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The Role of Hardware in Security

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Acknowledgments

- The presentation includes material from
  - Nicolò MAUNERO
  - Gianluca ROASCIO

  whose valuable contribution is here acknowledged and highly appreciated.

Goal

- Understanding why hardware plays a key role in the protection of any system.
- Introducing a clear distinction between the 3 main roles of hardware when dealing with security, and namely:
  - *Hardware Security*
  - *Hardware-based Security*
  - *Hardware Trust.*

Prerequisites

- None

Outline

- The role of Hardware in Security
- Hardware Security
- Hardware-based Security
- Hardware Trust

Why *Hardware* & Security?

- As with software, data and communication infrastructures, the hardware must be *designed*, *built*, *tested*, *used*, *maintained*, and *dismissed* considering possible cyber attacks and their consequences.

Motivations

- Hardware runs software and is, in fact, *the last line of defense*

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Consequences (1)

- If the hardware is corrupted, all the mechanisms introduced to make the software secure (at any level) may become useless

Important side effect

- Hardware runs software and is, in fact, *the last line of defence*

Consequences (2)

- A *trusted* and *secure* Hardware can effectively be used to protect other system components (e.g., software, data communication infrastructures)

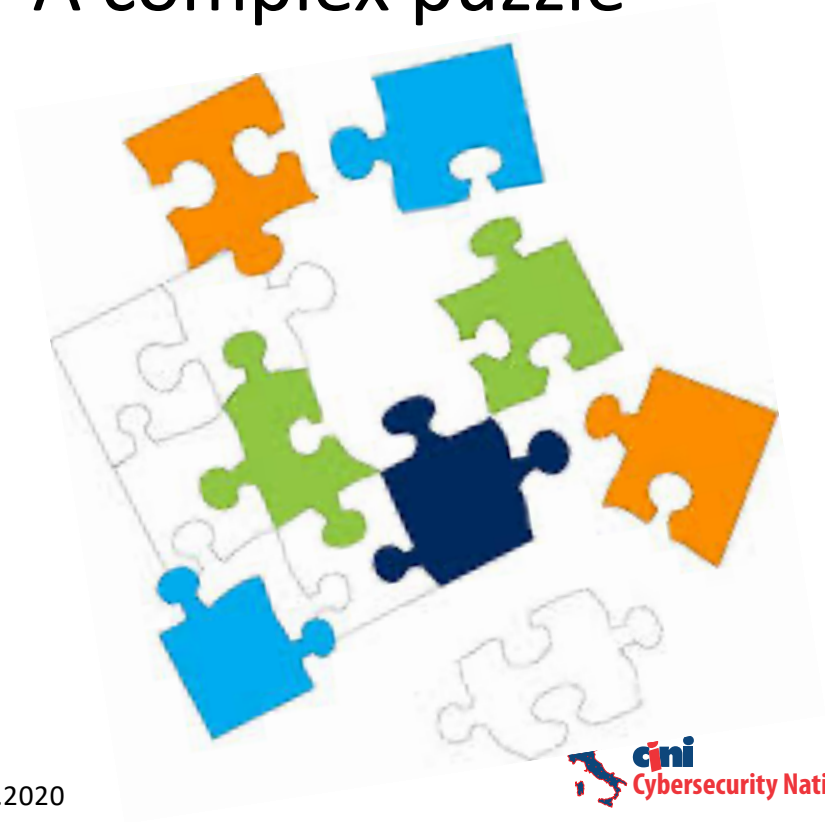
What are we talking about

- A multi-faceted reality

What are we talking about

- A multi-faceted reality

- A complex puzzle



Hardware & Security: a complex puzzle

- Hardware Vulnerabilities
- Hardware Attacks
- Hardware Trust
- Hardware Counterfeiting
- Hardware-based Defenses
- Security-oriented Architectures
- Built-in security features
- PUFs (Physically Unclonable Functions)
- …

For each tile, many dimensions

- *Technology*
- *Target abstraction level*
- *Types of components*
- *Application domain*
- *System complexity*
- *System criticality*
- …

The role of Hardware in Cybersecurity

- Trying to move from a *mess* to a more *rigorous view*, the role of Hardware in security can be seen as follows:

