LR^2: Leakage-Resilient Layout Randomization for Mobile Devices

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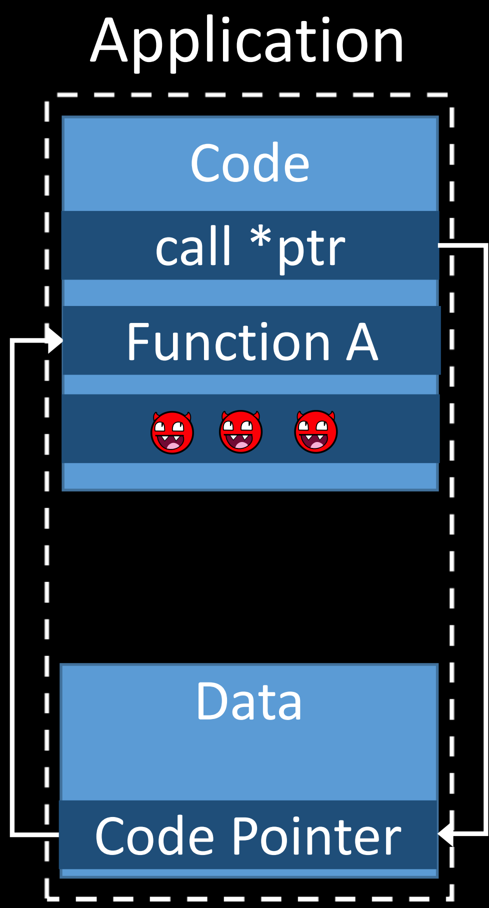
PROTECT
ALL THE NATIVE
CODES

Today's Exploits & Mitigations



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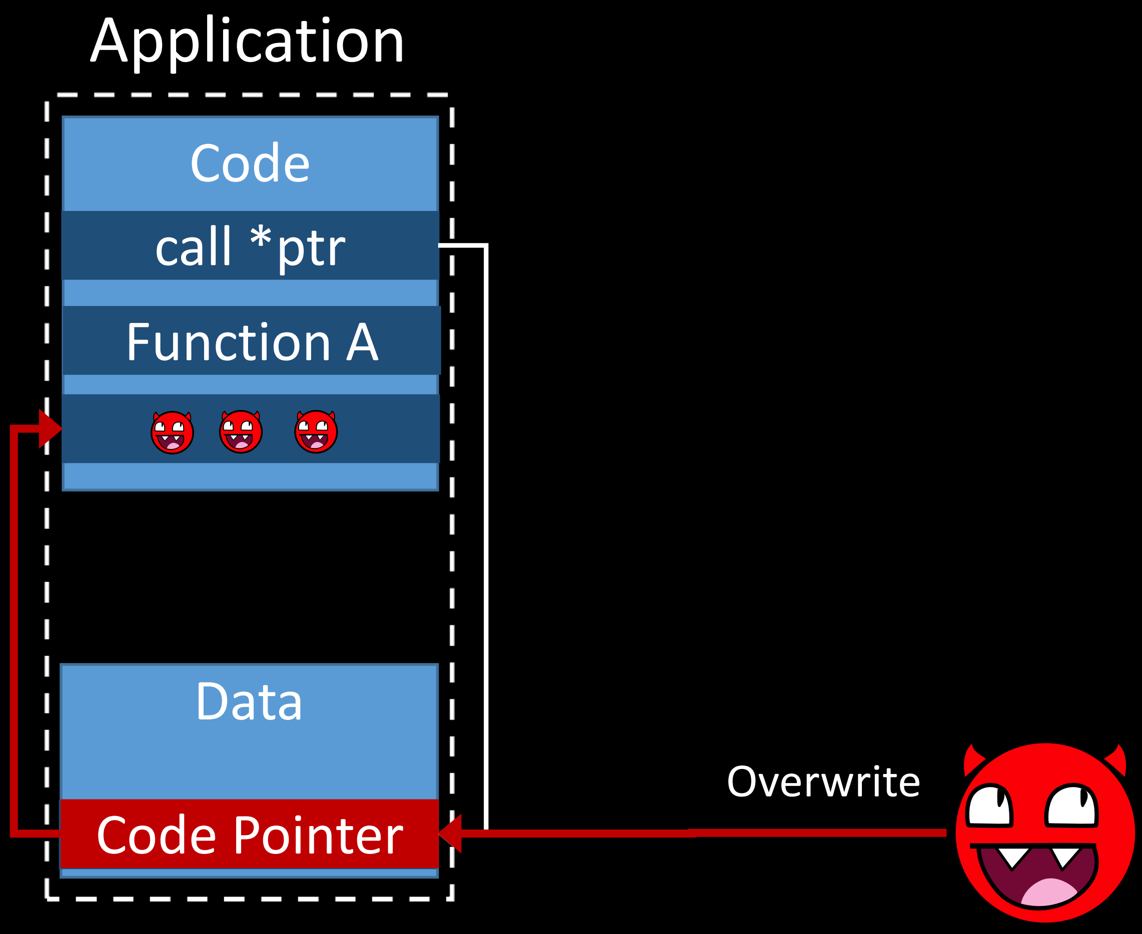

