Mitigating Exploits, Rootkits and Advanced Persistent Threats

David Durham, Senior Principal Engineer
Intel Corporation

Hot Chips Tutorial

Agenda

Problem
Better Protection
Solid Foundations
Usages
Minimizing TCB
Summary

Problem

Better Protection

Solid Foundations

Usages

Minimizing TCB

Summary

Increasingly Sophisticated Attacks

Operation Aurora: "Google announced an attack targeting it and what is believed to be more than 30 other companies …."

CNET January 12, 2010

Stuxnet: "…a novel way to use computers to sabotage an enemy's lifeline infrastructure suggests a powerful new kind of weapon is moving within reach of weak states, militant groups and criminals…"

Reuters Nov 30, 2010

The Heartbleed Vulnerability: What It Is and How It Affects You: "…Heartbleed is not a virus, but rather a mistake written into OpenSSL" April 2014

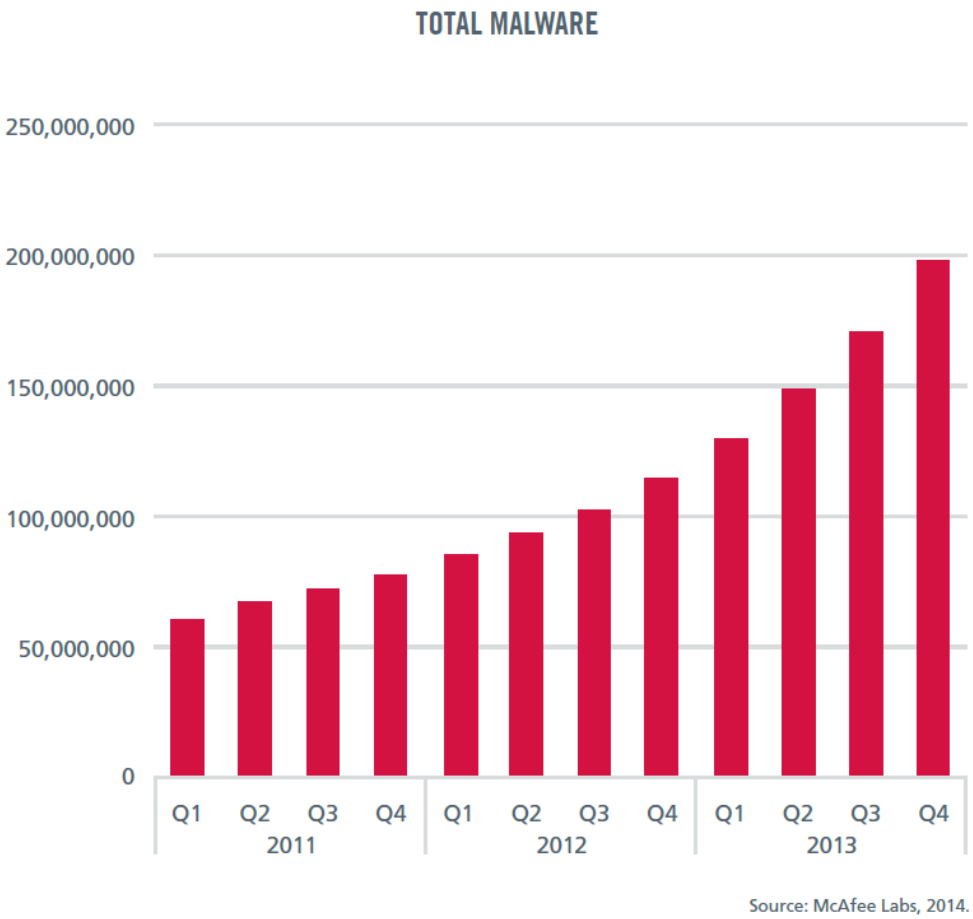
Banking Malware (SpyEye) Monitors Victims by Hijacking Webcams and Microphones May 2012, ***PCWorld***

Meet 'Flame,' The Massive Spy Malware

"…designed primarily to spy on the users of infected computers and steal data from them, including documents, recorded conversations and keystrokes." May 2012, ***Wired***

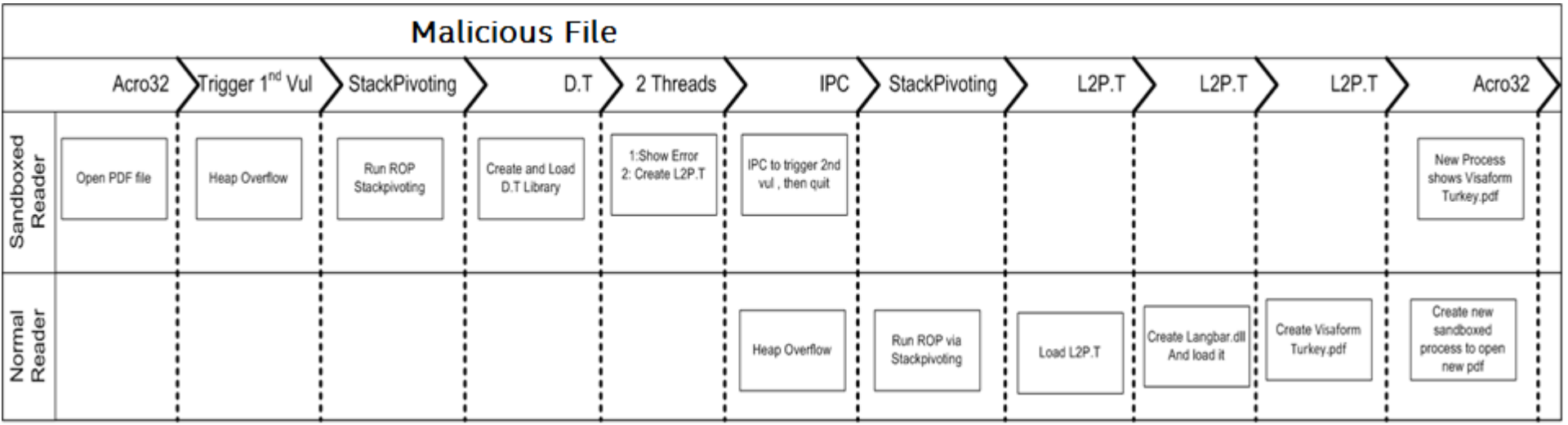
Malware Signatures More & More…

- Malware samples continue sharp rise
- Polymorphic viruses
- Methods of packing, redistributing existing malware
- Looking for known malware misses 0-days and targeted attacks

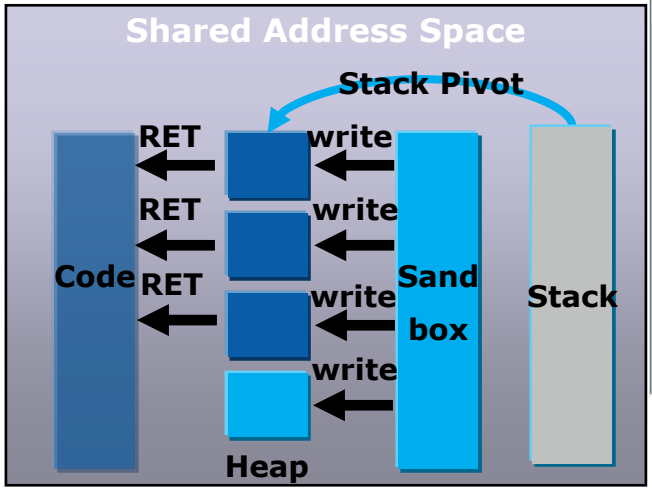


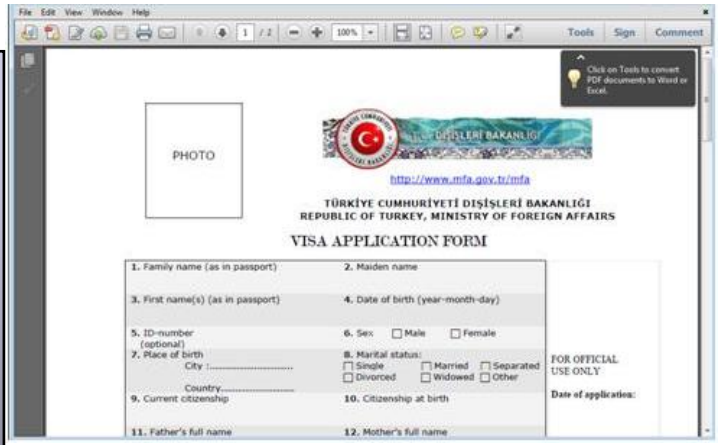
0-Day: Vulnerability, Armed, Exploited

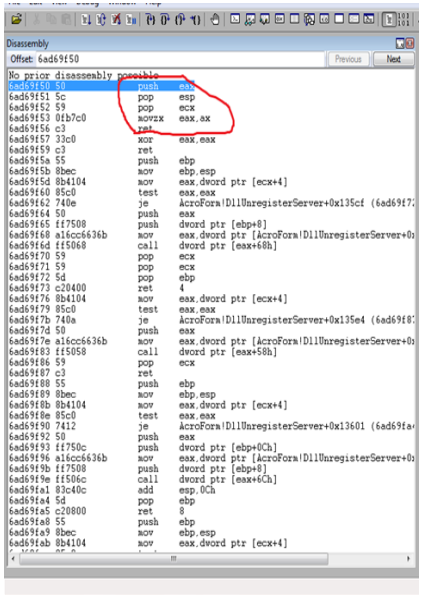
Sample: APSA13-02 Exploit Analysis



Stack Pivot





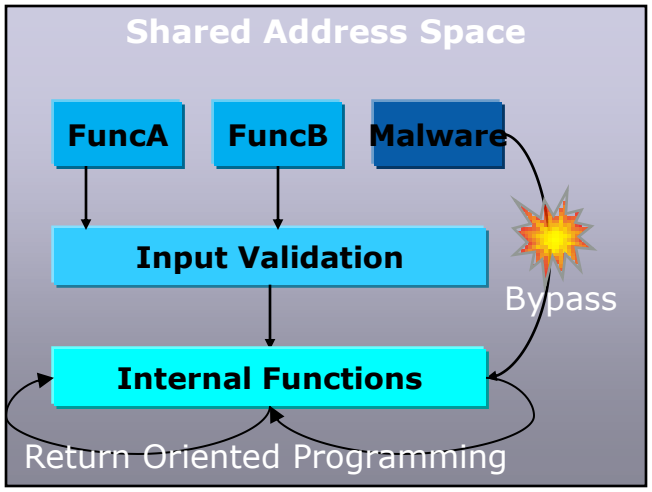


Emerging 'Stack Pivoting' Exploits Bypass Common Security- APSA13-02 exploit:

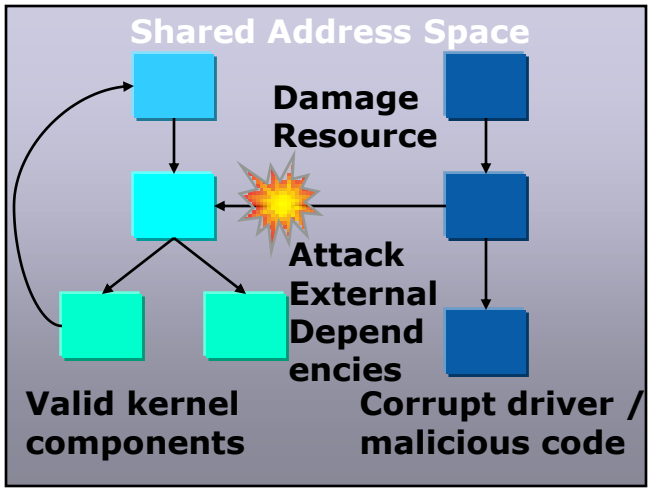
http://blogs.mcafee.com/mcafee-labs/emerging-stack-pivoting-exploits-bypass-common-security