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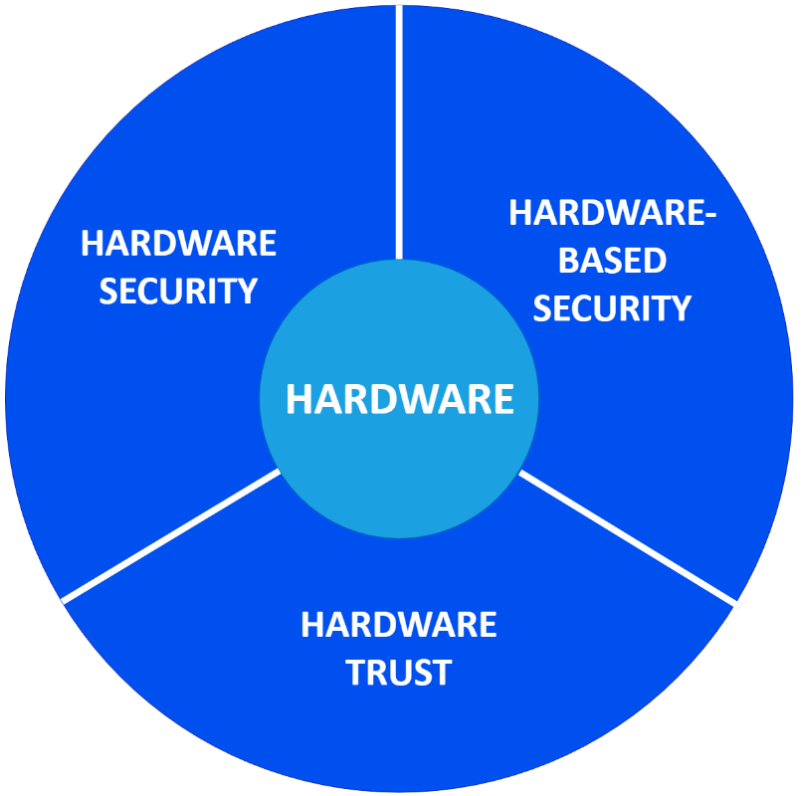

Outline

- The role of Hardware in Security
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- Hardware-based Security
- Hardware Trust

Hardware Security: What

- "*Everything*" related to:
  - *hardware vulnerabilities*:
    - Their analysis, identification, detection, prevention, remediation, patching, …
    - prevention of their exploitation
  - *hardware attacks*:
    - Any technique and solution aimed at preventing, mitigating, defeating, making them ineffective, regardless the tools and the abstraction levels (e.g., software or any upper level) used to carry them out
  - *protection solutions*:
    - aimed at preventing hardware vulnerabilities and hardware attacks.

Hardware Security: When

- Hardware Security issues can be faced:
  - During the design and production phases (*Security-by-design*)
  - When hardware is already operating in the field.

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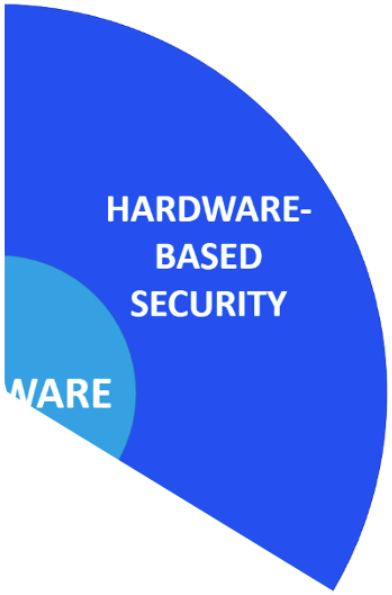
Hardware-based Security



- Refers to all those solutions aimed at resorting to hardware devices to protect the system from attacks that exploit vulnerabilities of *other* components of the system itself.

