# HARDWARE SECURITY IS HARD:

## HOW HARDWARE BOUNDARIES DEFINE PLATFORM SECURITY

@matrosov

ZERO NIGHTS 2019 EDITION

Offensive Security REsearch at

Former Principal Security Researcher @Cylance @Intel @ESET

Doing Security REsearch since 1997

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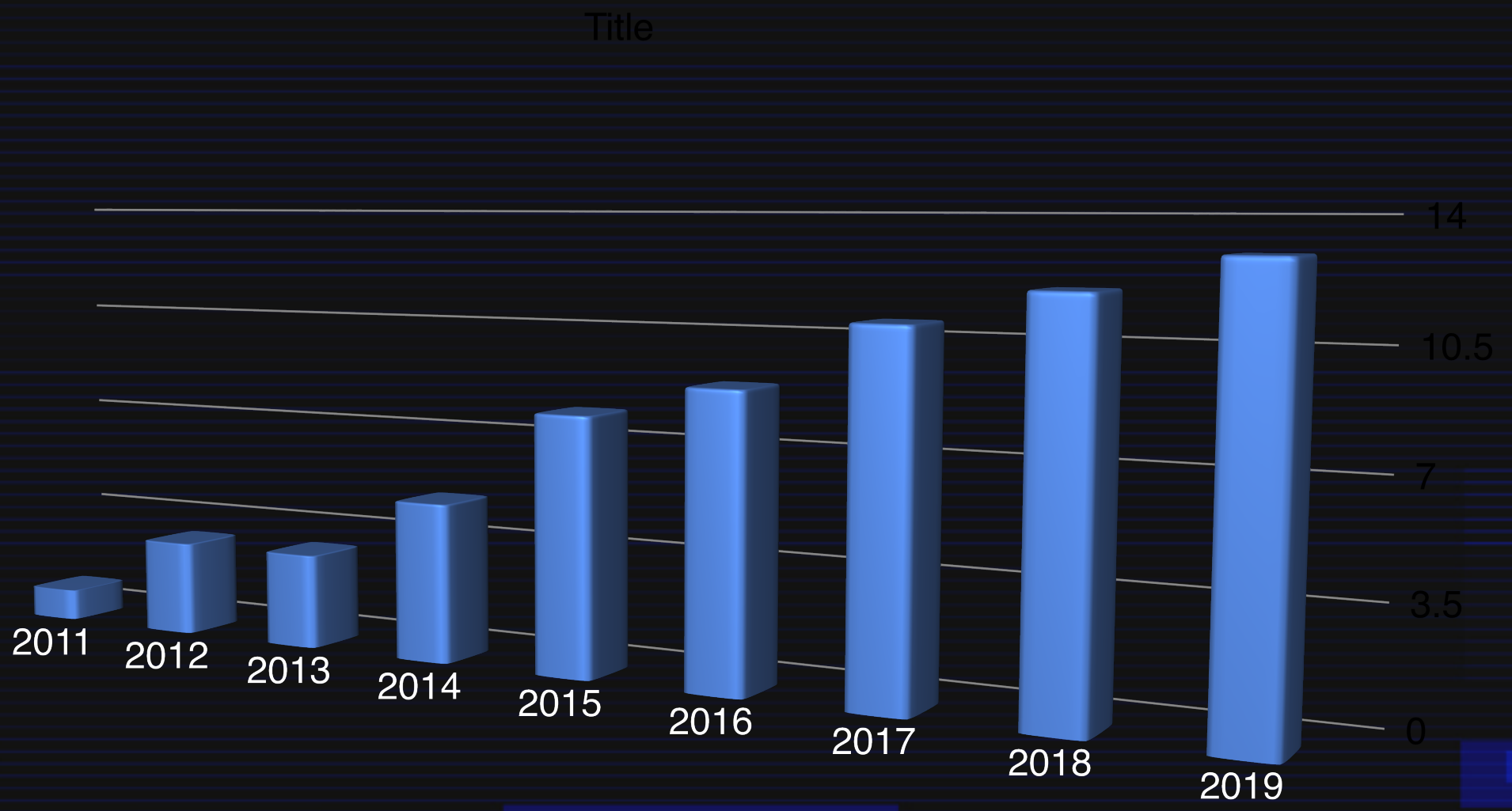
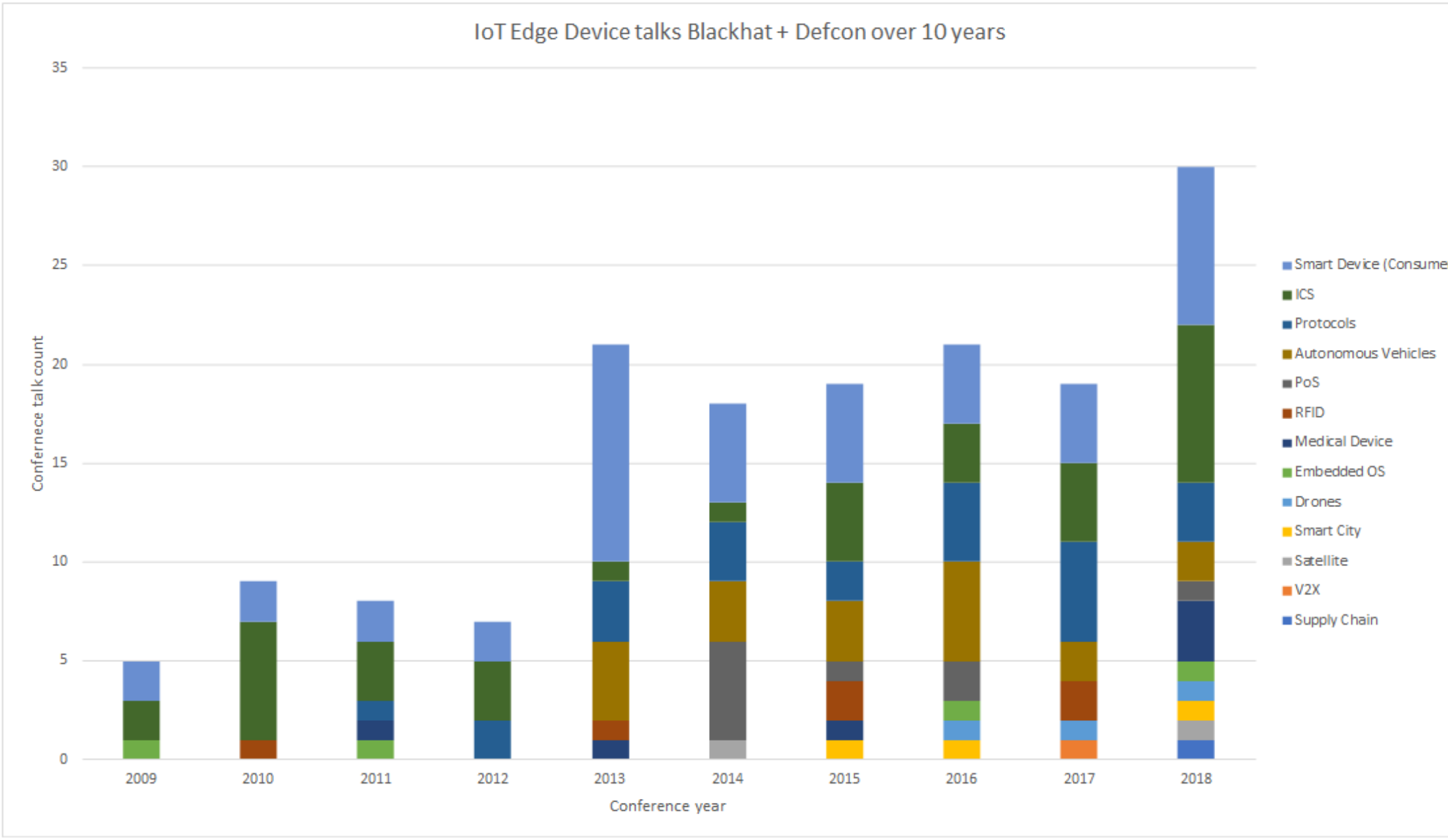
# Constant HW security talks growth at ZN




IoT Edge Device talks Blackhat + Defcon over 10 years
Confernece talk count
35
30
25
20
15
10
5
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Conference year
Smart Device (Consume
ICS
Protocols
Autonomous Vehicles
PoS
RFID
Medical Device
Embedded OS
Drones
Smart City
Satellite
V2X
Supply Chain

# The Advanced Threats Evolution: REsearchers Arm Race

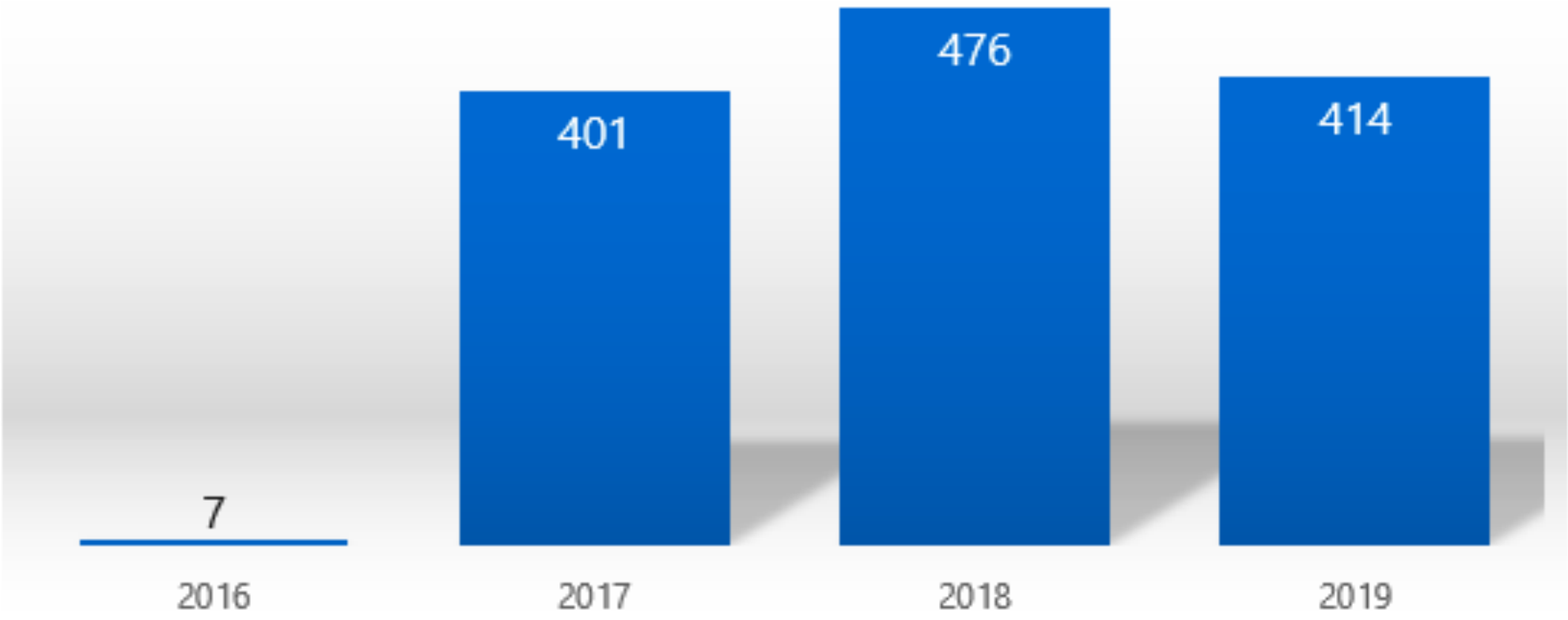
https://www.platformsecuritysummit.com/2019/speaker/matrosov/

