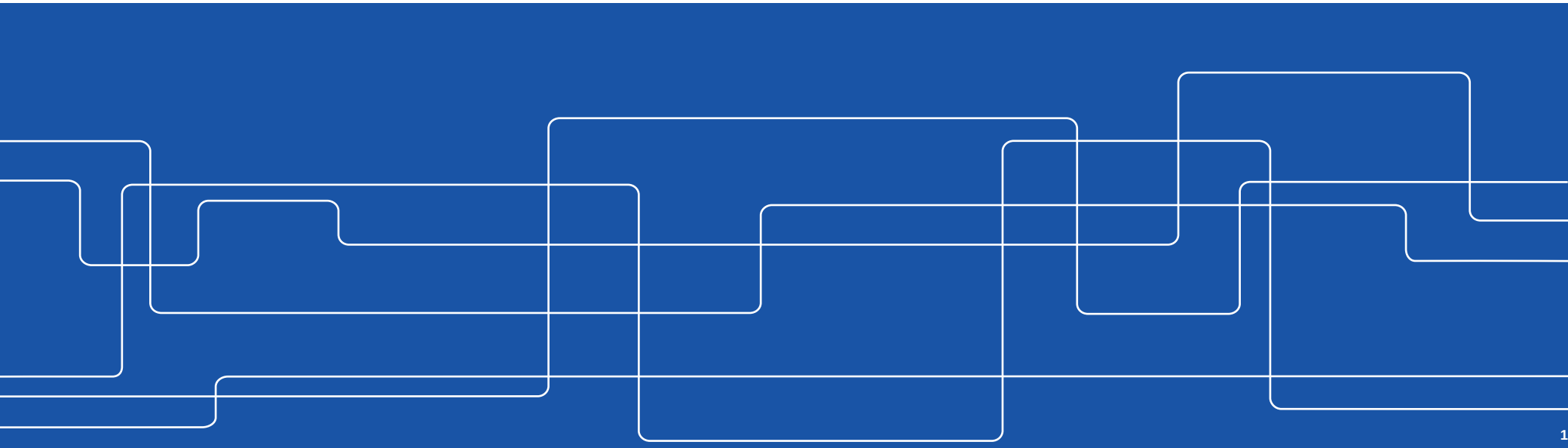
Securing Reconfigurable Hardware in the Era of AI

Elena Dubrova
School of Electrical Engineering and Computer Science
Royal Institute of Technology (KTH)



Motivation

- Reconfigurable hardware, such as Field Programmable Gate Arrays (FPGAs), is widely used for implementing cryptographic algorithms and accelerating AI-related workloads
- Available defense mechanisms do not provide adequate protection against physical attacks using ML techniques

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0000 0000 0048 0000 0000 0006 2000 0000
0000 0000 0000 0000 0000 0000 0000 0009
7300 0000 0000 0000 0000 0000 0000 0000
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b502 2000 0000 0100 d102 2000 0000 0000
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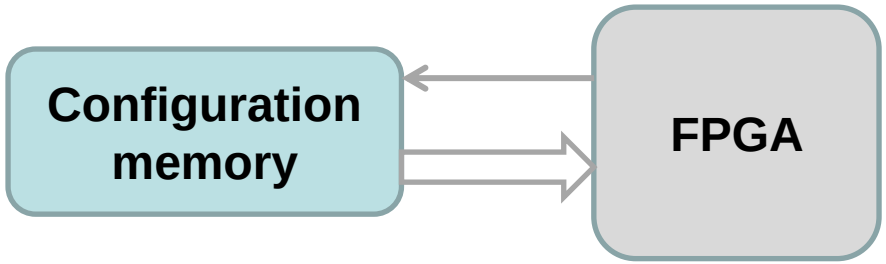
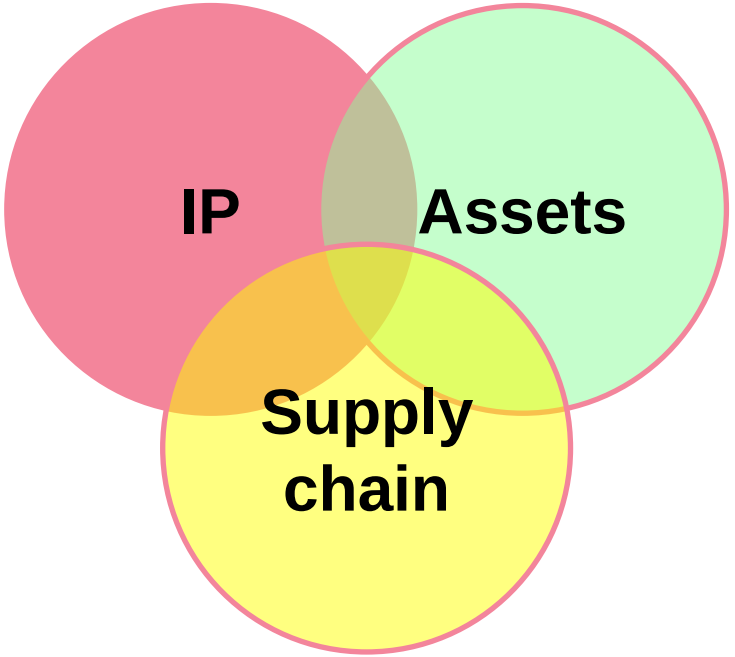
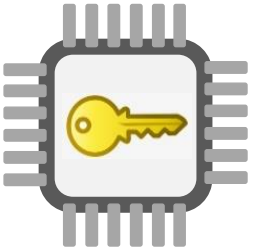


