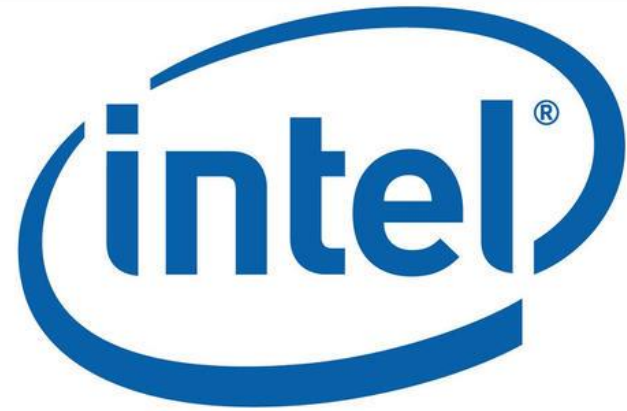


*presented by*



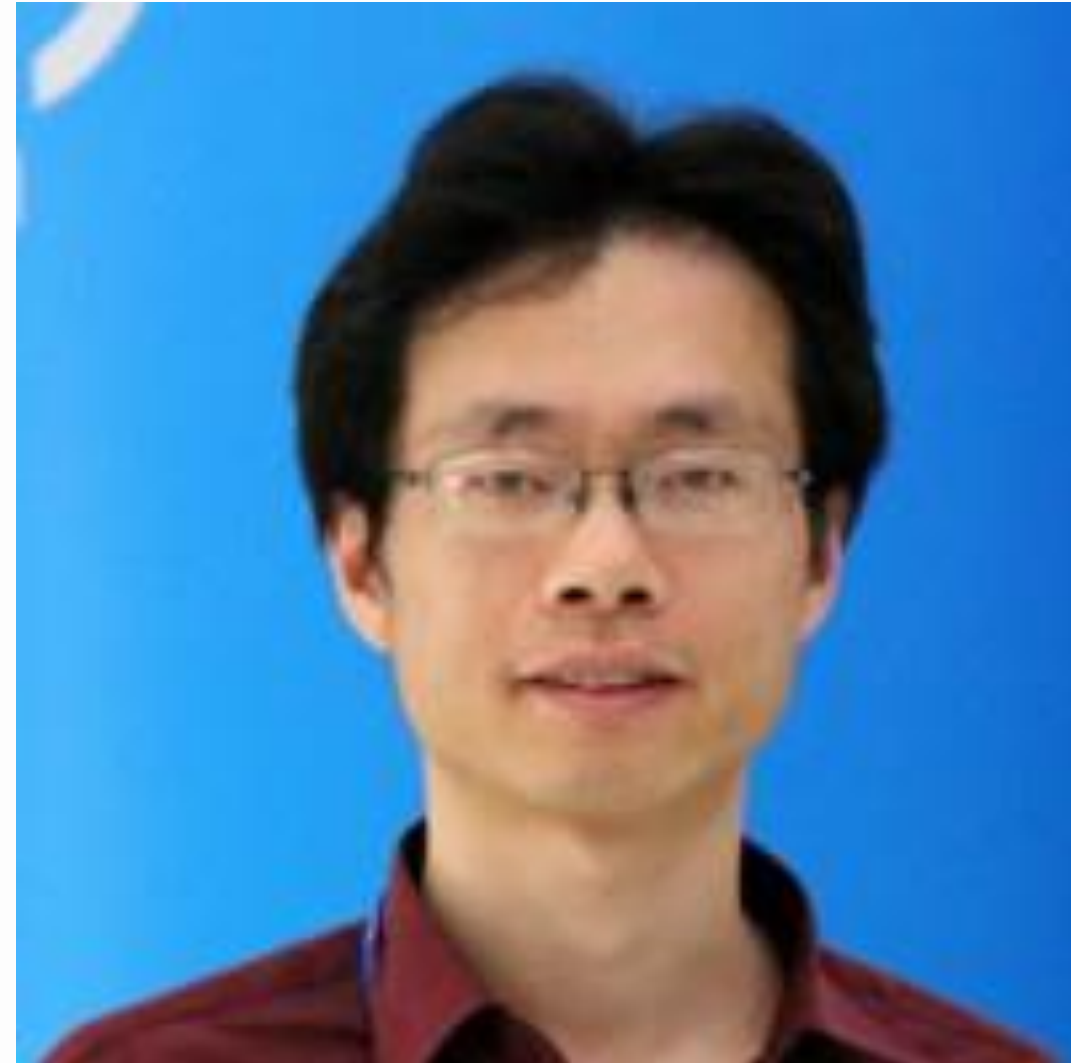
# Enabling RUST for UEFI Firmware

UEFI 2020 Virtual Plugfest  
August 20, 2020

Jiewen Yao & Vincent Zimmer, Intel Corporation

# Jiewen Yao

- **Jiewen Yao** is a principal engineer in the Intel Architecture, Graphics, and Software Group. He has been engaged as a firmware developer for over 15 years. He is a member of the UEFI Security sub team, and the TCG PC Client sub working group.



# Vincent Zimmer



- **Vincent Zimmer** is a senior principal engineer in the Intel Architecture, Graphics, and Software Group. He has been engaged as a firmware developer for over 25 years and leads the UEFI Security sub team.



Vincent Zimmer  