Security Industry Visibility Point

Modern Persistence Techniques

https://www.platformsecuritysummit.com/2019/speaker/matrosov/

# Number of firmware vulnerabilities




Source: National Vulnerabilities Database

# HW TREATS MODEL

||

# FW THREAT MODEL

# NOWADAYS IT'S HARD TO SPOT REAL BOUNDARIES BETWEEN HARDWARE AND FIRMWARE

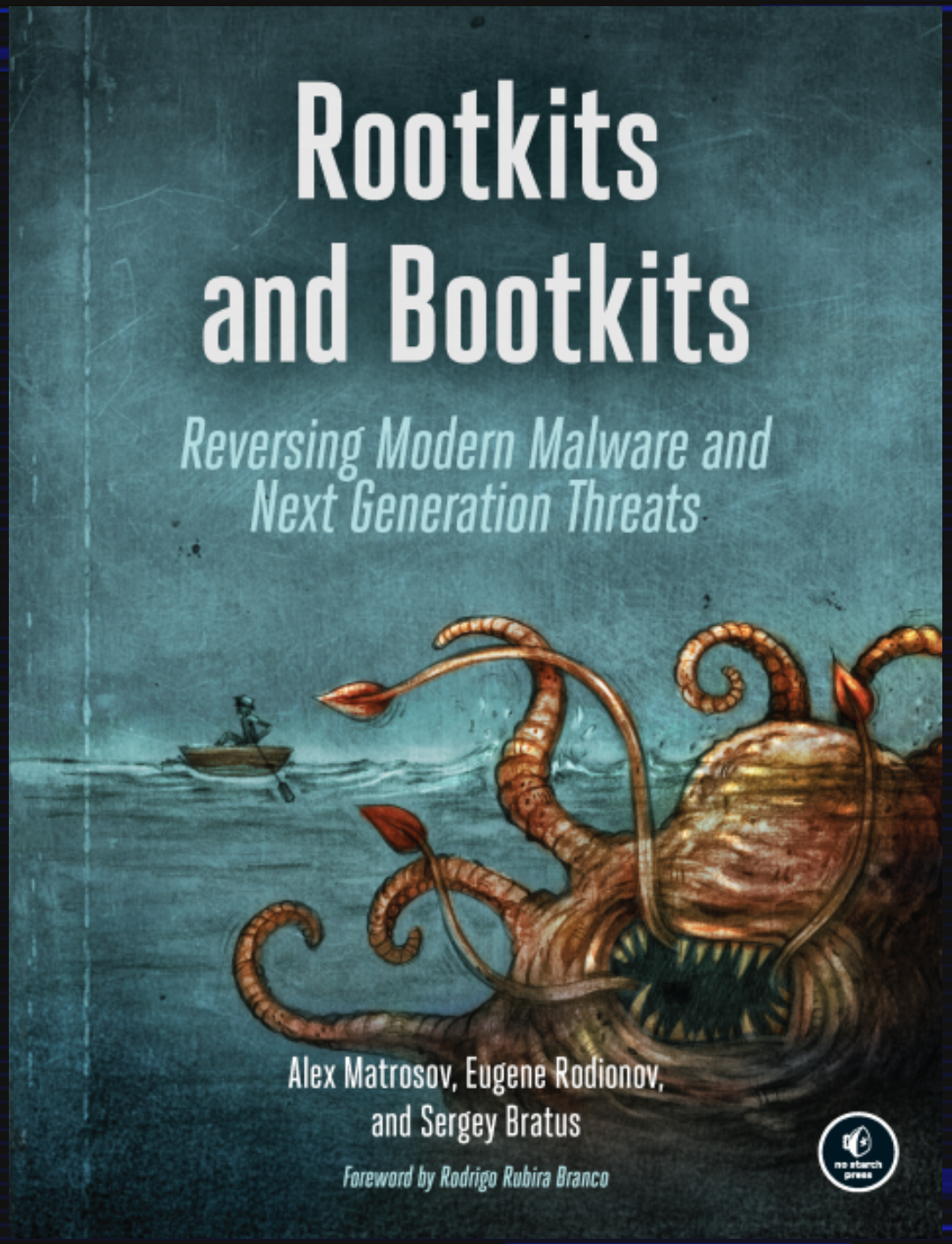
# HW TREATS MODEL && FW THREAT MODEL

# Identify Threats

- Threats can be identified by analyzing the security requirements and platform diagram
- Threats should be categorized for further analysis
  - Techniques for analyzing threats: STRIDE, DREAD, PASTA, LINDDUN, etc.

https://uefi.org/sites/default/files/resources/UEFI%20SDL%20Webinar_Final%20Slides%20-%20PDF.pdf

# IT'S HARD TO FIND REAL SECURITY PROBLEMS IN PLATFORM DIAGRAM AND REQUIREMENTS


Rootkits and Bootkits
Reversing Modern Malware and Next Generation Threats
Alex Matrosov, Eugene Rodionov, and Sergey Bratus
Foreword by Rodrigo Rubira Branco
no starch press

# Rootkits

# TRADITIONALLY HARDWARE DESIGN OBJECTIVES ARE DRIVEN BY COST AND PERFORMANCE, BUT NOT SECURITY

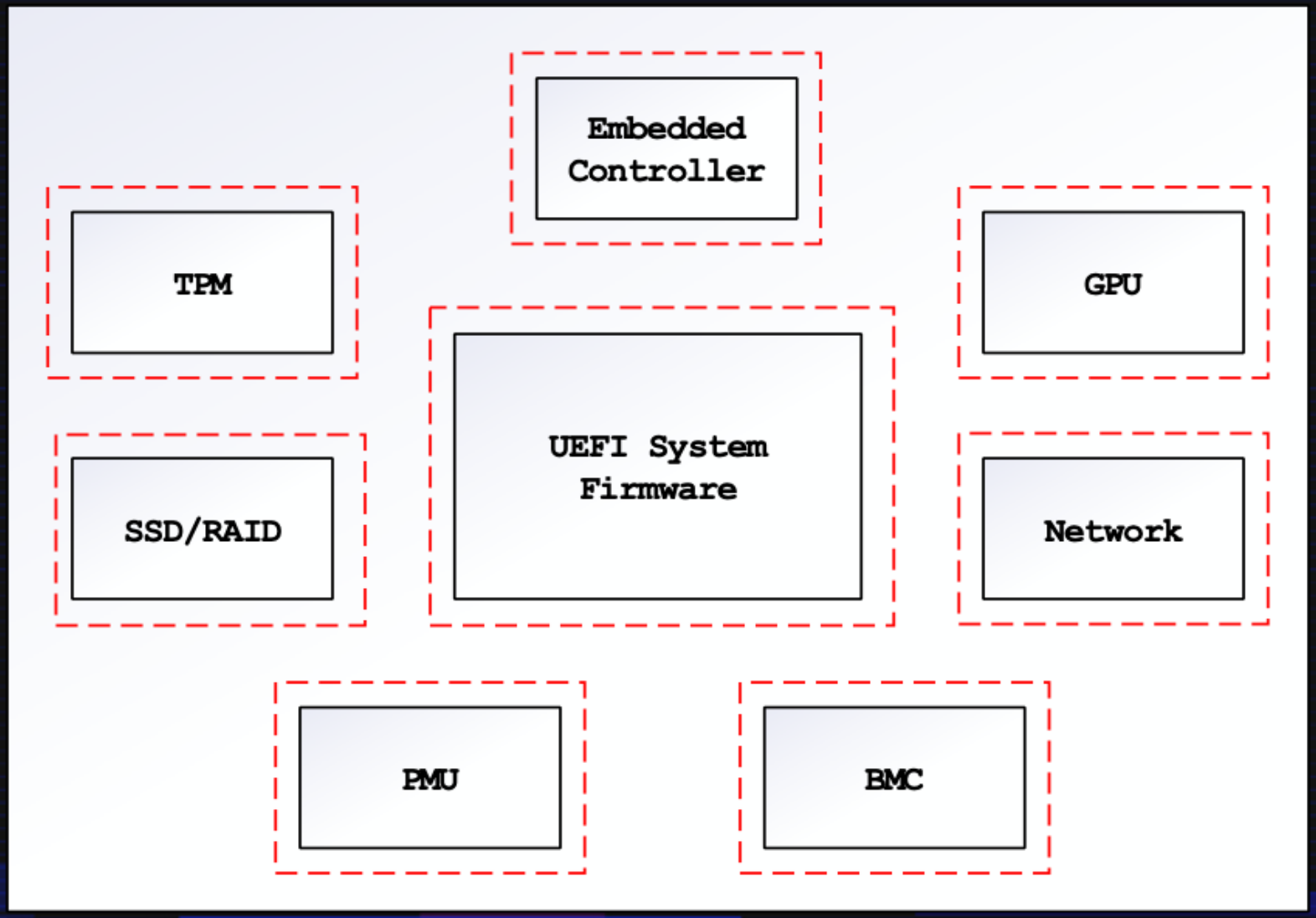
# Security Through Obscurity

- Firmware binaries are freely available online
- Tools to analyze binaries are available
- Security researchers are decompiling binaries
  - Most 3rd party reports received include disassembled code

not a binaries technology specs please

https://uefi.org/sites/default/files/resources/UEFI%20SDL%20Webinar_Final%20Slides%20-%20PDF.pdf

# HW/FW Security != sum of all Boundaries



# Hardware Security Boundaries

Most of those chips are:

- Not under direct control from hardware vendors
- Involved in security features implementation
- Connected to UEFI firmware (BIOS)
- Considered to generate trusted I/O
- Mostly out of the supervision scope of the main CPU

How can we trust anything that is not under our system control?

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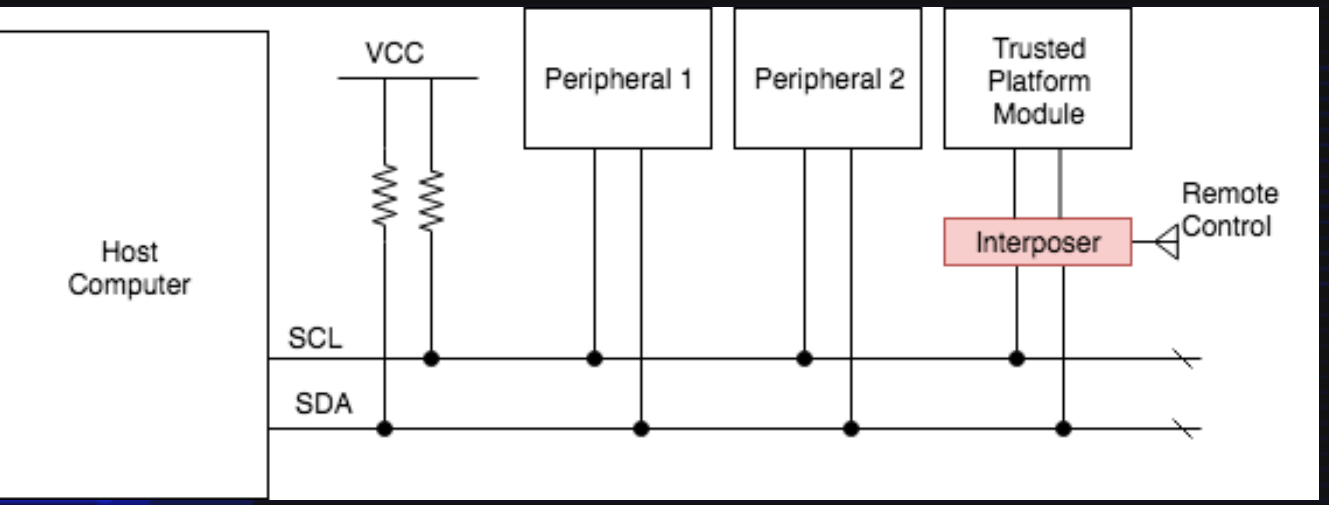
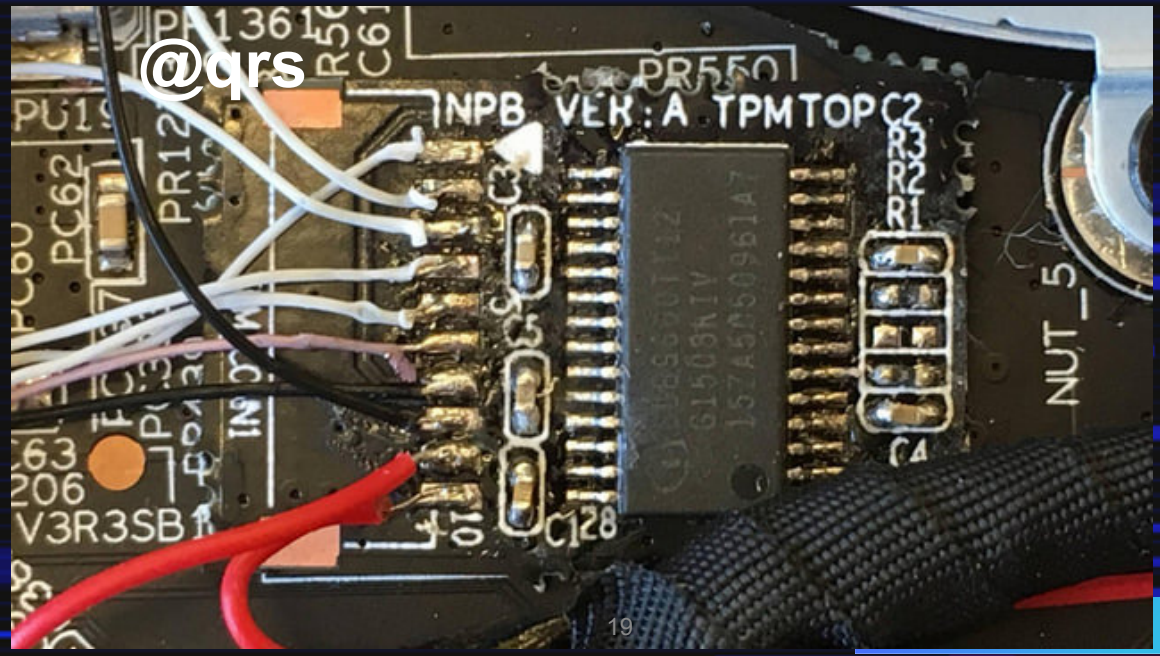
# In current threat model HW is trusted 😈