Remark

- To offer security features to upper layers, hardware itself must be secure at first
- From this point of view, *Hardware Security* play the role of a key *enabler* for *Hardware-based Security.*

Hardware-based Security Role

- *”Although hardware-based security is not a silver bullet, it does provide a “chain of trust” rooted in silicon that makes the device and extended network more trustworthy and secure.”*

[https://www.intel.com/content/dam/www/public/us/en/documents/solution-briefs/intel-security-essentials-solution-brief.pdf]

Hardware-based Implementations

- Hardware-based Implementations can be clustered as:
  - *System level solutions*
  - *Architectural level solutions*
  - *Security-oriented components*
  - *Proprietary Solutions*
  - *Open Security Platforms*
  - *Built-in Security Features*

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System level solutions

- Two significant standards:
  - *Trusted Platform Module*
  - *Trusted Execution Environments*

System level solutions

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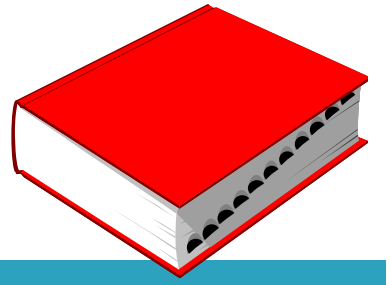
  - *Trusted Platform Module*
  - *Trusted Execution Environments*

Trusted Platform Module – TPM

- Standard guideline for developing chips with strong cybersecurity features
- Trustworthiness of TPM is based on different *Root of Trust* components and well-defined interactions among them

Root of Trust



- Component that needs to always behave in the expected manner because its misbehaviour cannot be detected

Root of Trust

- Trust in the *Roots of Trust* can be achieved through a variety of means including technical evaluation by competent experts.

Root of Trust - Role

- Is used as basic block for the construction of a *Chain of Trust*

TPM History

- Specification initially released by the *Trusted Computing Group* in 2003

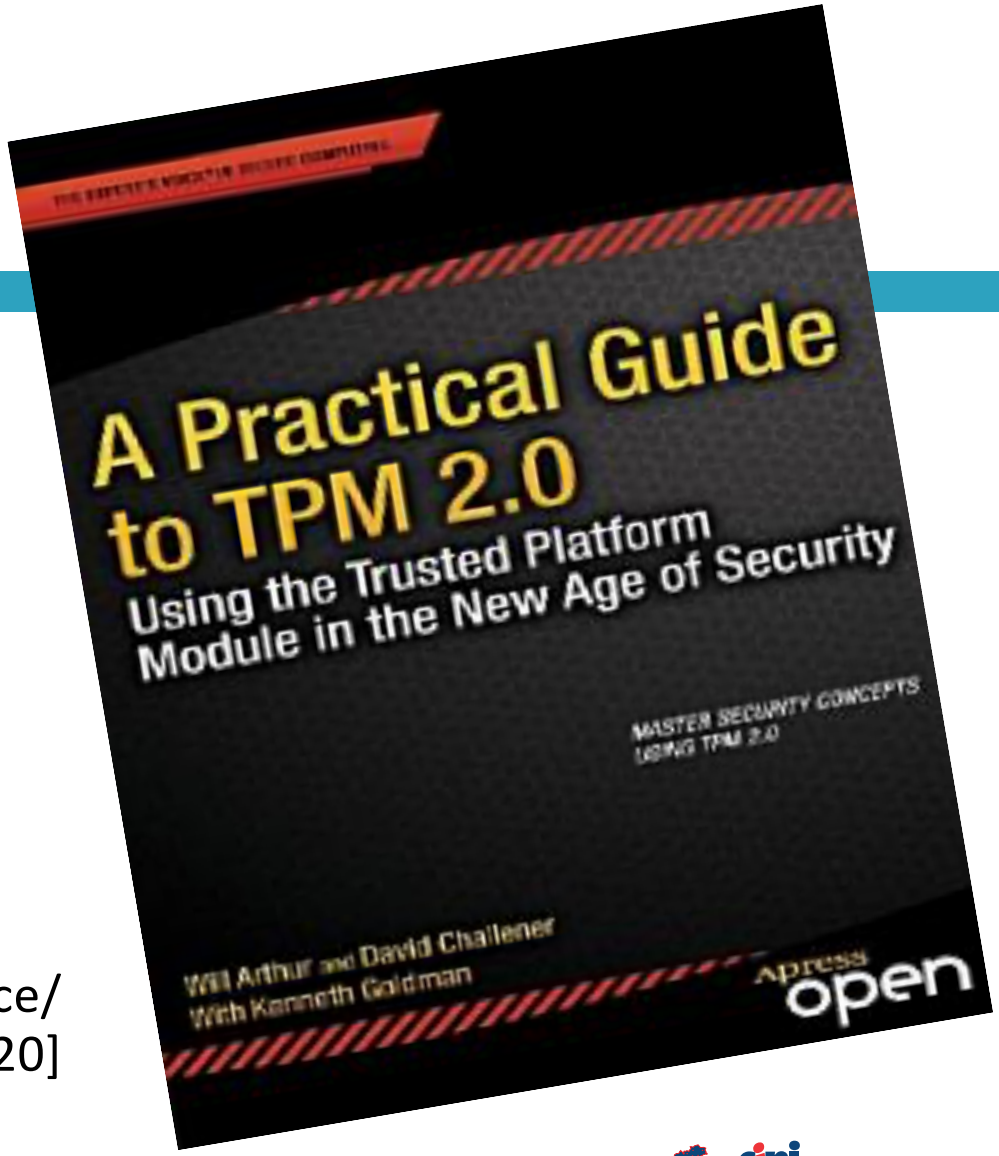
[https://trustedcomputinggroup.org/]

