Digital Vellum

Vint Cerf
Google

November 2017

Archiving Static Content

PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

Vol I.
For *Anno* 1665, and 1666.

In the *SAVOY*,
Printed by *T. N.* for *John Martyn* at the Bell, a little without *Temple-Bar*, and *James Allestry* in *Duck-Lane*,
Printers to the *Royal Society*.


EC5274 5B/5D
ИЗОМ
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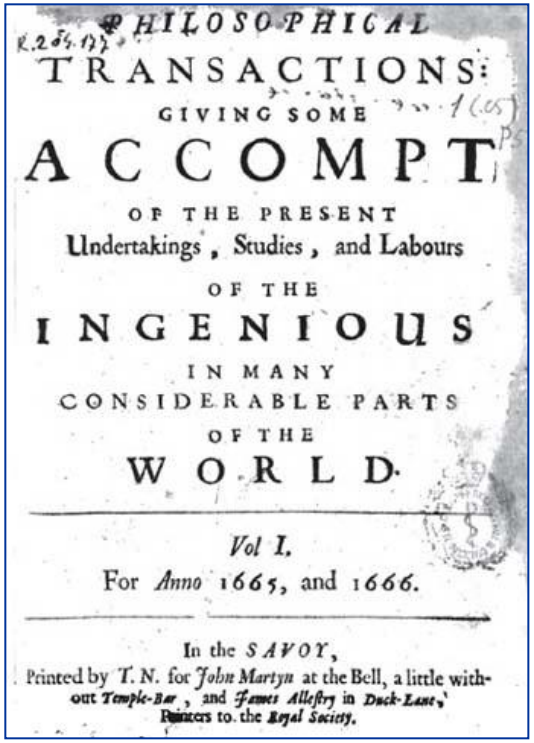
5,25" HD,DS
WRITE ENABLE
WRITE PROTECT


BUYDIG.COM


TDK


DVD
BluRayDisc

Archiving Static Text/Image Content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YouTube

flickr

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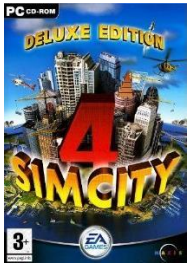
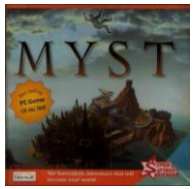
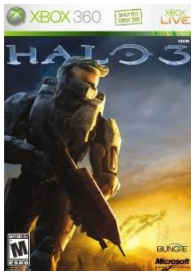
22nd Century
Doris Kearns Goodwin

- A Team of Rivals (Lincoln)
  - How did she reconstruct the dialog??
  - 100 Libraries and repositories w/physical correspondence
- What will the 22nd C. Doris Kearns Goodwin find?
- What will the National Archives be able to offer?
- What will our descendants know of our 21st Century?
  - Correspondence, entertainment, advertising, education, jobs, family life,…

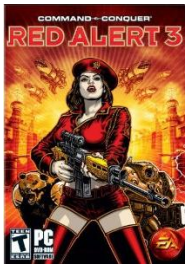
What About Executable Content?







Games



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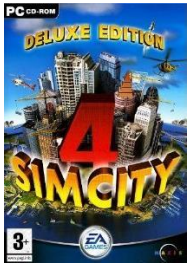
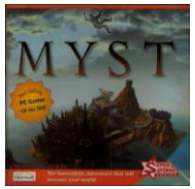
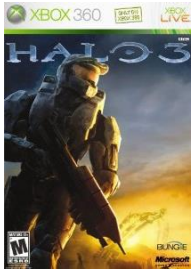
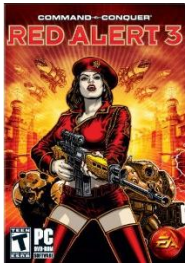


