Hypervisor Memory Forensics

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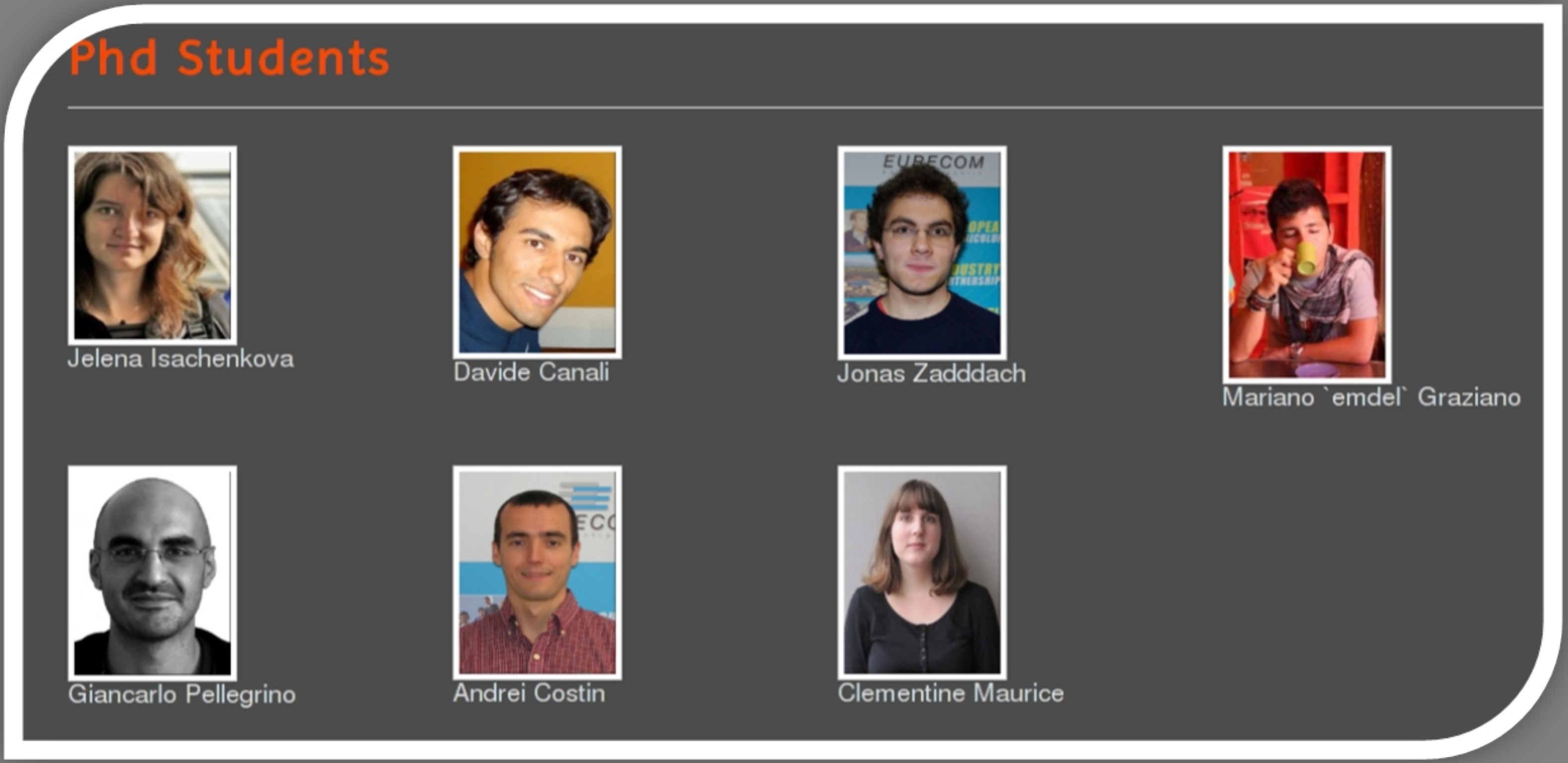

