SECURE-IC
THE SECURITY SCIENCE COMPANY

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# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY: A NEW PARADIGM

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# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## INTRODUCTION

- Cyberspace: Are humans thrown on scrapheap?


DARPA's Cyber Grand Challenge: World's first automated network defence tournament

# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## INTRODUCTION

- **New trends, new risks, new strategy?**
  - Manpower: short on cybersecurity professionals
  - Cyber-attack: “Zero-day attacks” are on the rise
  - Physical-attack: IoT - Internet of things VS Internet of threats/targets

- **Sword and shield dialectic: find the right balance to stay ahead of the threat**

“Are we going to be able to predict every attack? No. Are we going to be better about predicting trends and threats so that we’re ahead of the game? Yes.”

**Terry Halvorsen**

Chief Information Officer, U.S. Department of Defense

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## AGENDA

INTRODUCTION: New risks, new strategy?

- ML-ENHANCED SECURITY ANALYSIS
  - ML-based Side-Channel Analysis
  - Secure-IC's CTZ: Analysis booster
  - ML- enhanced Cache timing attack
- AI-ENABLED CYBER-PHYSICAL SECURITY
  - Context & Motivations
  - Secure-IC's SMART MONITOR: Features & Benefits
  - Roadmap

CONCLUSION: Trustworthy AI

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## ML-ENHANCED SECURITY ANALYSIS

### ML-based Side-Channel Analysis

- **Profiling-based attacks** when leakage model unknown
- ML = alternative to traditional statistical tools;
- Ad-hoc metrics for cyber-security such as Data Confusion Factor, etc.

### A wealth of ML algorithms

- E.g. Support Vector Machines (SVM), Random Forest (RF), Rotation Forest (RTF), MultiBoost
- Complex and crucial parameter tuning

Side-Channel Analysis and Machine Learning: A Practical Perspective

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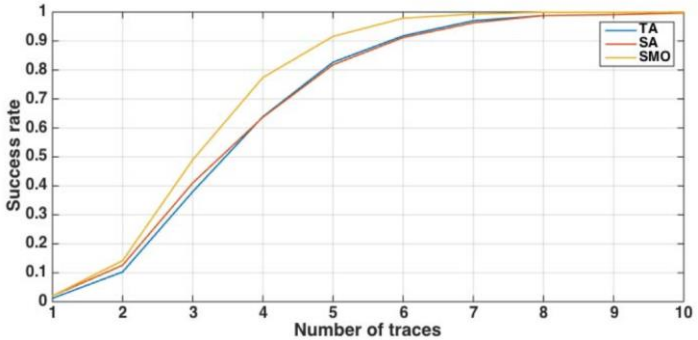
‡University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia
§Department of Computer Science, North Dakota State University, Fargo, ND, USA
¶TELECOM-ParisTech, Paris, France and Secure-IC S.A.S., Rennes, France



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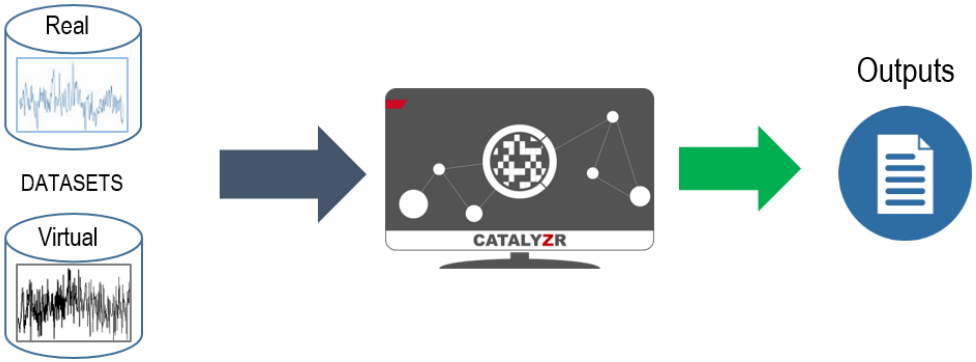
## ML-ENHANCED SECURITY ANALYSIS

