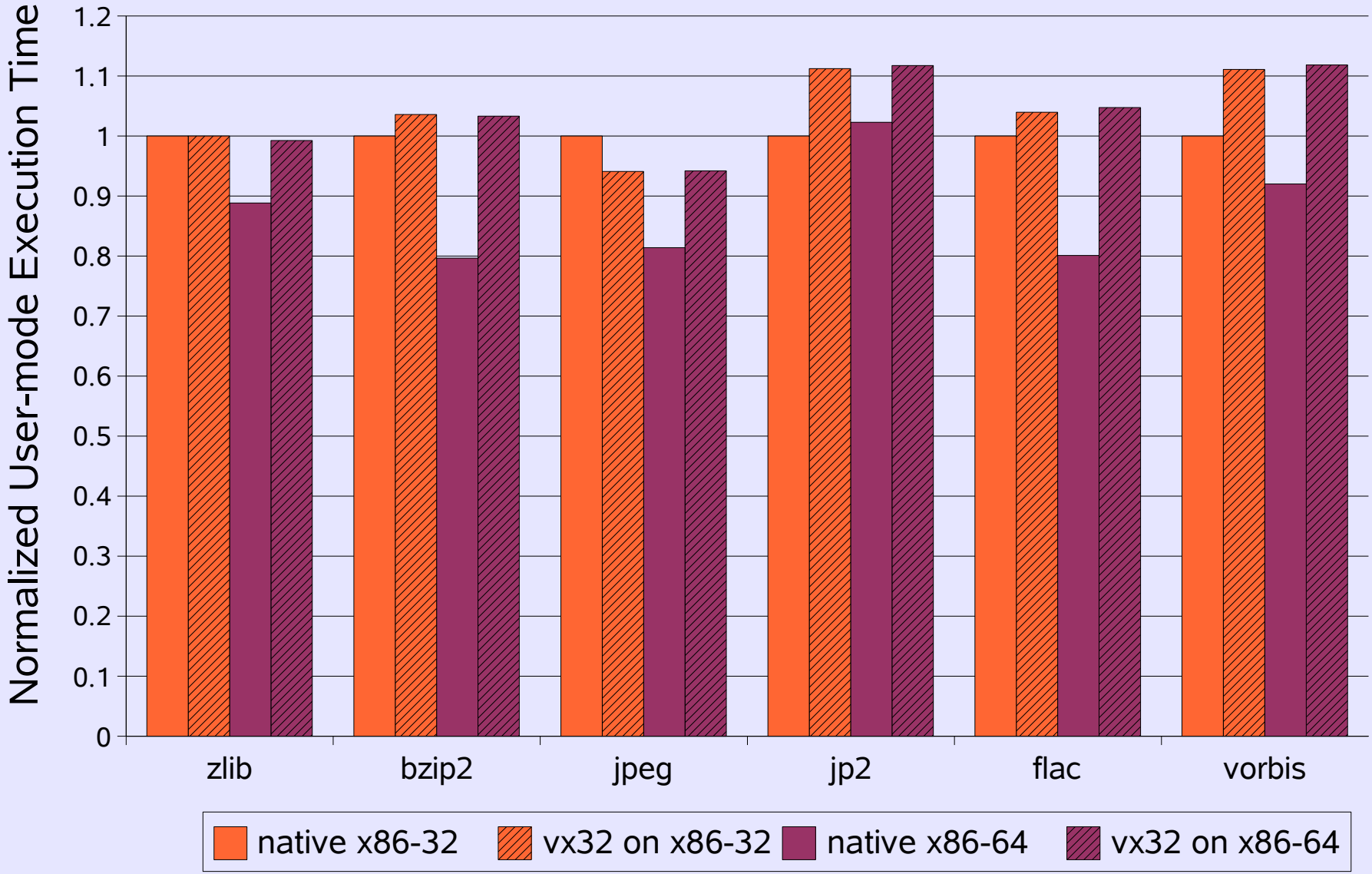

Storage Overhead

Archiver stores only one copy of each decoder

- Storage cost amortized over all files of same type
- Relative overhead depends on size of archive

Therefore, measure only *absolute* decoder size

(compressed, as stored in archive)