@uffeux

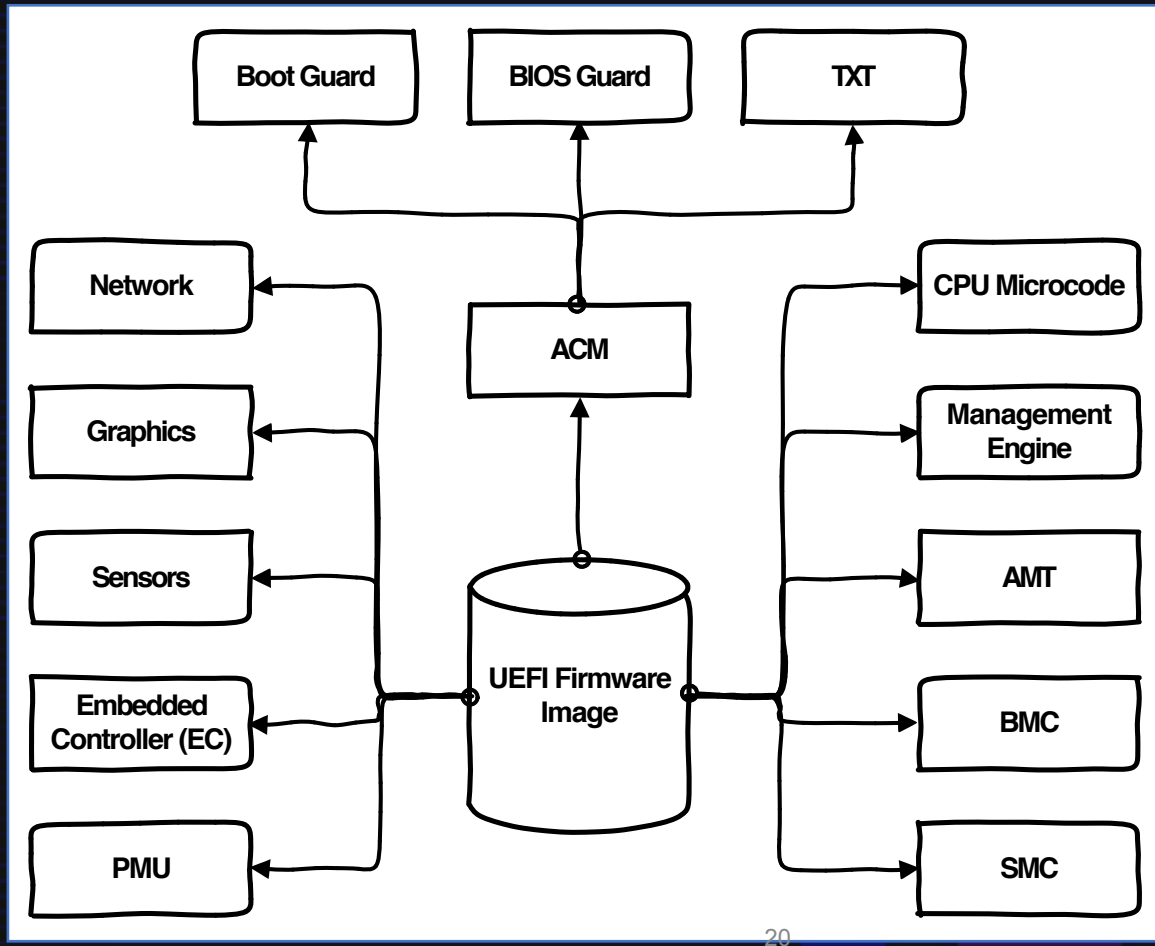



@qrs



# How many 3rd-party chips in your laptop?

- TPM module
- USB controller
- Embedded Controller (EC)
- Fingerprint Reader
- Touchpad
- and many others



# BMC is inside trusted boundaries

UEFI firmware blindly trust all hardware

But hardware can attack UEFI firmware 😈



https://airbus-seclab.github.io/ilo/ZERONIGHTS2018-Slides-EN-Turning_your_BMC_into_a_revolving_door-perigaud-gazet-czarny.pdf

# Lenovo Thinkpad EC update process

OS

**Lenovo TDK update tool**

map EC update image to memory

set NVRAM var 'LenovoEcfwUpdate'

```
while ( v7 - &LenovoEcfwUpdate <= v5 );
memset_(buffer, 0, 1u);
buffer[0] = 1;
TdkBinCreateFromBuff(buffer, 1ui64, &tdk_bin);
result = TdkVariableSet(&a1, &a2, 7u, tdk_bin);
```

**Lenovo EcFwUpdateDxe (not SMM)**

```
res = LoadFirmware();
if ( res >= 0 )
{
  res = ValidateFirmwareHeader();
  if ( res >= 0 )
  {
    UpdateEcFw(ecfw_bin);
    res = 0i64;
  }
```

BIOS

https://medium.com/@matrosov/breaking-through-another-side-bypassing-firmware-security-boundaries-85807d3fe604

# Lenovo Thinkpad EC update process

OS

Len

map EC image to

```
while ( v7 -
memset_(buff
buffer[0] =
TdkBinCreate
result = Tdk
```

```
case 0x83u:
  v5 = "ECFW image file is invalid";
  break;
case 0x84u:
  v5 = "Failed to load ECFW image file";
  break;
case 0x85u:
  v5 = "This system BIOS supports signed ECFW image only.";
  break;
case 0x86u:
  v5 = "This system BIOS supports unsigned ECFW image only.";
  break;
```

T540p case

ot SMM)

```
Header();
```

BIOS



https://medium.com/@matrosov/breaking-through-another-side-bypassing-firmware-security-boundaries-85807d3fe604

# CVE-2019-6171/LEN-27764

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Revision History:

| Revision | Date | Description |
|---|---|---|
| 9 | 2019-11-11 | Updated fix targets |
| 8 | 2019-10-09 | Updated fix targets |
| 7 | 2019-10-06 | Updated fix targets and added fixes |
| 6 | 2019-09-25 | Updated fix targets and added fix |
| 5 | 2019-08-29 | Updated fix targets and added fix |
| 4 | 2019-08-27 | Added fixes |
| 3 | 2019-08-13 | Updated fix target for some products |
| 2 | 2019-08-09 | Updated Product Impact |
| 1 | 2019-08-08 | Initial release |

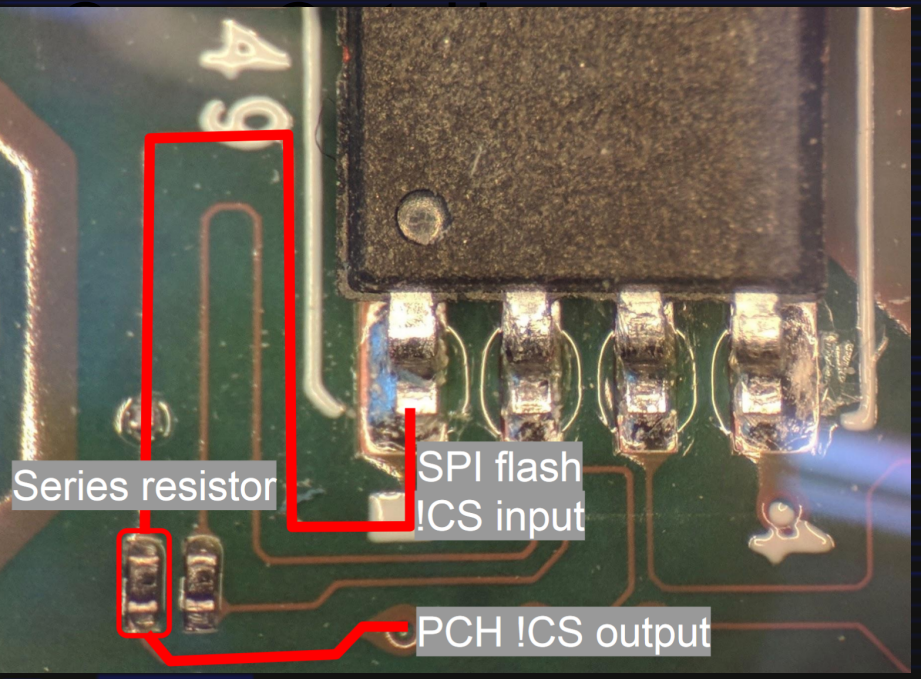
Product Impact:

| Product | Model | Minimum Fix Version | Download Link | Last Updated |
|---|---|---|---|---|
| ThinkPad 10 | 20E3, 20E4 | Target availability 2019-11-27 | | 2019-10-06 |
| ThinkPad 11e/Yoga 11e 3RD GEN | 20G9, 20GB, 20G8, 20GA | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 11e/Yoga 11e 3RD GEN | 20G9, 20GB, 20G8, 20GA | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 11e/Yoga 11e 4TH GEN | 20HT, 20HV, 20HS, 20HU | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 11e/Yoga 11e 4TH GEN | 20HT, 20HV, 20HS, 20HU | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 11e/Yoga 11e 5TH GEN (GML) | 20LR, 20LQ, 20LN, 20LM | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 11e/Yoga 11e 5TH GEN (KBY-Y) | 20LR, 20LQ, 20LN, 20LM | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 13 (KBL) | 20J1, 20J2 | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad 13 (KBL) | 20J1, 20J2 | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad A275 | 20KC, 20KD | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad A285 | 20MW, 20MX | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad A475 | 20KL, 20KM | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad A485 | 20MU, 20MV | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E450/E450c/E550/E550c | 20DC, 20DD, 30EH, 20DF, 20DG, 20E0 | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E460/E560 | 20ET, 20EU, 20EV, 20EW | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E465/E565 | 20EX, 20EY | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E470/E570 | 20H1, 20H2, 20H5, 20H6 | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E475/E575 | 20H4, 20H8 | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E480/E580 | 20KN, 20KQ, 20KS, 20KT | Target availability 2019-11-20 | | 2019-09-25 |
| ThinkPad E485/E585 | 20KU, 20KV | Target availability 2019-11-20 | | 2019-09-25 |

https://support.lenovo.com/us/en/product_security/len-27764

# IN CURRENT REALITIES HW AND FW THREAT MODELING SHOULD BE UNDIVIDED

# Intel Boot Guard TOCTOU from SPI flash

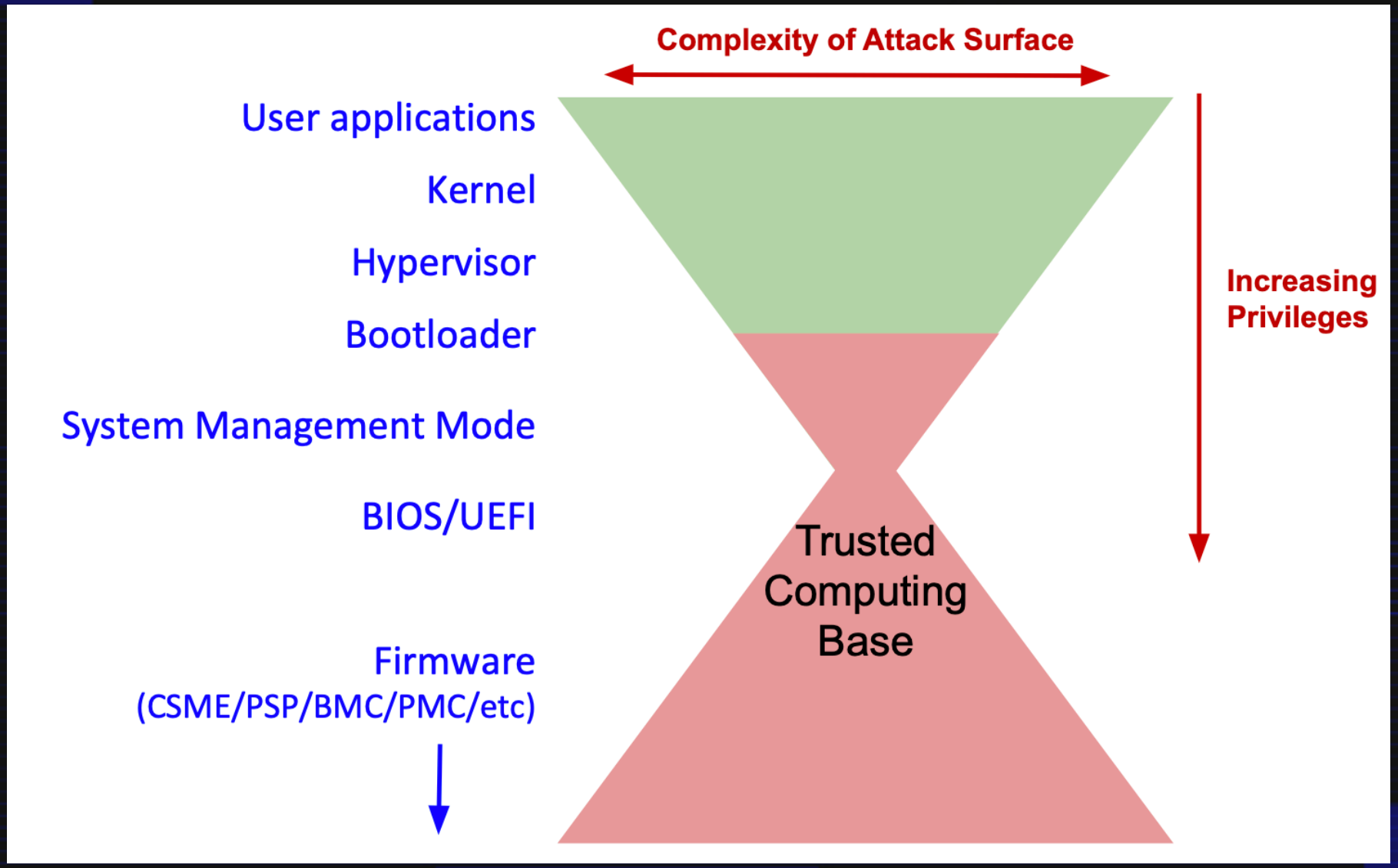



**Authenticated once != trusted forever**



26

https://edk2-docs.gitbooks.io/security-advisory/content/bootguard-toctou-vulnerability.html