- The current version is TPM 2.0, which is standardized under ISO/IEC 11889

[https://www.iso.org/standard/66510.html]

[https://ebrary.net/24701/computer_science/a_practical_guide_to_tpm_20]

TPM 2.0



[https://ebrary.net/24701/computer_science/a_practical_guide_to_tpm_20]

System level solutions

- Two significant standards:
  - *Trusted Platform Module*
  - *Trusted Execution Environments*

Trusted Execution Environment

- TEE is a concept that provides a secure area of the main processor

  "to provide end-to-end security by protecting the execution of authenticated code, confidentiality, authenticity, privacy, system integrity and data access rights"

[Global Platform Device Committee, "EE protection profile," version 1.2, Public Release, November 2014, Document Reference: GPD_SPE_021 https://csrc.nist.gov/publications/detail/fips/140/2/final]

Trusted Execution Environments

- TEEs are secure area of a System-on-Chip that guarantee code and data protection
- They typically offer the minimal security required by low-end, closed embedded systems, such as IoT and “bare-metal” (i.e., without any Operating System) solutions.

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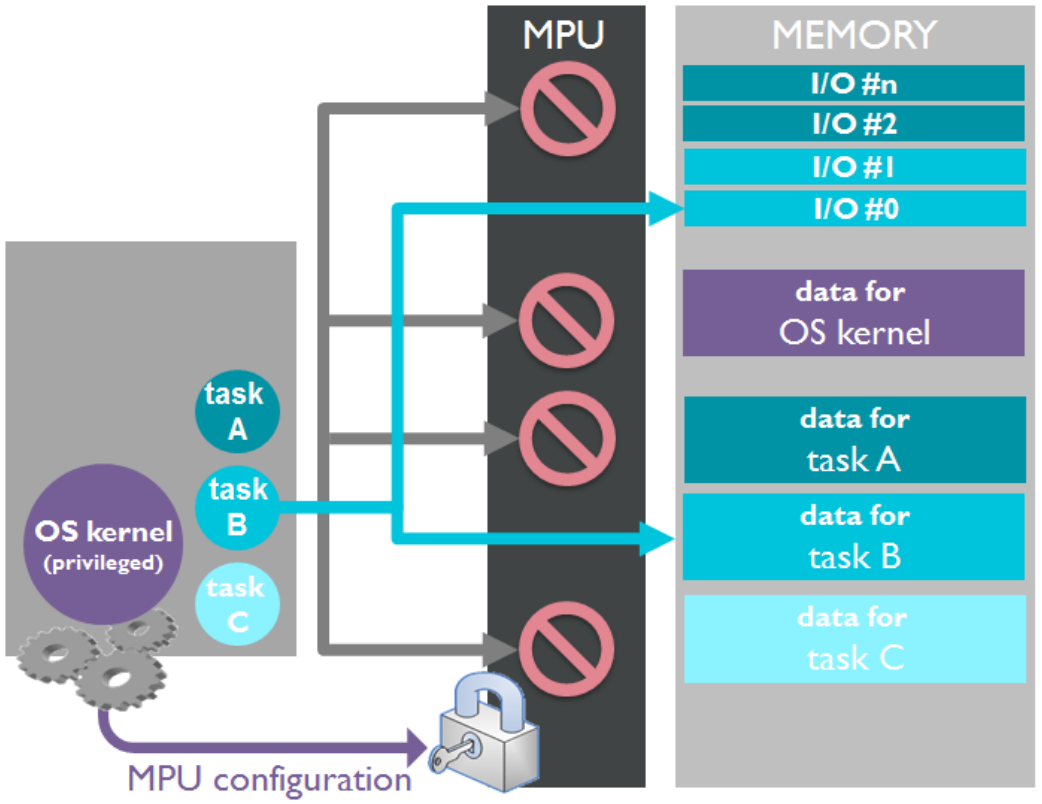
Architectural level solutions

