Virtualization

CS642: Computer Security

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Administrative

- Homework 4 will be posted today or tomorrow
- Last week of class – project presentations
  - 10-15 minute presentations
  - Turn in slides (PDF or, preferably, PPTX)
    - Must be comprehensive: extra slides not covered in talk should be added to flesh out details
    - Or: optional supporting writeup (PDF)
  - I'll email about a Doodle to sign up for presentation day/time

Virtualization and cloud security

VMs

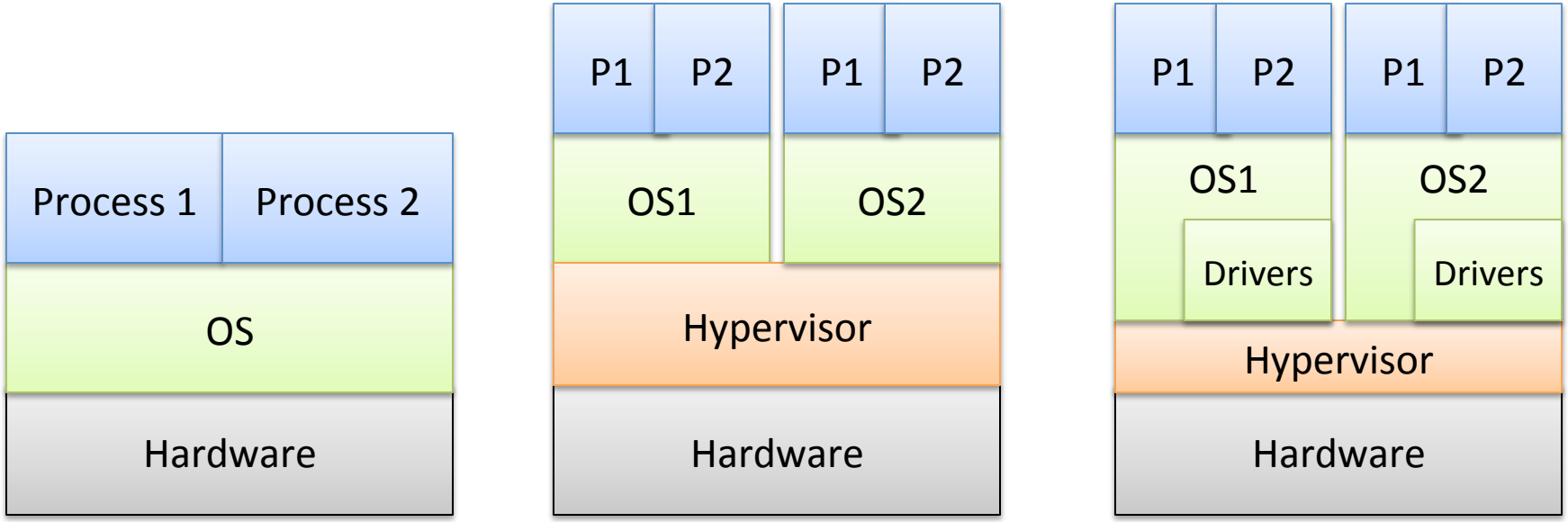
Cloud computing paradigms

VM image security issues

VM Introspection

Introspection

Virtualization