https://www.platformsecuritysummit.com/2019/speaker/wood/

# WE TRUST TOO MUCH IN HARDWARE SECURITY BY DEFAULT

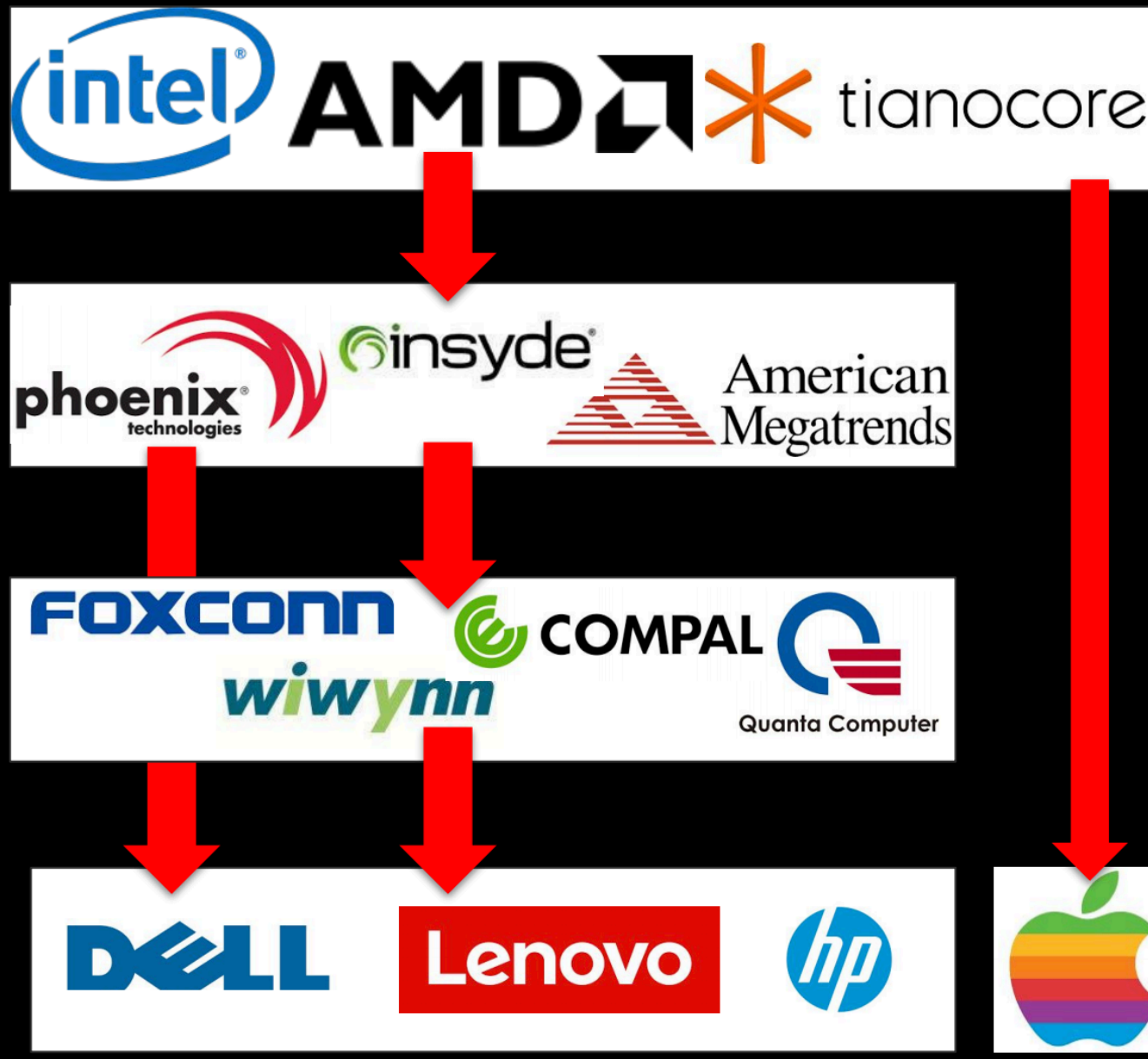
Reference Implementations

Independent BIOS Vendors (IBV)

Device Manufacturers (ODM)

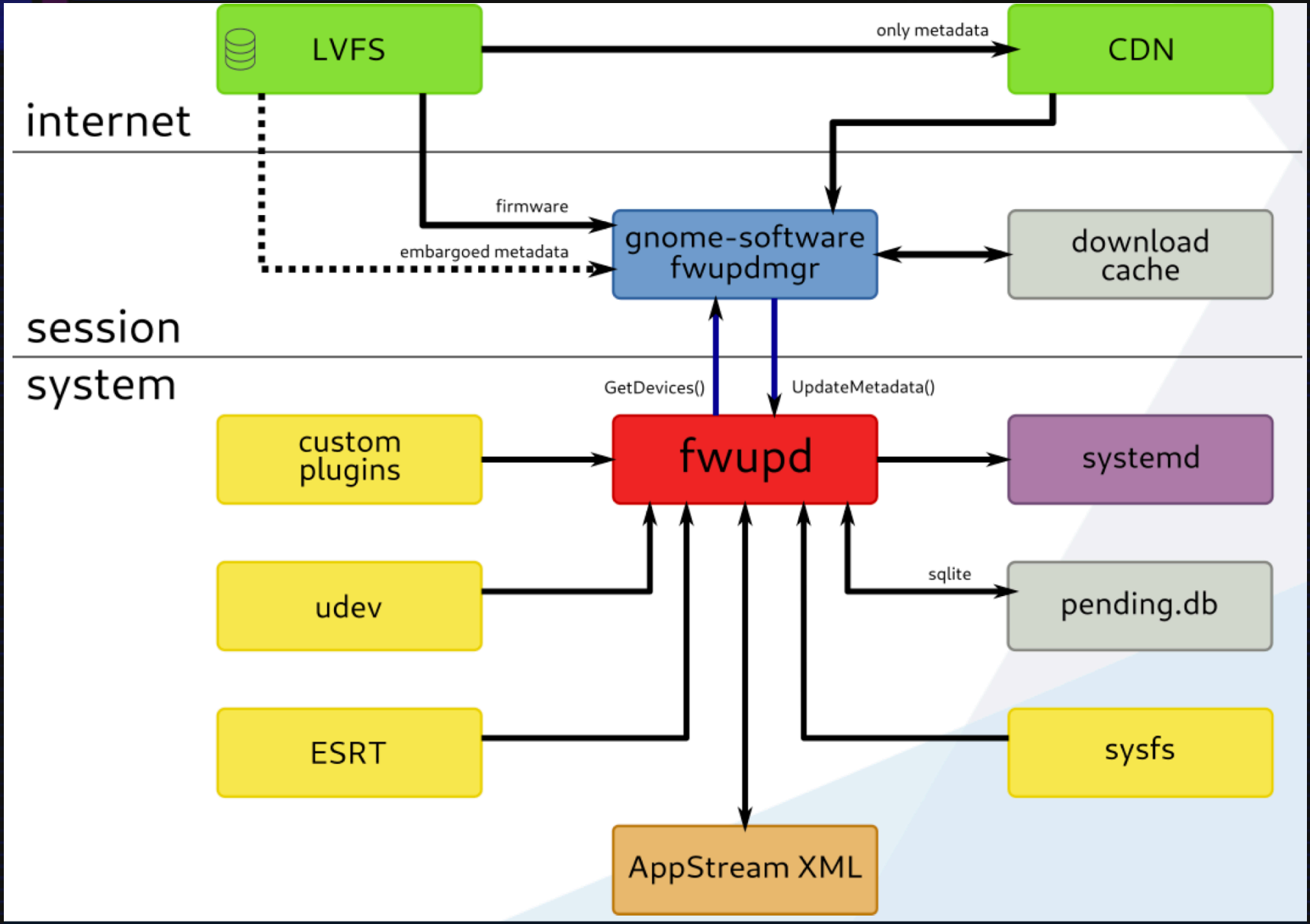
Less than 10% of BIOS code!

Original Equipment Manufacturers (OEM)