### Secure-IC's CTZ: Analysis booster




**REVEAL**

Signal Processing
Pattern Recognition

**LOCATE**

Features Extraction
Leakage Detection

**EXTRACT**

Data Mining
Machine Learning

# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## ML-ENHANCED SECURITY ANALYSIS

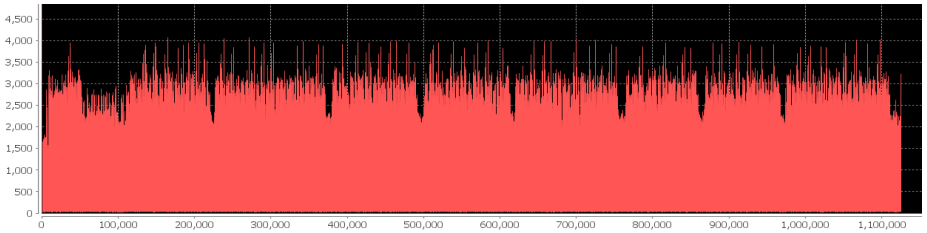
### Secure-IC's CTZ: Analysis booster

**Target:** **Elliptic Curve Cryptography (ECC)** from a widely used encryption library
Attacked Operation: Point Multiplication during an authentication in an advanced system (smartphone, complete SoC)

**Goal:** Extract the crypto-processor signal and relate it to the code executed

**Problems:** Highly challenging attack on classical tools:

- Large, high frequency and very noisy measures
- Only one measure available!