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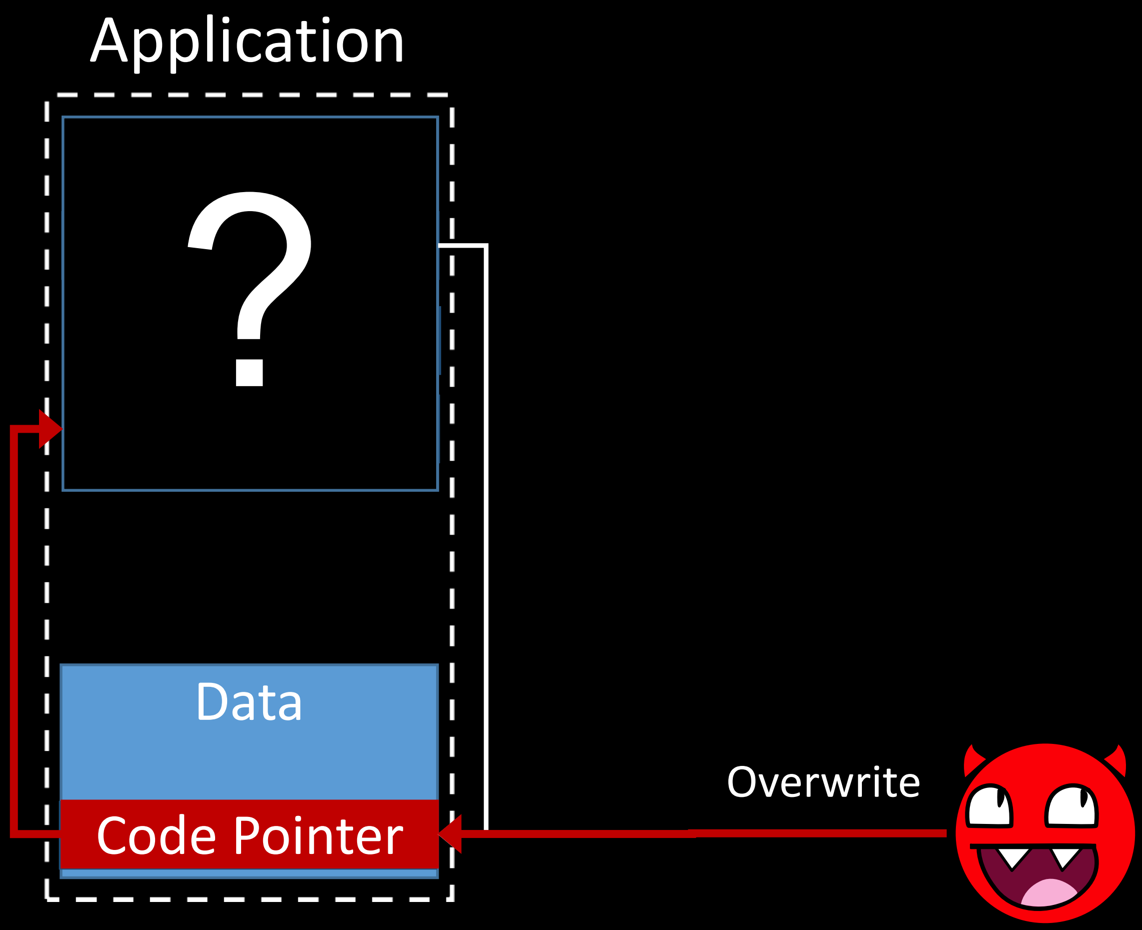

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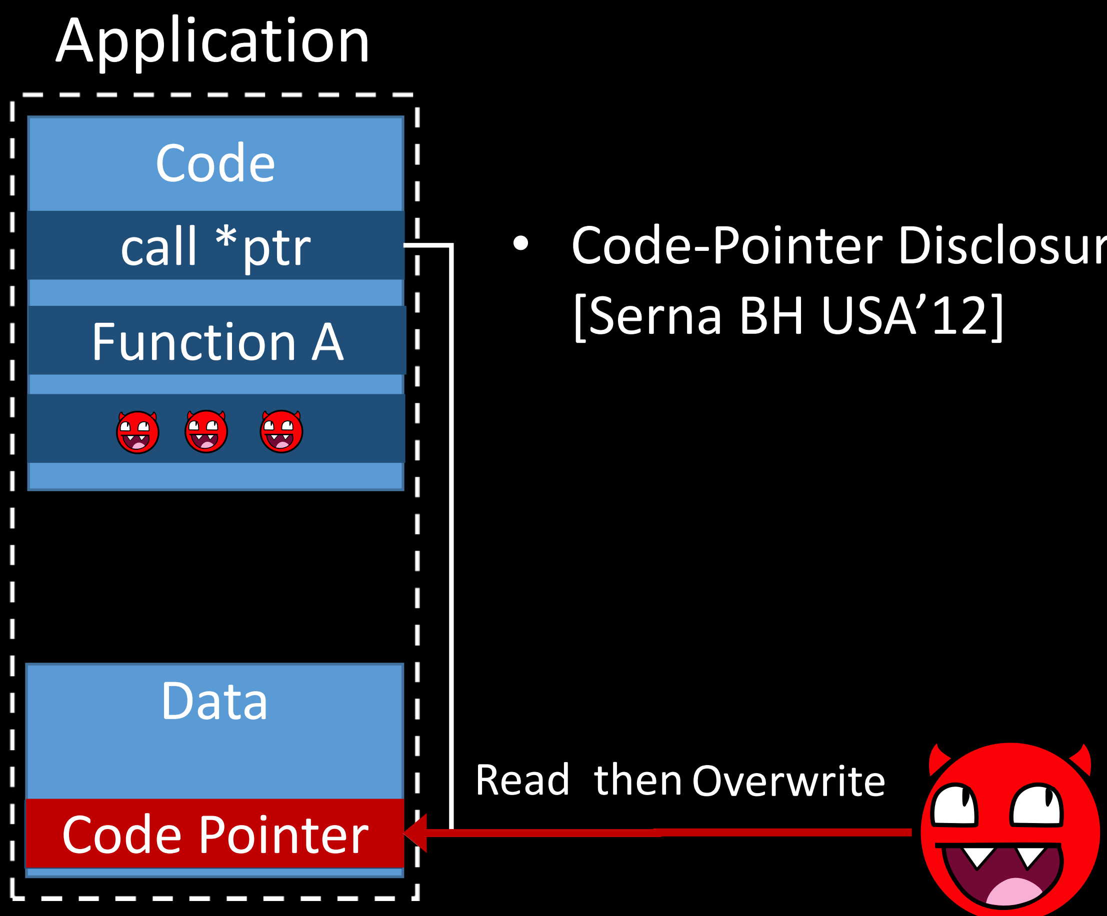

- Code-Pointer Disclosure [Serna BH USA'12]