Generalized Attack Vectors

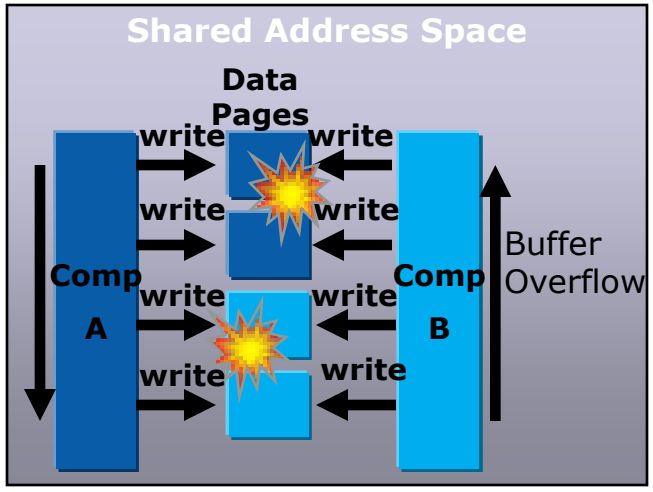
Circumvent



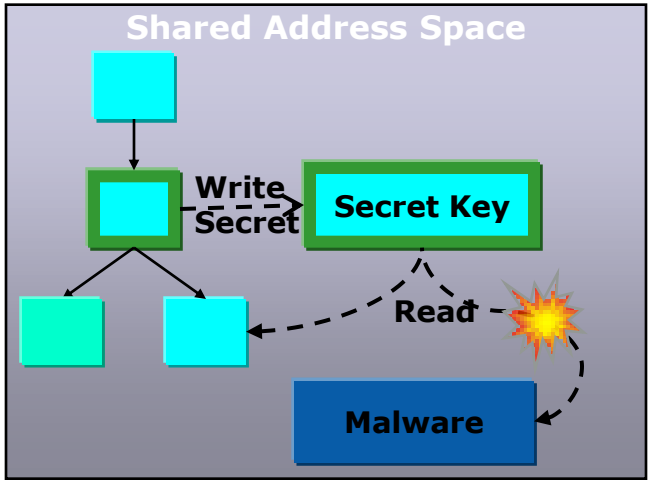
Disable



Inject/Modify



Eavesdrop



Problem

Better Protection

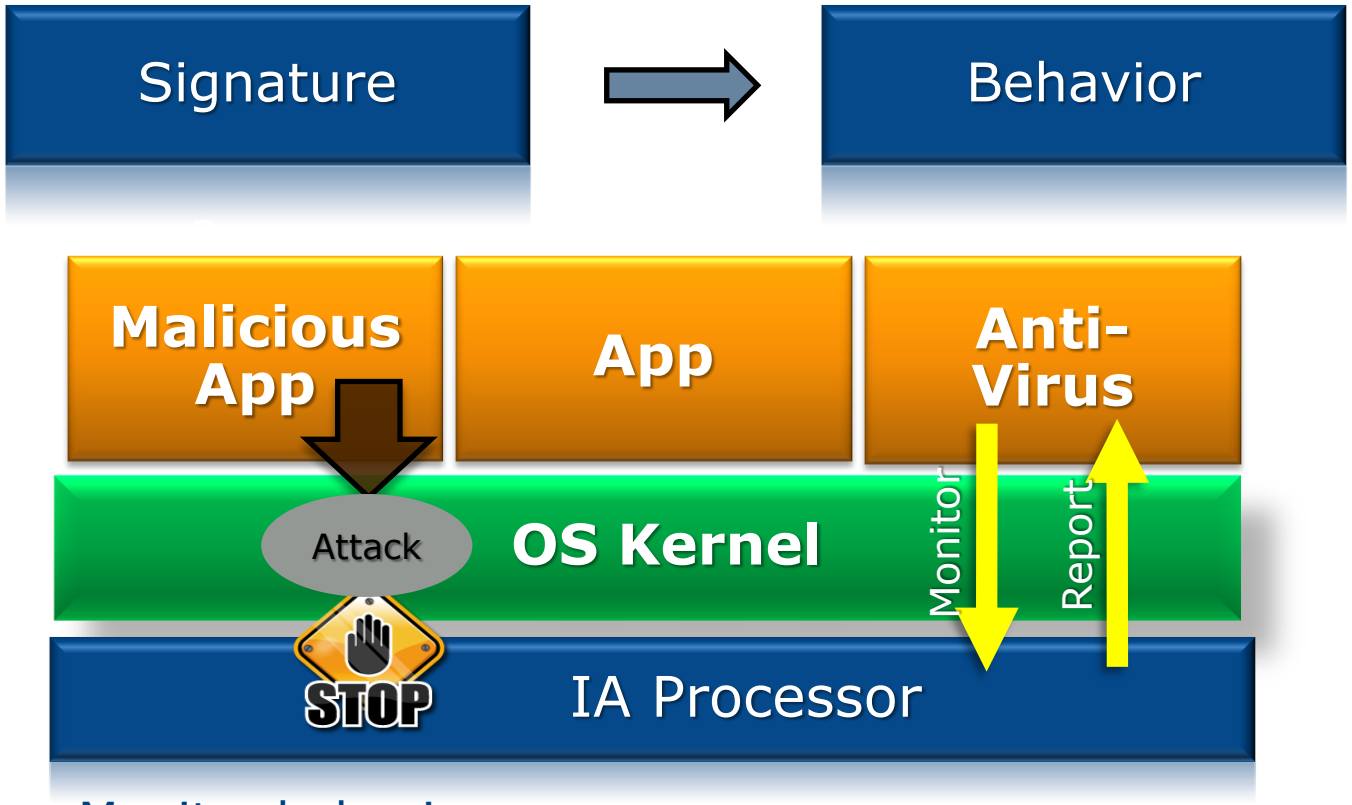
Solid Foundations

Usages

Minimizing TCB

Summary

Paradigm Shift



Monitor behavior

Detect onset of the attack

Prevent suspicious access

"Behavior-based" detection to stop zero-day attacks

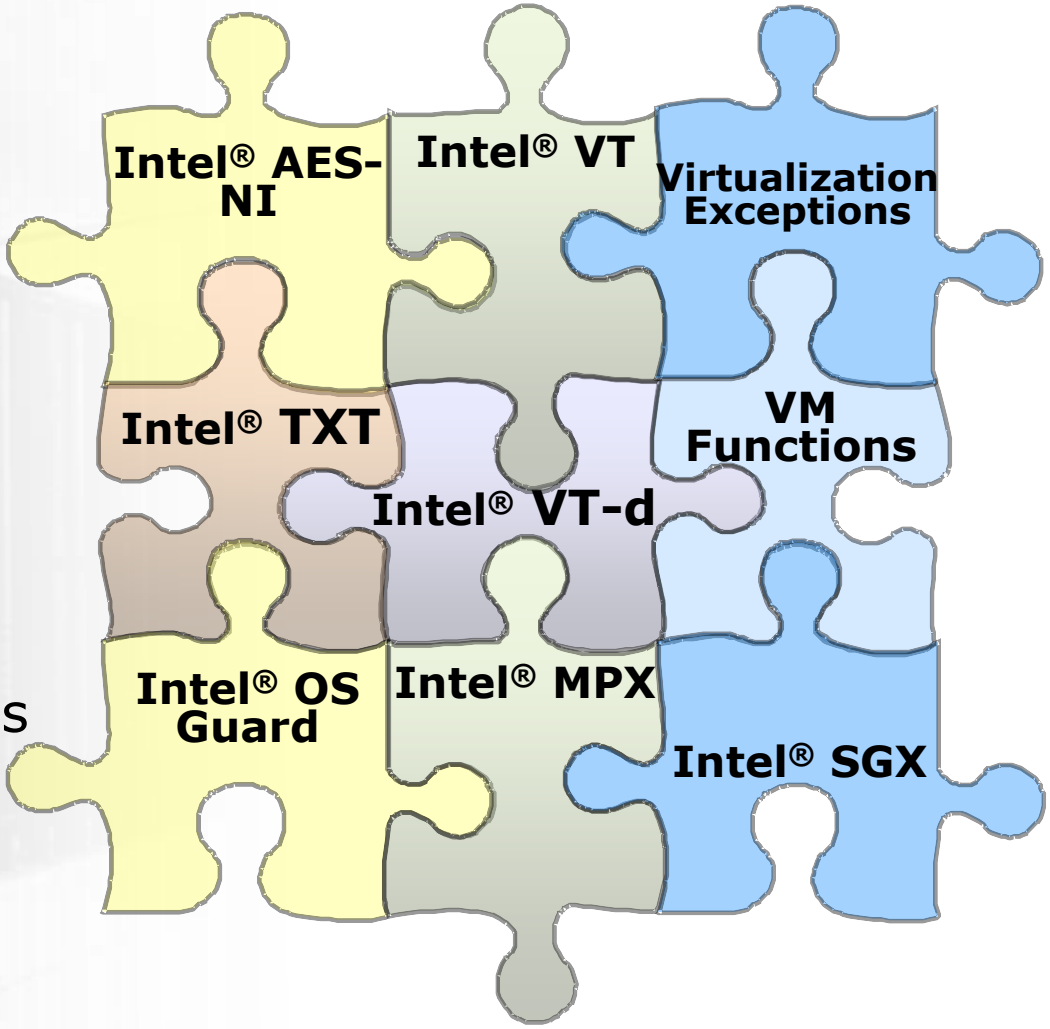
Putting the Defenses Together

- Trusted Launch
- Measurement
- Software Isolation
- Device Isolation
- Crypto Acceleration
- Introspection Acceleration
- Supervisory Execution Prevention