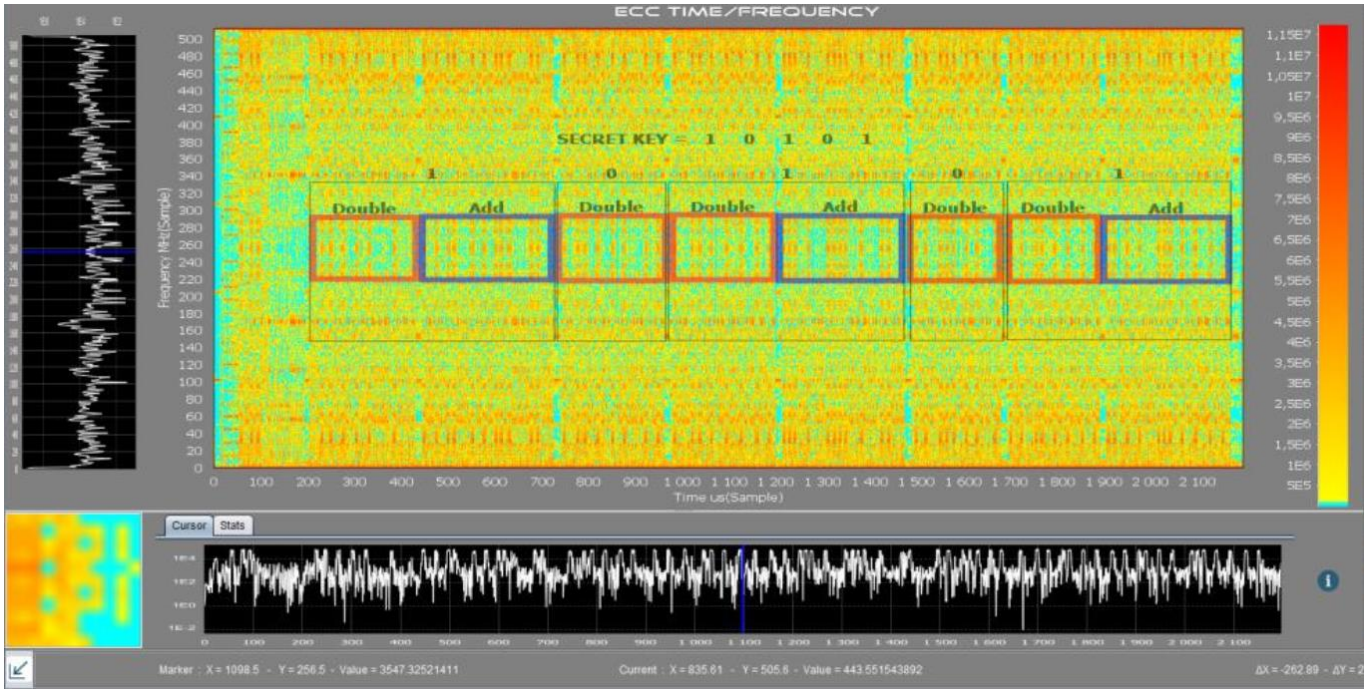


# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## ML-ENHANCED SECURITY ANALYSIS

### Secure-IC's CTZ: Identification, Classification and Extraction of Secret

- Apply Data Mining and Machine Learning on the new data representation



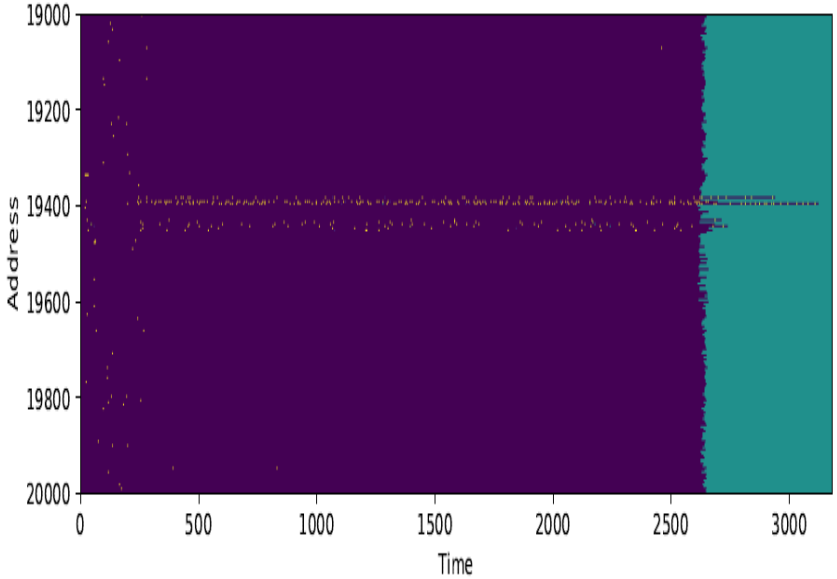

[1] Nakano, Y., Souissi, Y., Sauvage, L., Danger, J. L., Guilley, S., et al (2014, June). A pre-processing composition for secret key recovery on Android smartphone. In *IFIP International Workshop on Information Security Theory and Practice* (pp. 76-91). Springer Berlin Heidelberg.

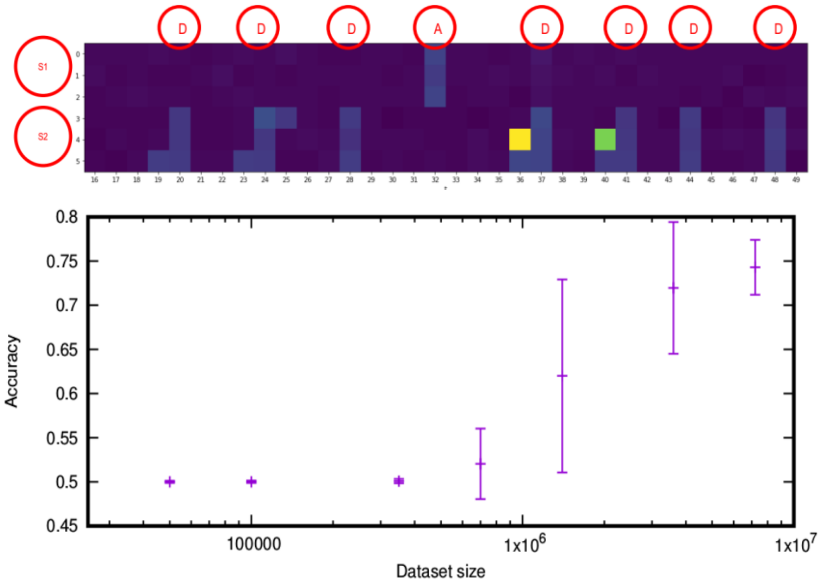
# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## ML-ENHANCED SECURITY ANALYSIS