What needs protection?

Saab@MarcusWandt

Proprietary designs
Proprietary algorithms
Proprietary bitstreams

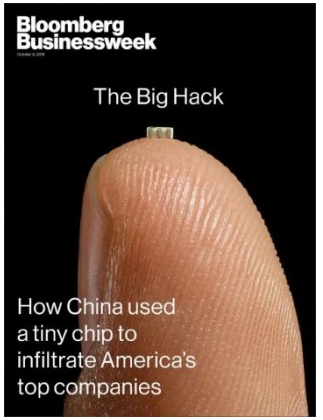




On-device data
On-device keys

source: http://www.publicintegrity.org/ 2011/11/07/ 7323/counterfeit-chips-plague-pentagon-weapons-systems

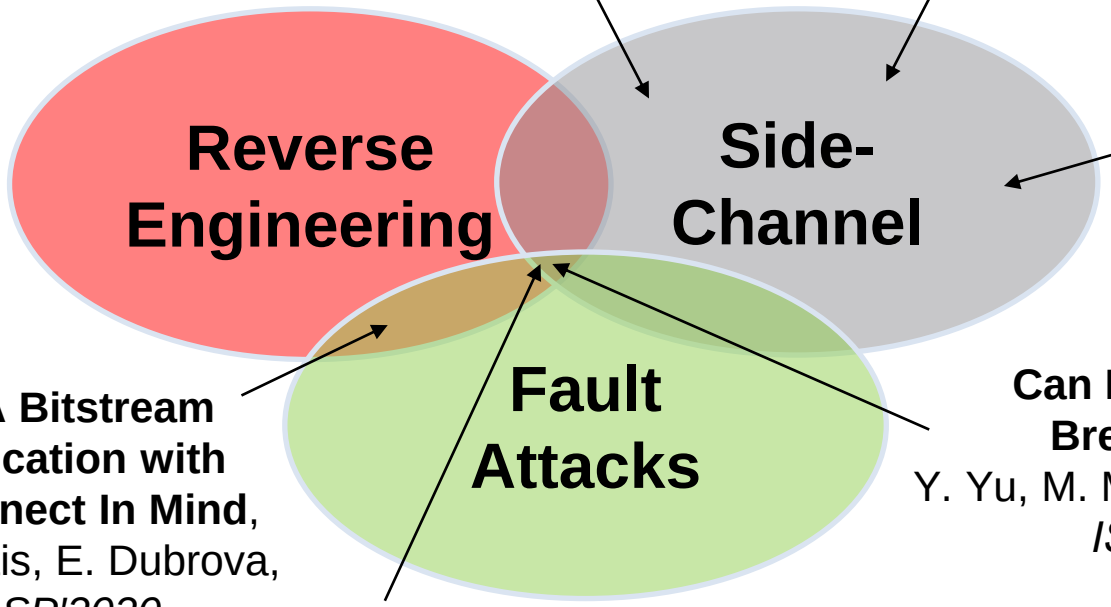
Preventing Hardware Trojans, counterfeit, overproduction



Physical attacks vectors

How Deep Learning Helps Compromising USIM, M. Brisfors, S. Forsmark, E. Dubrova, CARDIS'2020

A Side-Channel Attack on a Masked IND-CCA Secure Saber KEM, K. Ngo, E. Dubrova, Q. Guo, T. Johansson, *CHES'2021*



Far Field Side-Channel Attack on AES Using Deep Learning, R. Wang, H. Wang, E. Dubrova, *ASHES'2020*