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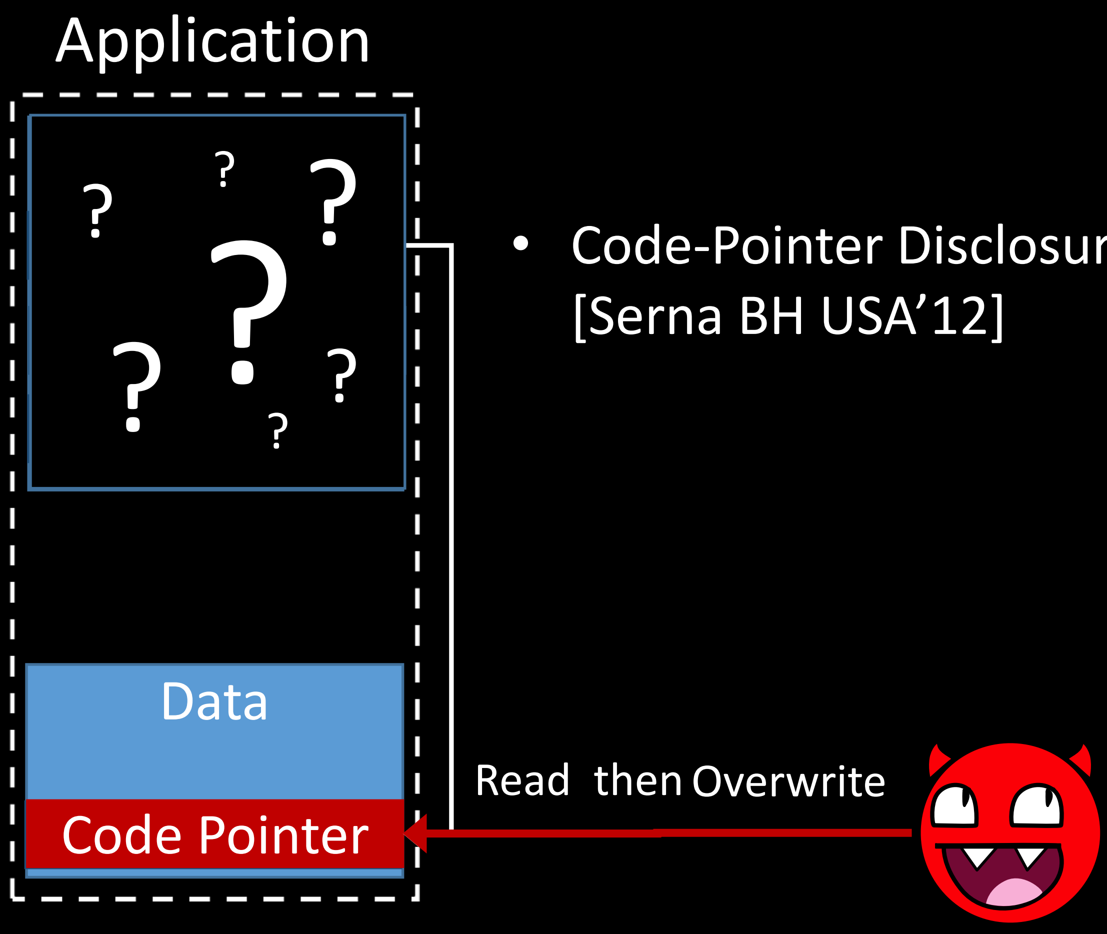
- Fine-grained Code Randomization



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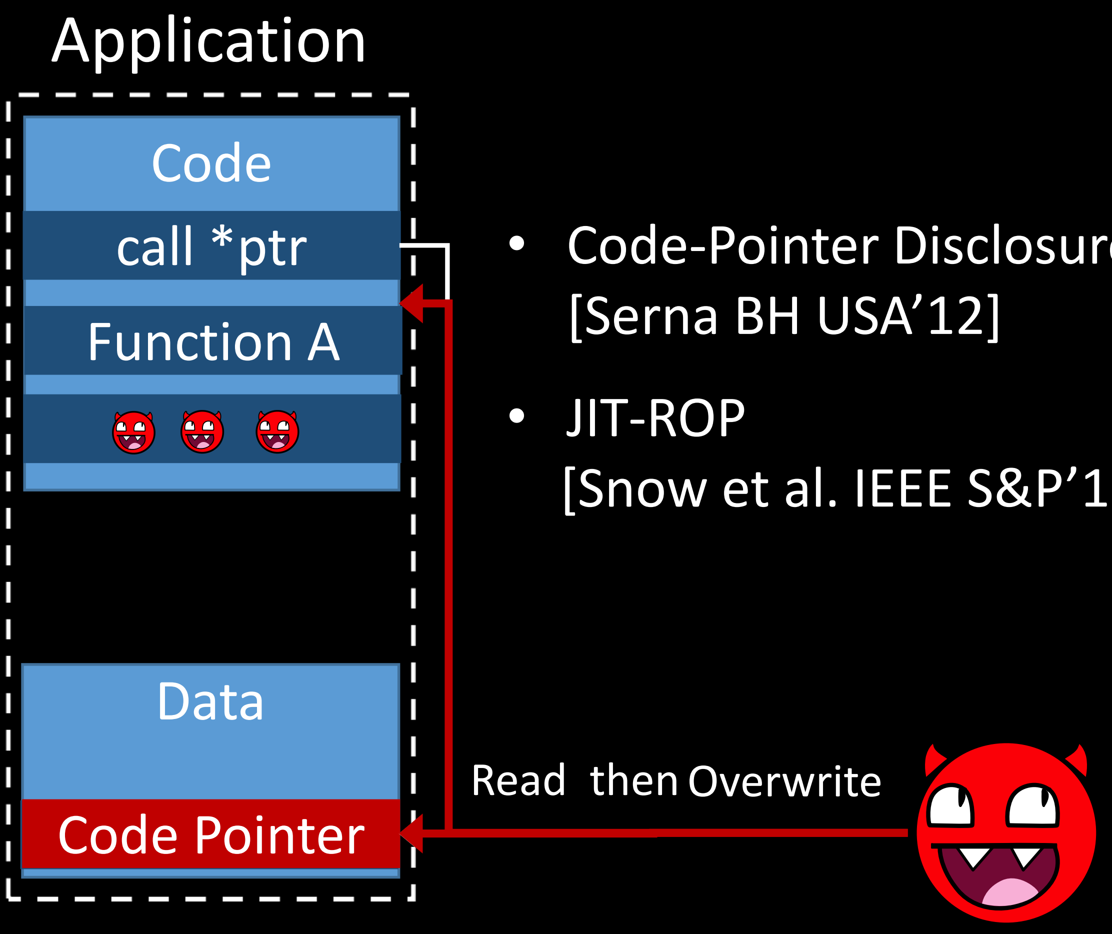