### ML-enhanced Cache Timing attack

- Cache miss & Cache hit patterns could reveal sensitive information (leakage)
- Deep-learning on cache access patterns
- E.g. OpenSSL ECDSA - Nonce LSB recovery using convolutional neural networks



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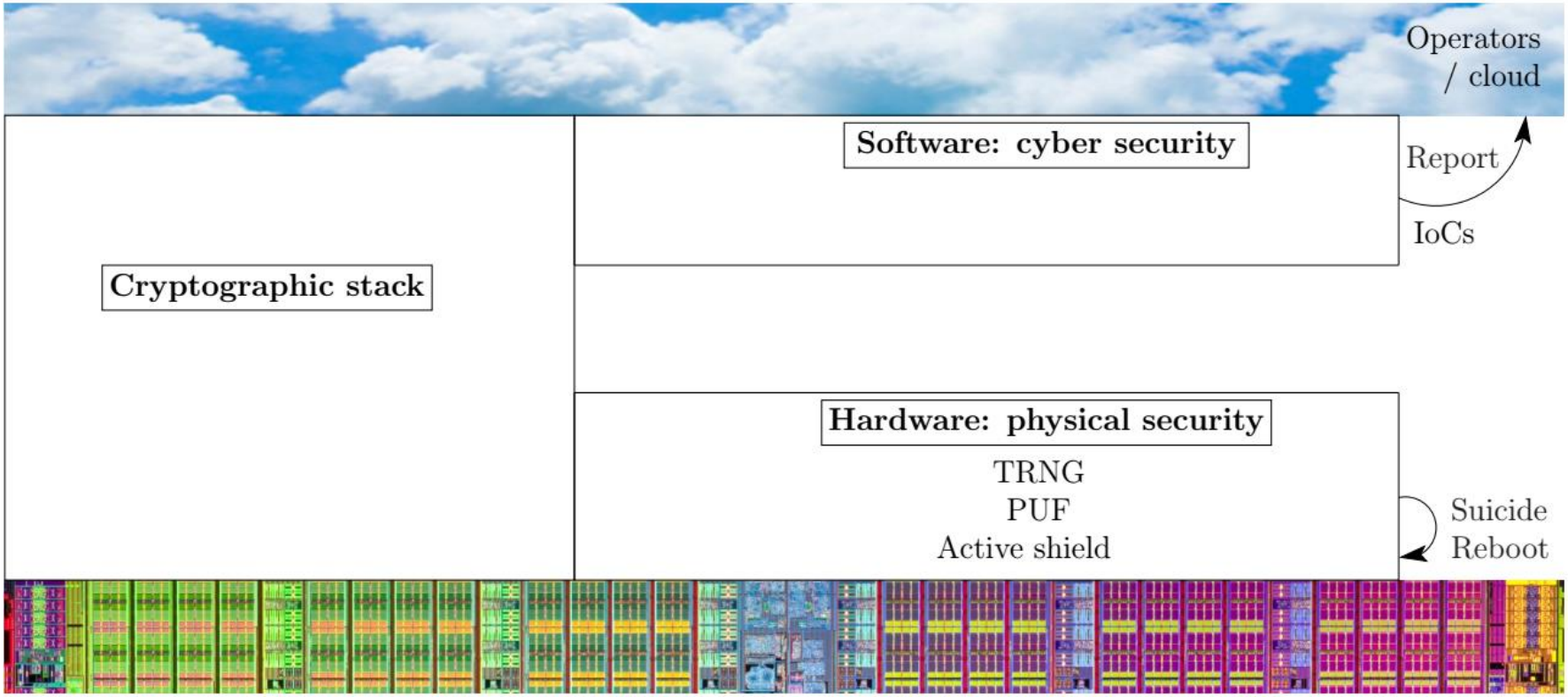
## AI-ENABLED CYBER-PHYSICAL SECURITY