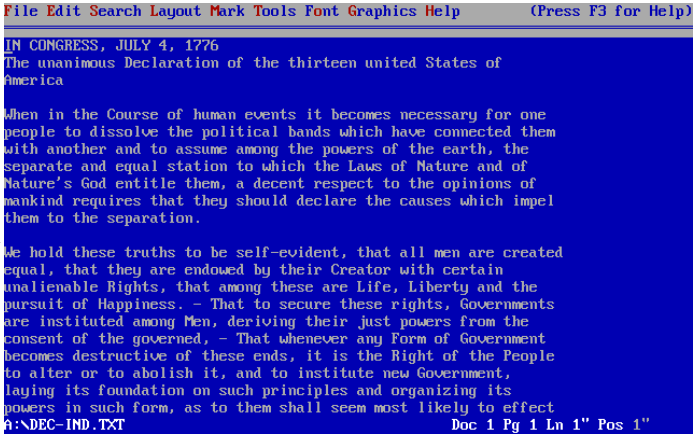


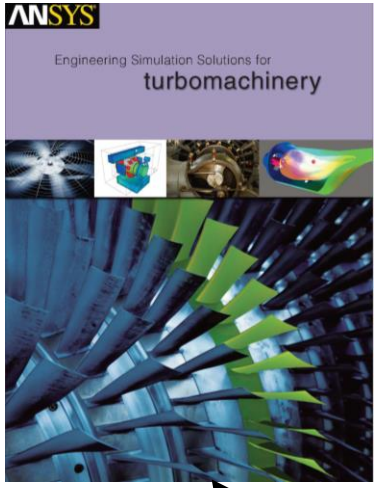


Games

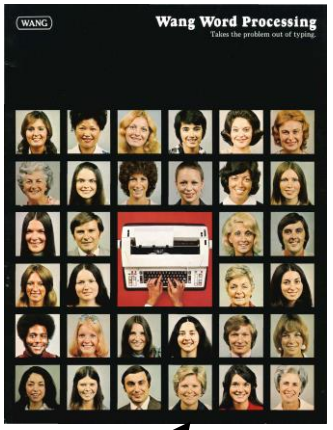


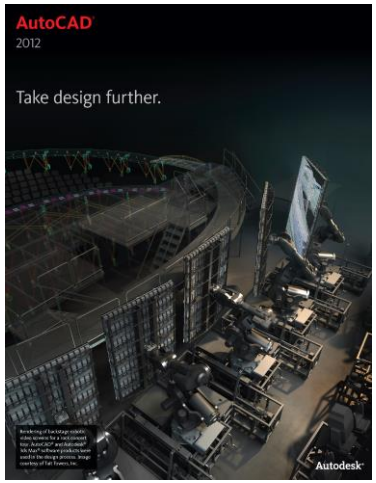
WordPerfect 1.0 doc
Can you read it today?
100 years from now?





Application-specific content





Simulation model
Can you re-run old model with new data?

Original Wang doc
Can you read it today?
100 years from now?

Challenges

- Interpretation of bits
- Metadata capture
- Source or executable code
- “Digital X-ray”
- Capacity for BIG DATA
- Bankruptcies, sunsetting of apps, OS, hardware
- Intellectual Property Rights
- Legal frameworks, exceptions for preservation

The OLIVE Project

- Carnegie-Mellon University
- Mahadev Satyanarayanan (“Satya”)
- NSF funded project on digital preservation

Execution Fidelity

Ability to precisely reproduce execution

Many moving parts

- **hardware**
- **operating system**
- **dynamically linked libraries**
- **configuration parameters**
- **language settings**
- **time zone settings**
- **…**

Inspiration: "Digital X-Ray" of the hardware and operating software

Very difficult to achieve and then maintain

Transform into a Scaling Problem

Pack up and carry the entire environment with you

- including the OS
- transitive closure of everything you need

Central idea of a (hardware) *virtual machine (VM)*

But VMs are huge

- many GB to tens of GB
- waiting to download → long launch delay
- inspiration from YouTube: *stream* instead of downloading

VM Streaming Not So Easy

Access to VM image is not linear

Reference pattern depends on many runtime factors

- **data dependencies**
- **human interaction**
- **spatial and temporal locality (program behavior)**