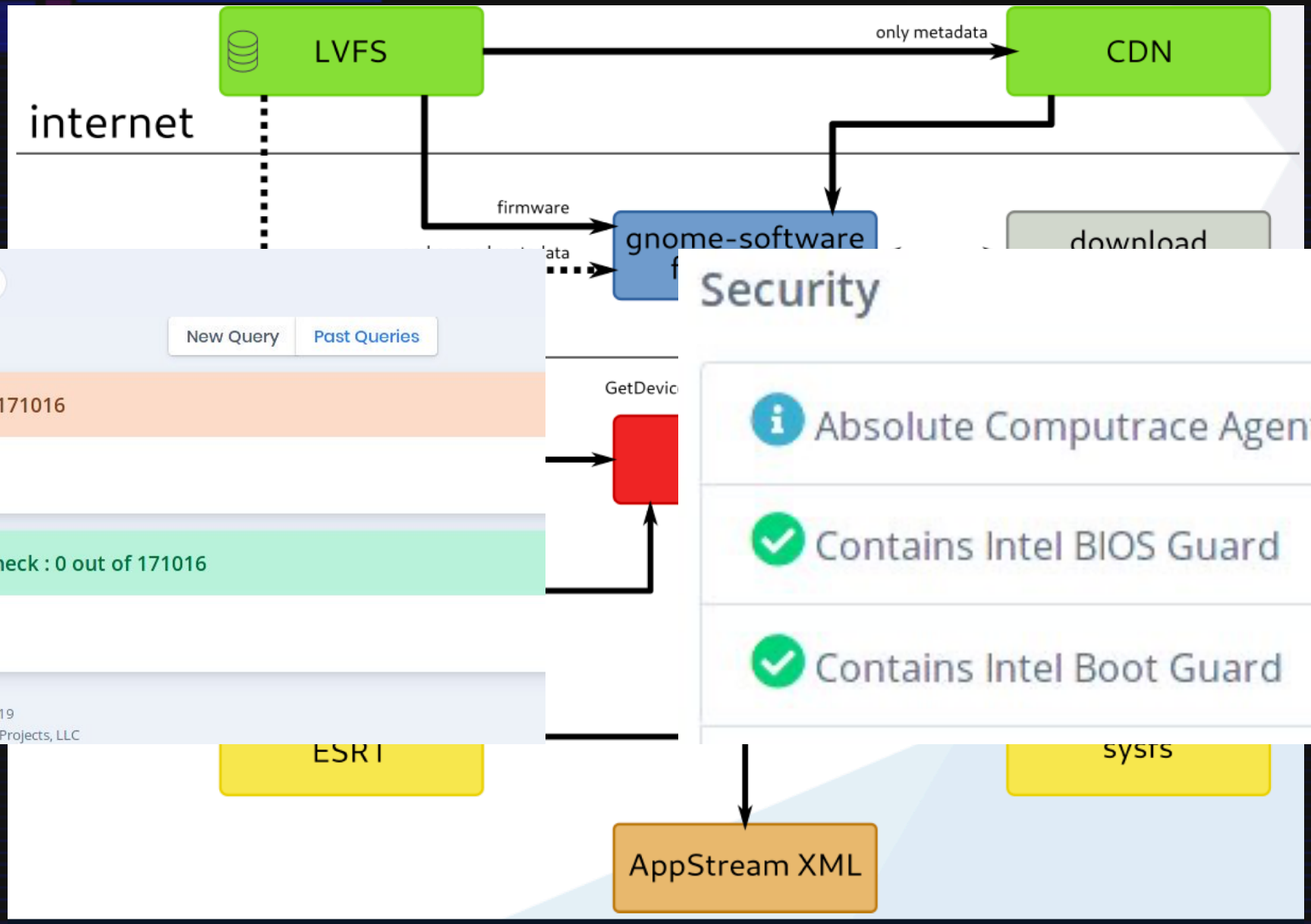


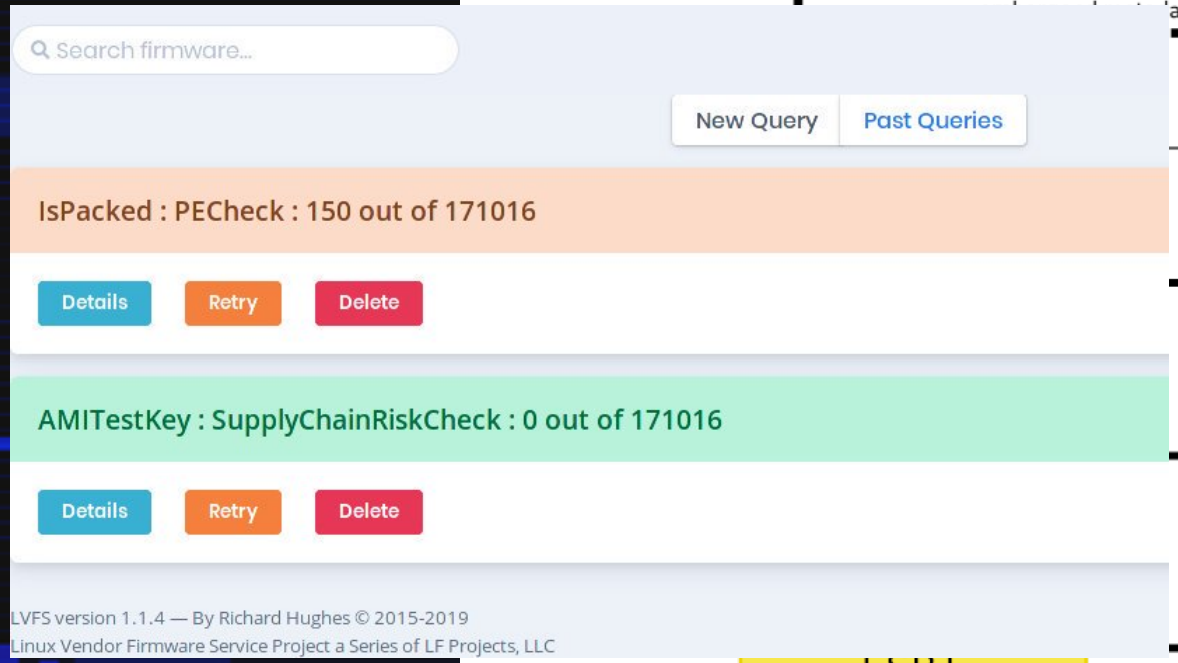

https://media.hardwear.io/roots-of-trust-and-attestation/

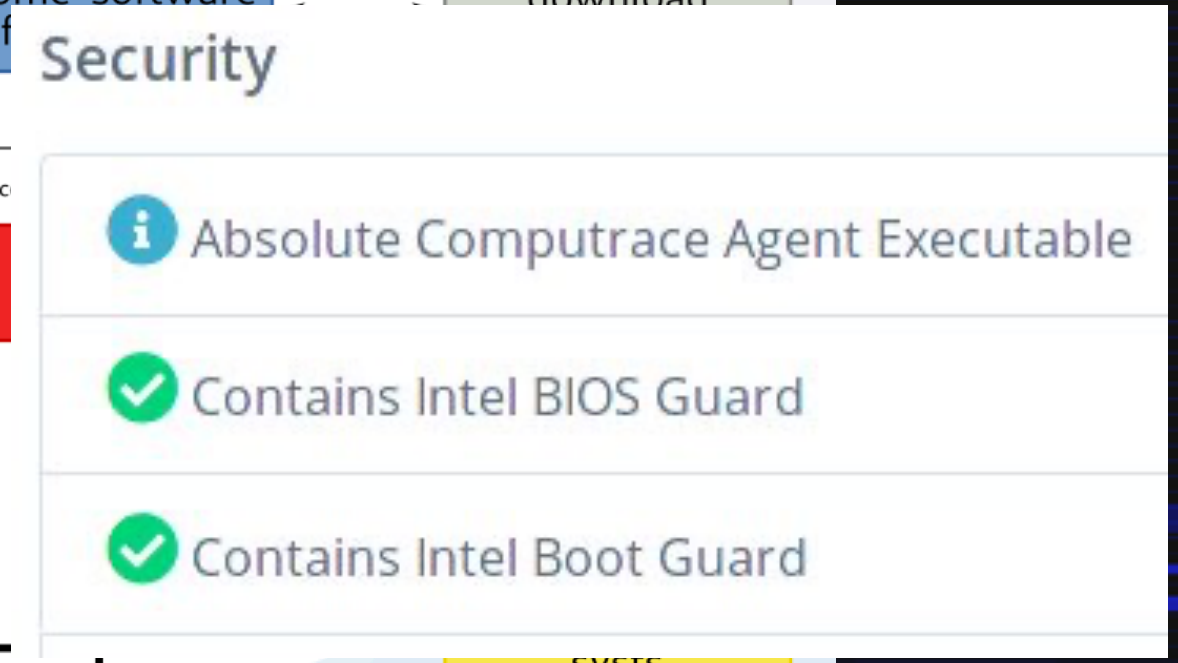
# WE TRUST BLINDLY ANYTHING WHICH IS SIGNED AND COME FROM TRUSTED SOURCE




https://osfc.io/uploads/talk/paper/9/Introducing_the_Linux_vendor_Firmware_service.pdf



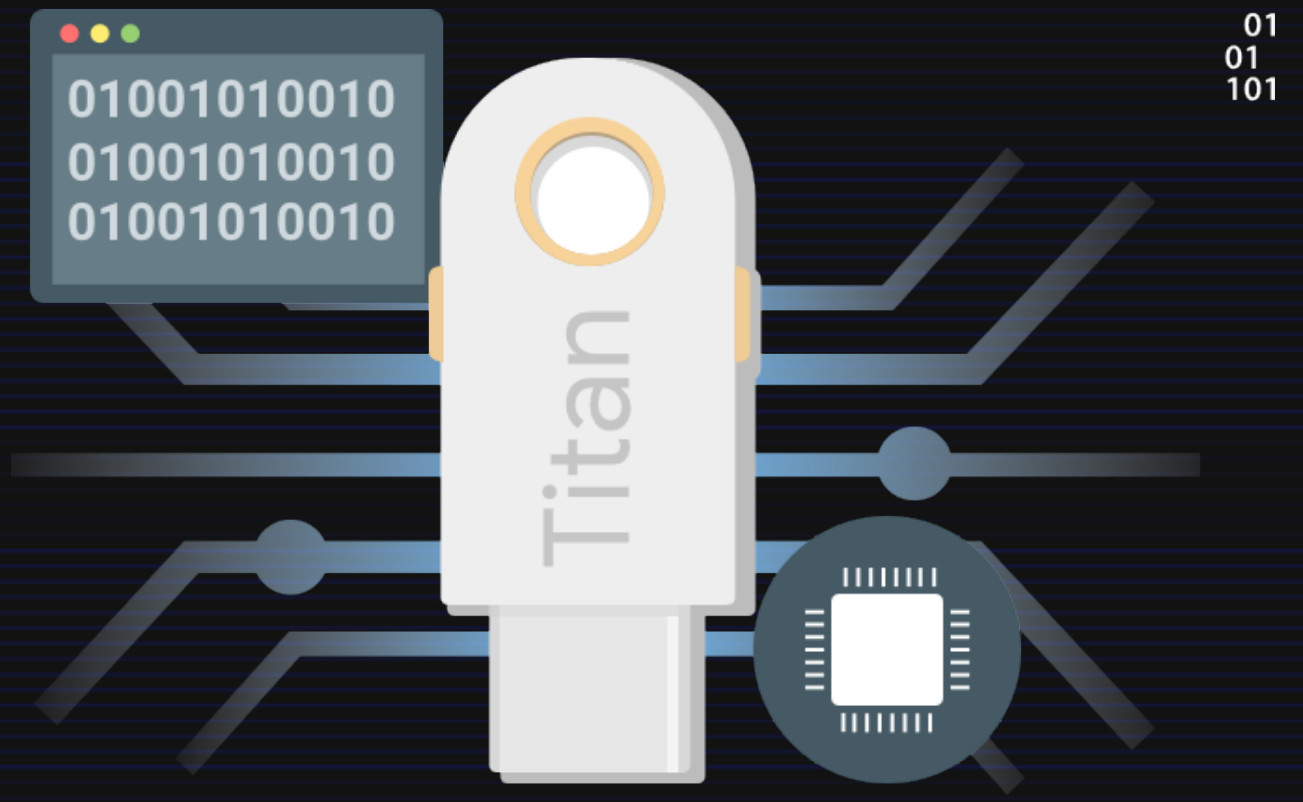




https://osfc.io/uploads/talk/paper/9/Introducing_the_Linux_vendor_Firmware_service.pdf

# ZERO TRUST ALSO MEANS "TRUST HW NOT USER". I WILL NEVER CONSIDER HW 100% TRUSTED

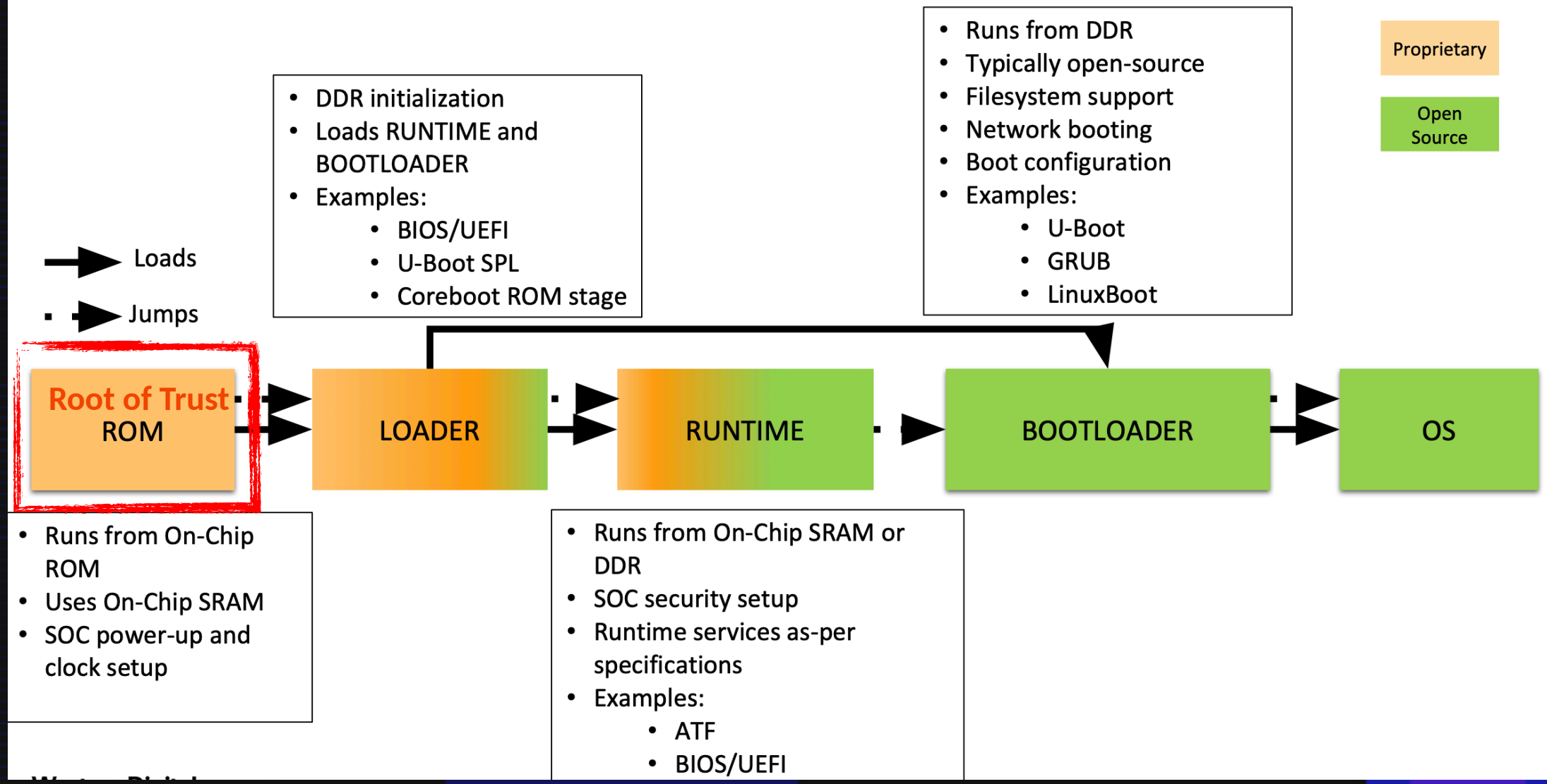
https://www.youtube.com/watch?v=YFE4RqHRYOA