Intel

# Agenda



- EDKII Security Summary
- RUST Language
- Enabling RUST for EDKII
- Summary / Call to Action



# EDKII Security Summary

# BIOS Memory Issue in Hack Conf



## Attacking Intel® BIOS

Rafal Wojtczuk and

## Extreme Privilege Escalation on Windows 8/UEFI Systems

Attacking Intel TXT® via SINIT code execution hijacking

@coreykal

@xenokovah

Rafal Wojtczuk  
rafal@invisiblethingslab.com joann

Sam C

## A New Class of Vulnerabilities in SMI Handlers

Advanced Threat Research ([www.intelsecurity.com/atr](http://www.intelsecurity.com/atr))

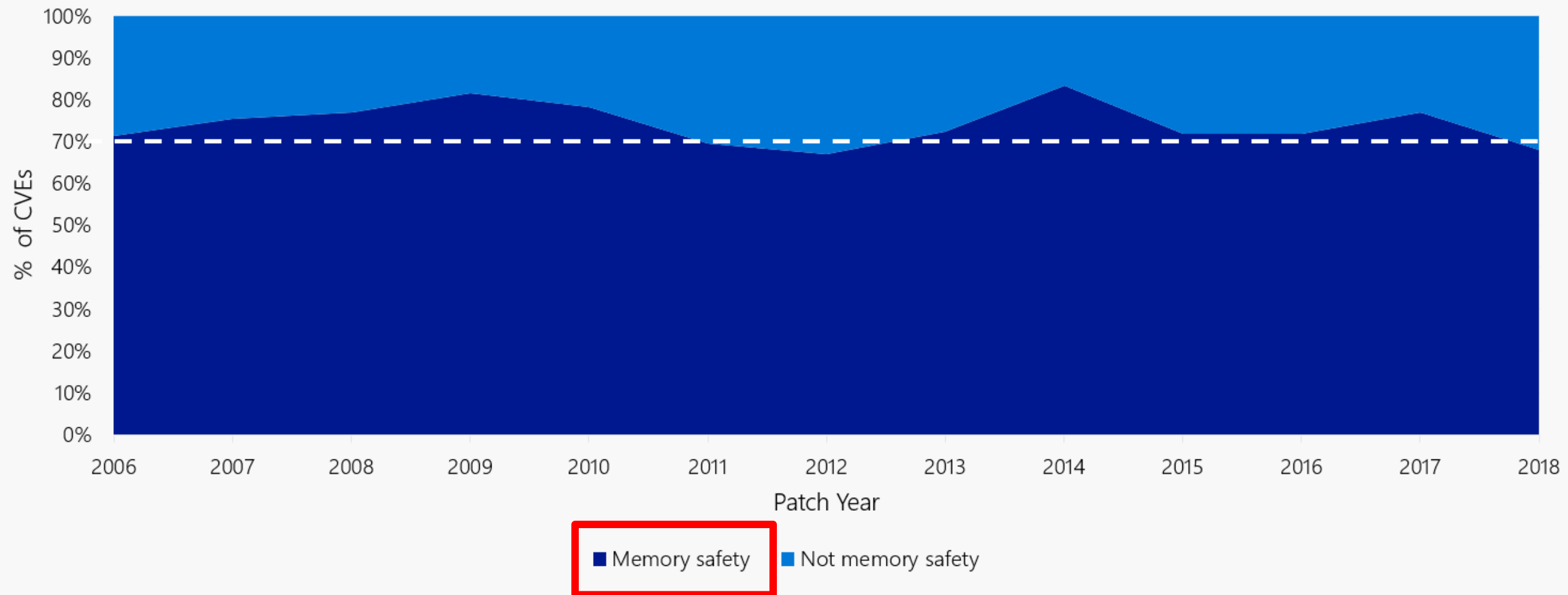
Oleksandr Bazhaniuk, Yuriy Bulygin, **Andrew Furtak**, Mikhail Gorobets, **John Loucaides**, Alexander Matrosoy, Mickey Shkatov

