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# Runtime Code Polymorphism as a Protection against Physical Attacks

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► **To cite this version:**

Damien Couroussé, Bruno Robisson, Thierno Barry, P Jaillon, Olivier Potin. Runtime Code Polymorphism as a Protection against Physical Attacks. Workshop on Cryptographic Hardware and Embedded Systems, Sep 2015, Saint-Malo, France. . emse-01232662

**HAL Id: emse-01232662**

**<https://hal-emse.ccsd.cnrs.fr/emse-01232662>**

Submitted on 23 Nov 2015

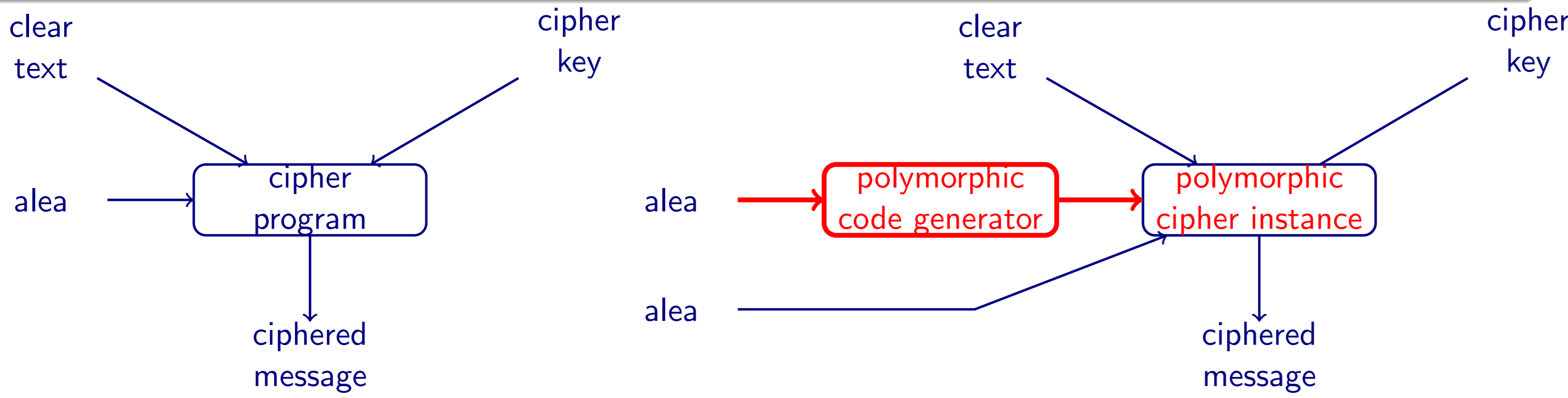
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## Core Idea: Runtime Code Polymorphism

### Definition

Regularly **changing the behaviour** of a (secured) component, **at runtime**, while maintaining **unchanged its functional properties**



Default cipher scheme (static)

With runtime code polymorphism

### Definition

Regularly **changing the behaviour** of a (secured) component, **at runtime**, while maintaining **unchanged its functional properties**.