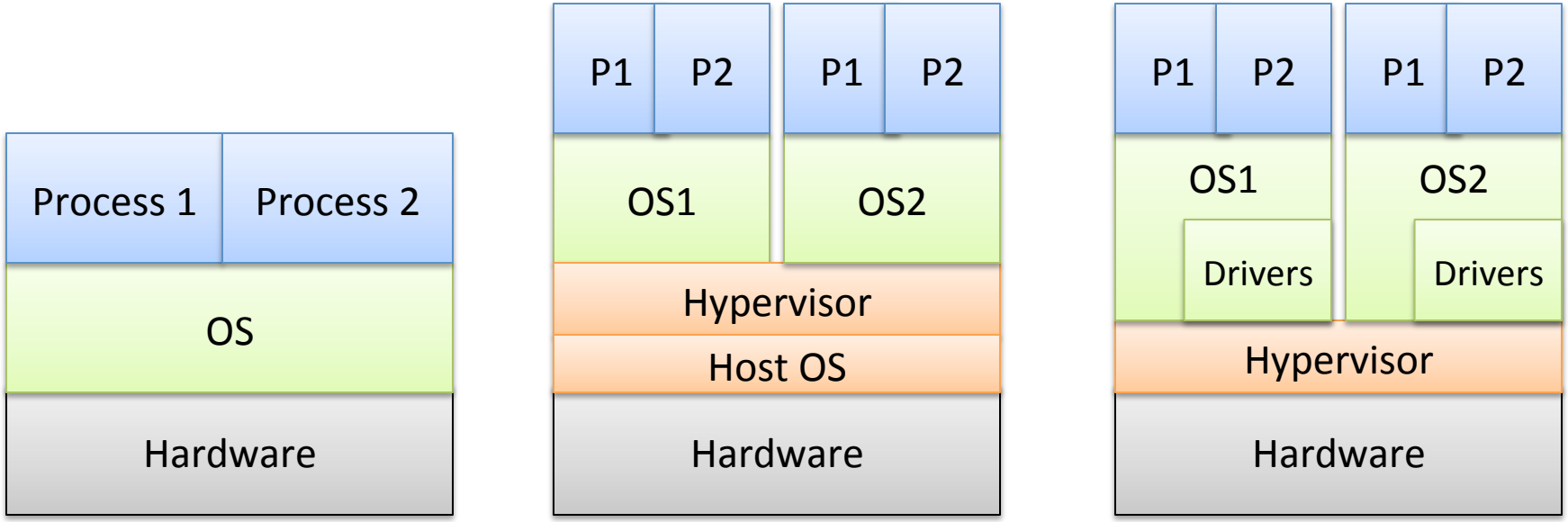
No virtualization

Full virtualization

Paravirtualization

Type-1: Hypervisor runs directly on hardware

Virtualization



No virtualization

Full virtualization

Paravirtualization

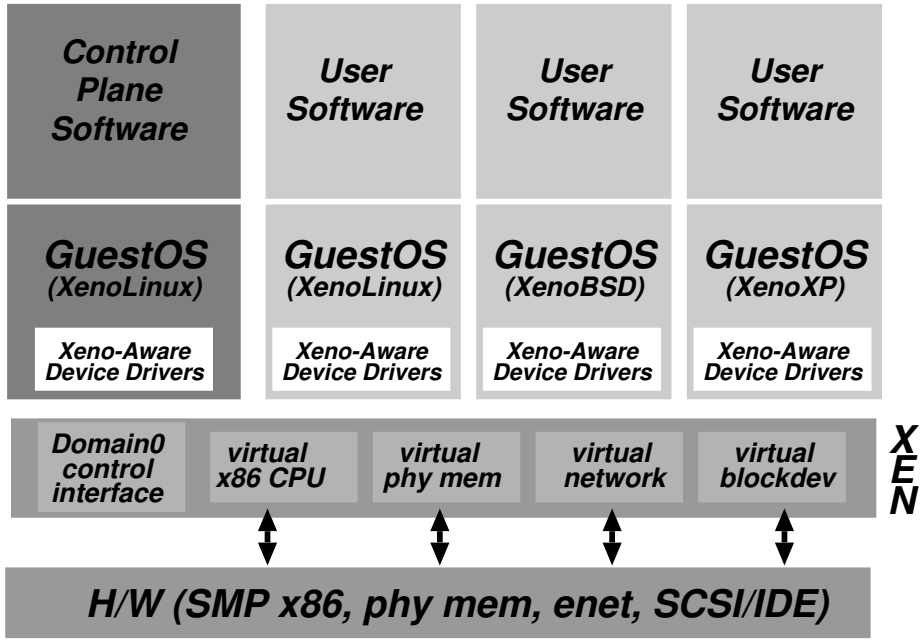
Type-1: Hypervisor runs directly on hardware
Type-2: Hypervisor runs on host OS

IBM VM/370

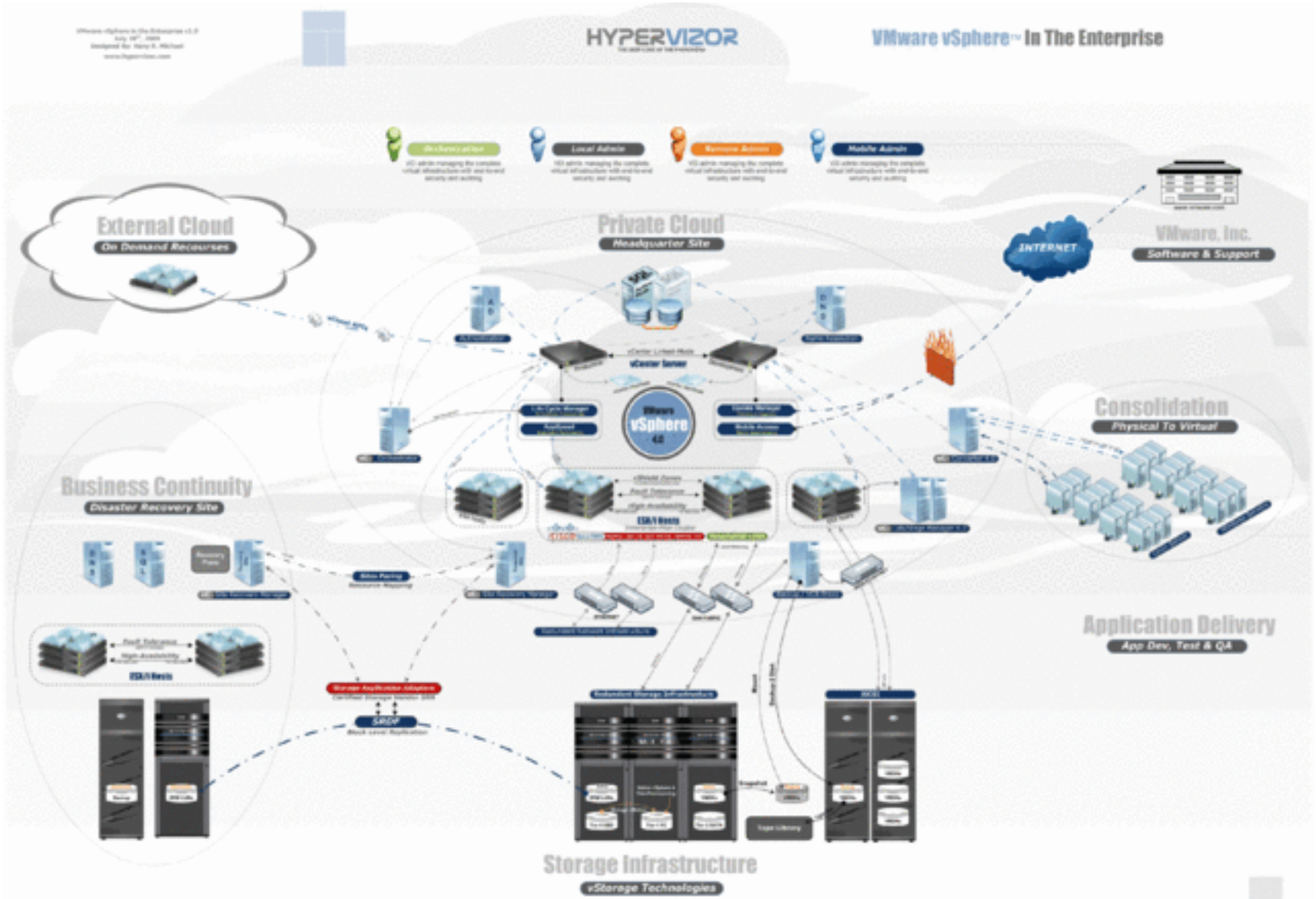
- Released in 1972
  - Used with System/370, System/390, zSeries mainframes
  - Full virtualization
- Supported CP/CMS operating system
  - Initial application was to support legacy OS
- z/VM is newer version, most recent version 2010
  - Better use of 64-bit mainframes