# BIOS Security Bug



Top Issue	Open Source	Close Source
Buffer Overflow/ Integer Overflow	50%	38%
SMM	7%	18%
Variable	8%	5%
Register Lock	3%	10%

# Vulnerabilities in C/C++



Source: Trends, challenges, and strategic shifts in the software vulnerability mitigation landscape  
– Microsoft, Bluehat IL 2019



# Firmware as Software



- Many software issues are also firmware issues.
  - Buffer Overflow
  - Integer Overflow
  - Uninitialized Variable
- Software mitigation can be used for firmware mitigation.
  - (See next page)

# 3 Levels of Prevention



Prevention	Method	EDKII Open Source Example
Eliminate Vulnerability	Reduce Attack Surface	SMI Handler Profile
	Static Analysis / Dynamic Analysis	Clang Static Analysis, Memory Sanitizer, KLEE
	Security Test / Fuzzing	Host-based Firmware Analyzer, Peach, AFL
	Vulnerability Scan	Chipsec
Break Exploitation	Stack Guard	MSVC:/GS, GCC:-fstack-protector
	Address Space Layout Randomization	DXE/SMM ASLR
	Non Executable Data	SMM Memory Protection
	Control Flow Guard	SMM Control-flow Enforce Technology (CET)
	Code Integrity	UEFI Secure Boot
Contain Damage	Sandbox	EBC
	Deprivilege	Ring3-based third-party Code (?)
	Isolation	(?)

# What's More: Type Safe Language



*Rather than providing guidance and tools for addressing flaws, we should strive to prevent the developer from introducing the flaws in the first place.*

Source: <https://msrc-blog.microsoft.com/2019/07/16/a-proactive-approach-to-more-secure-code/>



# RUST Language Introduction

# RUST Language



## Why Rust?

### Performance

Rust is blazingly fast and memory-efficient: with no runtime or garbage collector, it can power performance-critical services, run on embedded devices, and easily integrate with other languages.

### Reliability

Rust's rich type system and ownership model **guarantee memory-safety** and thread-safety — enable you to eliminate many classes of bugs at compile-time.

### Productivity

Rust has great documentation, a friendly compiler with useful error messages, and top-notch tooling — an integrated package manager and build tool, smart multi-editor support with auto-completion and type inspections, an auto-formatter, and more.