- General purpose *Design-for-Security* solutions adopted at the architectural level, mainly to improve the security of the CPUs and of the involved memories.

Memory Protection Unit - MPU

- Present in a wider and wider number of processors
- Each memory page can be read, written or executed just by a predefined set of tasks/processes
- Access rights are decided by the kernel, which runs privileged
- Addresses sent to the memory are automatically processed by the MPU without the intervention of the kernel
- Violations cause the immediate abortion of the task



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Security-oriented components

- Set of custom, special purpose components used for performing specific security-oriented operations, including:
  - *Hardware Cyphers*
  - *Smart Cards & SIM Cards*
  - *Secure storage devices*
  - *Random Number Generators*

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Proprietary Solutions

- *Intel® vPro® Platform*
- *AMD Secure Technology™*
- *ARM® TrustZone®*
- *Microsoft BitLocker*
- *Synopsys DesignWare® tRoot™*
- *Apple Secure Enclave Processor*
- *Google Titan*
- *Cisco® Trust Anchor*
- *…*

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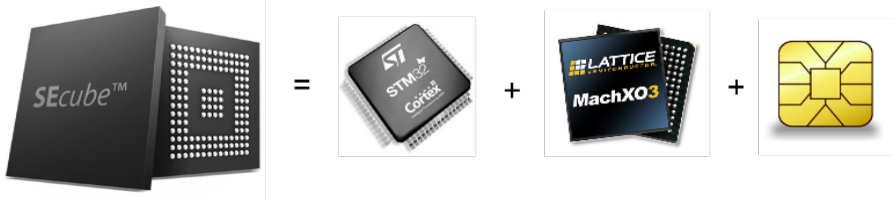
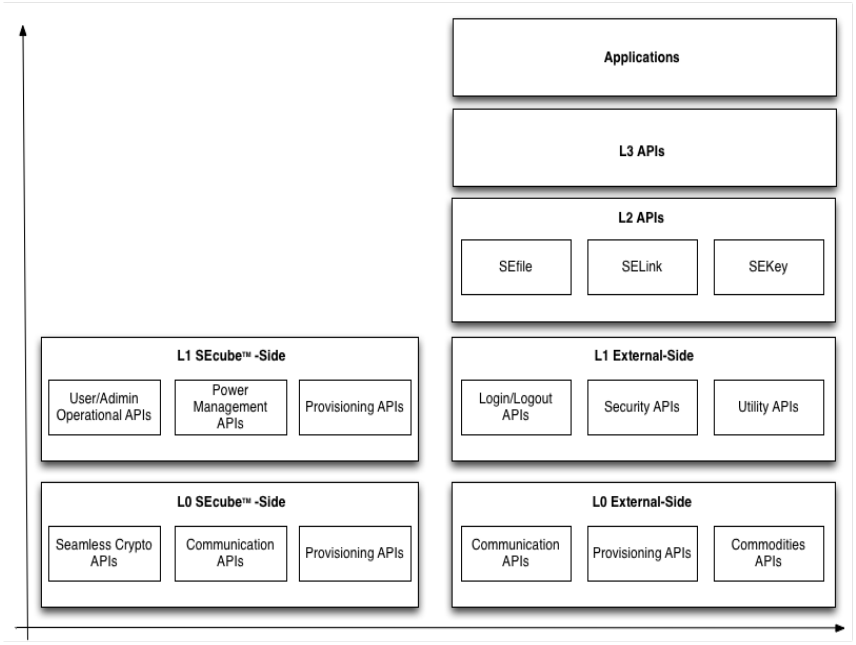
Open Security Platforms