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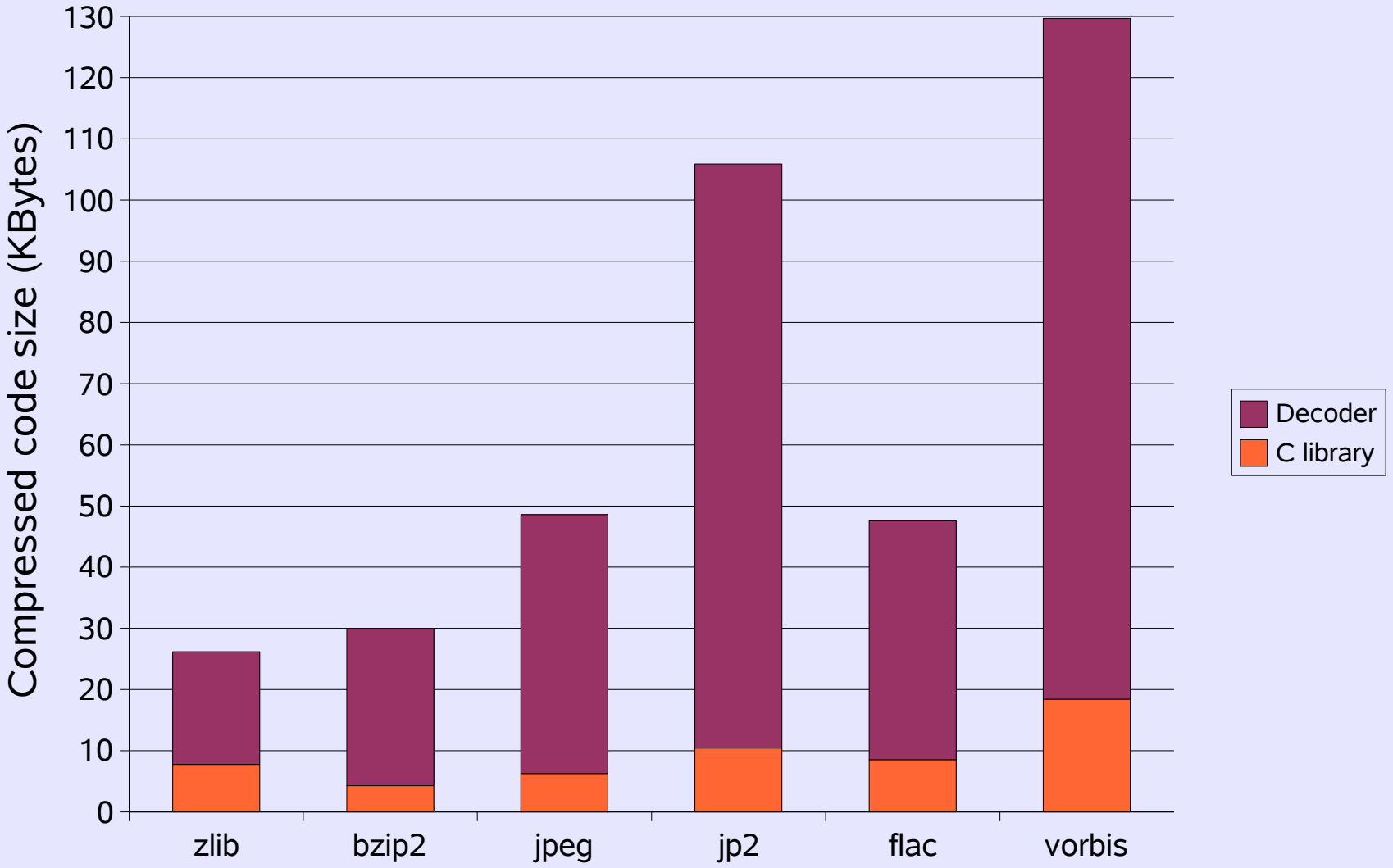

Conclusion

VXA makes self-extracting archives...

- **Safe:** decoders fully sandboxed
- **Future-proof:** simple, OS-independent environment
- **Easy:** re-use existing decoders, languages, tools
- **Efficient:** ≤ 11% slowdown vs native x86-32

Available at: http://pdos.csail.mit.edu/~baford/vxa/