Forward Looking…

- Buffer Overflow Protections
- Minimal TCB

…



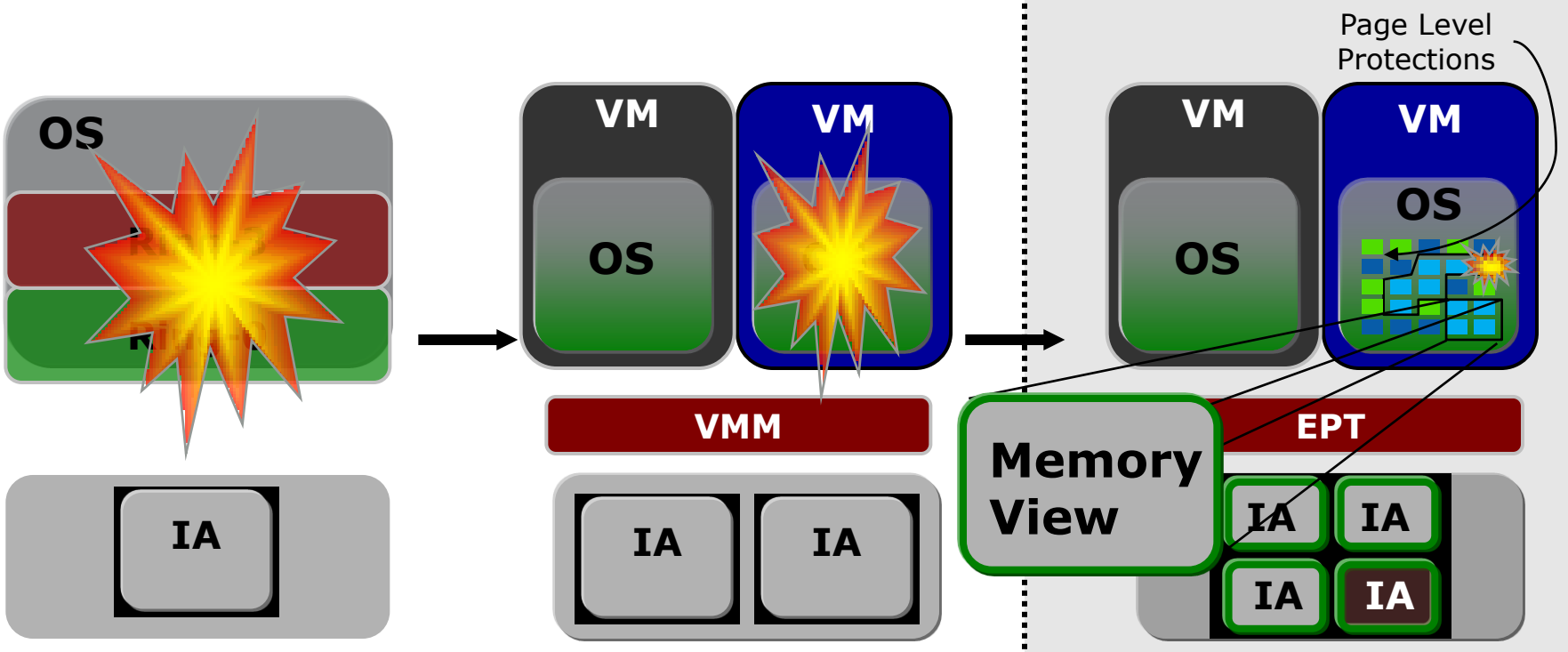
Intel® Trusted Execution Technology (Intel® TXT)
Intel® Virtualization Technology (Intel® VT) for Directed I/O (Intel® VT-d)
Intel® Virtualization Technology (Intel® VT)
Intel® Memory Protection Extensions (Intel® MPX)
Intel® Software Guard Extensions (Intel® SGX)

Evolution of Memory Protections

Privilege levels based on protection rings

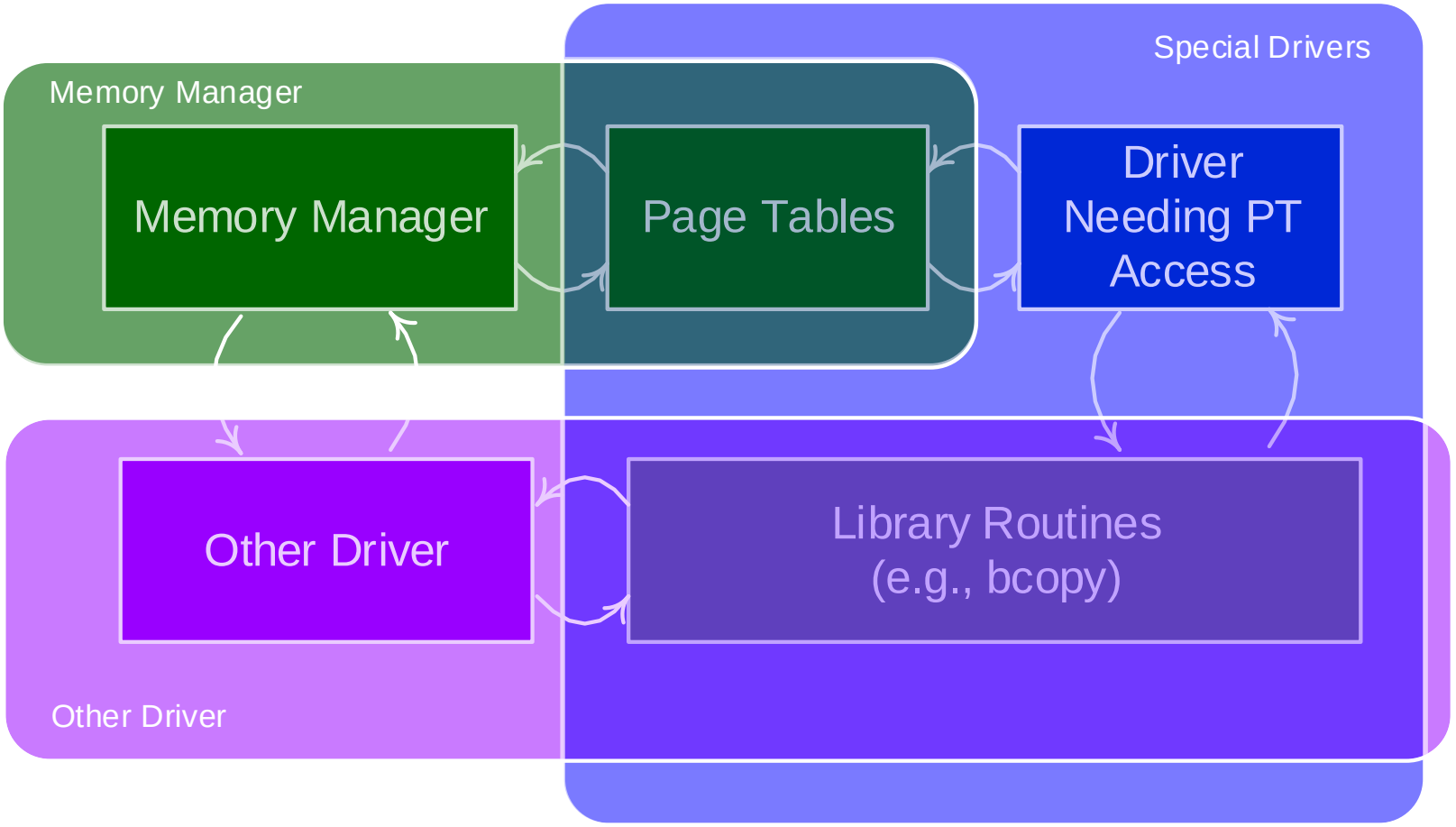
Multiple virtual machine isolation

Granular isolation within an address space



Reduce the attack surface while minimizing overhead

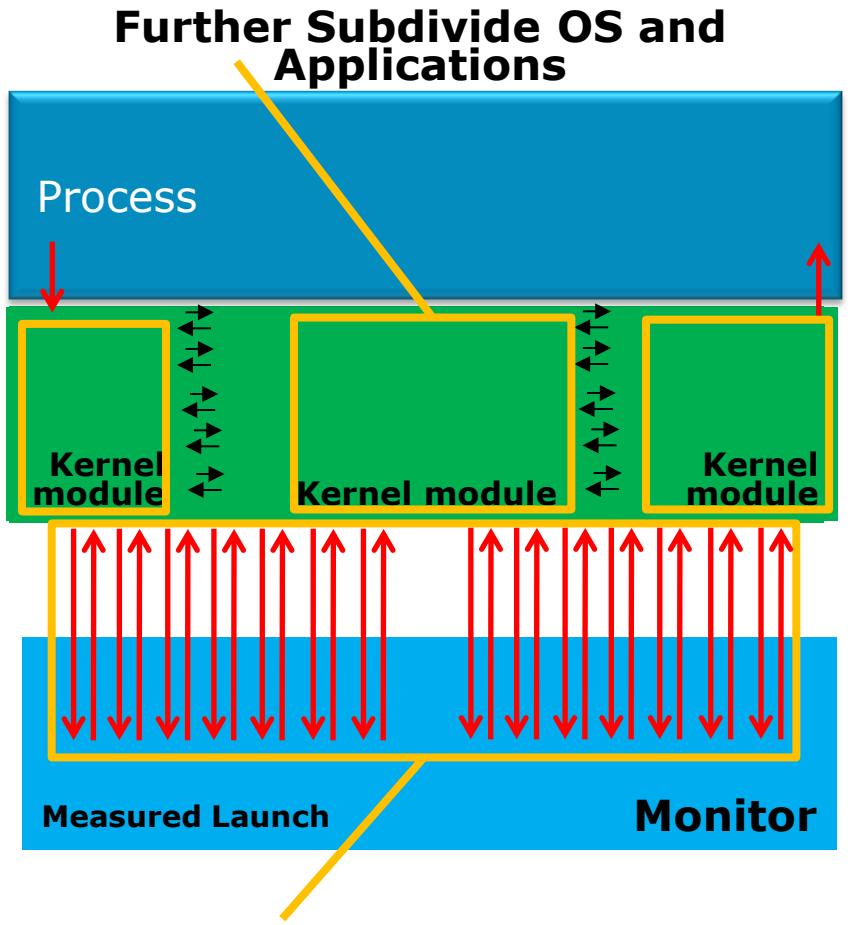
Overlaying Granular Protections



Accommodates existing OS methodology and legacy code

Accelerating Granular Isolation

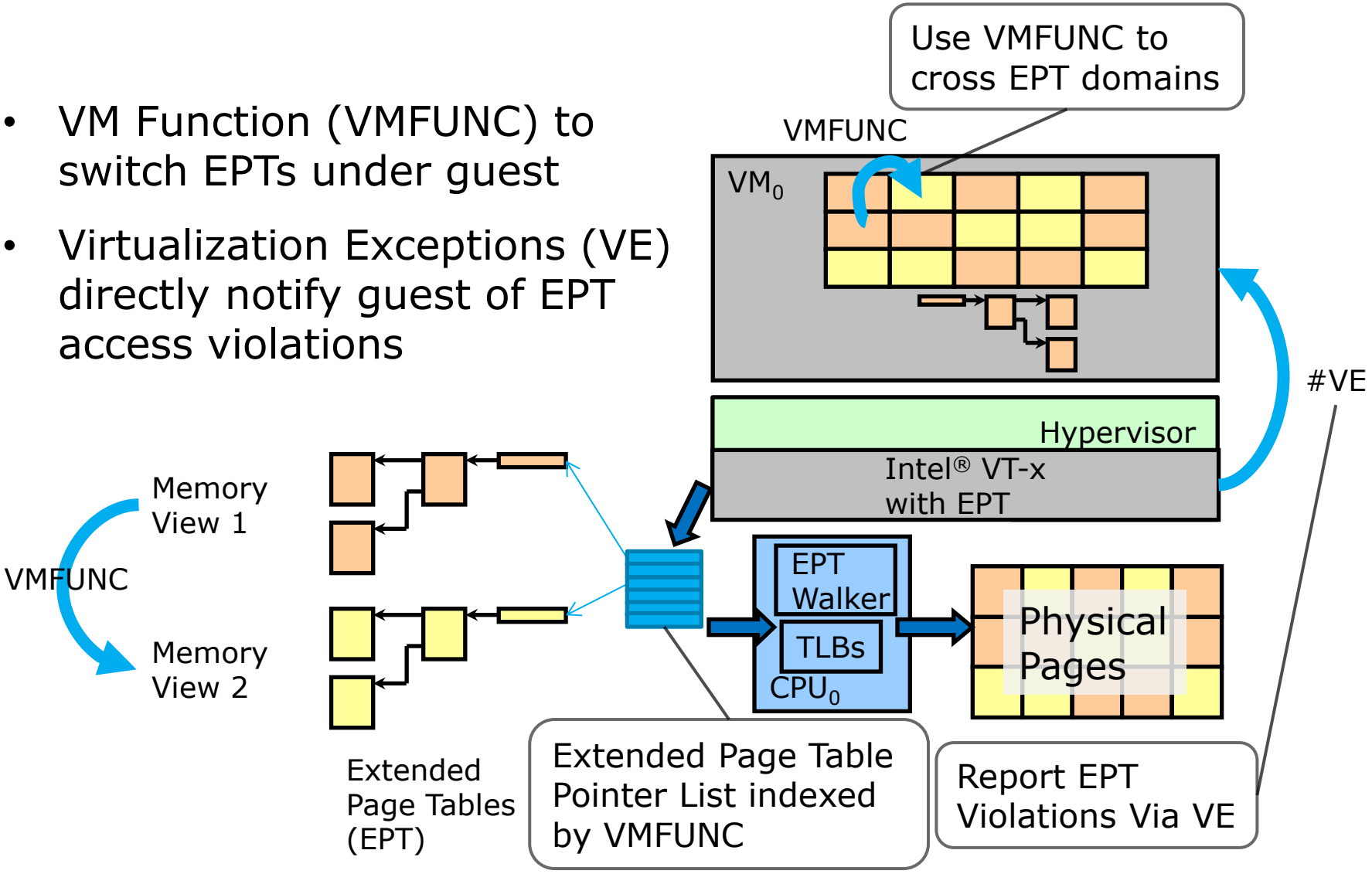
- Intel® Virtualization Technology (Intel® VT) enables protections beyond the OS
- Overlays additional protections and monitoring policies by enabling memory views
- Provides continuous detection of illicit behaviors
- Accelerated using VM Functions and Virtualization Exceptions…