Our approach

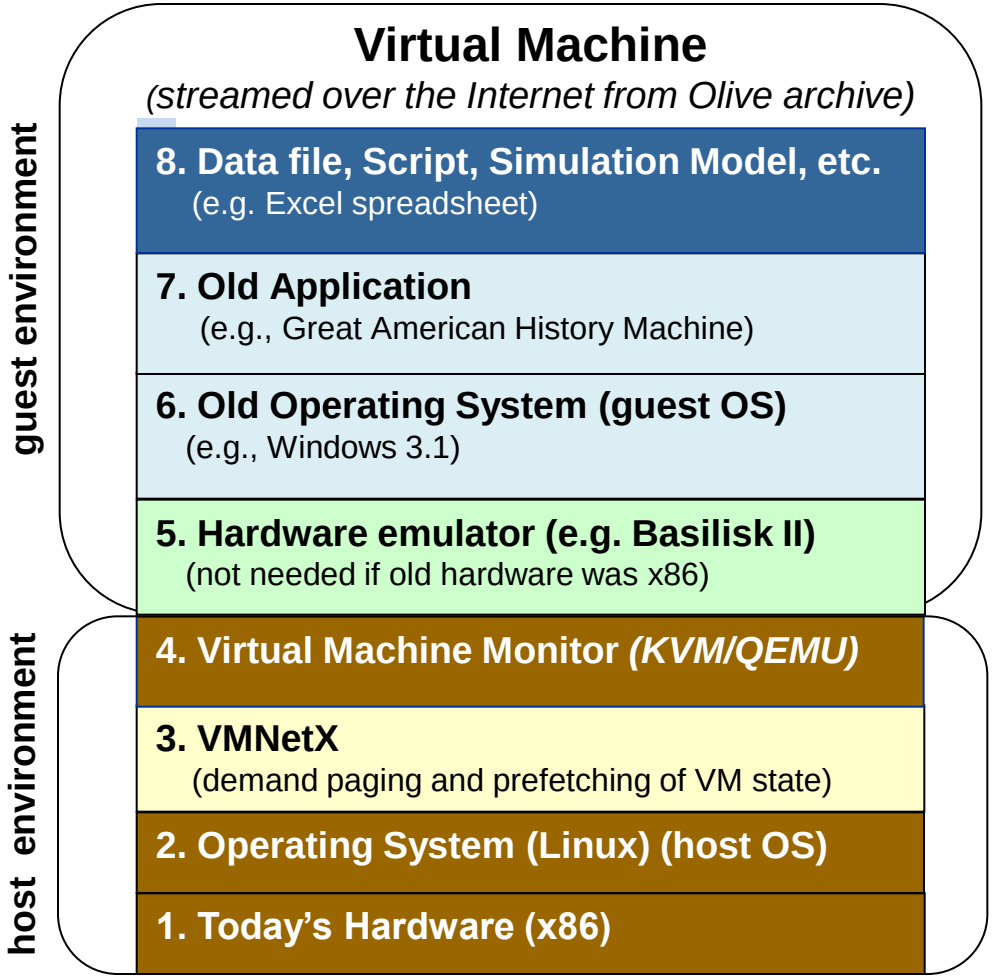
- ***demand paging***

  intercept missing VM pieces and fetch over Internet

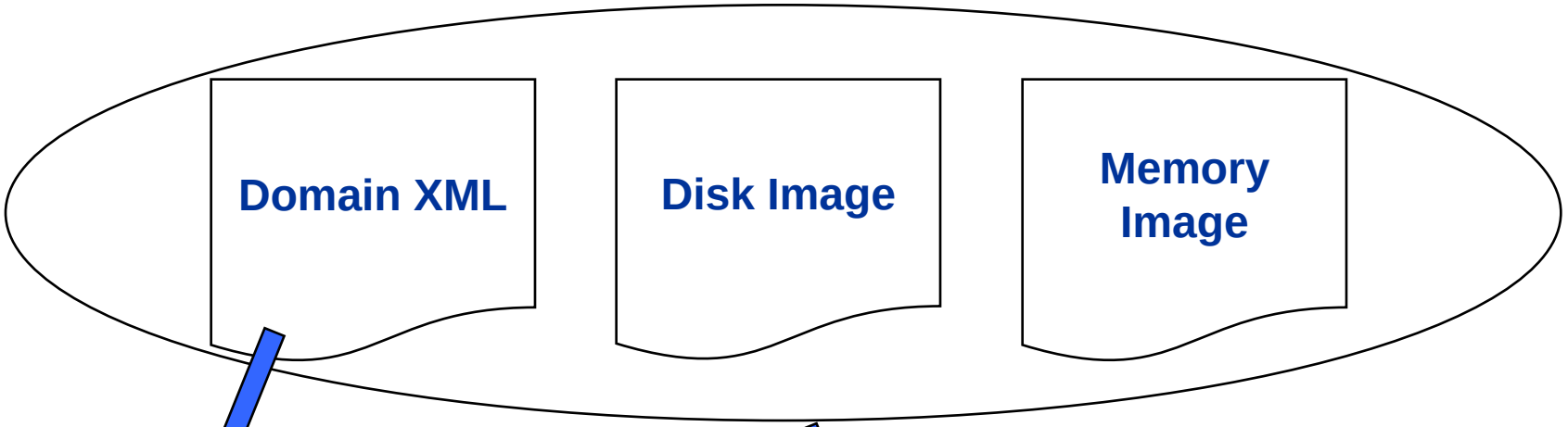
- ***prefetching***

  mask stalls due to demand misses
  (if hints are good)