- Platforms designed with cybersecurity in mind and packed with strong cybersecurity features:
  - Hardware accelerators for cryptography
  - Anti tamper
  - Secure boot process
- They include:
  - SE*cube*™
  - USB Armory

Hardware Platform – SE*cube*™

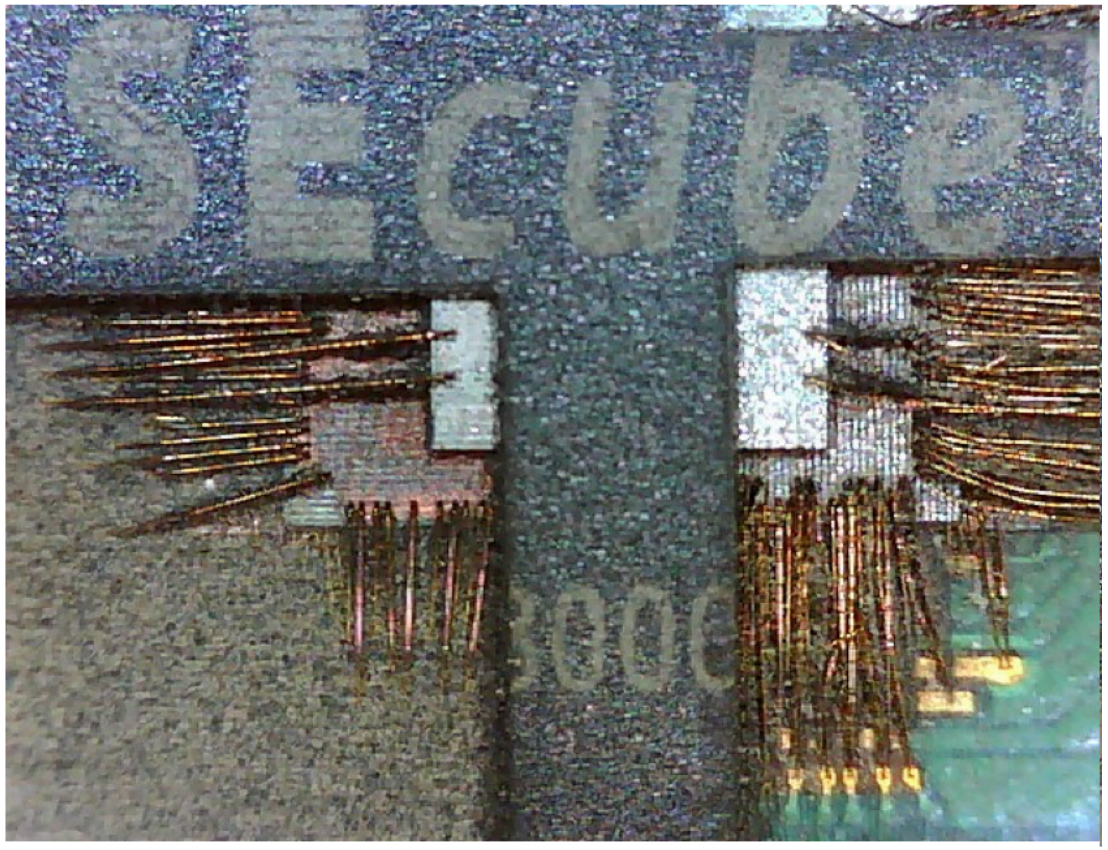
- System-In-Package developed by Blu5™ Group
  - Cortex-M4 microcontroller
  - Flexible and fast FPGA
  - SmartCard certified EAL 5+
- Strong Cybersecurity features and capabilities





[https://www.secube.eu/]

3D SiP – An Example: SEcube™



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Built-in Security Features

- Functionalities present in most of the modern microcontroller
- Mostly introduced for safety
- A proper exploitation could significantly increase the system protection against the common threats in the embedded system landscape

Outline

- The role of Hardware in Security
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Trust

- “A trusted component, operation, or process is one whose behavior is predictable under almost any operating condition and which is highly resistant to subversion by application software, virus, and a given level or physical interference.”