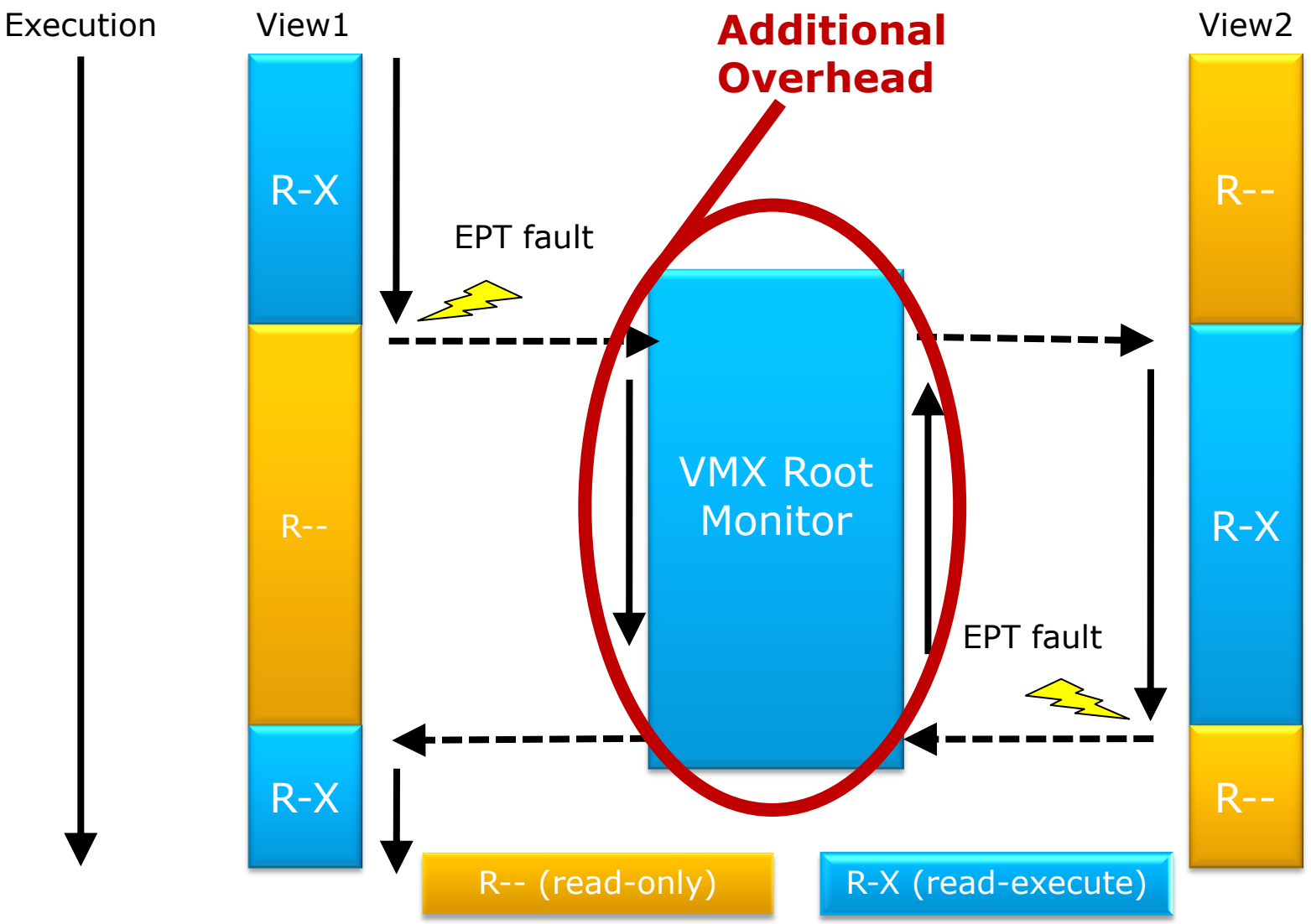
Additional Monitoring: Privileged software monitors OS activity

Extended Page Tables for Isolation within VM

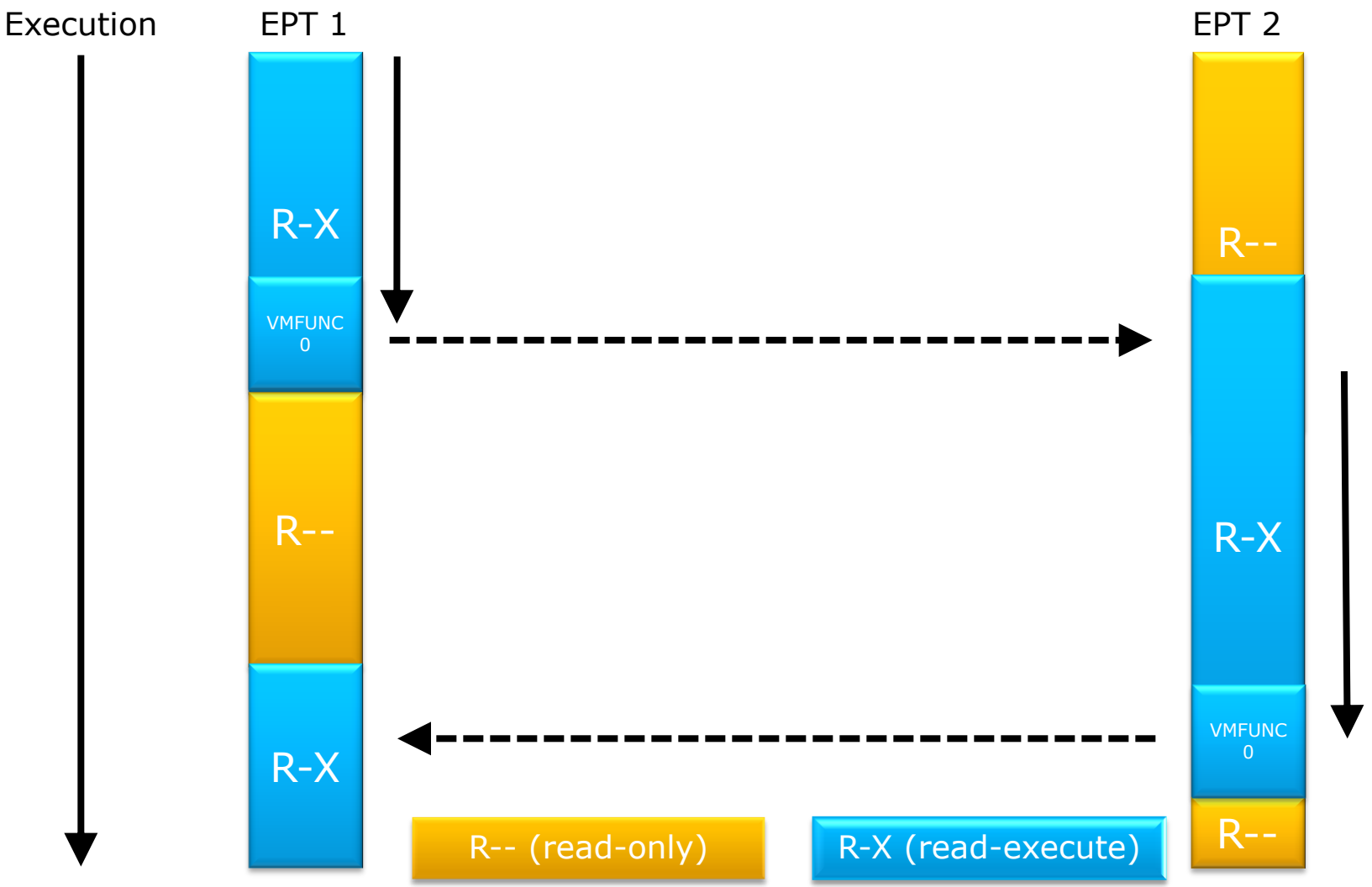
- VM Function (VMFUNC) to switch EPTs under guest
- Virtualization Exceptions (VE) directly notify guest of EPT access violations



Granular Isolation (Before)