Xen

- 2003: academic paper
  - "Xen and the Art of Virtualization"
- Paravirtualization
  - Hypercalls vs system calls
  - Modified guest OS
- Why?



VMWare

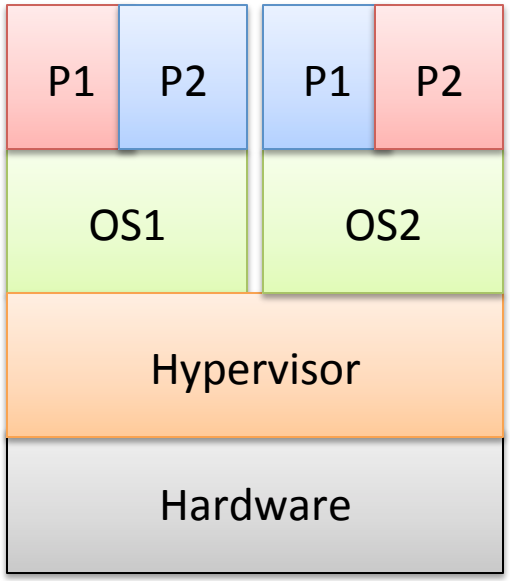

HYPERVIZOR
VMware vSphere™ In The Enterprise
External Cloud
On Demand Recourses
Private Cloud
Headquarter Site
INTERNET
VMware, Inc.
Software & Support
Consolidation
Physical To Virtual
Business Continuity
Disaster Recovery Site
Application Delivery
App Dev, Test & QA
Storage Infrastructure
vStorage Technologies

Example VM Use Cases

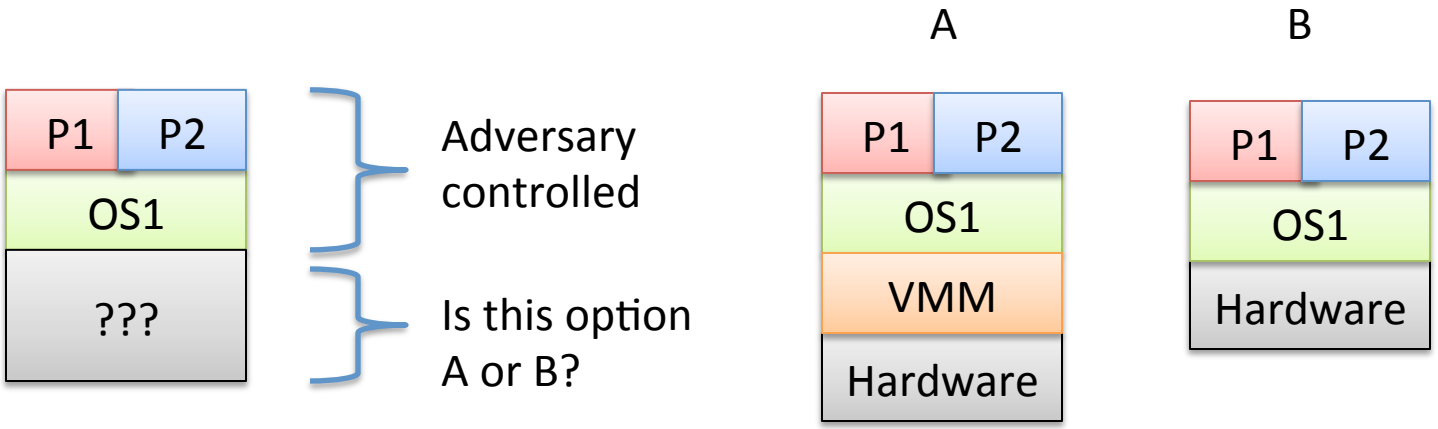
- Legacy support (e.g., VM/370)
- Development
- Server consolidation
- Cloud computing Infrastructure-as-a-Service
- Sandboxing / containment

Study of malware

- Researchers use VMs to study malware
- Example of VM sandboxing
  - Hypervisor must contain malicious code
- Introspection
- How would you evade analysis as a malware writer?
  - split personalities