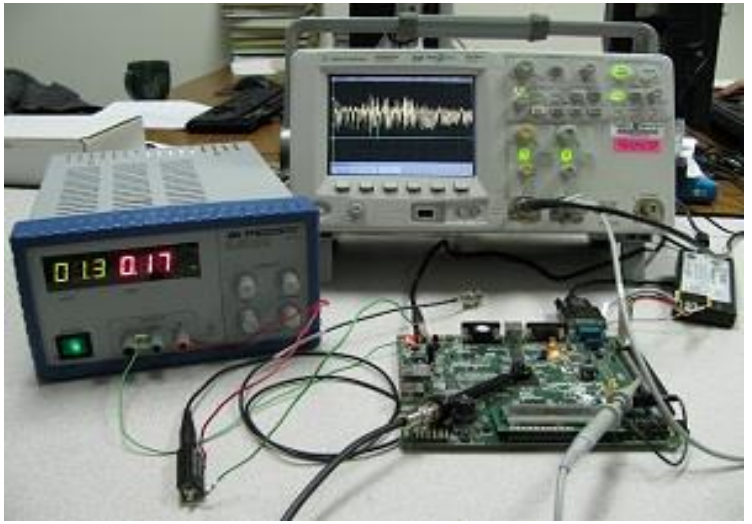
FPGA Bitstream Modification with Interconnect In Mind, M. Moraitis, E. Dubrova, *HASP'2020*

Can Deep Learning Break a TRNG? Y. Yu, M. Moraitis, E. Dubrova, *ISCAS'2021*

Why Deep Learning Makes it Difficult to Keep Secrets in FPGA-as-a-Service Setting, Y. Yu, M. Moraitis, E. Dubrova, *DYNAMIC'2020*

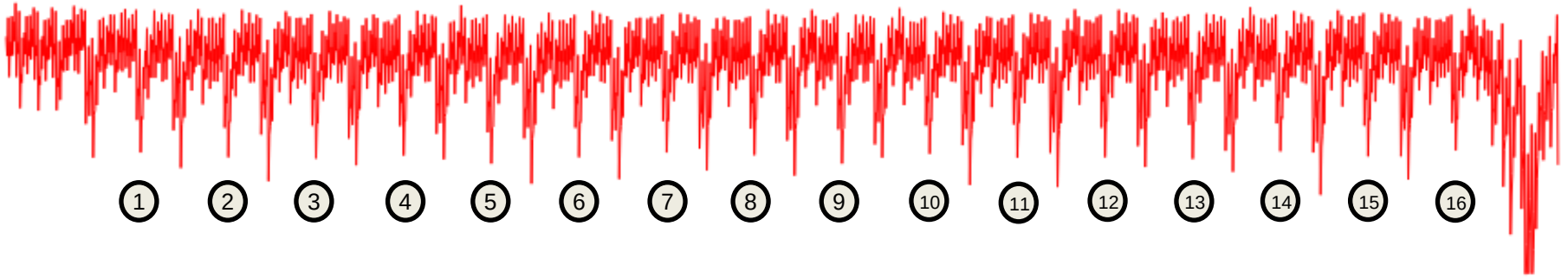
How side-channel attacks work

- Algorithms are implemented in physical devices which leak side-channel information
- It may be possible to recognize which data is processed by the device by measuring
  - Power consumption
  - Electromagnetic emission
  - Timing
  - …
- If data involves the secret key, the key may be recovered