Client Structure



VM Image Representation



Machine details

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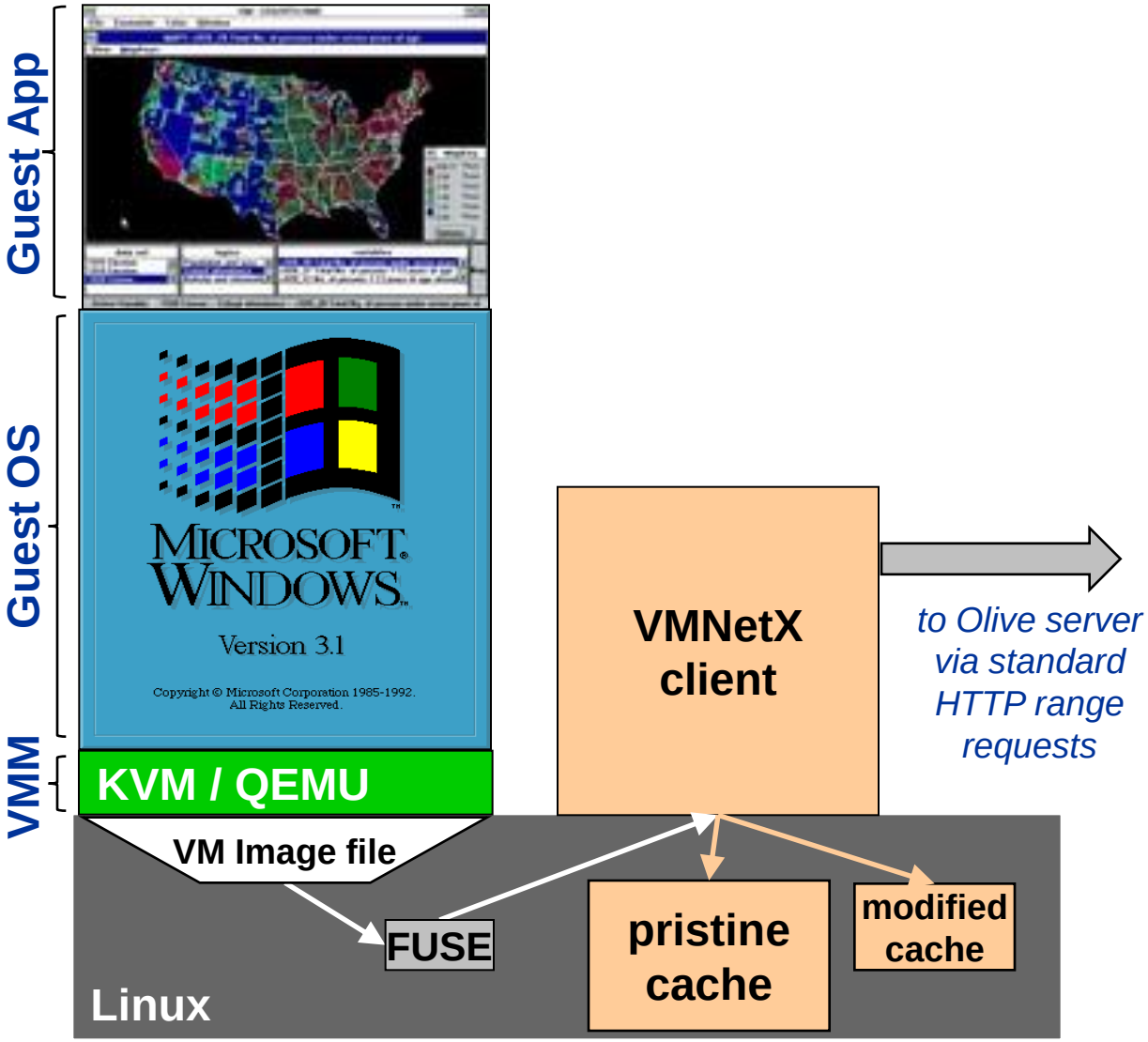
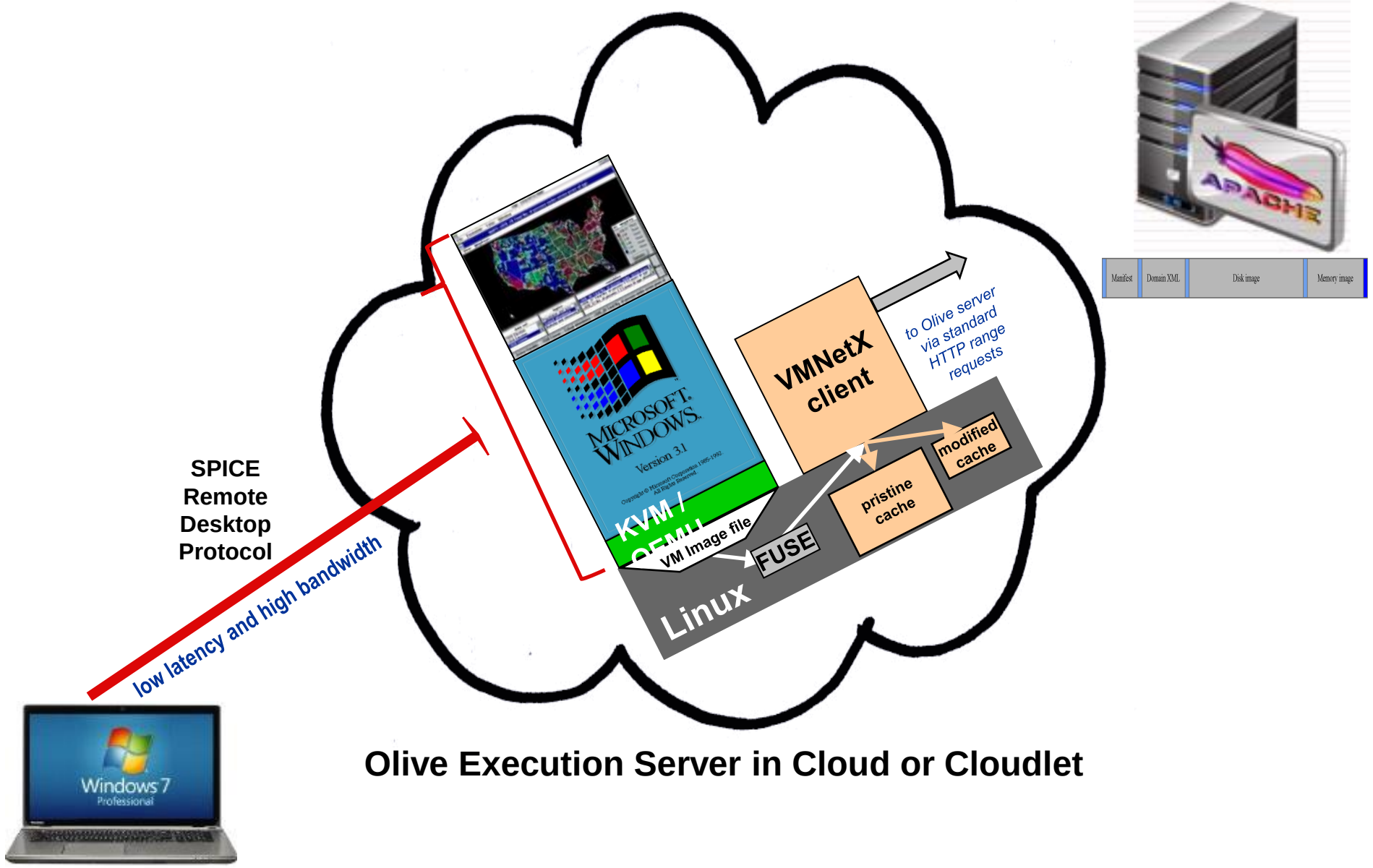
<domain type="kvm">
  <name>machine</name>
  <uuid>a7434757-631b-496d-a1ba-638014c74cc4</uuid>
  <memory>65536</memory>
  <currentMemory>65536</currentMemory>
  <vcpu>1</vcpu>
  <os>
    <type arch="i686" machine="pc">hvm</type>
    <boot dev="hd"/>
  </os>
  <features>
    <pae/>
  </features>
  <clock offset="utc"/>
  <devices>
    <emulator>/usr/libexec/qemu-kvm</emulator>
    <disk type="file" device="disk">
      <driver name="qemu" type="raw"/>
      <source file="/disk.img"/>
      <target dev="hda" bus="ide"/>
      <address type="drive" controller="0" bus="0" unit="0"/>
    </disk>
    <controller type="ide" index="0">
      <address type="pci" domain="0x0000" bus="0x00" slot="0x01" function="0x1"/>
    </controller>
    <interface type="user">
      <mac address="52:54:00:03:a0:11"/>
      <address type="pci" domain="0x0000" bus="0x00" slot="0x03" function="0x0"/>
    </interface>
    <input type="mouse" bus="ps2"/>
    <graphics type="vnc" autoport="yes"/>
    <video>
      <model type="vga" vram="9216" heads="1"/>
      <address type="pci" domain="0x0000" bus="0x00" slot="0x02" function="0x0"/>