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Actaeon

- Memory forensics of virtualization environments
- Locate any Intel Hardware assisted **Hypervisor**
- Detect **nested** Virtualization
- Provide transparent Guest **Introspection**

Winner of the 2013 Volatility Plugin Contest

Actaeon [Use Cases]

- Hypervisors are everywhere:
  - Xen, KVM, VirtualBox, Vmware, Hyper-V, bhyve
  - Cloud (Amazon, Microsoft, Google, Apple)
  - Domestic use (Running multiple operating systems)
  - Security Solutions (Sandboxes, DeepDefender, Bromium etc)
  - POC Malware (BluePill, Vitriol)
- The forensics community needs tools for digital investigations of virtual environments

What Actaeon is NOT

- Physical memory dumper
- Hypervisor-based malware detector

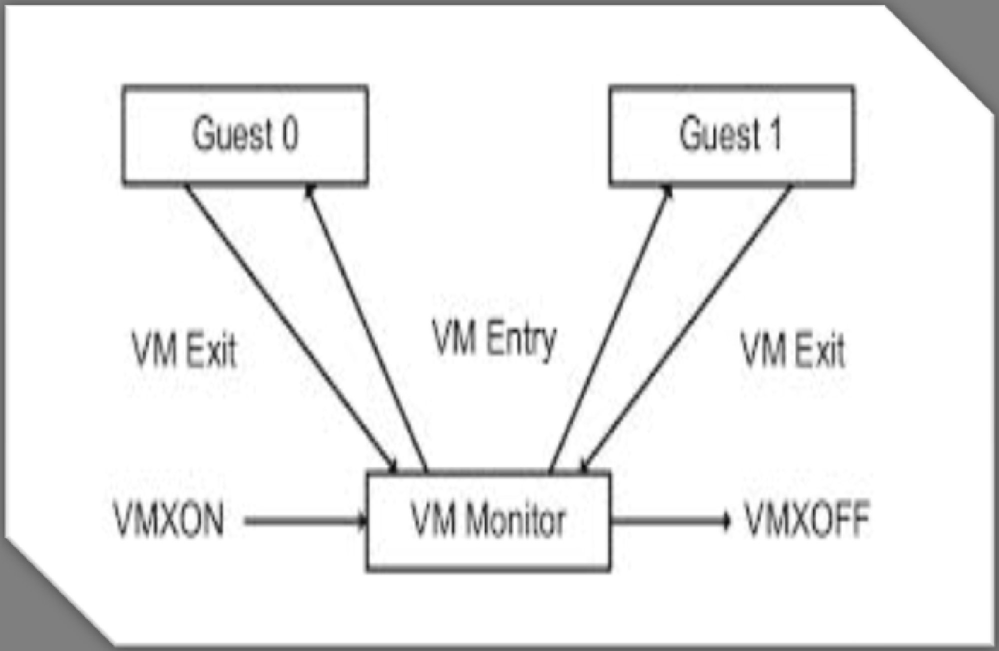
Actaeon framework

- VMCS memory layout dumper
- Hyperls
- Volatility patch for guest introspection

VMCS Dumper

[Theory]

- Intel processors provide hardware-level support for virtualization
- Two main VMX operations: root and non root



*From the Intel Manual

VMCS Dumper

- Virtual Machine Control Structure
- Data structure that controls both VMX non root operation and VMX transitions
- The format to store the VMCS data is implementation specific
- Every field is associated with a 32 bit value (its encoding) used by VMREAD/VMWRITE instructions
- The VMCS data is divided in 6 groups

VMCS Dumper [Reversing]

- Custom Hypervisor initialization code (based on HyperDbg) :
  - VMCS memory region allocation
  - Fill the region with an 16 bit incremental counter
  - Perform VMREAD operations
  - Same approach valid for nested VMCS structures

DEMO 0x00

Hyperls

- Volatility plugin
- Memory scanner looking for VMCS structures
- VMCS detection based on four fields:
  - REVISION_ID
  - VMX_ABORT_INDICATOR
  - VMCSLINKPOINTER
  - HOST_CR4
- These fields cannot be obfuscated