Source: <https://www.rust-lang.org/>

# RUST Project



## Firecracker

## libra

CircleCI license Apache codecov 57%



chat on gitter

## Rust SGX SDK

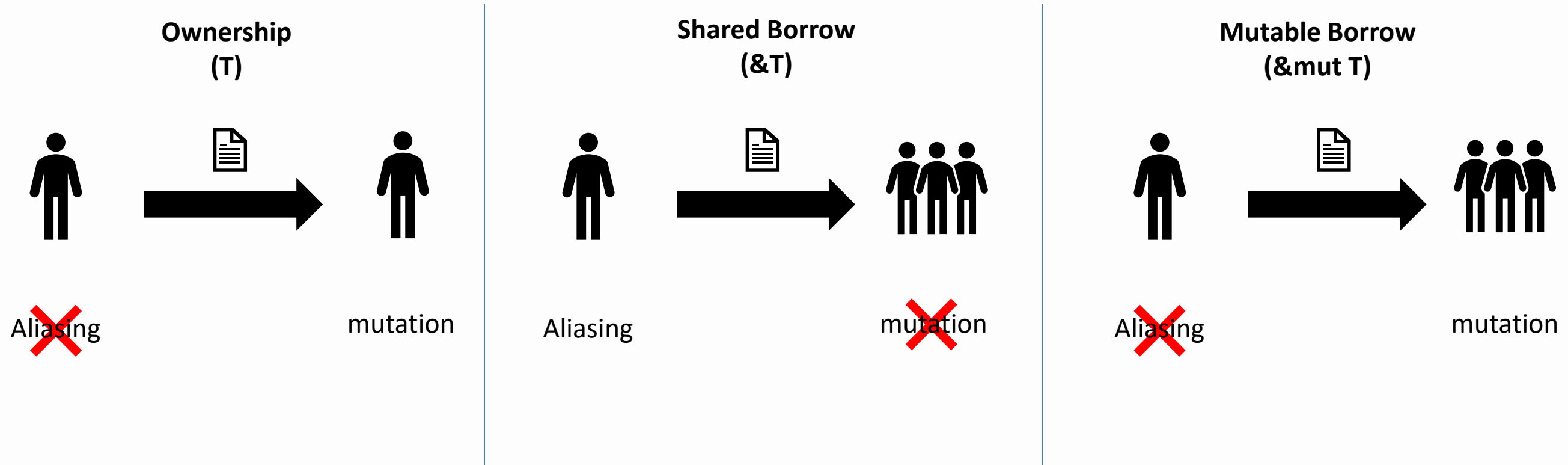


## redox-os

Group ID: 3

## Redox OS

# RUST Memory Safety



*rule out **mutation** in the presence of **aliasing***

# Memory Safety Issue in BIOS



Type	Sub Type	Threat in BIOS	Risk in BIOS (Probability/Impact)
Access Error	Buffer Overflow (Write)	Integrity	High / High
	Buffer Over-Read	Confidentiality	High / Low
	Use After Free (Dangling Pointer)	Availability	Medium / Low
	Double Free	Availability	Medium / Low
	Race Condition	Integrity	Low / Low
Uninitialized Data	Unitialized Variable	Availability	High / Medium
	Wild Pointer	Availability	Medium / Low
	NULL pointer deference	Availability	High / Medium
Memory Leak	Stack Exhausting	Availability	Low / Low
	Heap Exhausting	Availability	High / Low



# Memory Safety – in RUST



Type	Sub Type	RUST
Access Error	Buffer Overflow (Write)	Use Offset/Index for Slice Runtime Boundary Check – [panic_handler]
	Buffer Over-Read	Use Offset/Index for Slice Runtime Boundary Check – [panic_handler]
	Use After Free (Dangling Pointer)	Ownership - Compile Time Check
	Double Free	Ownership - Compile Time Check
	Race Condition	Thread Safety - Compile Time Check
Uninitialized Data	Uninitialized Variable	Initialization - Compile Time Check
	Wild Pointer	Initialization - Compile Time Check
	NULL pointer deference	Use Option<T> enum Allocation Check – [alloc_error_handler]
Memory Leak	Stack Exhausing	N/A
	Heap Exhausing	Allocation Check – [alloc_error_handler]

# Arithmetics – in RUST



Type	Method	RUST
Integer Overflow	Addition/ Subtraction/ Multiplication/ Division/ Shift/ Power Overflow	<b>DEBUG:</b> Runtime Check – [panic_handler] <b>RELEASE:</b> Discard overflow data <b>Compiler Flage:</b> -C overflow-checks=on/off <b>Function:</b> checked   overflowing   saturating   wrapping_ add   sub   mul   div   rem   shl   shr   pow()
Type Cast	Number Cast	<b>Must be explicit</b> – compile time check (Dest Size == Source Size) => no-op (Dest Size < Source Size) => truncate (Dest Size > Source Size) => { (source is unsigned) => zero-extend (source is signed) => sign-extend }

# Pointer in RUST



Type	Description	Example	Usage
Raw Pointer	Unsafe	*const T	Read only Memory
		*mut T	Read-write Memory
Reference	Memory owned by some other value	&T	Shared, Immutable Memory
		&mut T	Exclusive, Mutable Memory
Smart Pointer	Special Data Structure	Box<T>	Heap Memory Allocation



# Unsafe Code

- Dereference raw pointer (from C function)
- Call unsafe functions (to C function)
- Access RUST mutable global static variable
- Implement RUST unsafe trait
- Access RUST Union

*In this case, you trust me.  
- Dev To Rust*



# Enabling RUST for EDKII



# Build RUST in EDKII

- **EDKII Staging Branch** : edkii-rust
  - <https://github.com/tianocore/edk2-staging/tree/edkii-rust>
- **Compiler**: LLVM9.0 + RUST Cargo-xbuild
- **Target**: (supported in rust-lang master)
  - x86\_64-unknown-uefi
  - i686-unknown-uefi