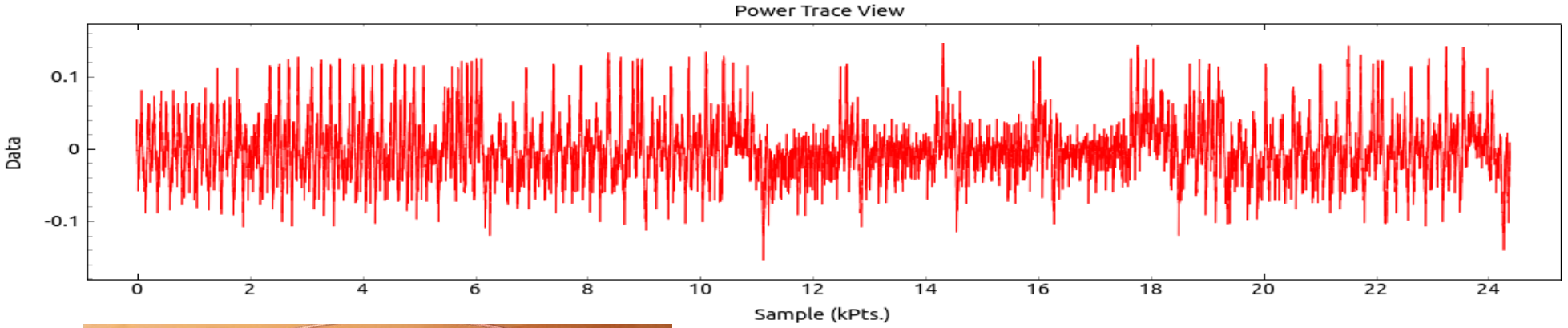


source: hackaday.com

Power trace representing 16 executions of AES S-box on 8-bit MCU (ATXmega128D4)



Previous related work: USIM power analysis



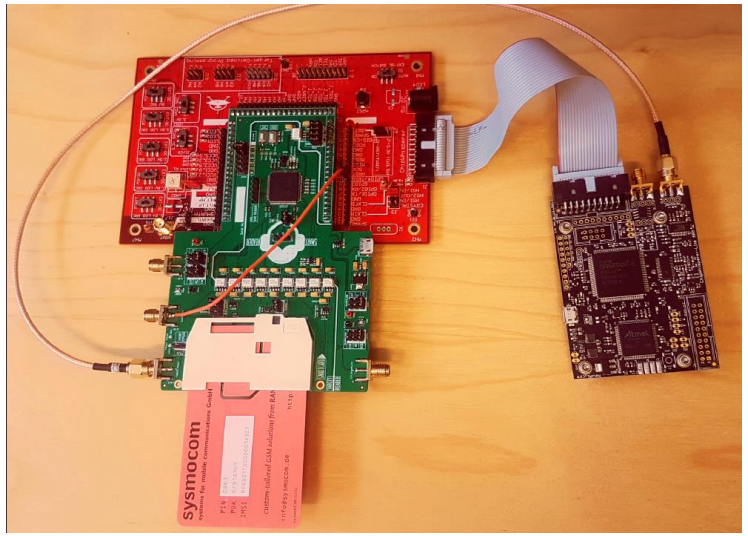


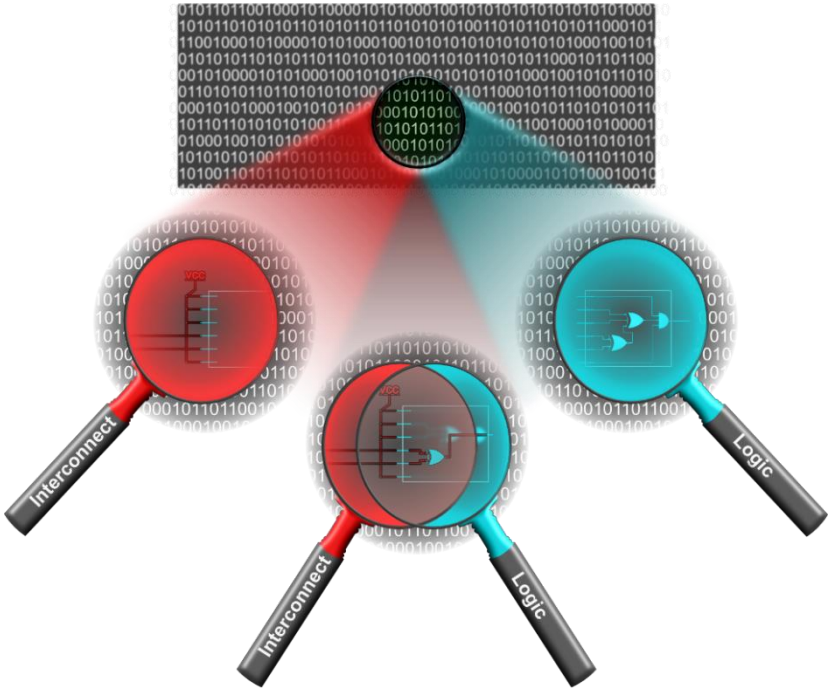
photo credit: Martin Brisfors

USIM's long-term key can be extracted from the USIM using 4 power traces on average (max 20)

How Deep Learning Helps Compromising USIM, M. Brisfors, S. Forsmark, E. Dubrova, CARDIS'2020, Nov. 18-19, 2020