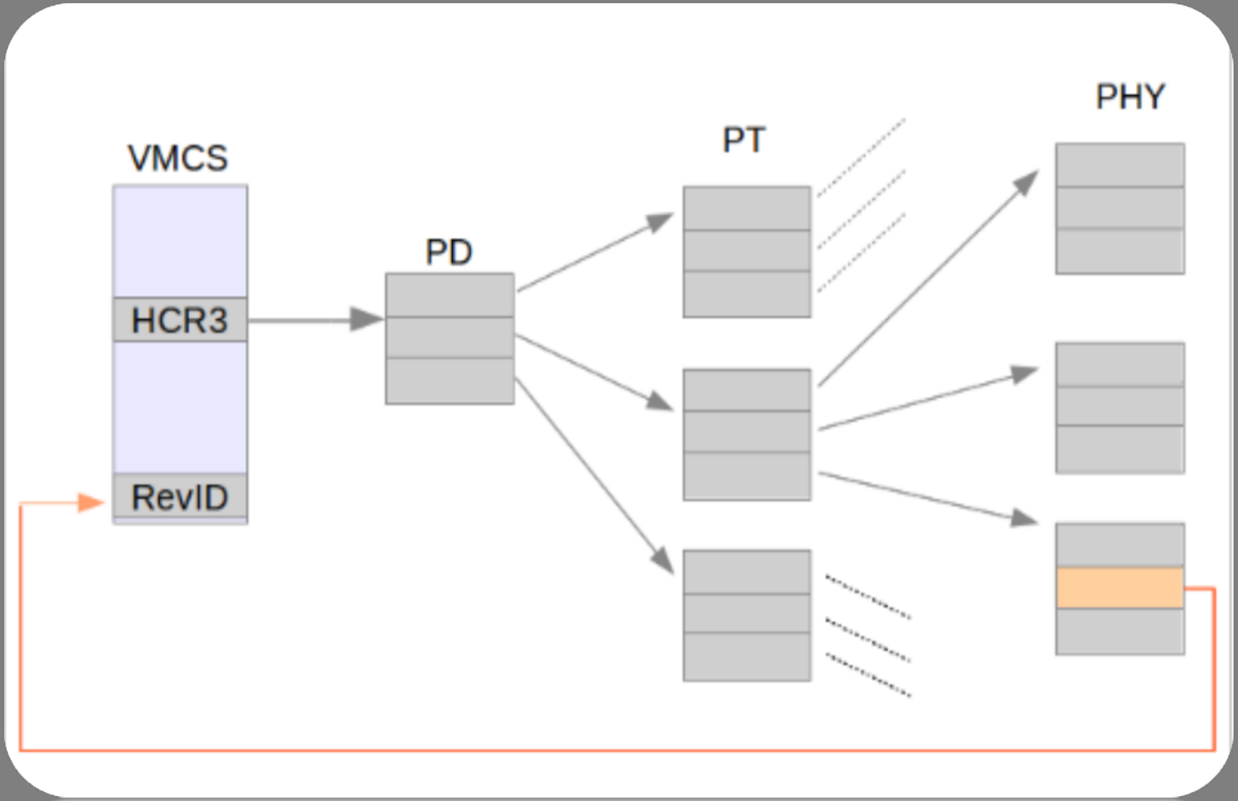
HyperIs [Validation]

- Property to rule out false positives:
  - HOST_CR3 register points to the hypervisor page tables
  - The page tables need to map the page containing the VMCS itself
- For every VMCS candidate we..
  - extract the HOST_CR3 field
  - walk the entire page tables
  - obtain all the allocated physical pages
- The VMCS is validated if and only if it is in the set of the allocated physical pages

HYPERVISOR MEMORY FORENSICS

Hyperls

[Validation]