# Rust Example for EDKII



- **fat-rust**: FAT file system library:
  - <https://github.com/jyao1/edk2/tree/edkii-rust/RustPkg/External/FatDxeLibRust>
- **efi-lib**: memory allocation, debug log, boot services, etc
  - <https://github.com/jyao1/edk2/tree/edkii-rust/RustPkg/External/efi-lib>
- **efi-str**: handle CHAR16 string in UEFI
  - <https://github.com/jyao1/edk2/tree/edkii-rust/RustPkg/External/efi-str>

# Rust Crypto Library for EDKII



- **ring**: for general purpose Cryptography (RSA, ECC, etc)
- **webpki**: for Public Key Infrastructure Certificate
  - Add extension for UEFI/EDKII.
  - [https://github.com/jyao1/ring/tree/uefi support](https://github.com/jyao1/ring/tree/uefi%20support)
  - [https://github.com/jyao1/webpki/tree/uefi support](https://github.com/jyao1/webpki/tree/uefi%20support)
- **efi-random**: RDRAND, RDSEED instruction
  - <https://github.com/jyao1/edk2/tree/edkii-rust/RustPkg/External/efi-random>



# Other EFI-Rust Project



- **r-efi:** UEFI Reference Specification Protocol Constants and Definitions
  - <https://github.com/r-util/r-efi>
- **uefi-rs:** Wrapper for writing UEFI applications in RUST.
  - <https://github.com/rust-osdev/uefi-rs>
- **Redox uefi support:** Wrapper for UEFI services.
  - <https://gitlab.redox-os.org/redox-os?utf8=%E2%9C%93&filter=uefi>
- **rust-hypervisor-firmware:** A simple KVM firmware for cloud hypervisor with minimal UEFI support.
  - <https://github.com/cloud-hypervisor/rust-hypervisor-firmware>
- **Rust-based Unit Test in EDKII:** Rust-based UefiVariablePolicyLib with Unit Test.
  - [https://github.com/corthon/edk2-staging/tree/rust\\_and\\_tests](https://github.com/corthon/edk2-staging/tree/rust_and_tests)



# Some Limitations

- UEFI specification and interfaces are defined in C.
- Cross module interaction is C-API.
- Unsafe Code is required.

# Where RUST Can Help



- **1. Eliminate Vulnerability** (Compile Time Check)
  - Uninitialized variable
  - Use After Free
  - Double Free
- **2. Break Exploitation** (Runtime Check)
  - **Memory Boundary Check**
  - Integer Overflow Check
- NOTE: Boundary Check Code is still required to prevent system from panic.



# Where RUST Cannot Help

- Silicon Register Lock
  - Need Chipsec
- Security Policy
  - Need policy checker
- TOC/TOU
  - Need design review
- SMM Callout
  - Need hardware restriction
- Unsafe Code Block
  - Need careful code review
  - NOTE: Putting C code in Rust Unsafe Block helps nothing.



# Summary & Call for Action

# Summary & Call for Action



- 50% of EDKII security issues are memory issues.
- RUST can help to mitigate memory issues.
- Write critical firmware modules in RUST.