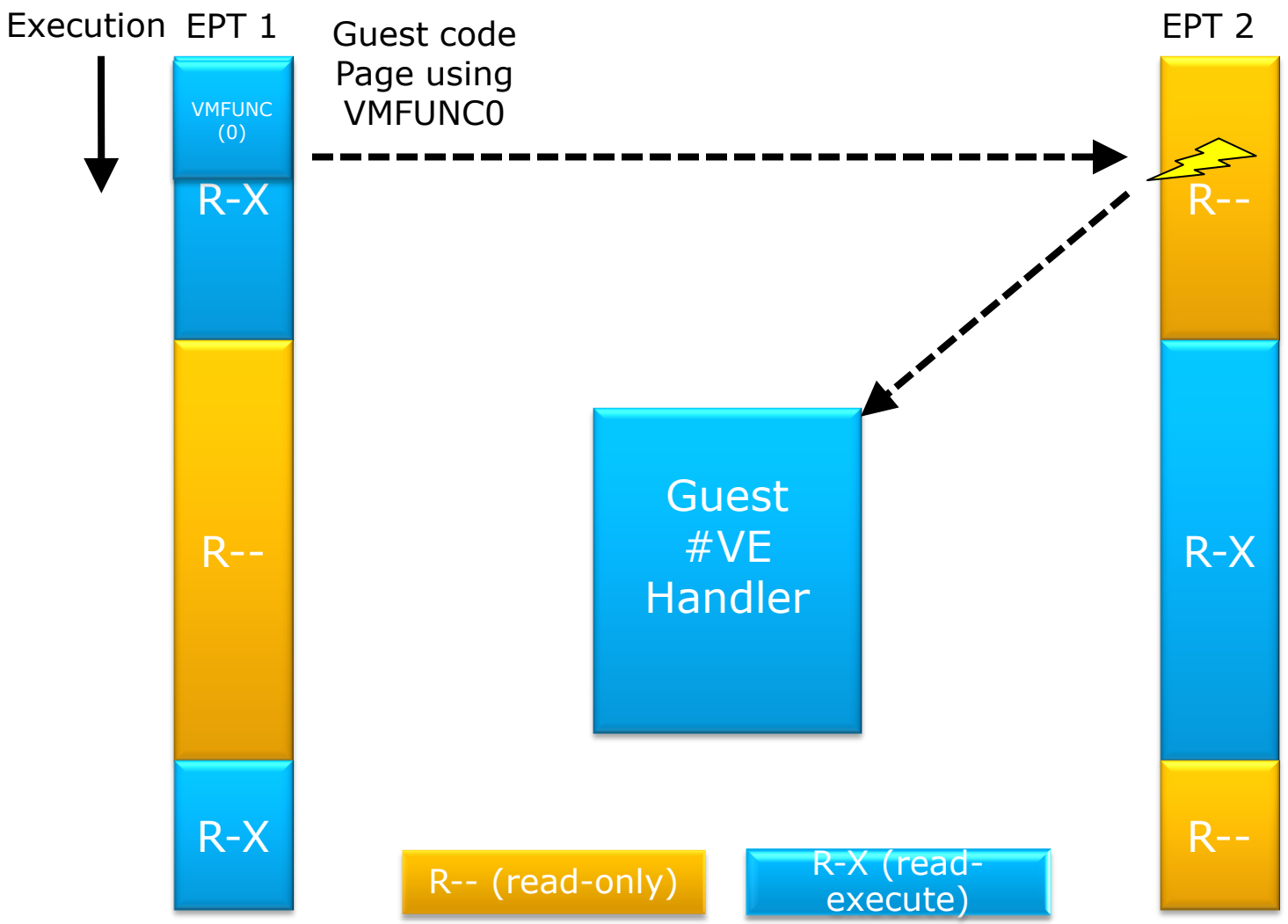


Granular Isolation with VM Functions



Enforce Control Flow Integrity with Intel® VT

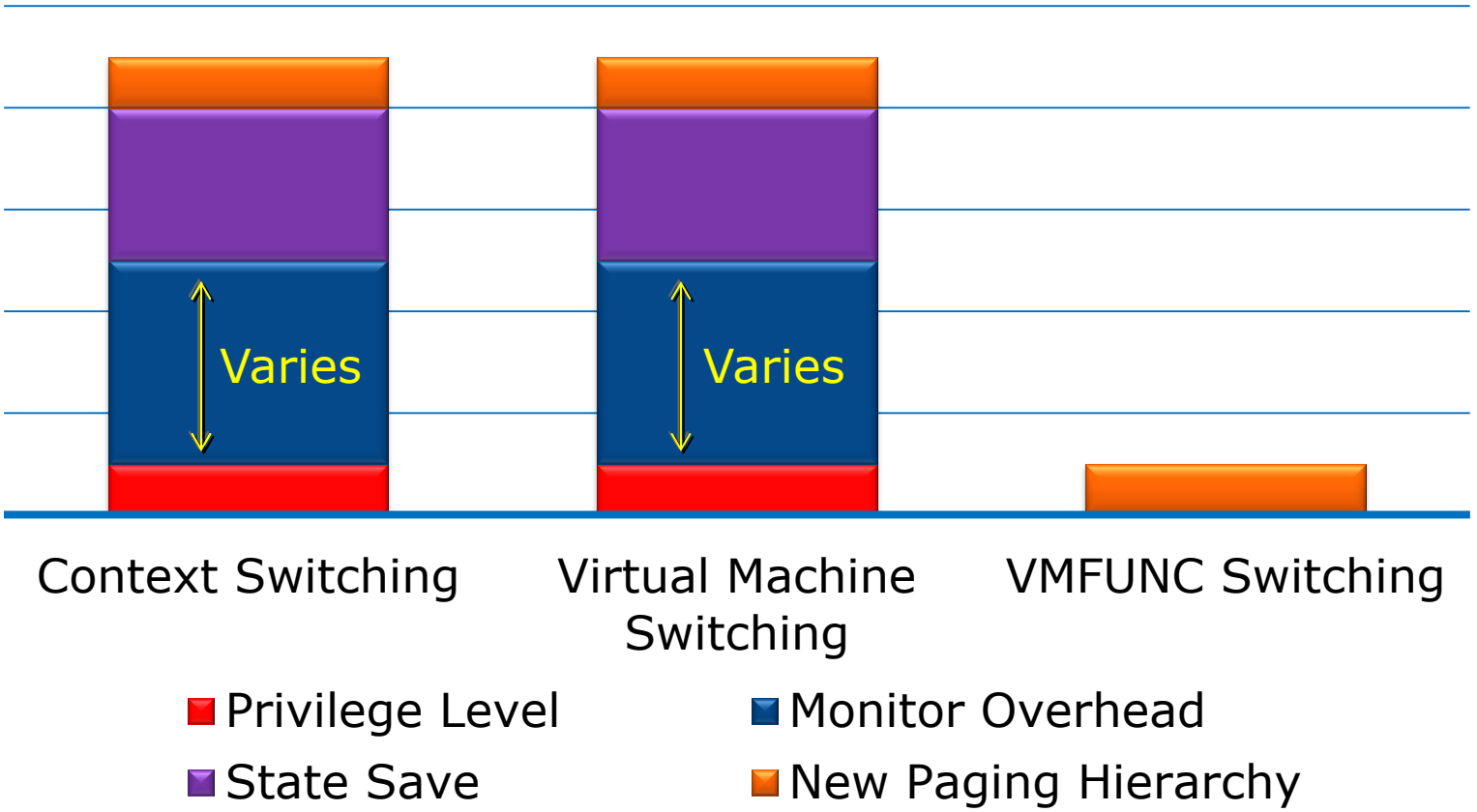
Monitoring with Virtualization Exceptions



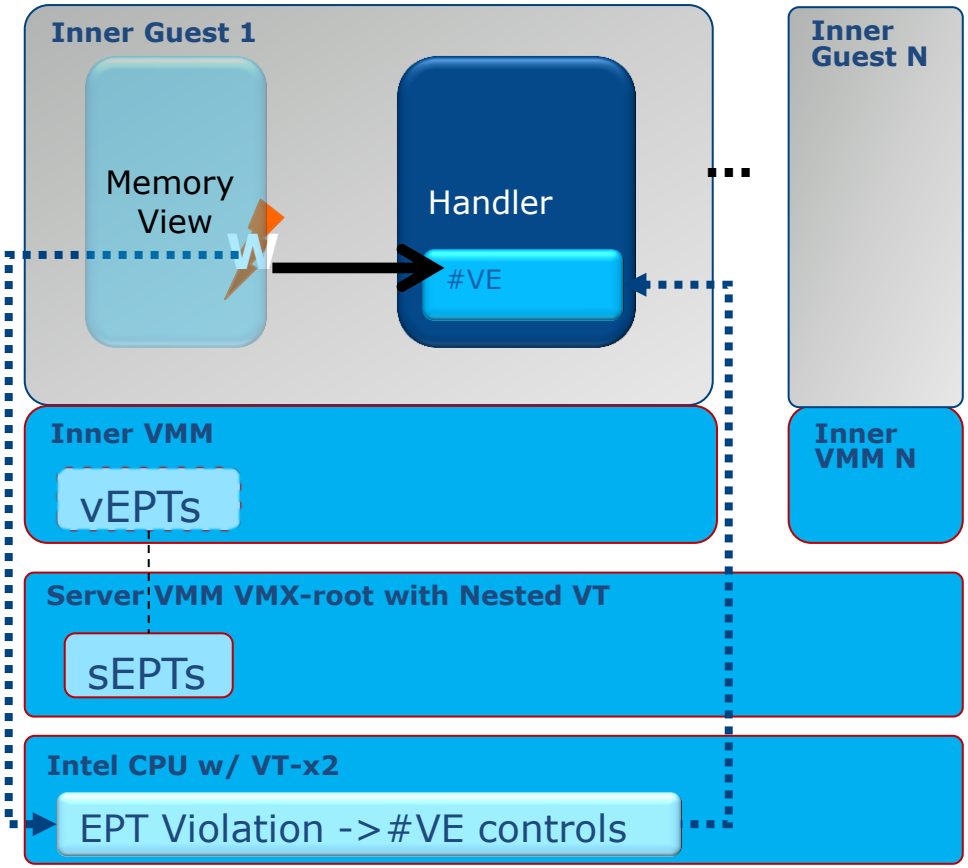
EPT Exceptions directed to the guest

VM Function for Switching

Relative Performance Comparison



Layering Virtualization and Introspection

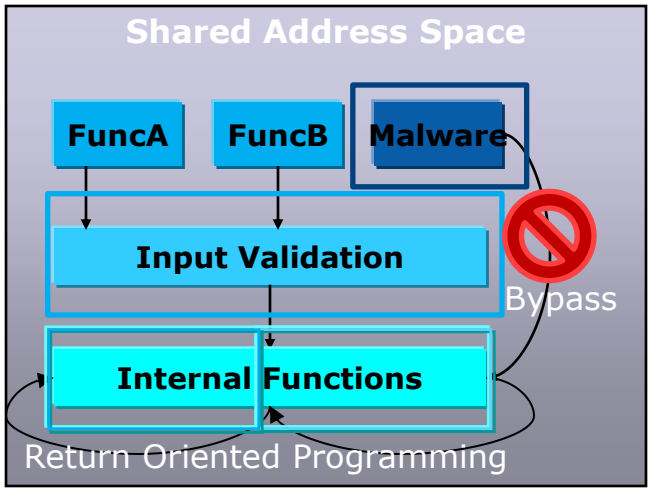


- Root VMM supports VT nesting (with EPT shadowing)
- Root VMM and guest opt-in to enable features
- VMFUNC switches authorized EPTs without engaging VMM(s)
- EPT violations reported via #VE to guest directly
  - No VM Exits for guest policies
  - No additional overhead for VMMs
- Root VMM decides which pages #VE and which will VM Exit
  - Disambiguates copy-on-write and other VMM notification needs

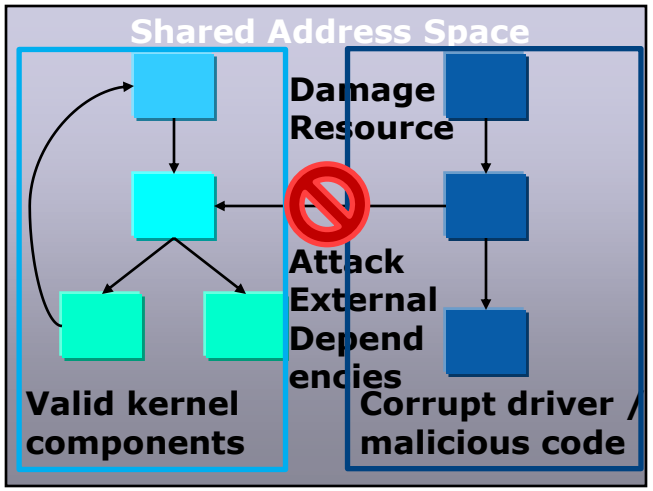
Enables efficient introspection across multiple VMs