Project goal

- Develop new hardware security assessment methods
- Design countermeasures against physical attacks on FPGA implementations
  - Secret key recovery
  - Neural network model extraction
  - Bitstream modification



picture credit: Michail Moraitis

Project structure

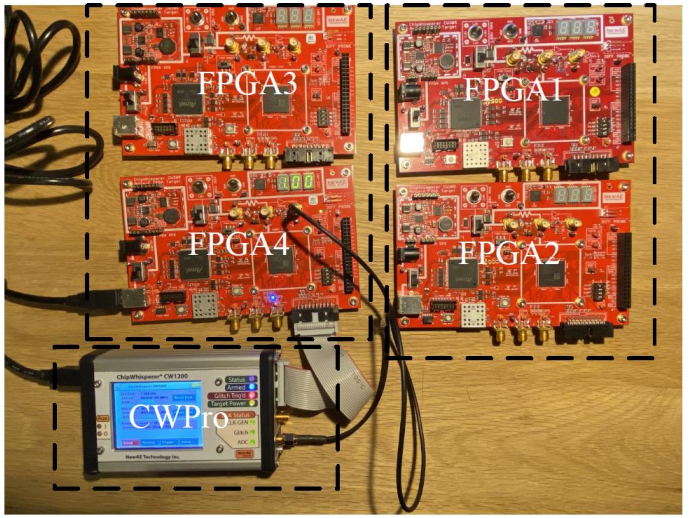


photo credit: Yang Yu

- 26 months project granted by VINNOVA (2021-07-01 - 2023-08-31)
- Two partners:
  - **KTH**: Elena Dubrova and two PhD students
  - **Ericsson**: Håkan Englund and Niklas Lindskog, Platform Security Group, Ericsson Research

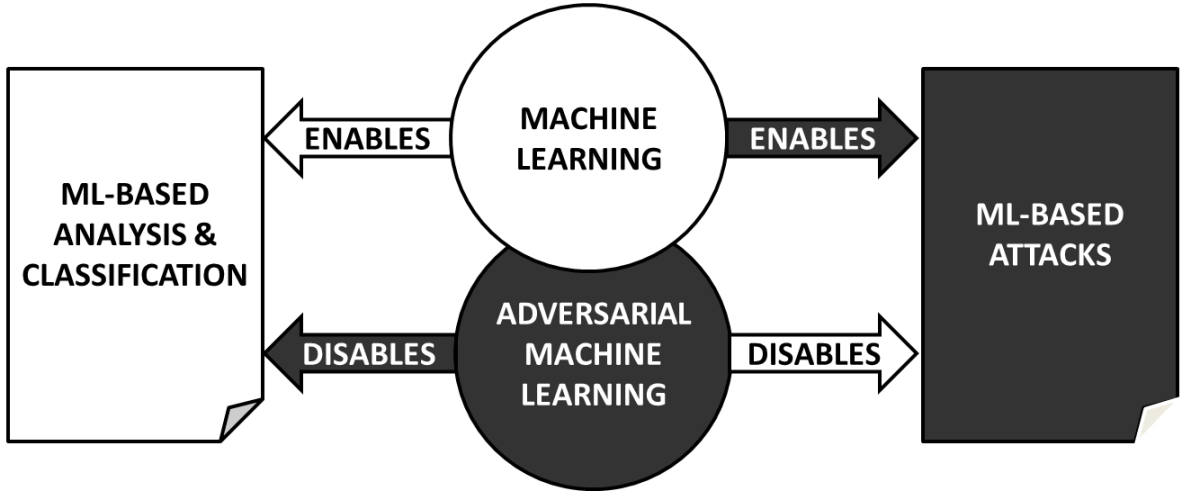
Results so far

- Work ongoing on:
  - Assesing security of bitstream encryption in Xilinx FPGAs
  - Designing countermeasures against bitstream modification
  - Searching for tamper-resistant key storage methods
- Dissemination activities
  - Hardware security course is offered as a Lifelong Learning course at KTH from 2020
  - Article in October issue of Elektroniktidningen

https://issuu.com/etndigi/docs/etn2110ld

Summary and next steps

- Deep learning side-channel attacks are very powerful, they can overcome traditional countermeasures
  - Masking, shuffling, noise addition, …
- We need to understand limitations of deep learning to design stronger countermeasures



Links to videos

How Deep Learning Helps Compromising USIM:

https://www.youtube.com/watch?v=7uJq1GIfTUY&feature=youtu.be

Far Field Side-Channel Attack on AES Using Deep Learning:

https://drive.google.com/file/d/1h7RmxIEFUQSFgwrIg8DnWPzDBws49FdG/view?usp=sharing

Saber Key Recovery demo:

https://youtu.be/5ydQAenyGSQ