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- Address Space Layout Randomization
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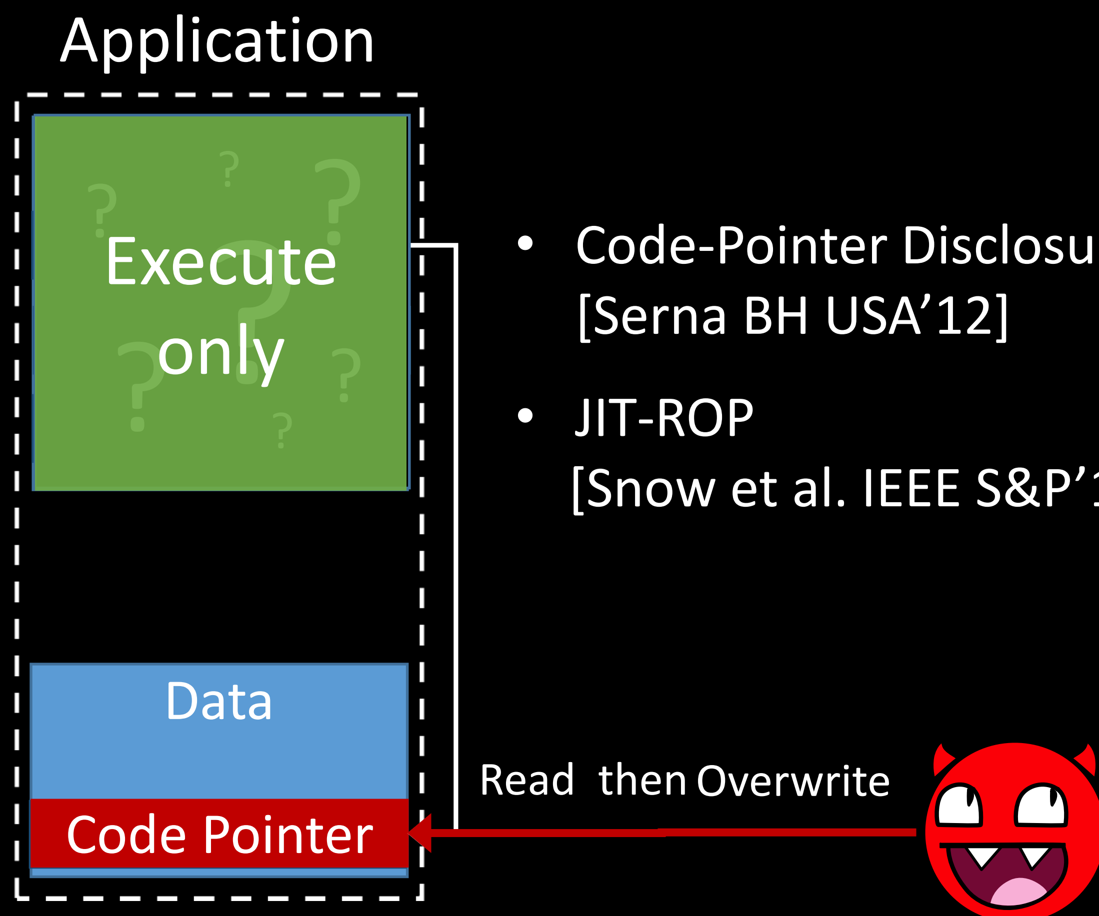

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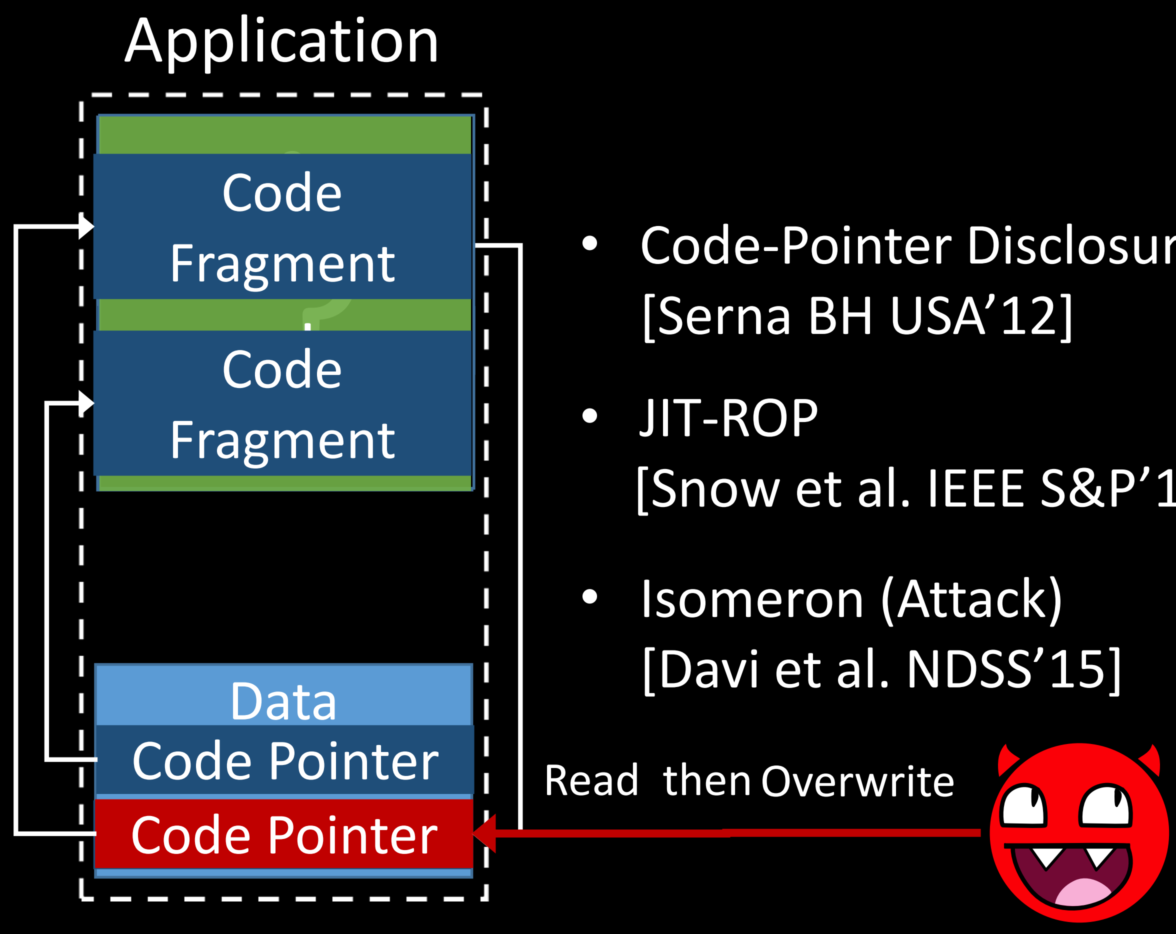