# Reference



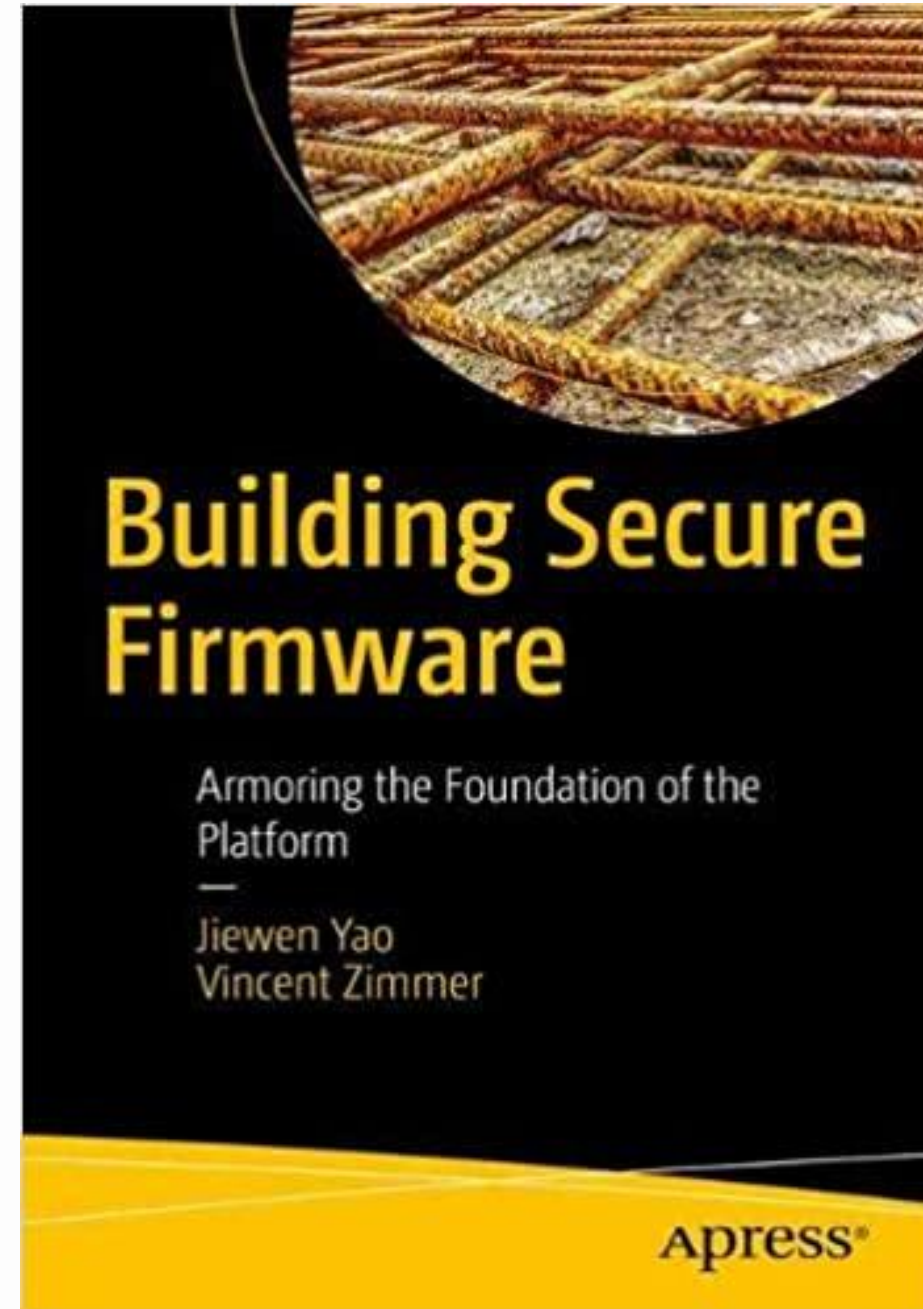
- Attack
  - <https://www.blackhat.com/presentations/bh-usa-09/WOJTCZUK/BHUSA09-Wojtczuk-AtkIntelBios-SLIDES.pdf>
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  - [http://www.c7zero.info/stuff/ANewClassOfVulnInSMIHandlers\\_csw2015.pdf](http://www.c7zero.info/stuff/ANewClassOfVulnInSMIHandlers_csw2015.pdf)
- EDKII Security Bug
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  - [https://bugzilla.tianocore.org/buglist.cgi?bug\\_status=\\_\\_all\\_\\_&list\\_id=16941&order=bug\\_id&product=Tianocore%20Security%20Issues&query\\_format=specific](https://bugzilla.tianocore.org/buglist.cgi?bug_status=__all__&list_id=16941&order=bug_id&product=Tianocore%20Security%20Issues&query_format=specific)
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  - <http://design.inf.unisi.ch/sites/default/files/seminar-niko-matsiakis-rustoverview.pdf>
- Rust Project
  - <https://github.com/libra/libra>
  - <https://github.com/apache/incubator-teaclave-sgx-sdk>
  - <https://github.com/firecracker-microvm/firecracker>
  - <https://github.com/oreboot/oreboot>
  - <https://gitlab.redox-os.org/redox-os>

# To Learn More About UEFI Security



**Building Secure Firmware:  
Armoring the Foundation  
of the Platform**

<https://www.amazon.com/gp/product/1484261054/>







**Questions?**



Thanks for attending the UEFI 2020 Virtual Plugfest

For more information on UEFI Forum and UEFI Specifications, visit <http://www.uefi.org>

*presented by*