    </video>
  </devices>
</domain>
```

Single file representation

Olive Implementation



Cloud Execution of Olive



Olive Execution Server in Cloud or Cloudlet

Many Future Technical Challenges

We are a long way from being "done"!

Scaling and performance issues

- VMs keep getting bigger, networks are never fast enough
- clever prefetching techniques

Precise emulation of hardware

- even x86 extended memory modes not quite right in QEMU (can't boot Windows 95 in KVM/QEMU)
- exotic hardware platforms
- host compatibility (e.g. CPU flags in x86) vs performance
- hardware performance accelerators (e.g. GPUs)

Multi-VM ensembles (e.g. HPC environments)

Tools for easy building of VMs (physical to virtual?)

Archiving entire cloud services

… *many others* …

Scope of Digital Preservation

- Digital object structures, representations, vocabulary and standard terminology (schema, OWL, …)
- Identifier spaces, registries, resolution mechanisms
  - The irony of WWW, URLs, DNS (TBL was at CERN)
  - Robert Kahn: Digital Object Architecture, CNRI
- Standard, rigorous ingestion processes
- Metadata (about the data, provenance, authenticity, calibration, ...)
- Legal frameworks for preservation (copyright, patents, licensing, special treatment for perserving bodies)
- Business Models for extended, long term operation

Milestones

- Technical means to capture and update digital storage media
- Capture and representation of relevant metadata
- Clearance of rights to share/execute digital objects
  - Possible legislation granting archives/libraries special “preservation” rights?
  - Might include both copyright and patent priviliges
- Provision for assuring integrity of digital objects
- Monitoring and management of changes to rights (e.g. expiration of copyright, patent)
- Development of business model(s) to sustain long-term preservation and access
  - Libraries, Archives, Universities, Museums
  - Long-lived institutions as vehicles or models?
    - E.g. Breweries, vineyards, Catholic (and other) Churches, Banks…. (!)
- Personalization of preservation options accessible to the general public

Other Projects

- The Internet Archive – Brewster Kahle et al
  - Library of Alexandria backup among others
  - Digital content, books, software
- The Computer History Museum
  - Software and computing artifacts
- Google Book Scans and Cultural Institute
- Digital Object Architecture and Identifiers (CNRI)

More Projects

- **RHIZOME, University of Freiburg**
- **Interplanetary File System (IPFS)**
- **International Internet Preservation Consortium**
- **UK Depositary Libraries Program**