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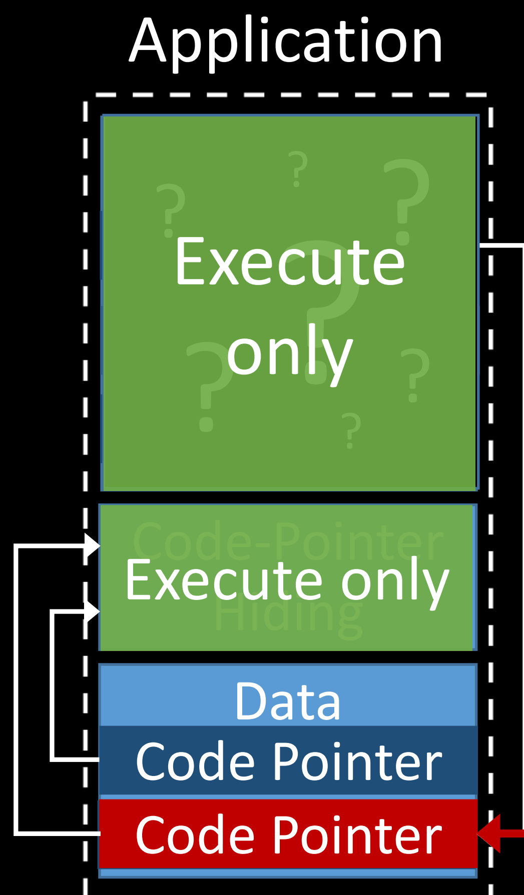

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Today's Exploits & Mitigations

Readactor [IEEE S&P'15]
Readactor++ [CCS'15]

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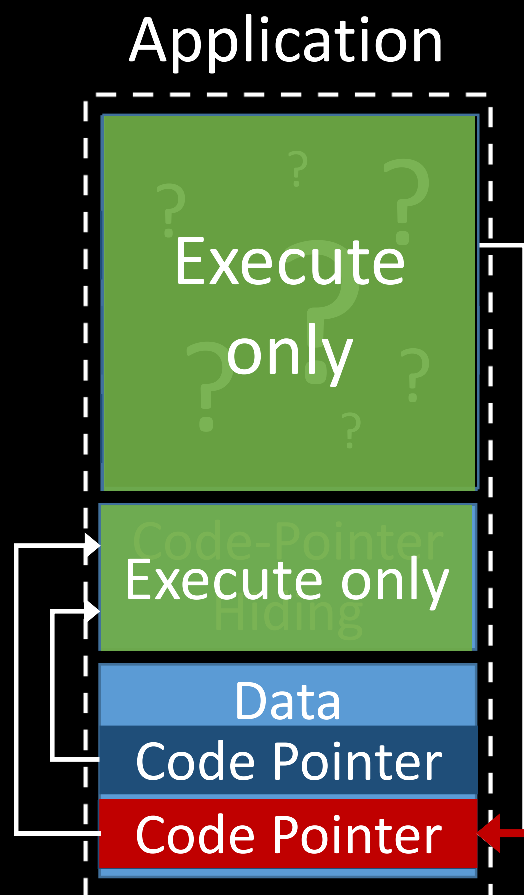

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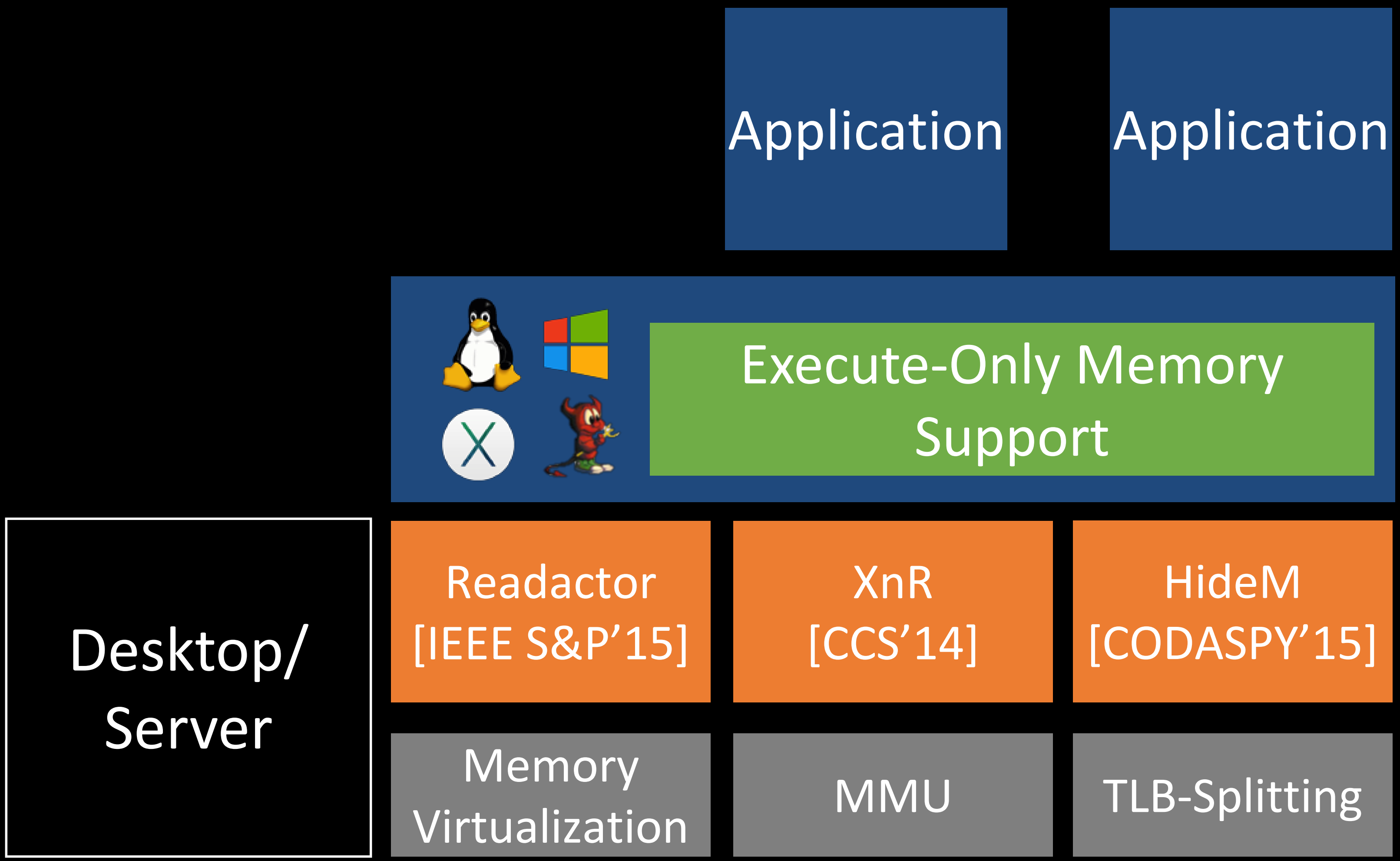
Execute-only Memory