VMM Transparency



- Adversary can detect if:
  - Paravirtualization
  - Logical discrepancies
    - Expected CPU behavior vs virtualized
    - Red pill (Store Interrupt Descriptor Table instr)
  - Timing discrepancies
    - Slower use of some resources

Garfinkel et al. "Compatibility is not transparency: VMM Detection Myths and Reality"

Detection of VMWare

```
MOV EAX,564D5868 <-- "VMXh"
MOV EBX,0
MOV ECX,0A
MOV EDX,5658 <-- "VX"
IN EAX,DX <-- Check for VMWare
CMP EBX,564D5868
```

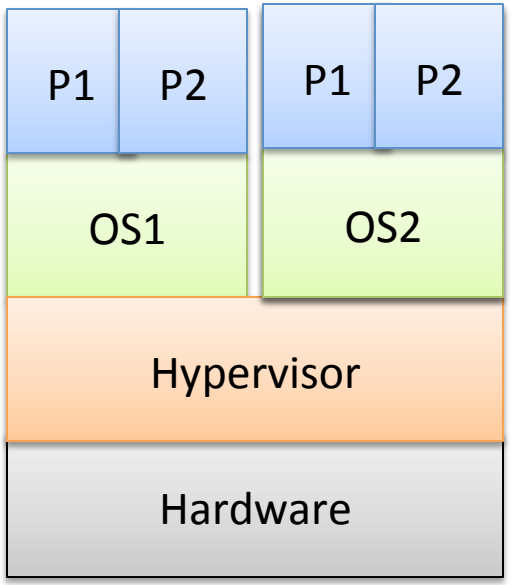
IN instruction used by VMWare to facilitate host-to-guest communication

VMWare:
    places VMXh in EBX
Physical:
    processor exception

From
http://handlers.sans.org/tliston/ThwartingVMDetection_Liston_Skoudis.pdf

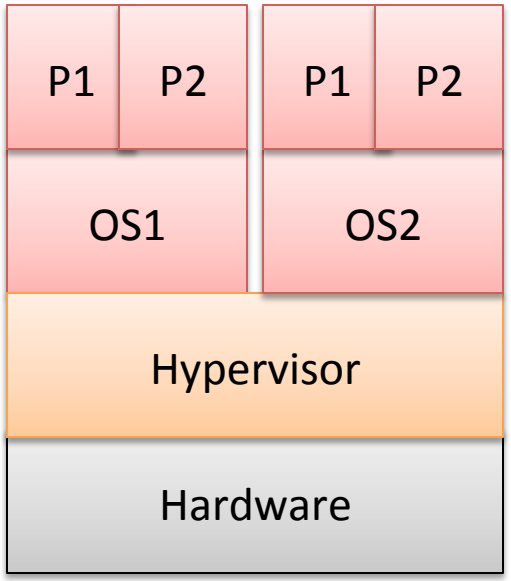
Server consolidation

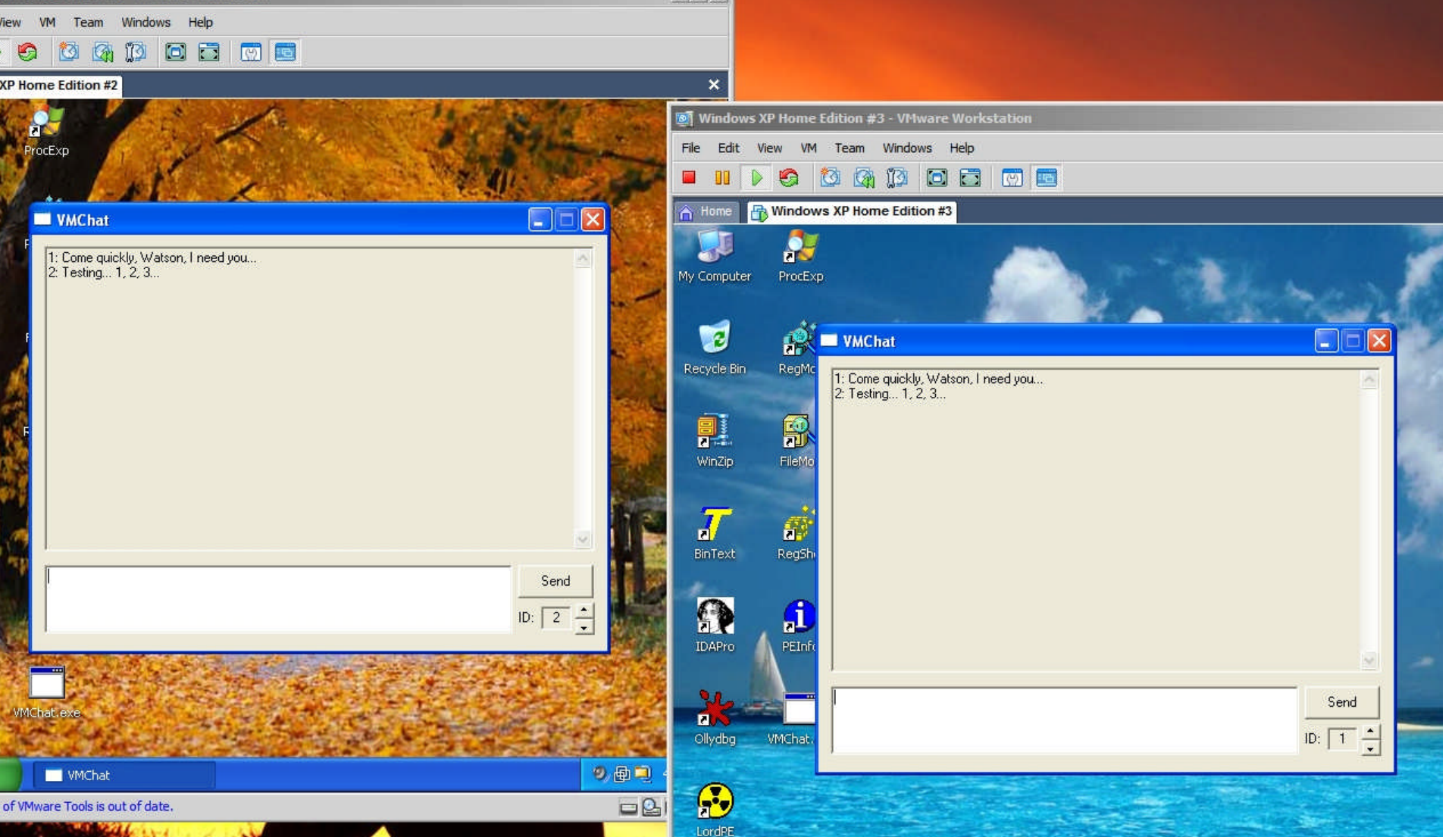
- Consolidation
  - Use VMs to optimize use of hardware
  - Pack as many VMs onto each server as possible
  - Turn off other servers
- Threat model?
  - Isolation
  - Containment
  - Assume guests are/can be compromised