Revisiting Attack Vectors

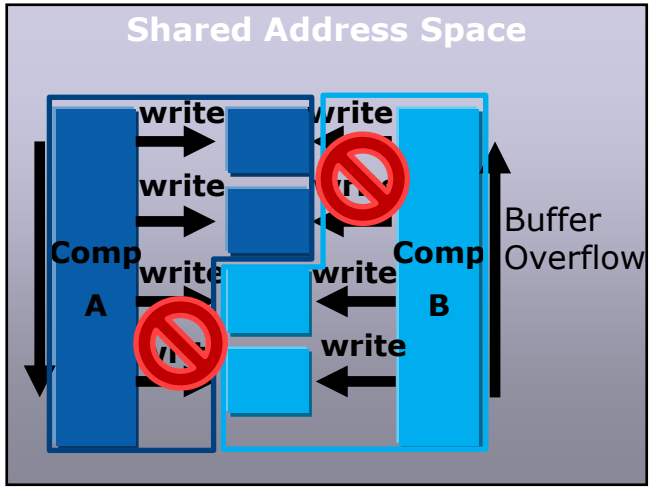
Circumvent



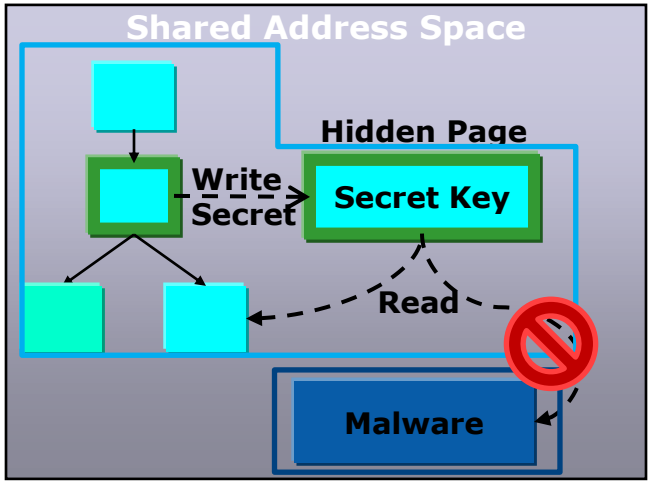
Disable



Inject/Modify



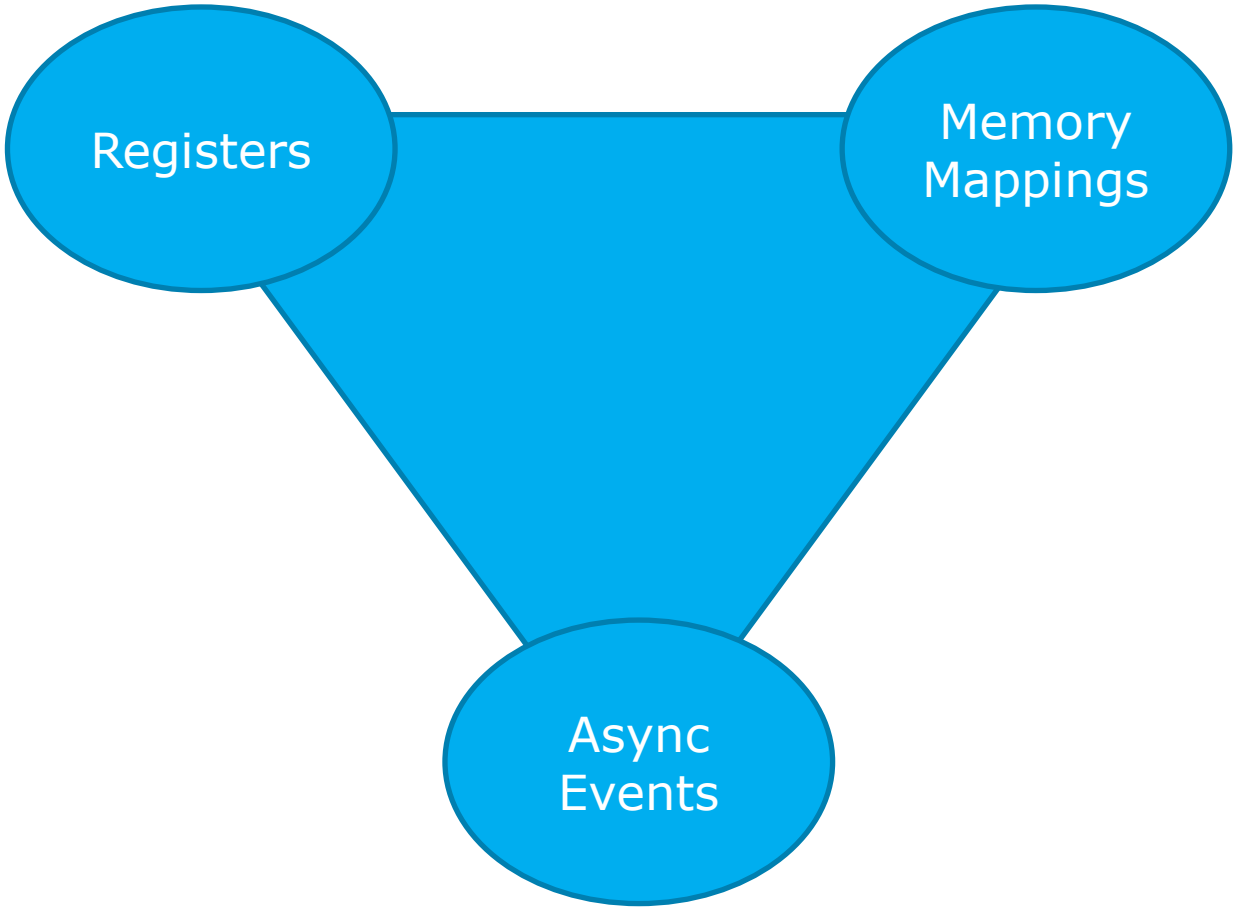
Eavesdrop



Overlay memory views to monitor software behavior

Problem
Better Protection
Solid Foundations
Usages
Minimizing TCB
Summary

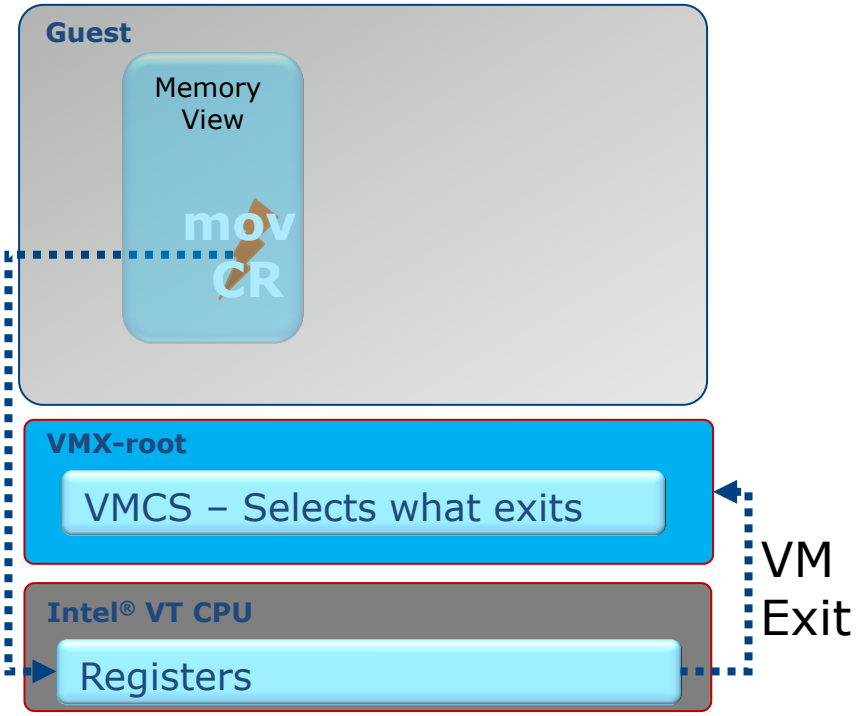
Overlaying Protections: Things to Consider…



May also address external devices depending on usage

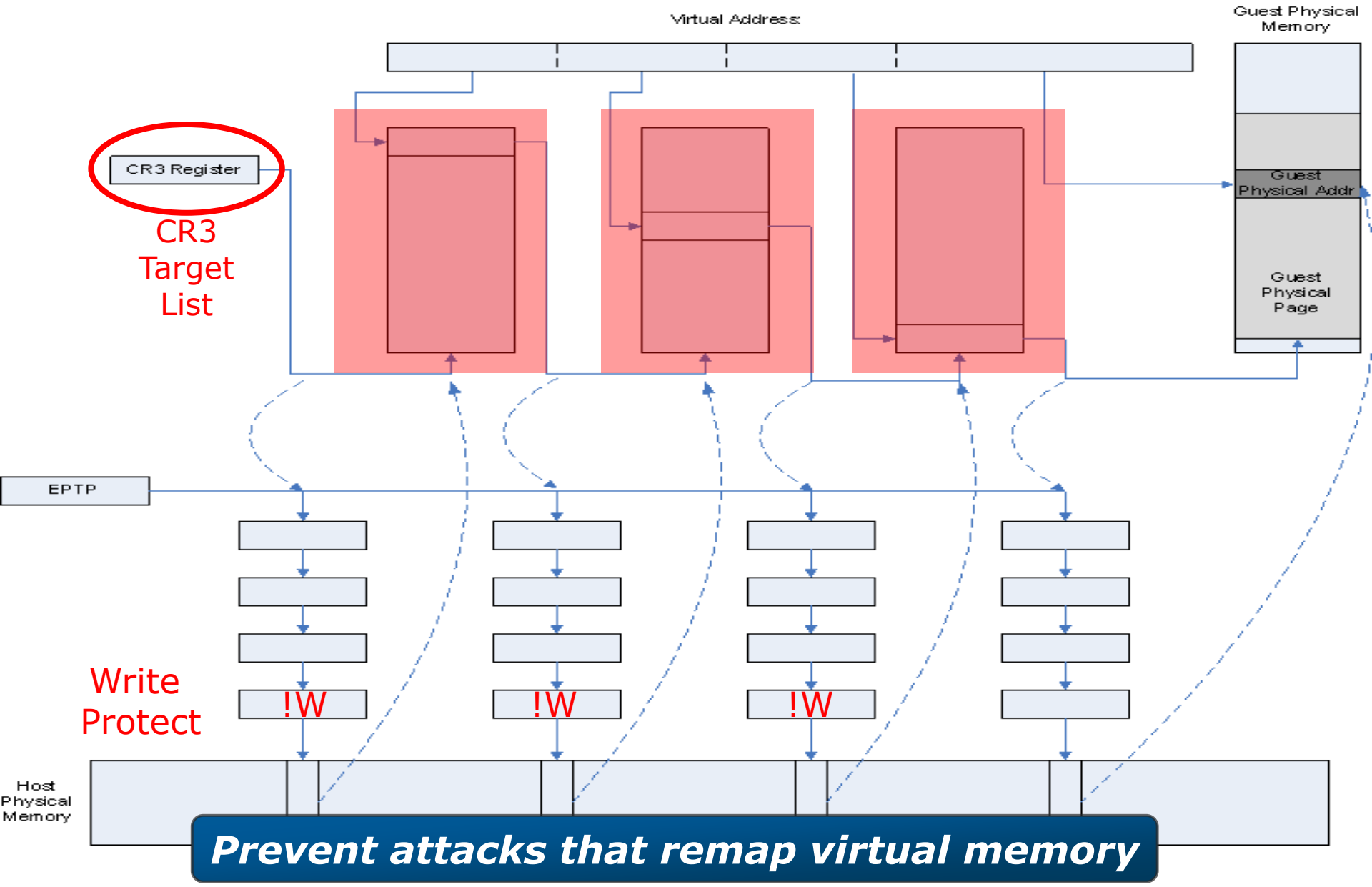
Monitoring Processor Registers

- VMM can be configured to intercept changes to:
  - Model Specific Registers
  - Control Registers
  - Debug Registers
  - Descriptor Tables (IDTR…)
  - Mode dependent…
- VMCS determines what registers to monitor
- GPRs including the stack pointer can be checked at boundaries and on events