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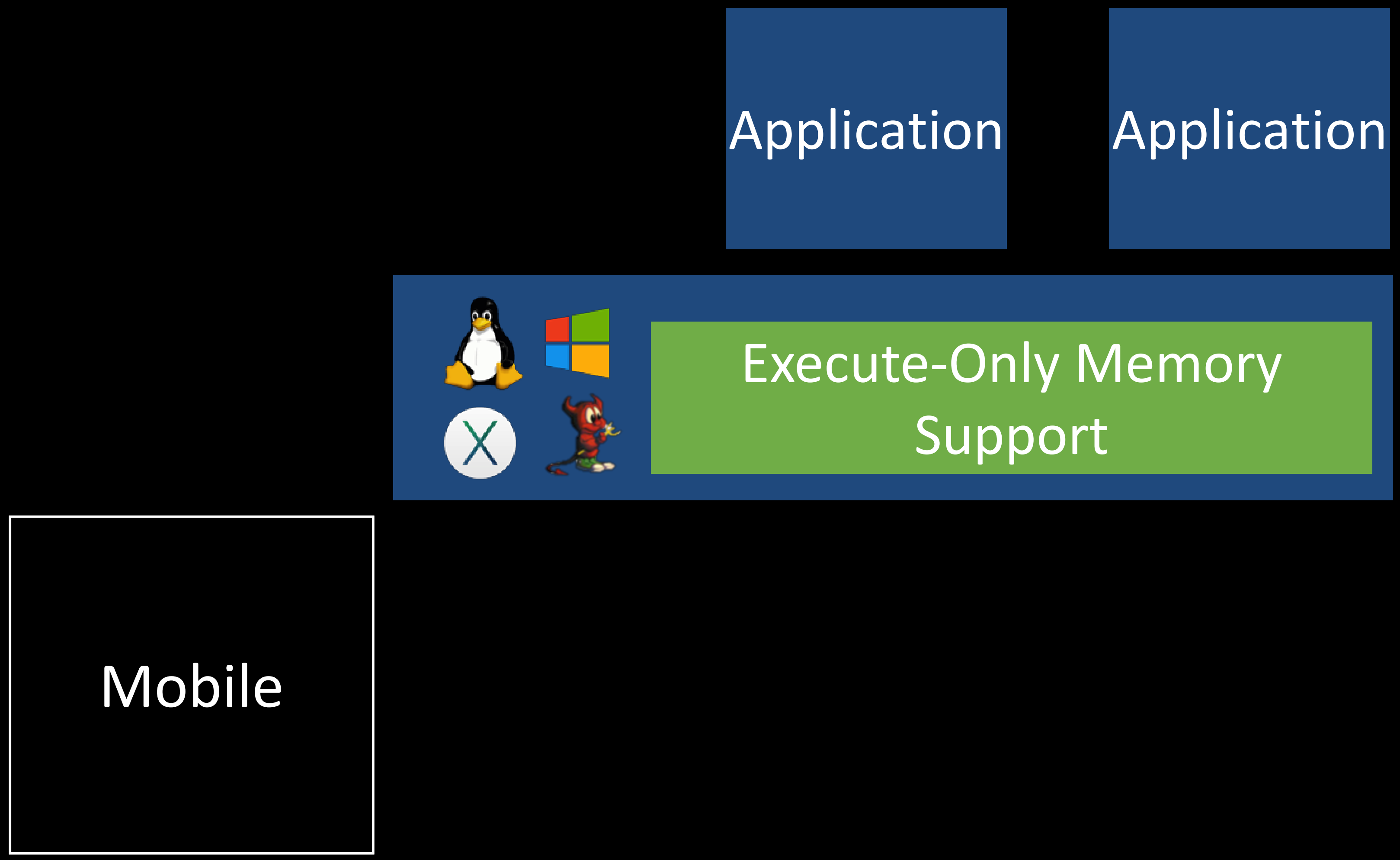

Execute-only Memory

Application

Application

Execute-Only Memory Support

Mobile

This Talk:

Execute-only Memory without Hardware Support

Threat Model

- Read Memory (Information Disclosure)
- Write Memory (Memory Corruption Vulnerability)
- Perform Computations (Scripting Engine or Locally)
- Cannot Inject New Code (DEP, W^X)

LR^2: Leakage-Resilient Layout Randomization

LR^2 Overview

- Fine-grained Code Randomization
- Software eXecute-only Memory (XoM)
- Code-Pointer Hiding
  - Return Addresses
  - Forward Pointers

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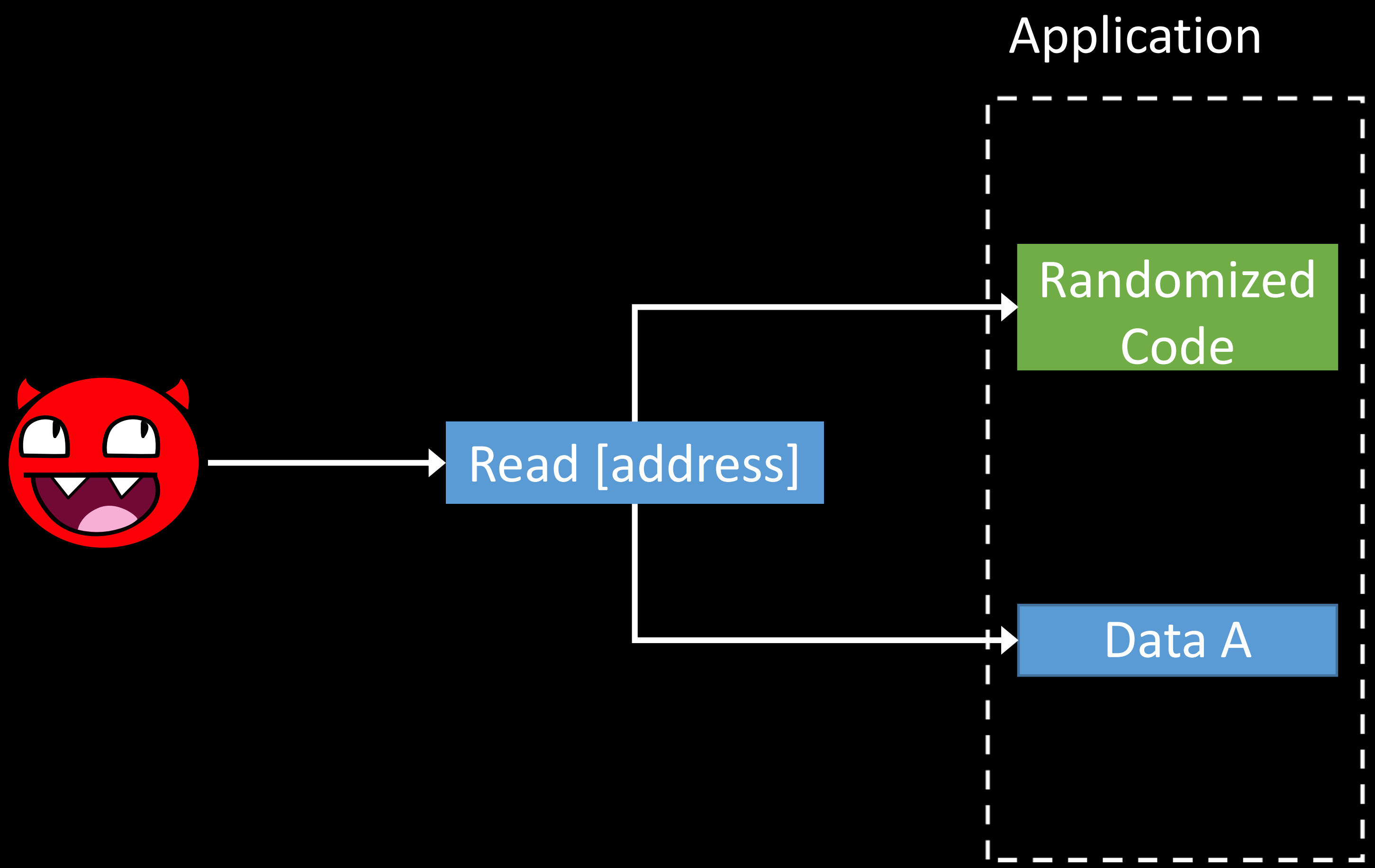
Software XoM: Idea