Violating isolation

- Covert channels between VMs
  - Illicit communications
  - Hard drives
  - Exploits against VMM

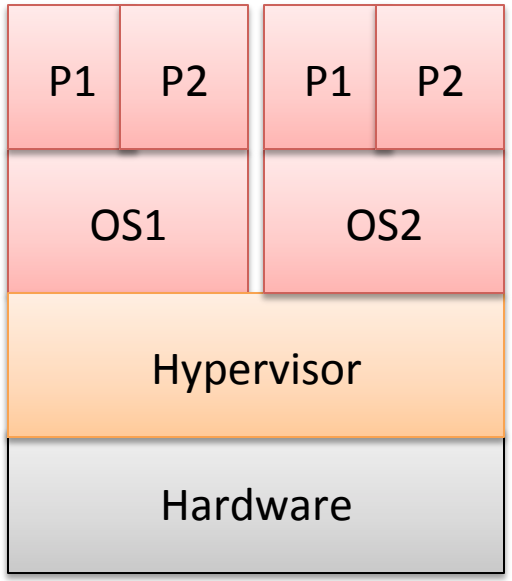




http://handlers.sans.org/tliston/ThwartingVMDetection_Liston_Skoudis.pdf

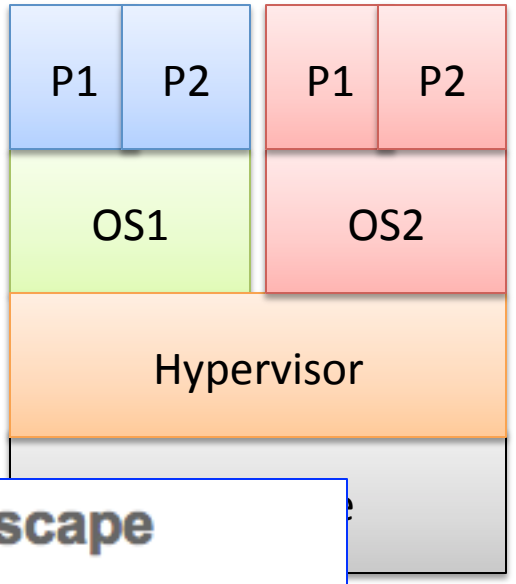
Violating isolation

- Covert channels between VMs
  - Illicit communications
  - Hard drives
  - Exploits against VMM
- Degradation-of-Service attacks
  - Guests might maliciously contend for resources
  - Xen scheduler vulnerability



Violating containment

- Escape-from-VM
  - Vulnerability in VMM or host OS (e.g., Dom0)
  - Seemingly rare, but exist



VMware vulnerability allows users to escape virtual environment

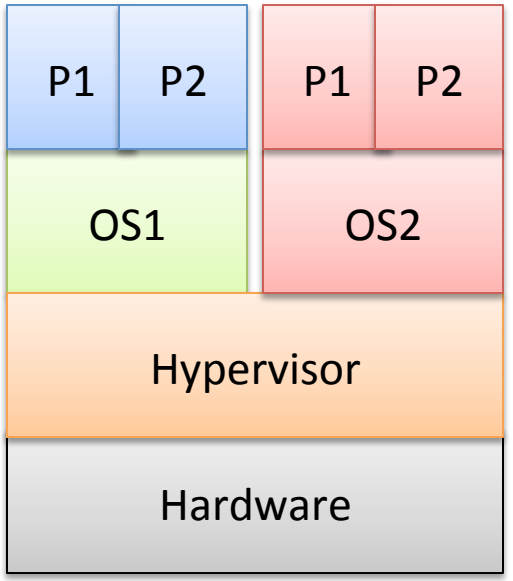
By Joab Jackson Feb 28, 2008

A new vulnerability found in some VMware products allows users to escape their virtual environments and muck about in the host operating system, penetration testing software firm Core Security Technologies **announced** earlier this week.