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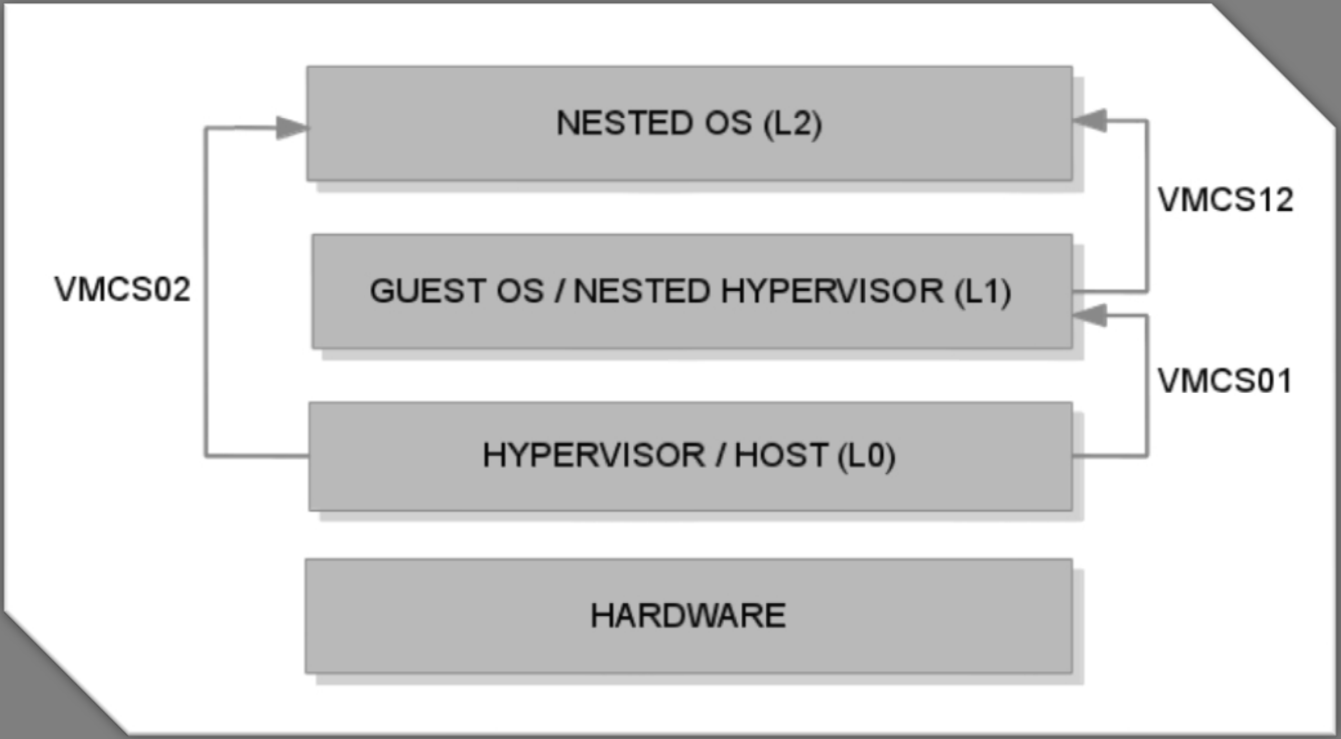
HyperIs [Nested]

- A guest virtual machine can run an hypervisor
- In x86 only one hypervisor is in root mode



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Guest Introspection [EPT]

- Extended Page Tables (EPT): Intel Hardware feature
- Address translation from Guest Physical Addresses (GPA) to Host Physical Addresses (HPA)
- It has different stages (very similar to IA-32e)

Guest Introspection [Algorithm]

- We extract the EPT_POINTER from the VMCS
- We translate, when required, all the GPA to HPA through the EPT table
- We patched Volatility to use this pointer during the address translation

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Limitations

- Actaeon supports only Intel hardware assisted hypervisors
- Actaeon supports EPT (no shadow page tables)
- Dump is not our concern (VT-d disabled)

Future Works

- We are currently working to support:
  - Hyper-V
  - Introspection for Linux Guests
  - VMCS Shadowing
  - VMWare ESXi
  - AMD

References

- ✓ S3 Group: http://s3.eurecom.fr
- ✓ Actaeon: http://s3.eurecom.fr/tools/actaeon/
- ✓ Actaeon Paper: http://s3.eurecom.fr/docs/raid13_graziano.pdf

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