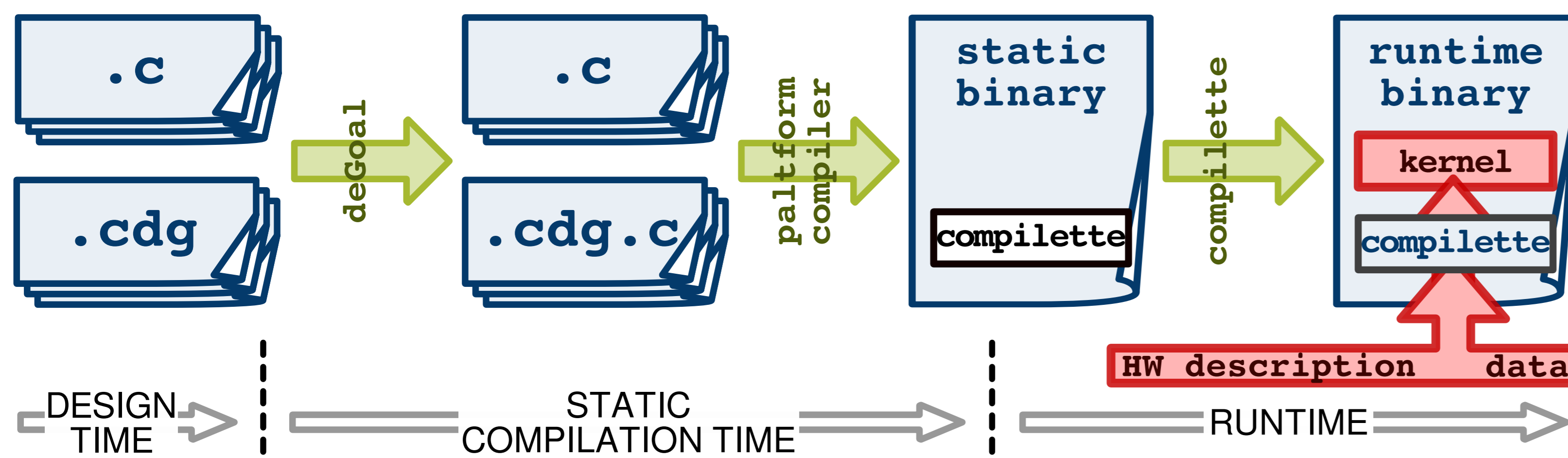
### What for?

- Protection against reverse engineering of SW
  - the secured code is not available before runtime
  - the secured code regularly changes its form (code generation interval  $\omega \geq 1$ )
- Protection against physical attacks
  - polymorphism changes the **spatial** and **temporal** properties of the secured code: side channel & fault attacks
  - combine with usual SW protections against focused attacks

### How?

- deGoal: runtime code generation for embedded systems
  - fast code generation
  - tiny memory footprint: proof of concept on TI's MSP430 (512 bytes of RAM)

## Complettes & deGoal in a Nutshell



### Aim

- Modify kernel's binary instructions
- according to the input data
- whenever needed at runtime

### The deGoal framework builds complettes

A complete is:

- an *ad hoc* code generator that targets *one* kernel
- aimed to be invocated at runtime

## Polymorphic Code Generation

### deGoal runtime capabilities

Performed *in this order*:

- register selection
- instruction selection
- instruction scheduling

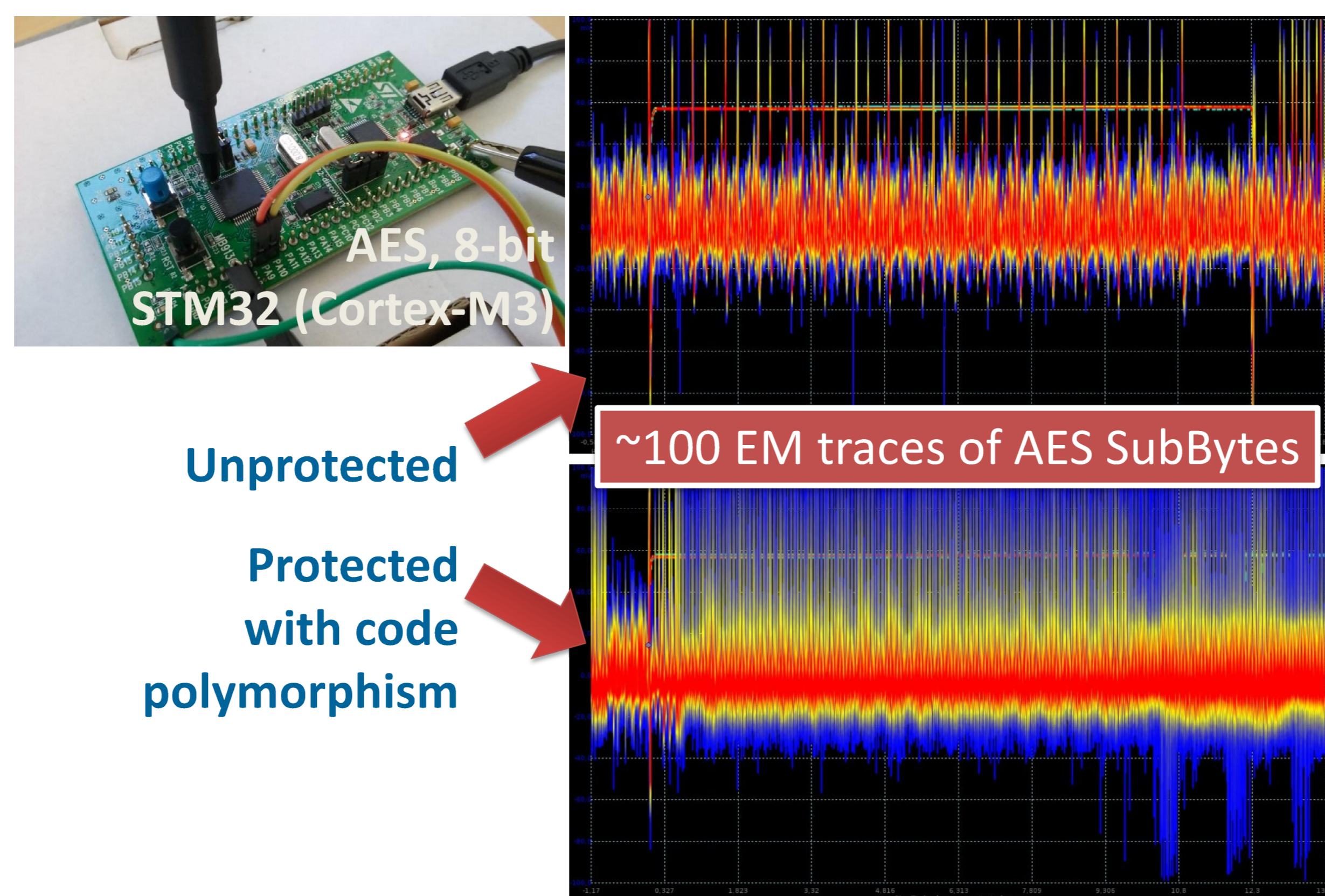
Adaptation to achieve runtime code polymorphism:

- Portability to very small processors and secure elements
  - Limited memory consumption
  - Fast runtime code generation
- Ability to combine with hardware countermeasures
- Introduce alea during runtime code generation [1,2,3]
- Polymorphism:
  - random mapping to physical registers [1]
  - use of semantic equivalences [2]
  - instruction scheduling [3]
  - insertion of dummy operations [3]

## Example: polymorphic AES

Polymorphic implementation of the SubBytes function:

```
void gen_subBytes( cdg_insn_t* code
                 , uint8_t* sbox_addr
                 , uint8_t* state_addr)
{
  #[
  Begin code Prelude
  Type uint32 int 32
  Alloc uint32 state, sbox, i, x, y
  mv state, #(state_addr)
  mv sbox, #(sbox_addr)
  mv i, #(0)
  loop:
    lb x, @(state+i) // x := state[i]
    lb y, @(sbox+x) // y := sbox[x]
    sb @(state+i), y // state[i] := y
    add i, i, #(1)
    bneq loop, i, #(16)
  rtn
  End
  ]#;
}
```



### Execution times (in cycles), over 1000 runs:

	min	max	average
reference	6385	6385	6385
code generator	5671	12910	9345
polymorphic instance	7185	9745	8303

### Impact of the code generation interval $\omega$ :

$\omega$	k	%
1	2.76	53.0%
5	1.59	18.4%
20	1.37	2.1%
100	1.31	1.1%

k: overhead vs. reference implementation  
 %: percentage contribution of runtime code generation to the performance overhead

### References

Overview of our approach for runtime code generation with complettes: H.-P. Charles, D. Couroussé, V. Lomüller, F. A. Endo, and R. Gauguey, "deGoal a Tool to Embed Dynamic Code Generators into Applications," in *Compiler Construction*, 2014, vol. 8409.

Runtime code generation for micro-controllers with less than 1kB RAM: C. Aracil and D. Couroussé, "Software Acceleration of Floating-Point Multiplication using Runtime Code Generation," in *Proceedings of the 4th International Conference on Energy Aware Computing*, 2013.

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