Monitor processor state to prevent attacks

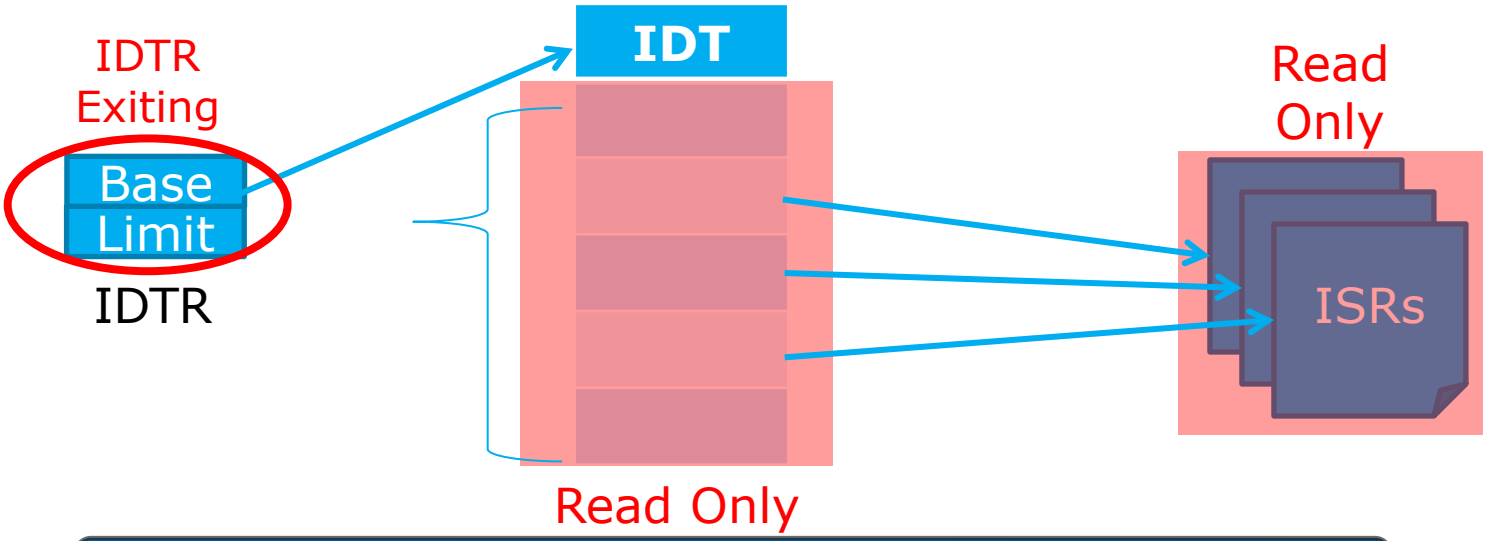
Page Table Edit Control



Prevent attacks that remap virtual memory

Interrupts & Asynchronous Events

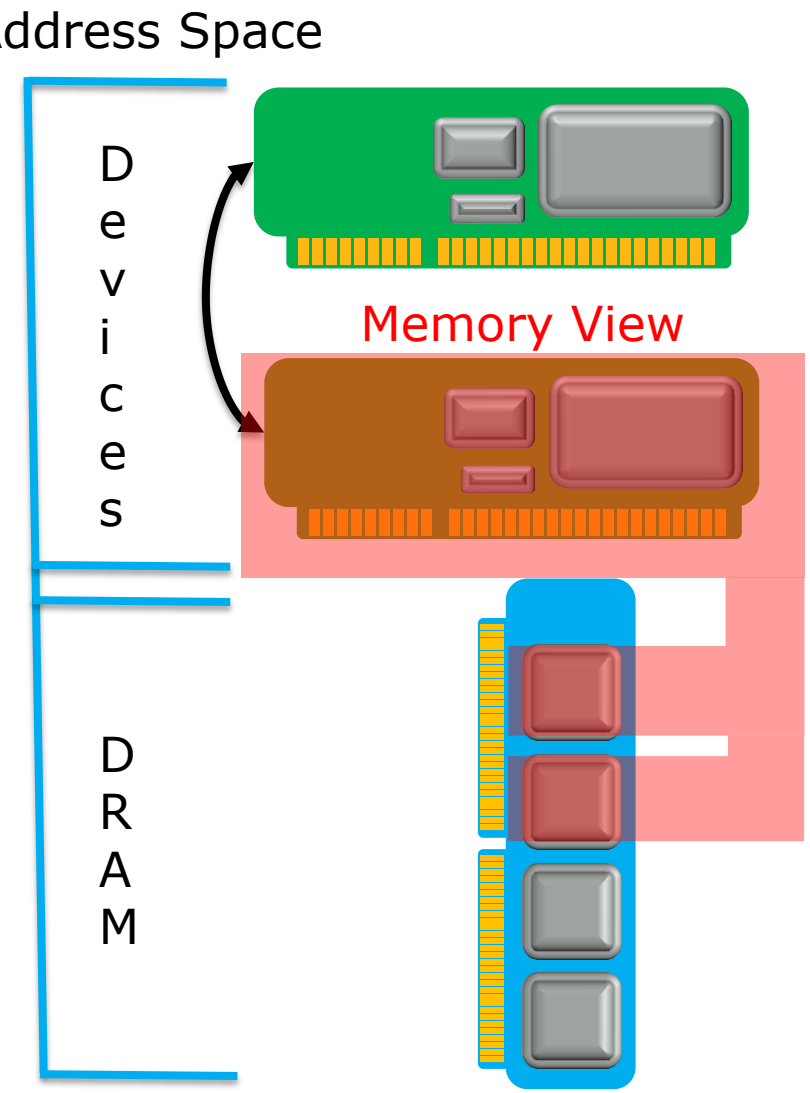
- Protect Interrupt Descriptor Table & Register
- Trust Interrupt Service Routines or own ISR stub
- Stub code protects state
  - Stack
  - General Purpose Registers



Protect or intercept asynchronous paths

Devices

- Device space configuration
  - Programmed IO in/out
  - Relocation of device registers in memory/BAR change
  - Trigger VM Exit
- Memory Mapped IO
  - Device registers
  - Covered by EPT policy
- DMA
  - Buffers in memory
  - Covered by EPT policy



Intel® VT-d protects against compromised devices

Problem
Better Protection
Solid Foundations
Usages
Minimizing TCB
Summary

McAfee® Deep Defender Overview

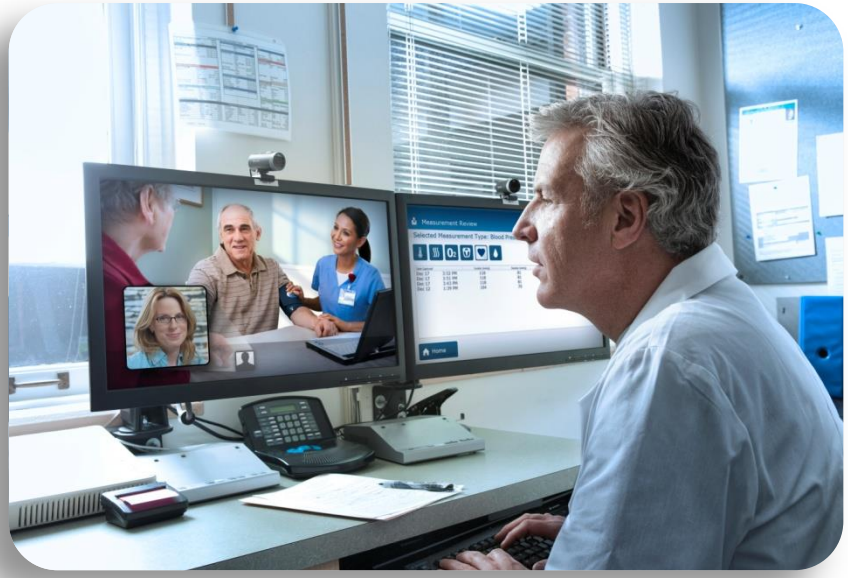
- McAfee® DeepSAFE™ technology in the McAfee® Deep Defender product can safely monitor writes to critical memory assets
- The Deep Defender component within the operating system understands the O/S layout and rootkit techniques
- The DeepSAFE component uses CPU primitives to monitor CPU and memory so that pages containing sensitive code and data are access-controlled

Providing Better Protections

Input

Audio

Storage

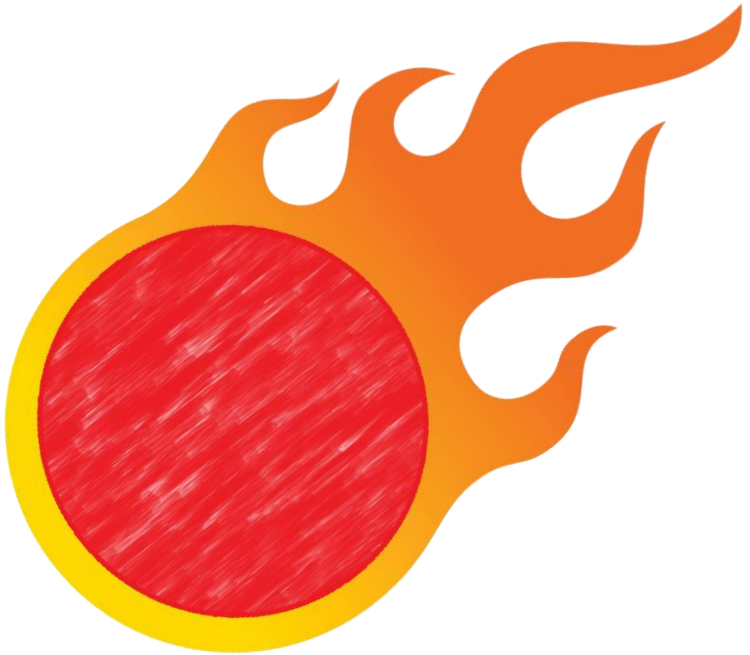


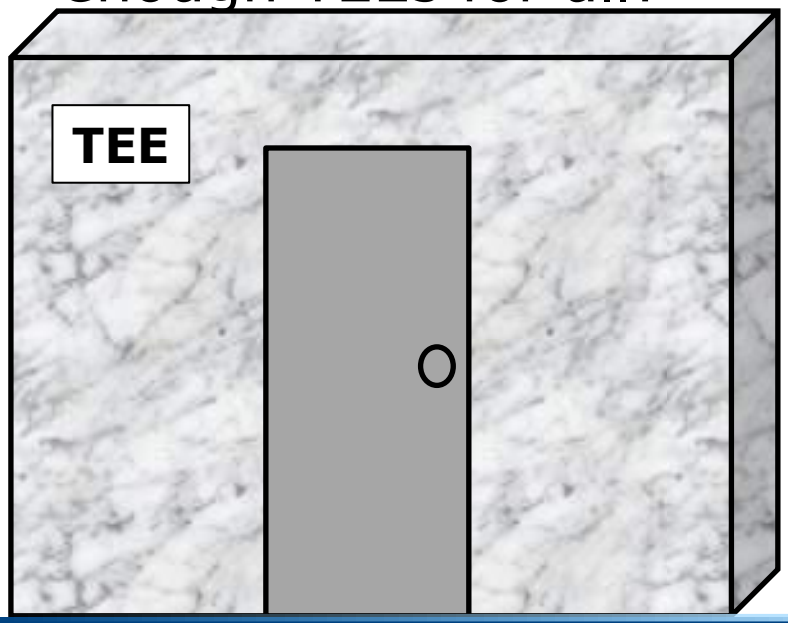
Video

Problem
Better Protection
Solid Foundations
Usages
Minimizing TCB
Summary

Democratizing Security

- Software relies on a Trusted Execution Environment (TEE) in case other defenses fail
- Isolated hardware and restricted modes limit use
- A future where there are enough TEEs for all?