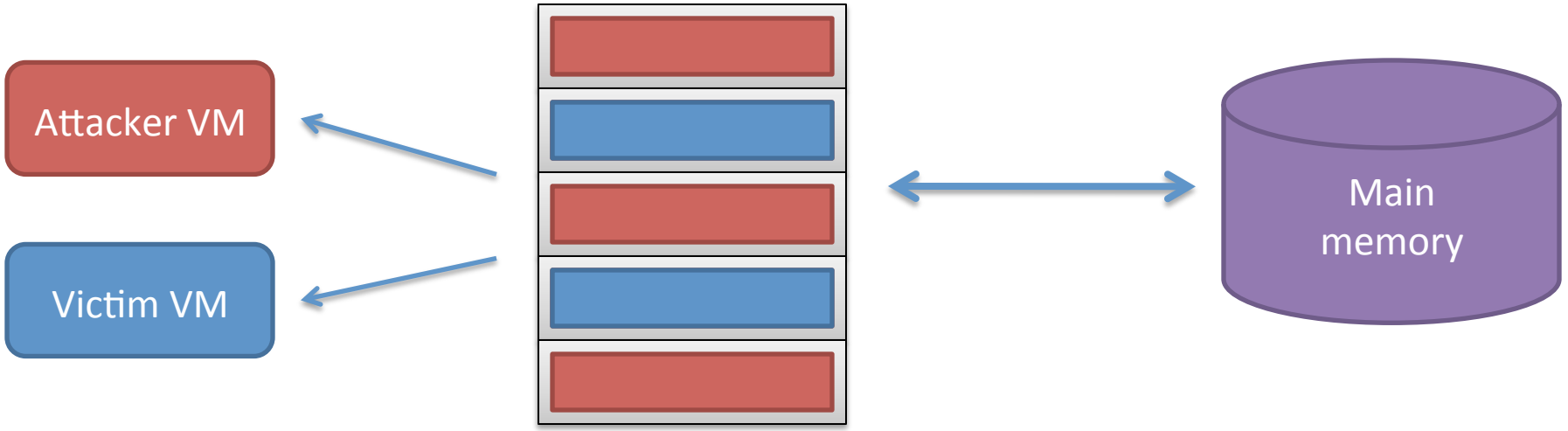
This vulnerability (CVE Name: CVE-2008-0923) could poise significant risks to enterprise users who are deploying VMware software as a secured environment.

Violating containment

- Escape-from-VM
  - Vulnerability in VMM or host OS (e.g., Dom0)
  - Seemingly rare, but exist
- Side channels
  - Spy on other guest via shared resources



Cross-VM side channels using CPU cache contention



1) Read in a large array (fill CPU cache with attacker data)

2) Busy loop (allow victim to run)

3) Measure time to read large array (the load measurement)

What else is shared?

Memory bus, Hard disk, i-Cache,
CPU registers, NIC, Hypervisor itself, …

Lessons

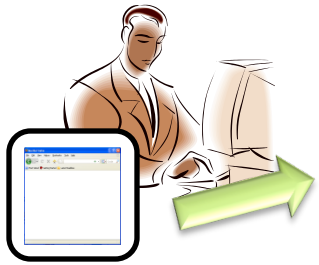
- Don't count on:
  - VMM transparency
  - Strong isolation (side channels exist)
- Don't rely on:
  - Containment
- Securing guest OS and host OS still very important

Virtual Machine Management

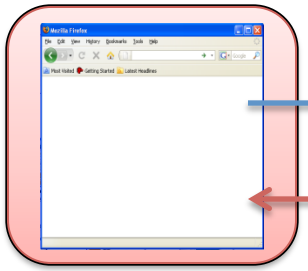
- Snapshots
  - Volume snapshot / checkpoint
    - persistent storage of VM
    - must boot from storage when resuming snapshot
  - Full snapshot
    - persistent storage and ephemeral storage (memory, register states, caches, etc.)
    - start/resume in between (essentially) arbitrary instructions
- VM image is a file that stores a snapshot

Virtual machines and secure browsing

"**Protect Against Adware and Spyware:** Users protect their PCs against adware, spyware and other malware while browsing the Internet with Firefox in a virtual machine."
[http://www.vmware.com/company/news/releases/player.html]