### Motivations: Security at OSI Level – Our Vision



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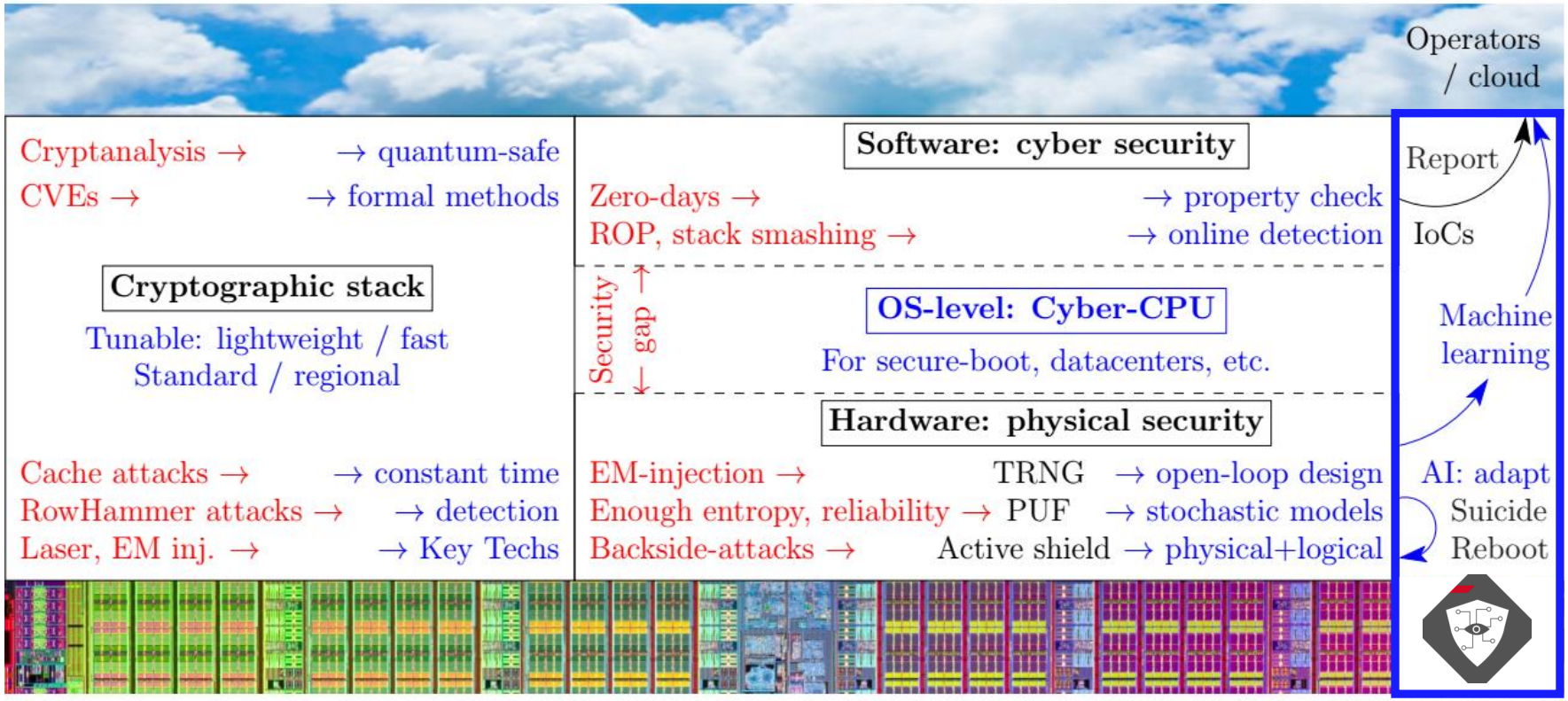