# Google recalls some Titan security keys after finding Bluetooth vulnerability

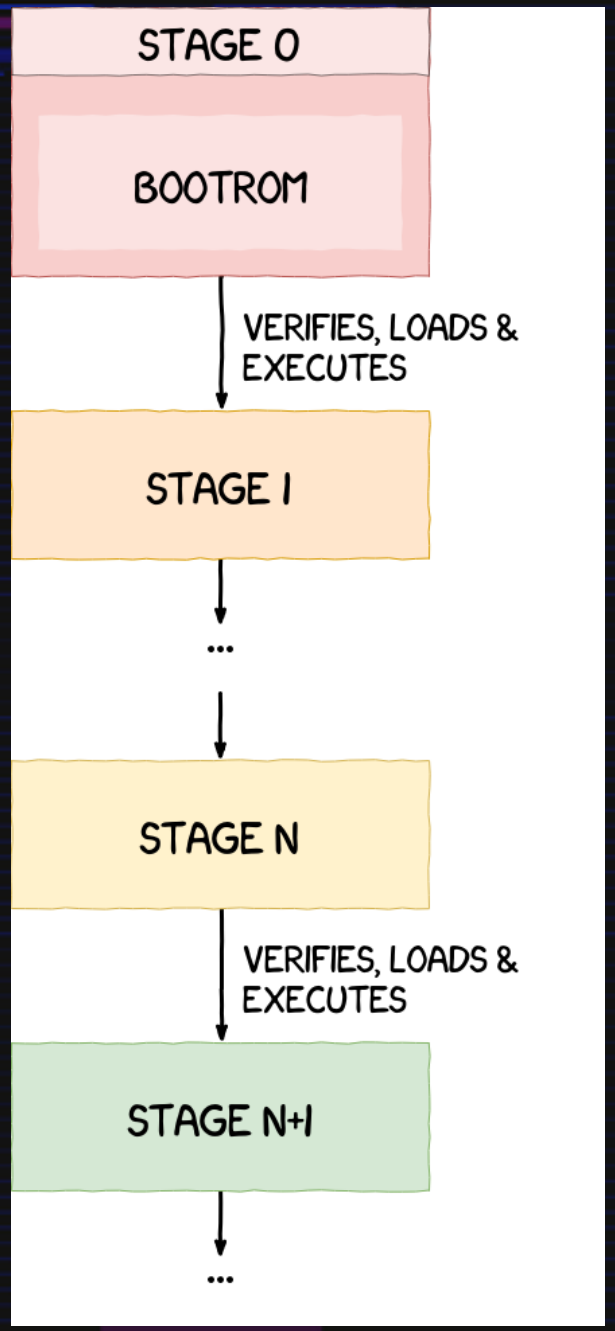
# Google recalls some Titan security keys after finding Bluetooth vulnerability

# Industry standard boot loaders

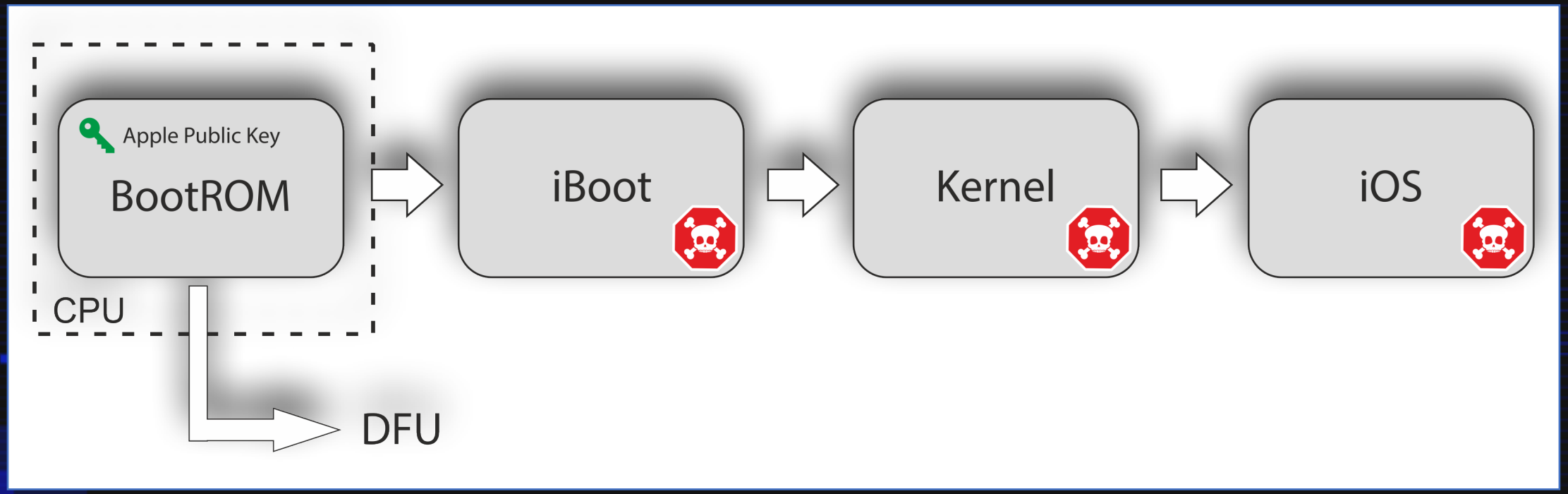



https://osfc.io/uploads/talk/paper/14/The_role_of_open_source_firmware_in_RISC-V.pdf

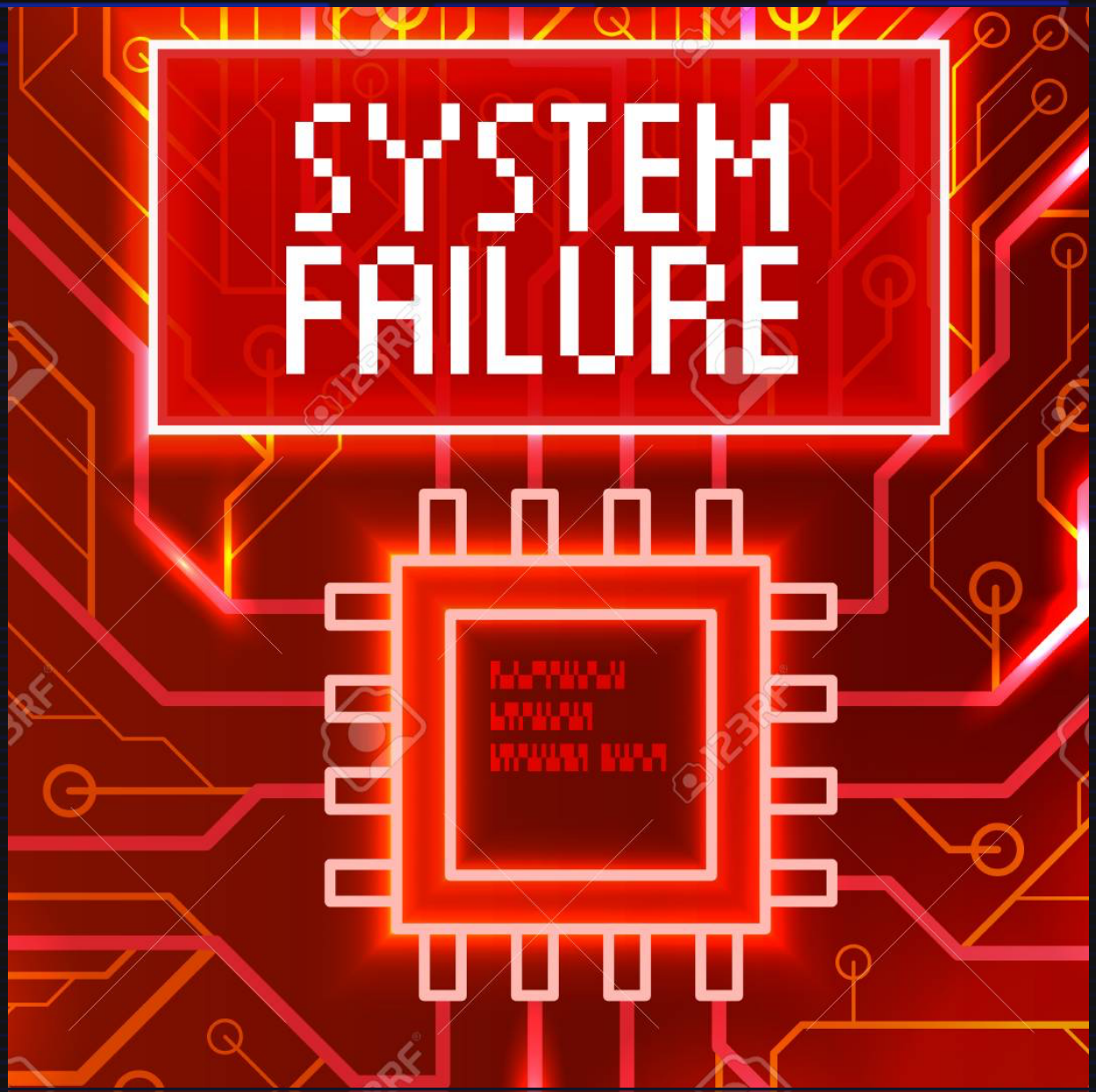
# SECURE BOOT FIX EVERYTHING?