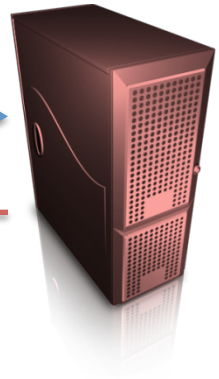


Clean snapshot of VM with browser running

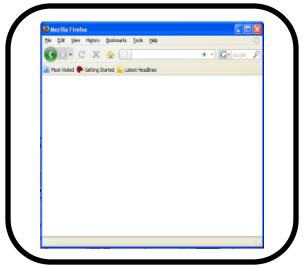


http://www.freesoftware.com/

browser exploit



Virtual machine compromised, but not host OS



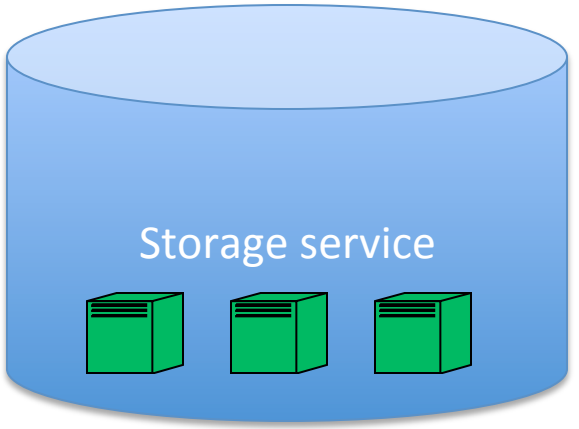
Resetting to snapshot removes malware

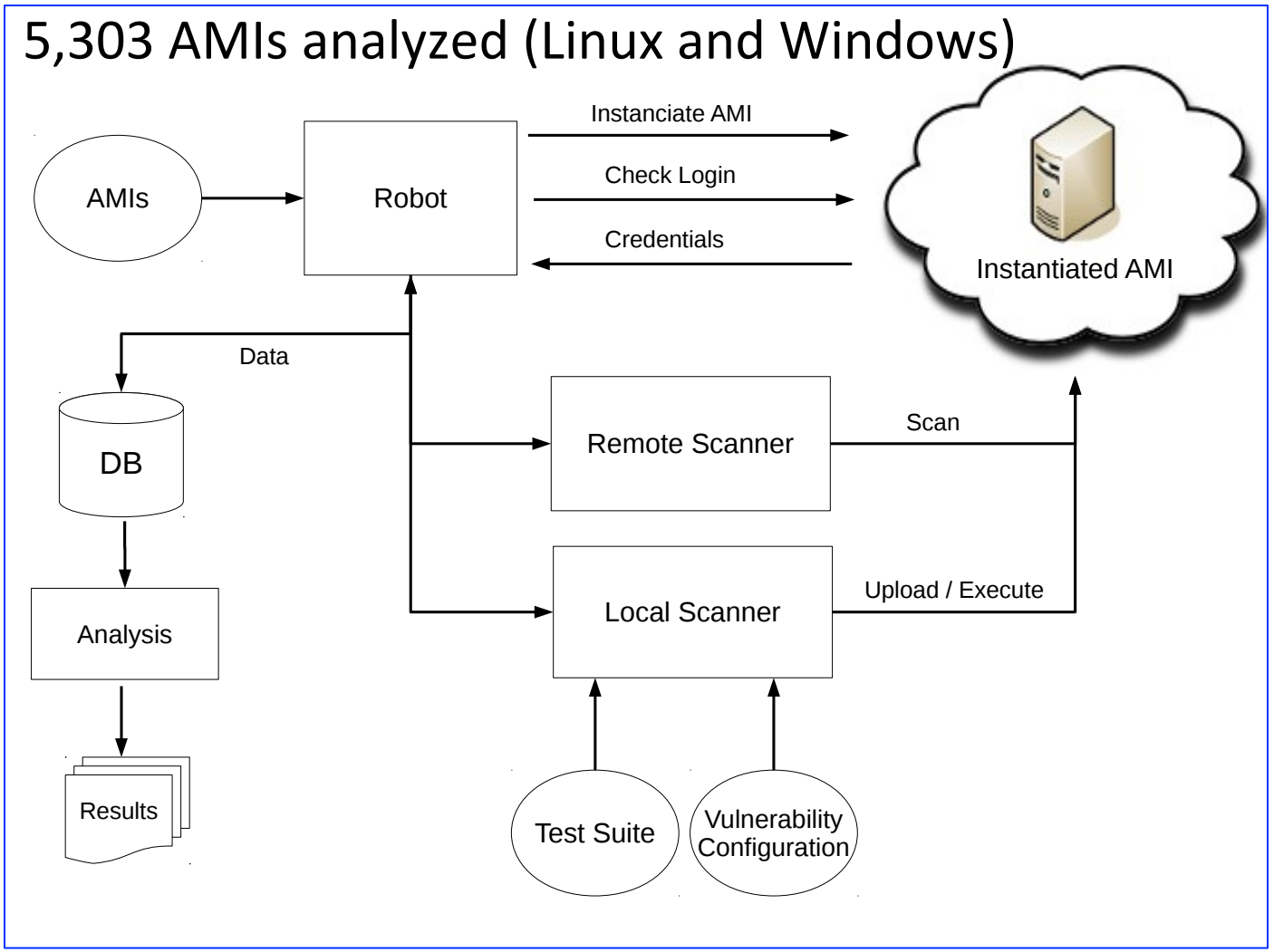
VM Management issues

- Reset vulnerabilities
  - We saw crypto/RNG related vulnerabilites a few weeks ago (reuse of randomness)
  - Guest OS and application quiescing
- Lack of diversity
- Identity management / credentials

Amazon Machine Images (AMIs)