**Caption:** attacks/threats in red, innovative solutions by SIC in blue.

# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## AI-ENABLED CYBER-PHYSICAL SECURITY

- **Secure-IC's SMART MONITOR: AI for embedded systems**

  - **Create collective intelligence between IPs and other whistleblowers**
    - Sources of information are diverse, abundant
    - Signals could come from on-chip analog sensors, digital sensors, software reports…
    - … or from opportunistic media (weak signals) = Indice of Compromission (IoC)

  - **By leveraging diversity and complementary**
    - Sensitive to physical vs logical malfunctions
    - Able to detect permanent problems vs transient issues
    - Instantiated multiple times

# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## AI-ENABLED CYBER-PHYSICAL SECURITY

- **Secure-IC's SMART MONITOR: AI for embedded systems**

### Gain assurance in Threat Detection

- Additional signals are aggregated for security event detection: multimodal analysis
- Learning phase to "lock down the perimeter" of attack
- Confidence & Robustness - Reduce false alarms and false positive event

### The right decision at the right time in full knowledge

- Anatomy of an attack (nature, temporality, locality, intensity, attack phase…)
- Gain advantage over attackers (attack diagnosis): reverse the advantage
- Built an on-chip security Headquarter to react properly – Security strategy

### Business Intelligence

- Know your device's every-day life
- Attack typology and statistics for ≠ device categories, geographic areas, technology nodes…

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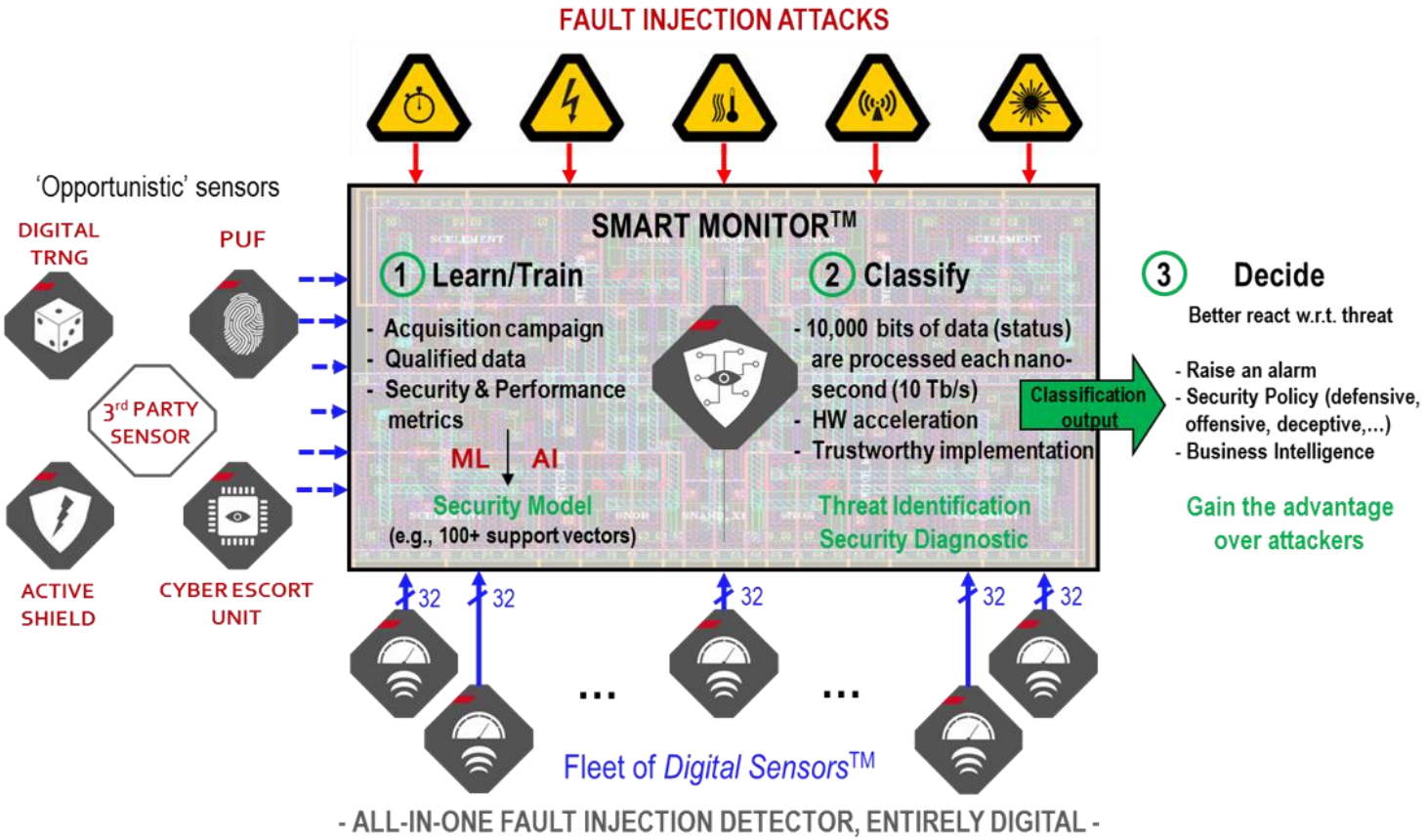
## AI-ENABLED CYBER-PHYSICAL SECURITY