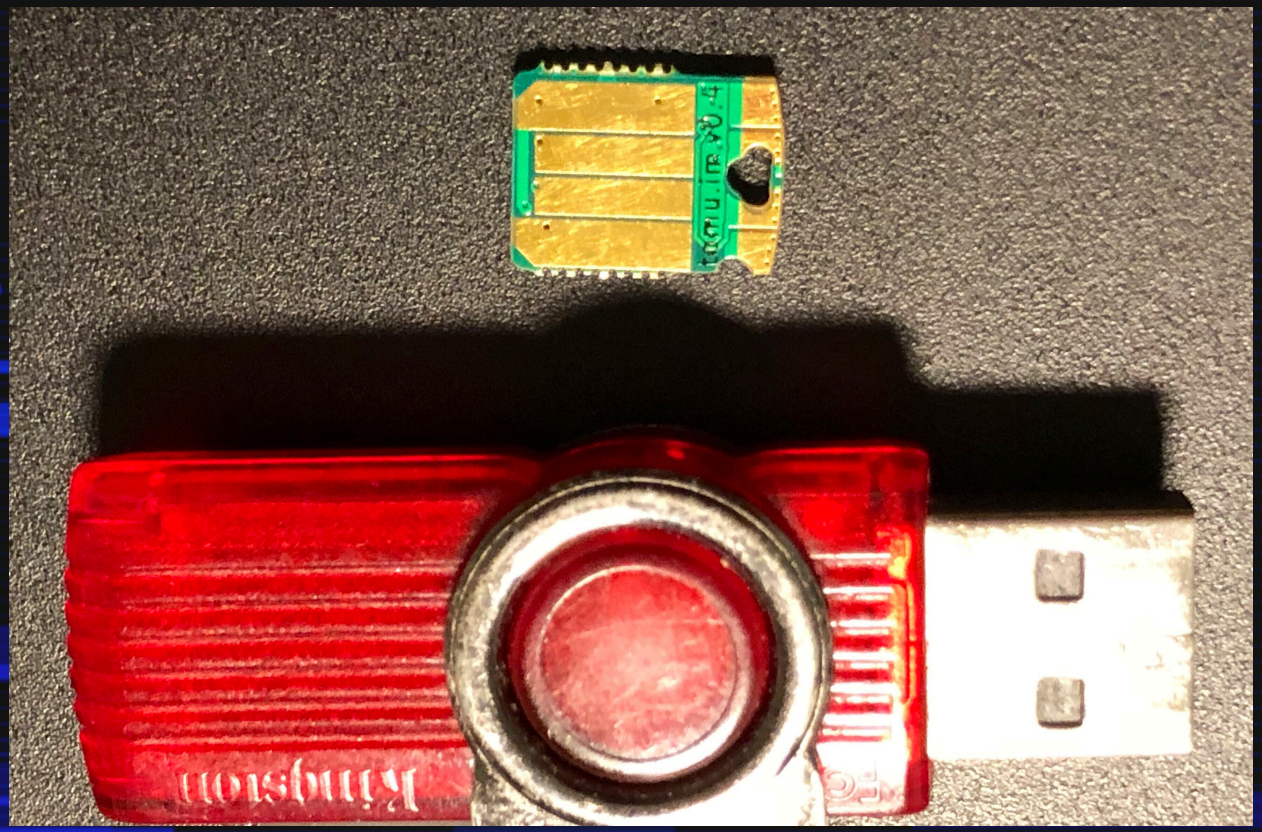


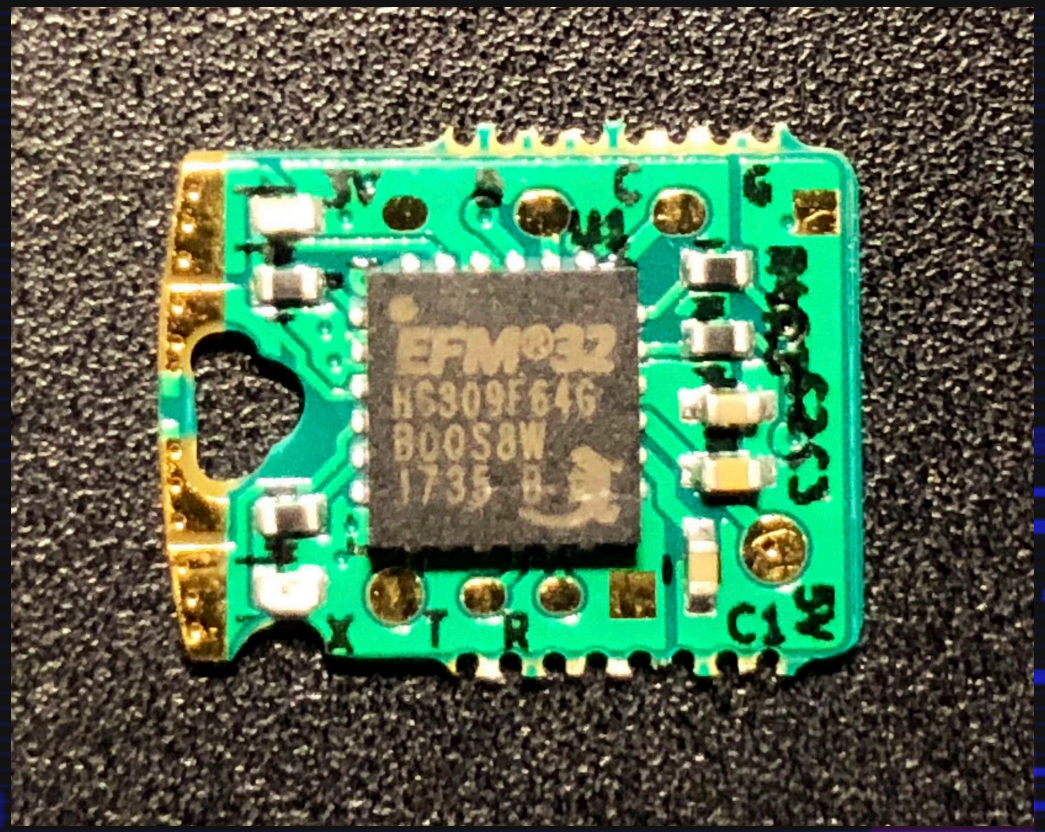

https://blog.quarkslab.com/analysis-of-qualcomm-secure-boot-chains.html




https://habr.com/en/company/dsec/blog/472762/


SYSTEM
FAILURE






https://www.crowdsupply.com/sutajio-kosagi/tomu

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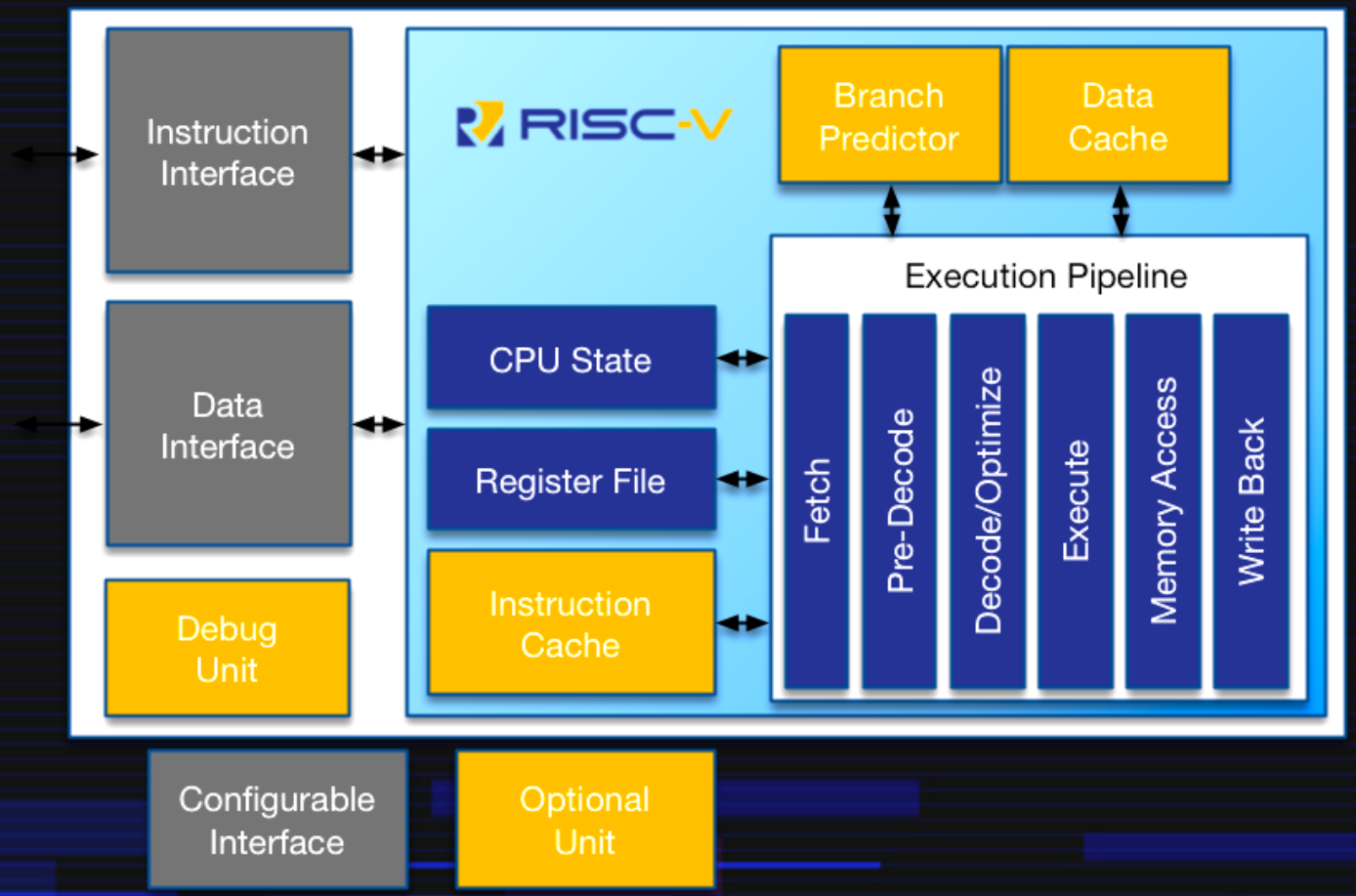
# RISC-V®

# RISC-V®


Instruction Interface
Data Interface
Debug Unit
RISC-V
Branch Predictor
Data Cache
Execution Pipeline
CPU State
Register File
Instruction Cache
Fetch
Pre-Decode
Decode/Optimize
Execute
Memory Access
Write Back
Configurable Interface
Optional Unit

# Freedom Unleashed SoC

Review

**IP Library** Go to Category ▾

Filter

ANALOG BITS
**Phase Locked Loop**
PLL 40-2400MHz DS

**Mastering**

AI ACCELERATOR

NVIDIA
**NVIDIA NVDLA (Deep Learning Accelerator)**
NVIDIA Deep Learning Accelerator
Open Source

CONFIGURABLE LOGIC

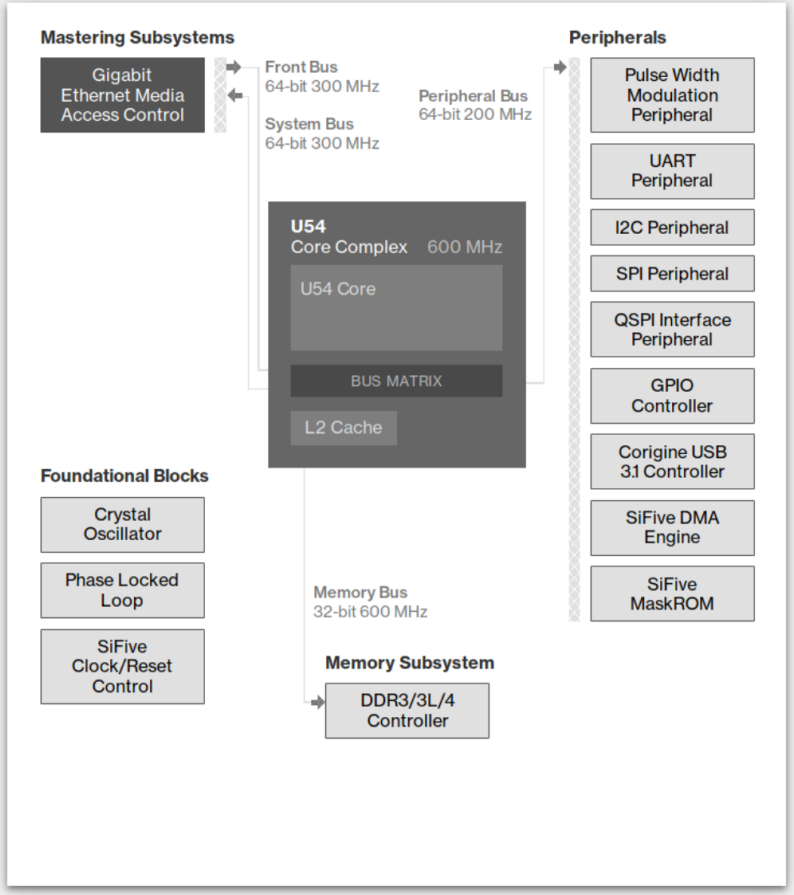
flexlogix
**Flex Logix EFLX-2.5K Embedded FPGA**
Embedded FPGA for reprogrammable hardware blocks DS

HIGH SPEED INTERFACE

mobiveil
**Mobiveil GPEX PCI-Express 4.0 Controller**
PCI Express Gen4 Controller DS

SECURITY

Rambus
**Rambus CryptoManager RT630**
A complete solution for chip and system security DS