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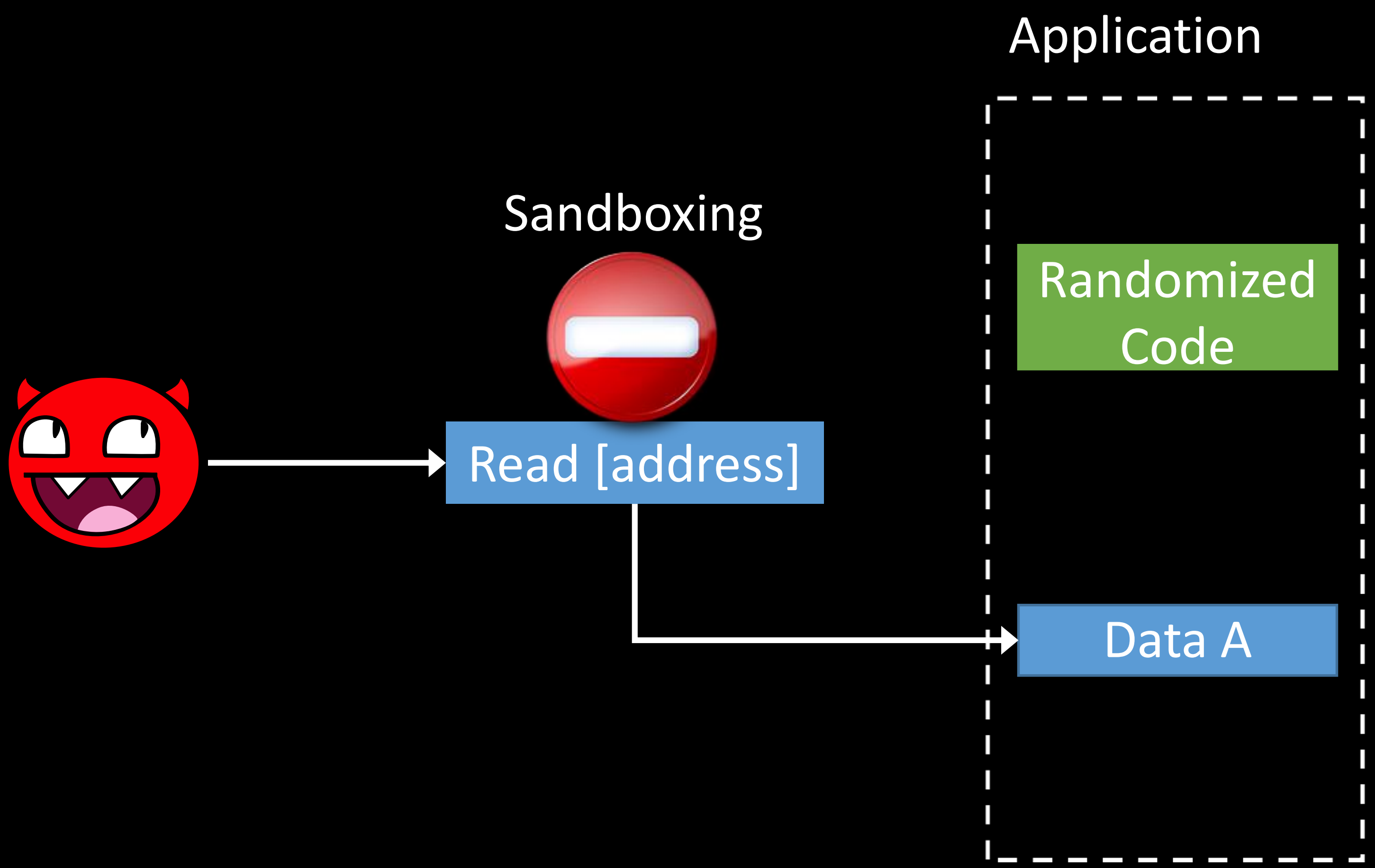
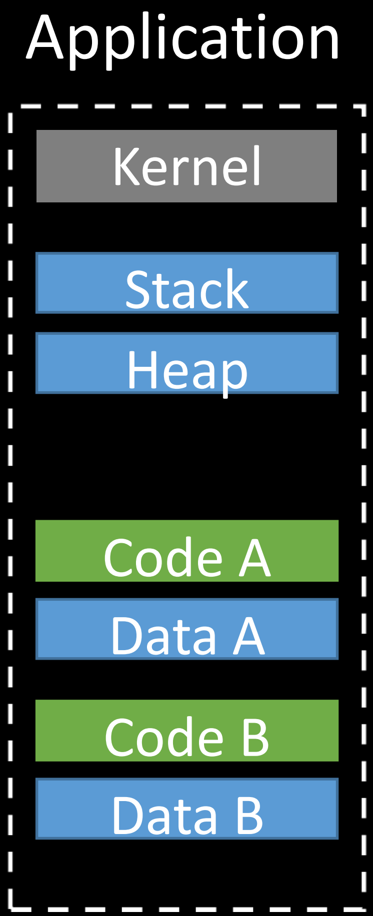