[ISO/IEC]

Authenticity and Trust

- *"An entity can be trusted if it always behaves in the expected manner for the intended purpose."*

[D. Grawrock, Dynamics of a Trusted Platform: A building block approach. Intel Press, 2008]

Hardware Trust : What

- "*Everything*" related to:
  - *hardware counterfeiting*:
    - Counterfeiting types
    - Counterfeiters
    - Counterfeiting detection approaches
    - Counterfeiting consequences
  - *protection from counterfeiting*:
    - Any technique and solution aimed at preventing counterfeiting in all the stages of the product lifecycle.

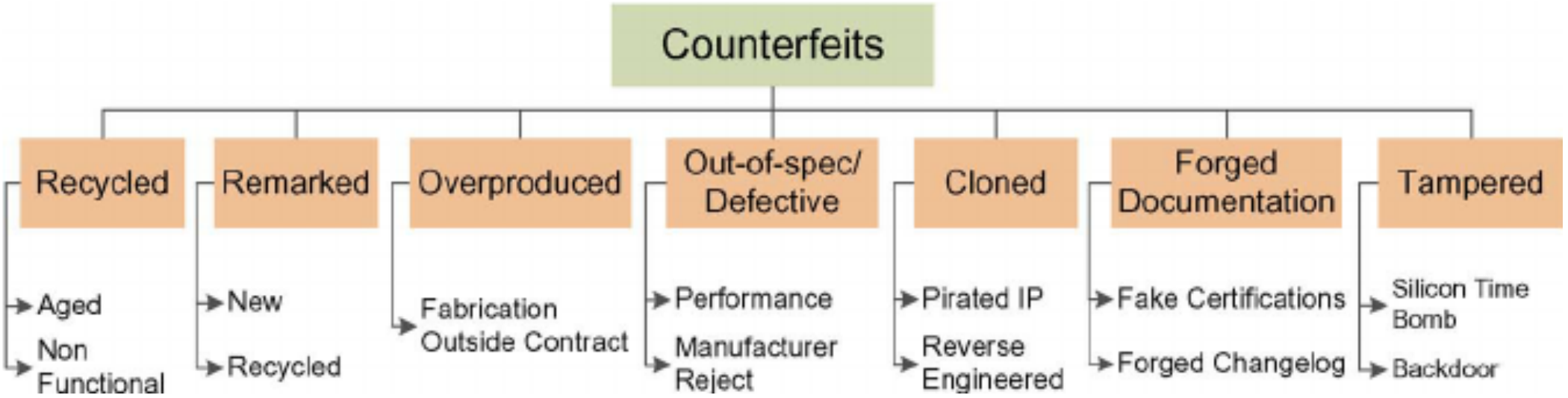
Hardware Trust : Role

- Hardware trust mainly concerns *Authenticity*.
- An asset treated or owned by an Information System component must come from an entity that is able to prove, beyond any reasonable doubt, its originality and genuineness.

Alarm

Counterfeiting of integrated circuits has become a major challenge in almost ALL industrial sectors !!

Counterfeiting types



[Ujjwal Guin, Ke Huang, Daniel DiMase, John M. Carulli, Mohammad Tehranipoor, and Yiorgos Makris: "Counterfeit Integrated Circuits: A Rising Threat in the Global Semiconductor Supply Chain", in Proceedings of the IEEE · August 2014 - DOI: 10.1109/JPROC.2014.2332291]

Counterfeiting

Causes

- Complexity of the electronic systems significantly increased over the past few decades
- To reduce production cost, they are mostly fabricated and assembled globally

Counterfeiting

Causes

- Complexity of the electronic systems significantly increased over the past few decades
- To reduce production cost, they are mostly fabricated and assembled globally