## Chip Details

**Platform:** Freedom Unleashed
**Process:** TSMC 28nm
**Base Design:** Application Processor

**Chip Settings**

CPU Clock: **600 MHz**
100MHz 500 900MHz

Peripheral Bus: **200 MHz**
50MHz 200 350 500MHz

Mastering Bus Clock Ratio

| 2:1 | 3:1 | 4:1 |
|---|---|---|

Memory Port Width (bits)

| 32 | 64 | 128 |
|---|---|---|

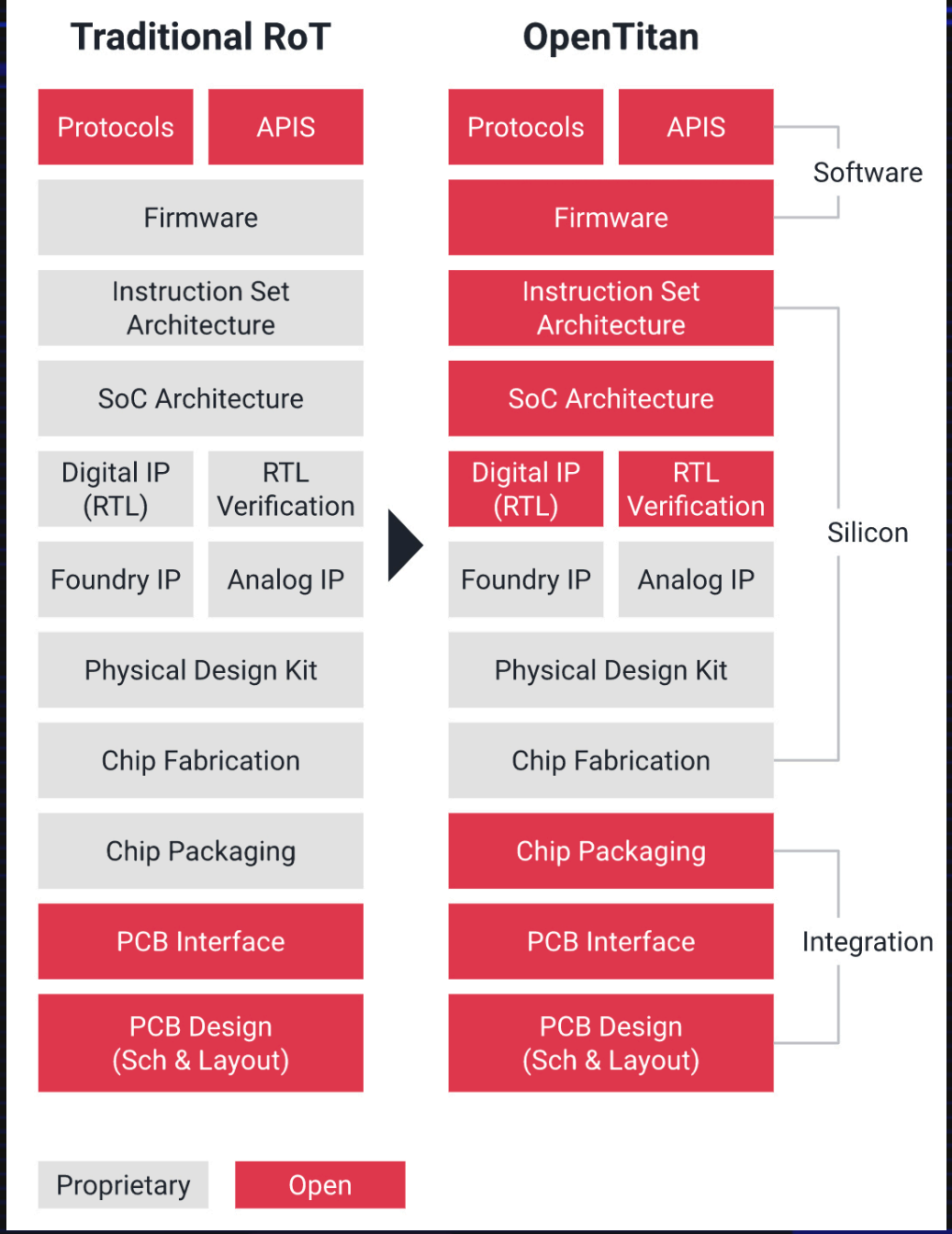
CPU Clock speed and Bus Clock Ratio determine Front and System Bus speeds.

Bus widths are determined by the choice of Core IP.

Memory Bus speed is determined by IP in the Memory Subsystem.



https://www.sifive.com/chip-designer




https://security.googleblog.com/2019/11/opentitan-open-sourcing-transparent.html

Fault injection attacks do not scale well, but their results do! Whenever something is extracted (E.g secrets, keys, firmware and vulnerabilities identified in the firmware), it will be distributable! Fault injection attacks are a first step in a complete chain of attacks!

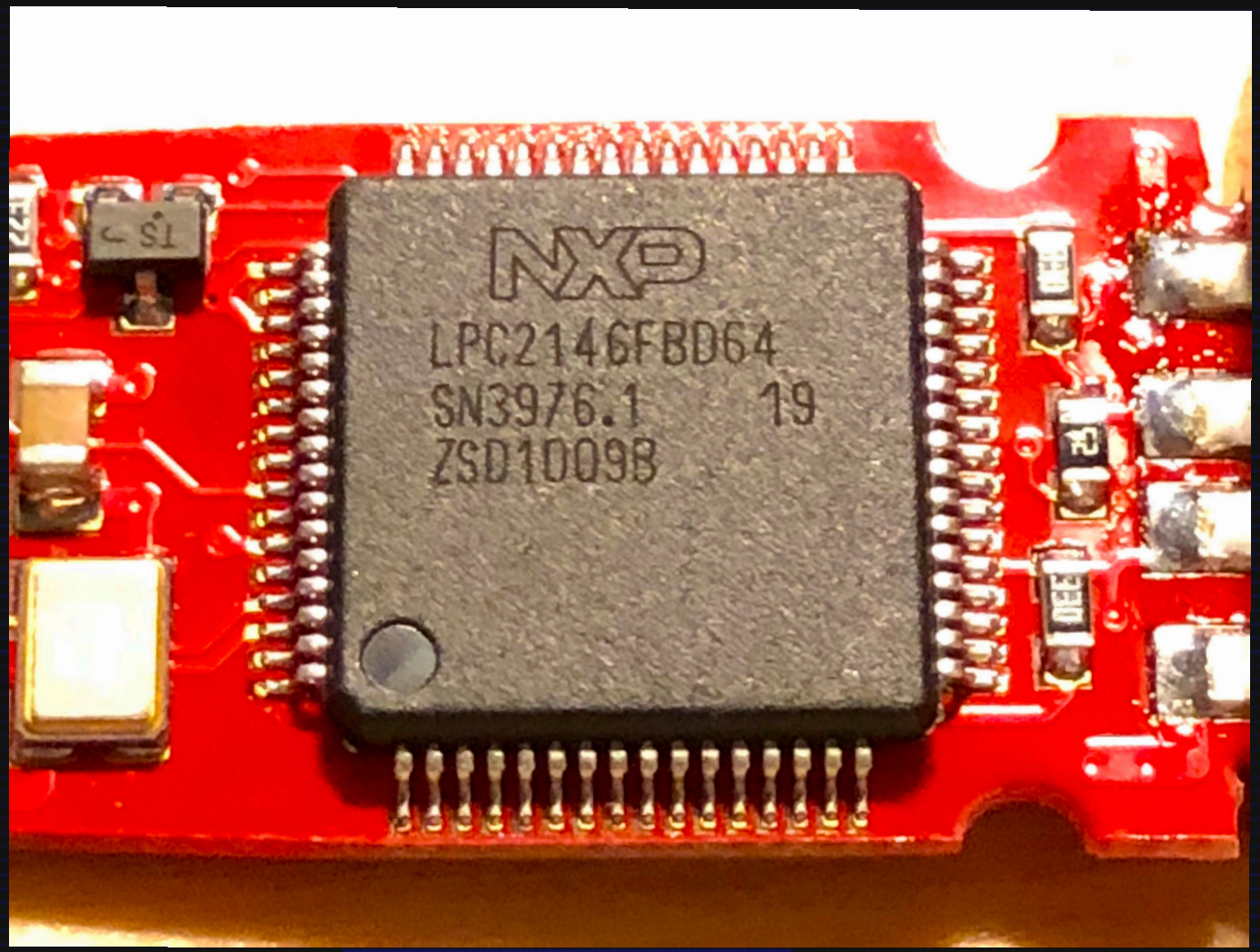
Niek Timmers (@tieknimmers)

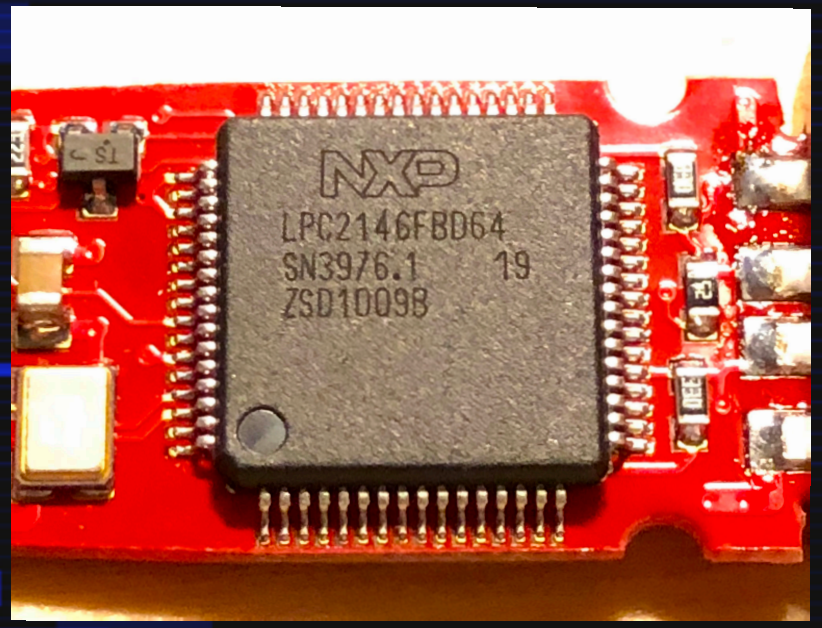
# Hardware Security Chip

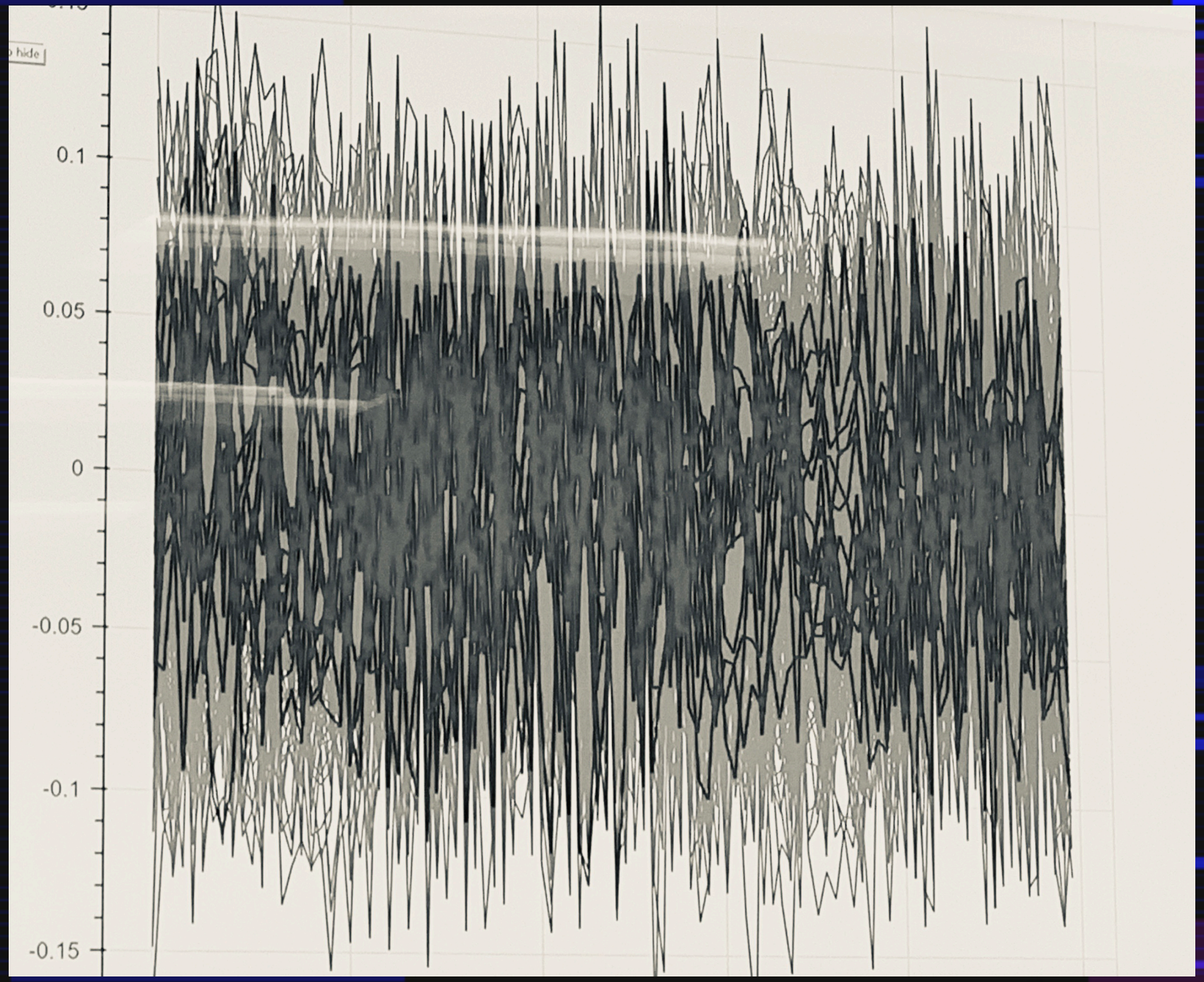
## E-Fuses

- ECC Private Keys
- AES Key
- Boot Key

- AES
- SHA2
- ECC
- RSA
- RNG


NXP
LPC2146FBD64
SN3976.1 19
ZSD1009B


NXP
LPC2146FBD64
SN3976.1 19
ZSD10098


0.1
0.05
0
-0.05
-0.1
-0.15

# HARDWARE SECURITY IS HARD!

# WE REALLY NEED TO RETHINK MEANING OF HW SECURITY IN REALITIES OF MODERN THREATS

# THANK YOU!

@matrosov