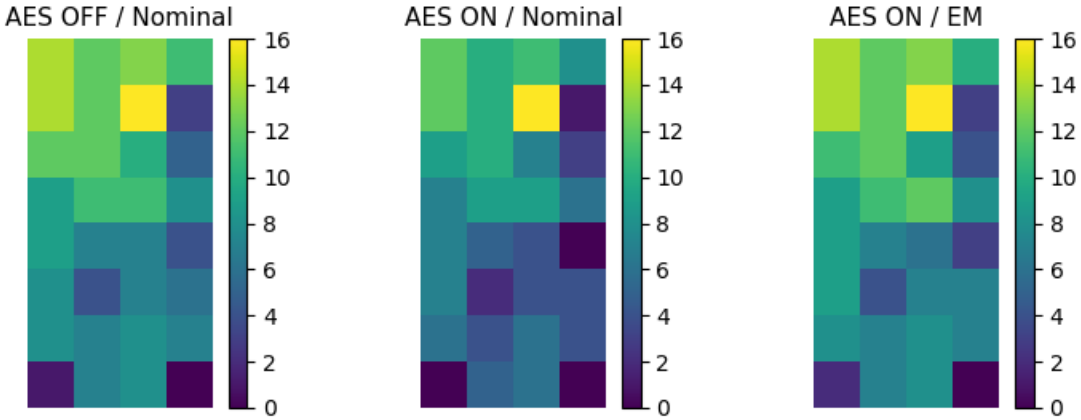
### Global Architecture: Supervisor – Command and control center

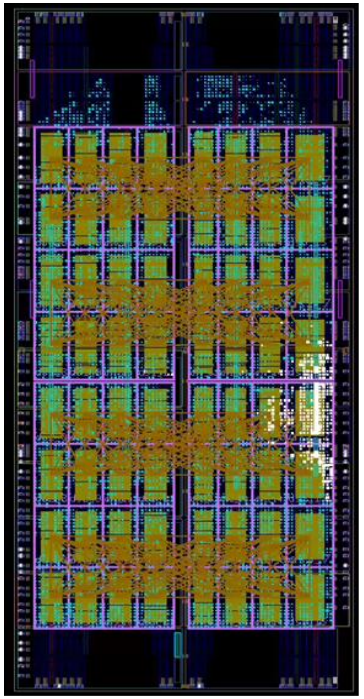


# HARDWARE-ENABLED AI FOR EMBEDDED SECURITY

## AI-ENABLED CYBER-PHYSICAL SECURITY

- Use-case : ML-enhanced EM Fault Injection Detection
  - A Fleet of Digital Sensors (DS) + HW AES on multiple targets (FPGA, ASIC)
    Individually, each DS allows to detect local variation of propagation time along a delay chain…



… but sensitivity is small, for internal activity or low power EMFI.