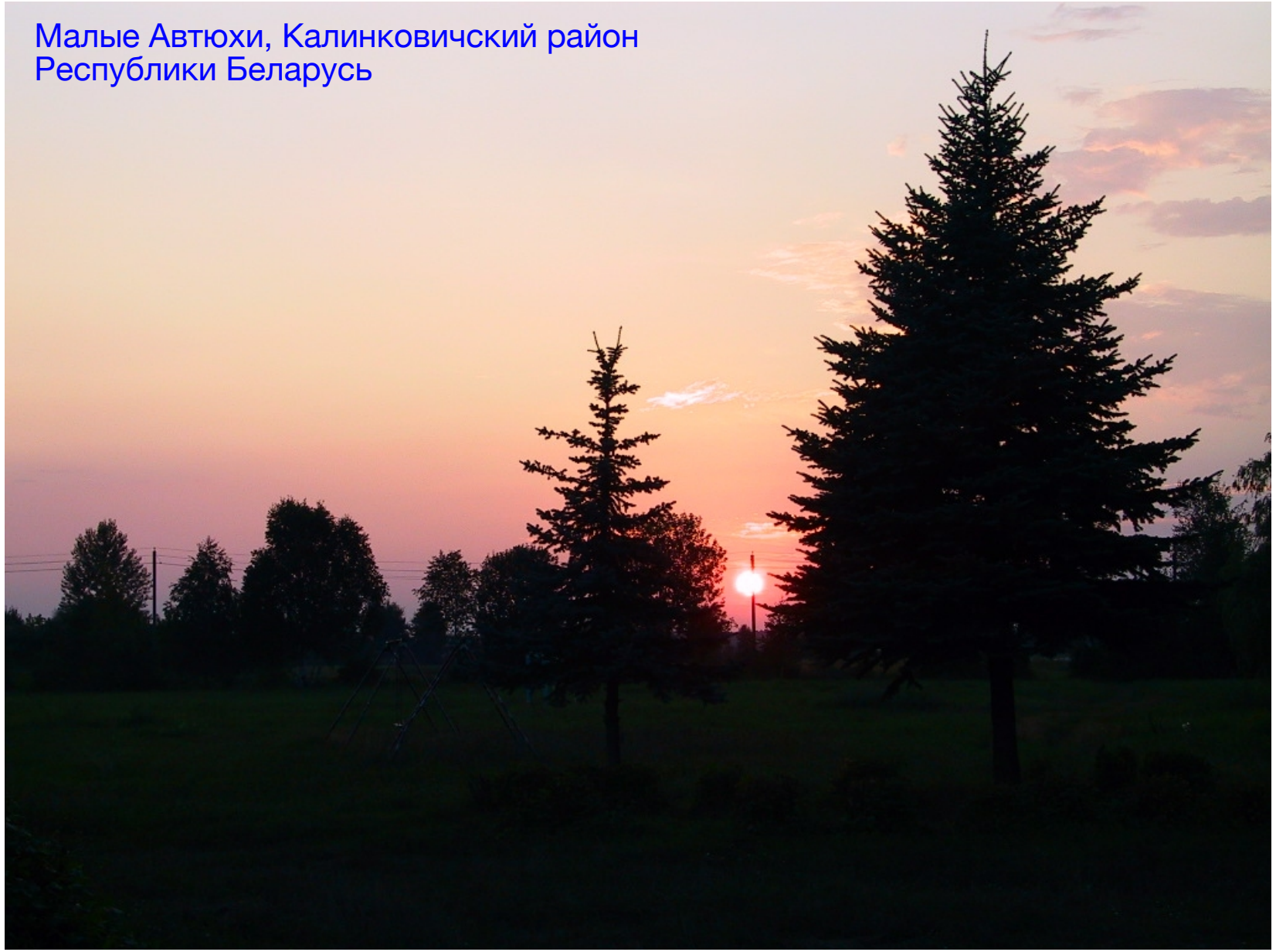
Consequences

- This globalization has led to an illicit market willing to undercut the competition with counterfeit and fake parts

Counterfeiting

Lacks

- Deficiencies in the existing test solutions
- Lack of low-cost and effective avoidance mechanisms in place



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