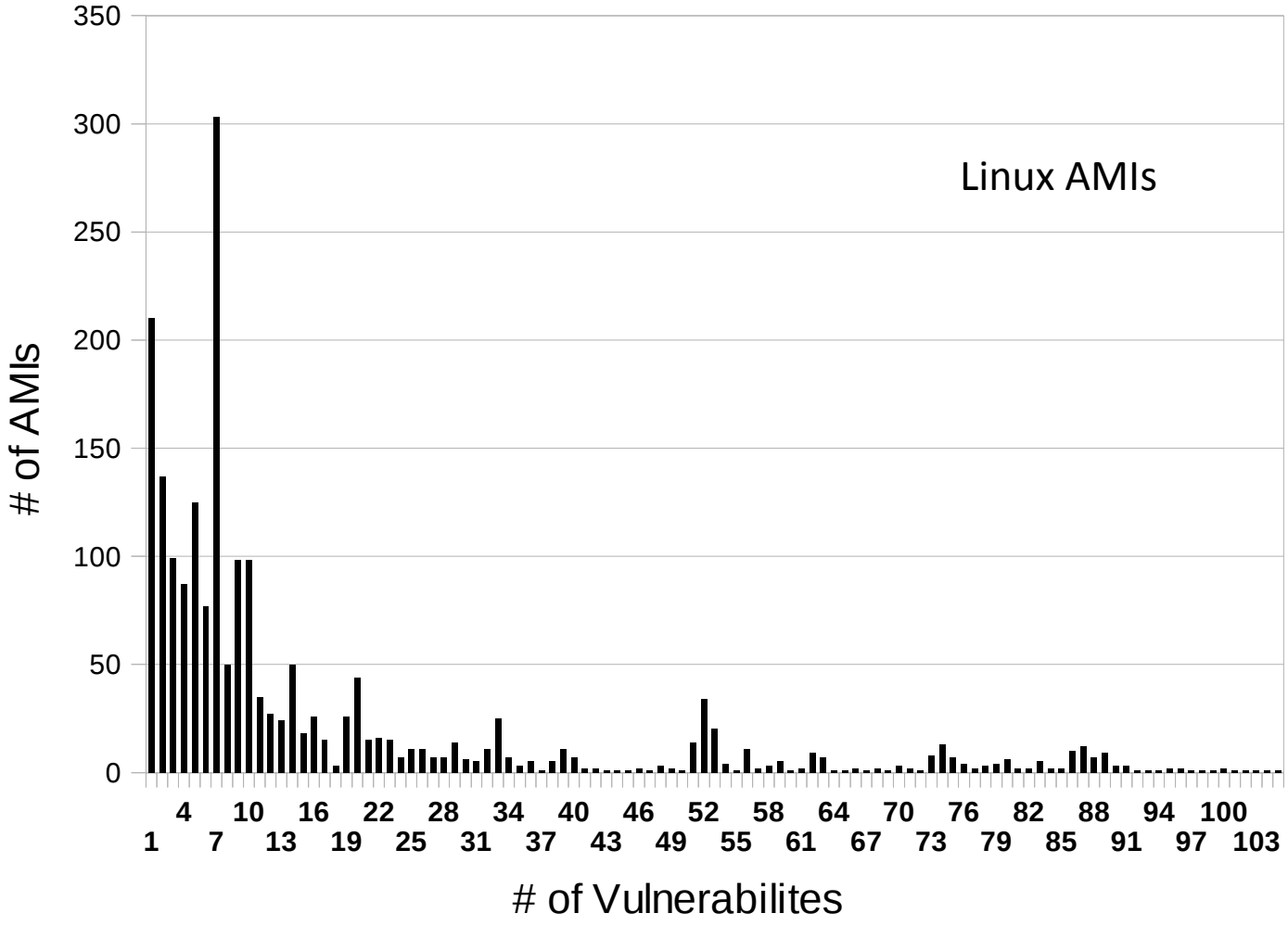
- Users set up volume snapshots / checkpoints that can then be run on the Elastic Compute Cloud (EC2)
- Can be marked as public and anyone can use your AMI





Balduzzi et al. “A Security Analysis of Amazon’s Elastic Compute Cloud Service – Long Version –”, 2011

See also Bugiel et al., “AmazonIA: When Elasticity Snaps Back”, 2011



Also: Malware found on a couple AMIs

Balduzzi et al. analysis

- Backdoors
  - AMIs include SSH public keys within authorized_keys
  - Password-based backdoors

	East	West	EU	Asia	Total
AMIs (%)	34.8	8.4	9.8	6.3	21.8
With Passwd	67	10	22	2	101
With SSH keys	794	53	86	32	965
With Both	71	6	9	4	90
Superuser Priv.	783	57	105	26	971
User Priv.	149	12	12	12	185

Table 2: Left credentials per AMI

Balduzzi et al. analysis

- Credentials for other systems
  - AWS secret keys (to control EC2 services of an account): 67 found
  - Passwords / secret keys for other systems: 56 found

Finding	Total	Image	Remote
Amazon RDS	4	0	4
dDNS	1	0	1
SQL	7	6	1
MySql	58	45	13
WebApp	3	2	1
VNC	1	1	0
Total	74	54	20

Table 3: Credentials in history files

Balduzzi et al. analysis

- Deleted files
  - One AMI creation method does block-level copying

Type	#
Home files (`/home, /root`)	33,011
Images (min. 800x600)	1,085
Microsoft Office documents	336
Amazon AWS certificates and access keys	293
SSH private keys	232
PGP/GPG private keys	151
PDF documents	141
Password file (`/etc/shadow`)	106

Table 5: Recovered data from deleted files

Response

"They told me it's not their concern, they just provide computing power," Balduzzi says. "It's like if you upload naked pictures to Facebook. It's not a good practice, but it's not Facebook's problem."

http://www.forbes.com/sites/andygreenberg/2011/11/08/researchers-find-amazon-cloud-servers-teeming-with-backdoors-and-other-peoples-data/

- Amazon notified customers with vulnerable AMIs
- Made private AMIs of non-responsive customers
- New tutorials for bundling systems
- Working on undelete issues…

Lessons

- New software management practices needed with VM snapshots
- Discussion:
  - New tool support?
  - How much worse is this than non-cloud server deployments?
- We have about ~1600 AMIs downloaded ourselves. Research project ideas?