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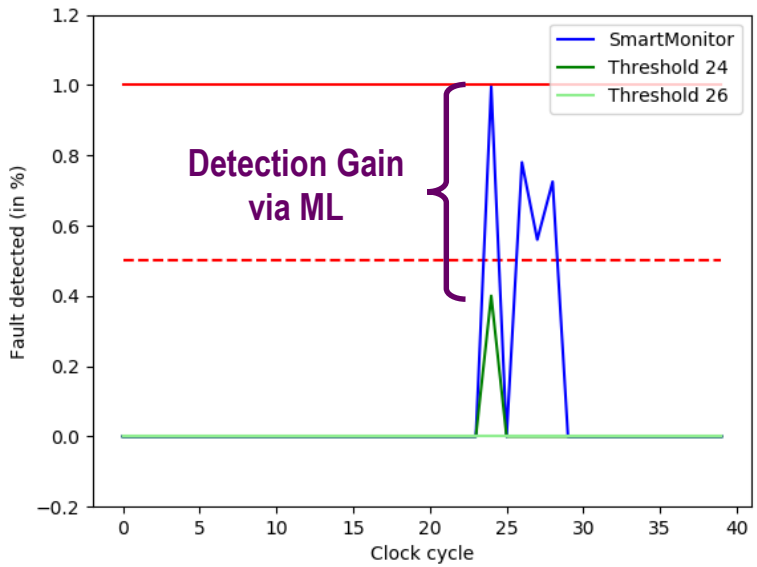
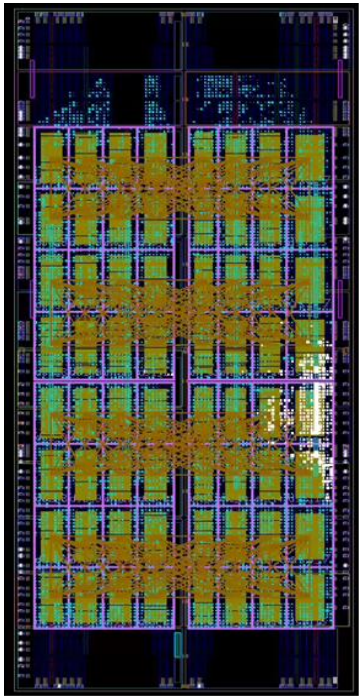
## AI-ENABLED CYBER-PHYSICAL SECURITY

- Use-case : ML-enhanced EM Fault Injection Detection
  - A Fleet of Digital Sensors (DS) + HW AES on FPGA

Collectively, DS status agregated and interprated by Secure-IC's Smart Monitor allow to improve notably the detection efficiency.



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## AI-ENABLED CYBER-PHYSICAL SECURITY

### Smart Monitor Roadmap

- Trade-off between performances & security: RAM cost, input signal rate, #classes, code size, etc..
- Study differential ageing of sensors / effect of sensor breakdown: a model per year?
- Dynamical feedback on the model (to adapt it) // AI
- Hardware, Software or a combination of both, depending whether reactivity or flexibility is most important

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## CONCLUSION

### Our convictions

- Bridging the gap between Hardware security and Cyber-security

Not just "patch and pray" but "security by design"

- AI is a real paradigm shift regarding cyber-protection… not just a new tool or an additional IP
- Make the hardware becoming a trust partner and not (another) attacker's accomplice

### Trustworthy AI

- Designing secure AI systems
- Validate and verify the safety and security of decision making systems (DMS)
- Adversarial ML

### Importance of Standardization

New SC 42 at ISO/IEC JTC 1 on AI (Trustworthiness = topic)

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# THANKS FOR YOUR ATTENTION

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