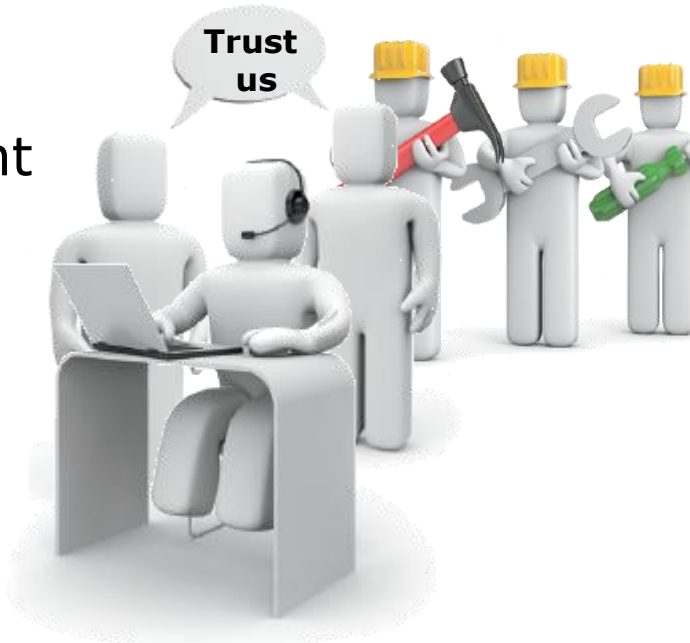




Scaling Trusted Execution Environments for the many

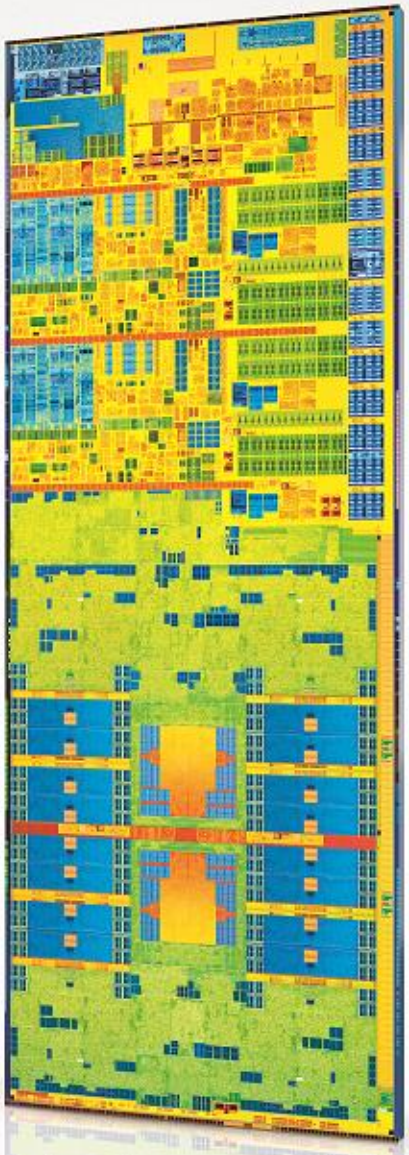
Trust How Many?

- Trusted Computing Base (TCB):
  - Set of all hardware, firmware & software part of a trusted environment
- Minimizing the TCB:
  - Remove Software Stacks
  - Remove Drivers
  - Remove Devices
  - Remove Firmware...



TCB

Trust The Processor



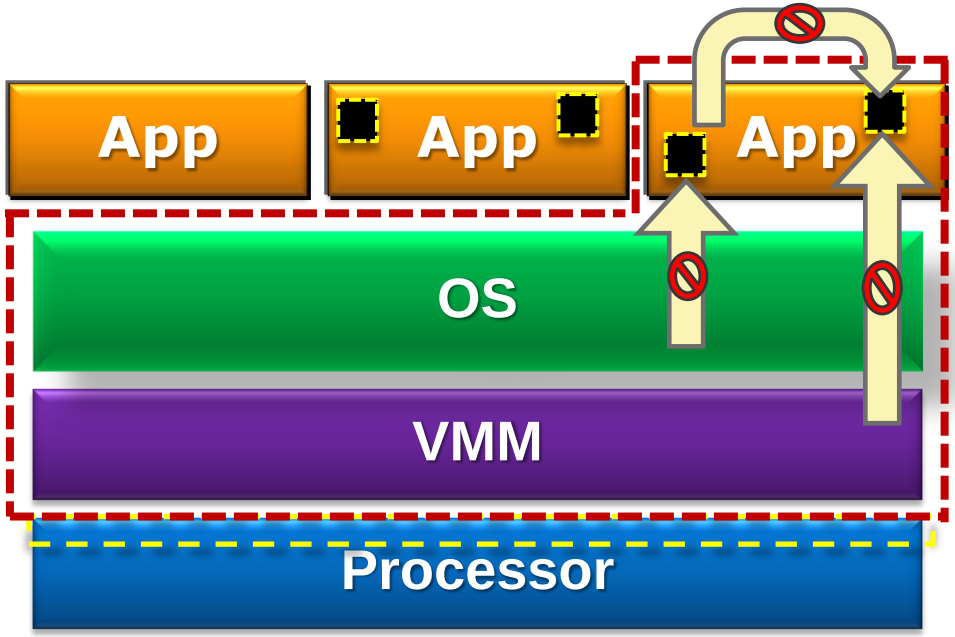
Scaling Trust with a Minimal TCB

Threat surface reduction

Define precise trust boundaries

Remove extraneous components from the trust boundary

Reduce TCB to the processor



Scalable security within mainstream environment

Intel® Software Guard Extensions Programming Reference:
https://software.intel.com/sites/default/files/329298-001.pdf

Utilize Existing Instruction Set Security Primitives

E.g. Intel® Advanced Encryption Standard New Instructions:

AESKEYGENASSIST

ShiftRows()
SubBytes()
MixColumns()
AddRoundKey()

AESIMC

InvShiftRows()
InvSubBytes()
AddRoundKey()

AESENC

InvShiftRows()
InvSubBytes()
InvMixColumns()
AddRoundKey()

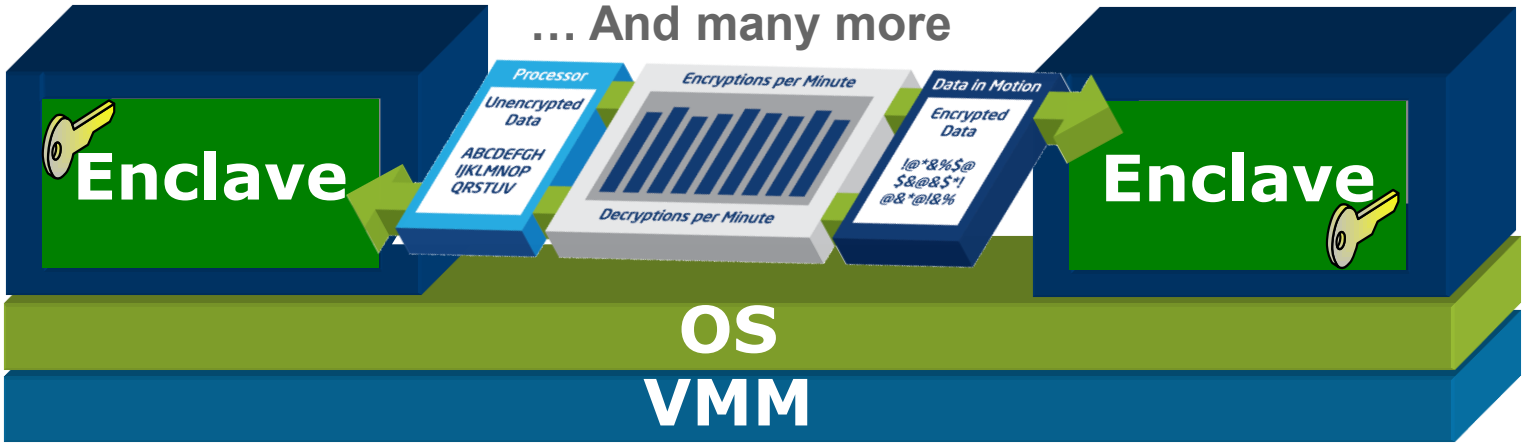
AESENCLAST

ShiftRows()
SubBytes()
AddRoundKey()

AESDEC

AESDECLAST

… And many more



https://software.intel.com/en-us/articles/intel-advanced-encryption-standard-instructions-aes-ni/

Problem
Better Protection
Solid Foundations
Usages
Minimizing TCB
Summary

Summary

- Increasingly sophisticated attacks require better defenses
- Moving from signatures to behavioral models
- Next generation processors deliver new capabilities for advanced software monitoring and protection
- Ability to layer protections over legacy software
- Minimizing the Trusted Computing Base is the next step…

Biography

David Durham is a Senior Principal Engineer and Director in Intel Labs. His research team developed anti-malware and cryptographic security features currently found in hundreds of millions of Intel processors. David also developed policy-based network management technologies, created security solutions shipping in Intel® vPro™ platforms and worked with McAfee to deliver virtualization-based anti-malware products. Collaborating with industry leaders, his team developed IEEE 802.1 security protocols and advanced network access control capabilities now embedded in tens of millions of Intel platforms. He is a prolific author on computer communications, having written a book, multiple publications and several Internet protocol standards deployed in millions of connected devices. David received two Intel Achievement Awards, was granted over 100 US and international patents and earned his B.S. and M.S. degrees in Computer Engineering from Rensselaer Polytechnic Institute.

Legal Disclaimer

INFORMATION IN THIS DOCUMENT IS PROVIDED IN CONNECTION WITH INTEL PRODUCTS. NO LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT. EXCEPT AS PROVIDED IN INTEL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, INTEL ASSUMES NO LIABILITY WHATSOEVER AND INTEL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO SALE AND/OR USE OF INTEL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

A "Mission Critical Application" is any application in which failure of the Intel Product could result, directly or indirectly, in personal injury or death. SHOULD YOU PURCHASE OR USE INTEL'S PRODUCTS FOR ANY SUCH MISSION CRITICAL APPLICATION, YOU SHALL INDEMNIFY AND HOLD INTEL AND ITS SUBSIDIARIES, SUBCONTRACTORS AND AFFILIATES, AND THE DIRECTORS, OFFICERS, AND EMPLOYEES OF EACH, HARMLESS AGAINST ALL CLAIMS COSTS, DAMAGES, AND EXPENSES AND REASONABLE ATTORNEYS' FEES ARISING OUT OF, DIRECTLY OR INDIRECTLY, ANY CLAIM OF PRODUCT LIABILITY, PERSONAL INJURY, OR DEATH ARISING IN ANY WAY OUT OF SUCH MISSION CRITICAL APPLICATION, WHETHER OR NOT INTEL OR ITS SUBCONTRACTOR WAS NEGLIGENT IN THE DESIGN, MANUFACTURE, OR WARNING OF THE INTEL PRODUCT OR ANY OF ITS PARTS.

Intel may make changes to specifications and product descriptions at any time, without notice. Designers must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined". Intel reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The information here is subject to change without notice. Do not finalize a design with this information.

The products described in this document may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order.

Copies of documents which have an order number and are referenced in this document, or other Intel literature, may be obtained by calling 1-800-548-4725, or go to: http://www.intel.com/design/literature.htm

Intel® Virtualization Technology (Intel® VT) requires a computer system with an enabled Intel® processor, BIOS, and virtual machine monitor (VMM). Functionality, performance or other benefits will vary depending on hardware and software configurations. Software applications may not be compatible with all operating systems. Consult your PC manufacturer. For more information, visit http://www.intel.com/go/virtualization.

Intel, Look Inside and the Intel logo are trademarks of Intel Corporation in the United States and other countries.

*Other names and brands may be claimed as the property of others.