Software XoM: Design



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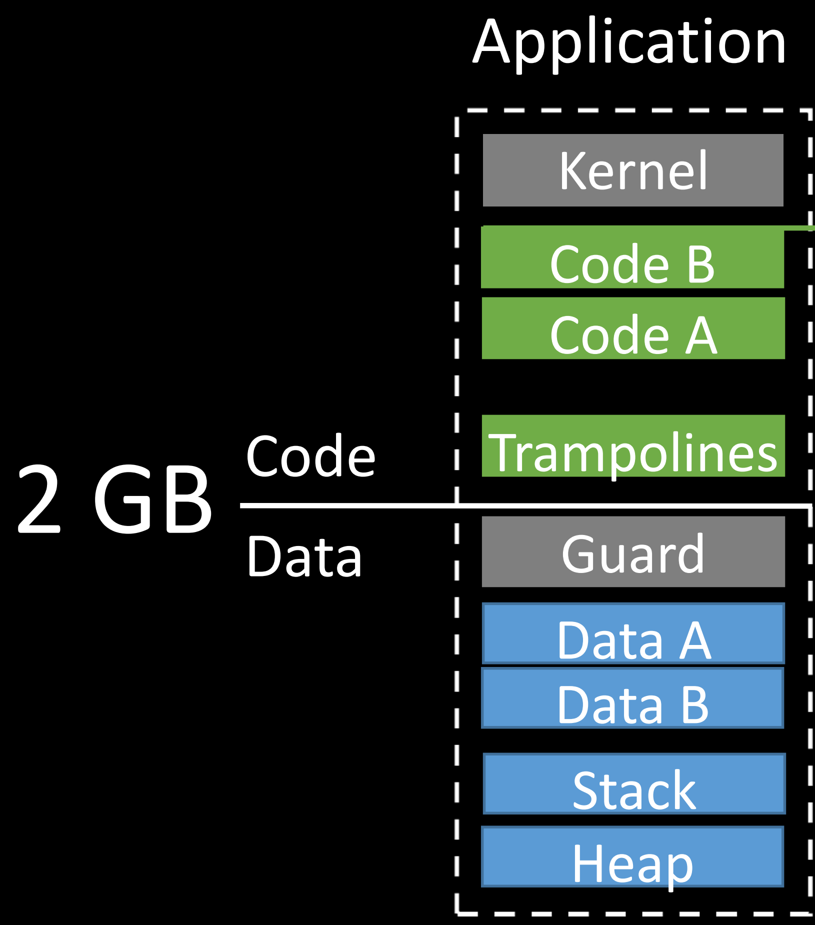
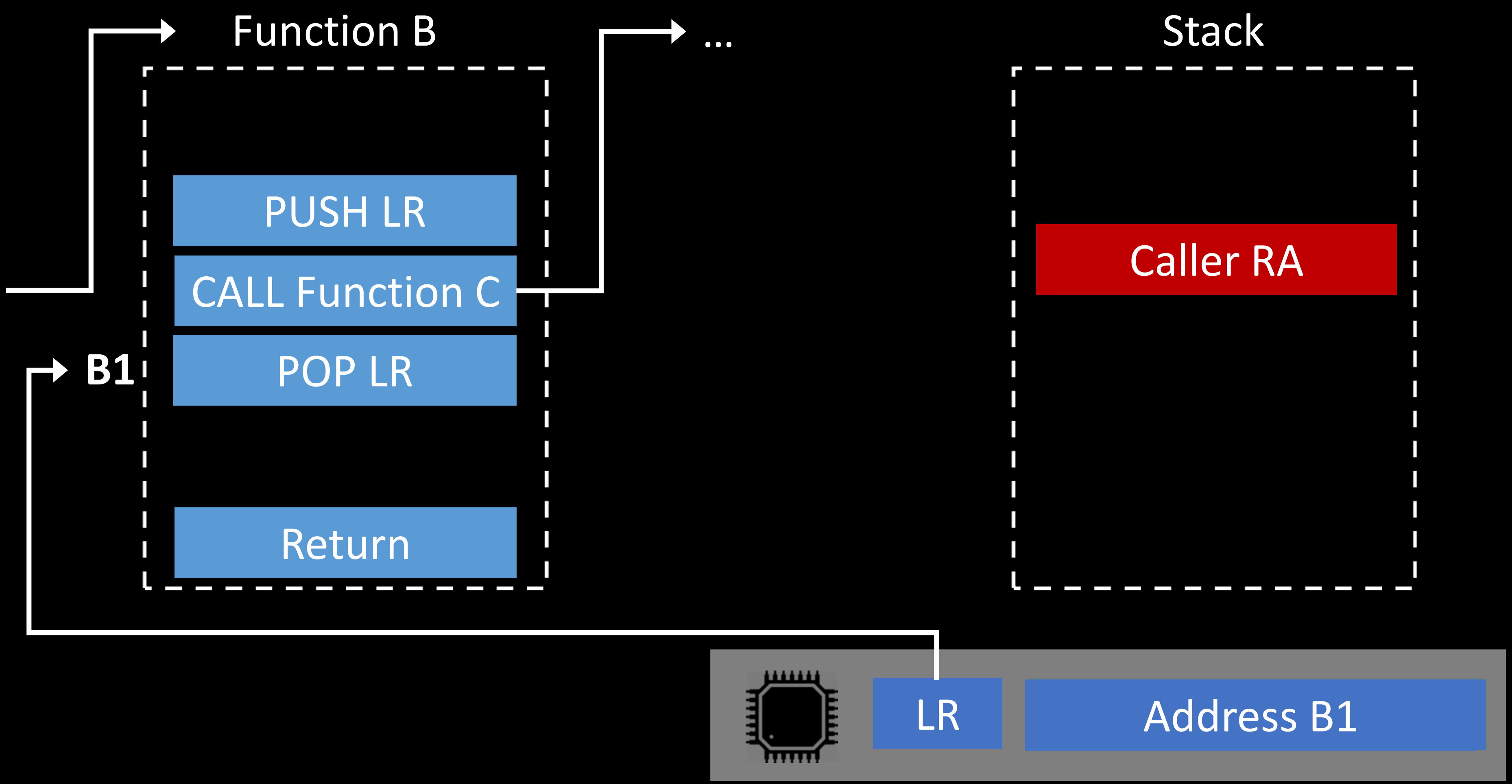


Sandboxing Read Instructions

```
r1 <- addr
r1 <- r1 & 0x7FFFFFFF
r0 <- [r1]
```

Code-Pointer Hiding: Return Addresses

Code-Pointer Hiding: Return Addresses



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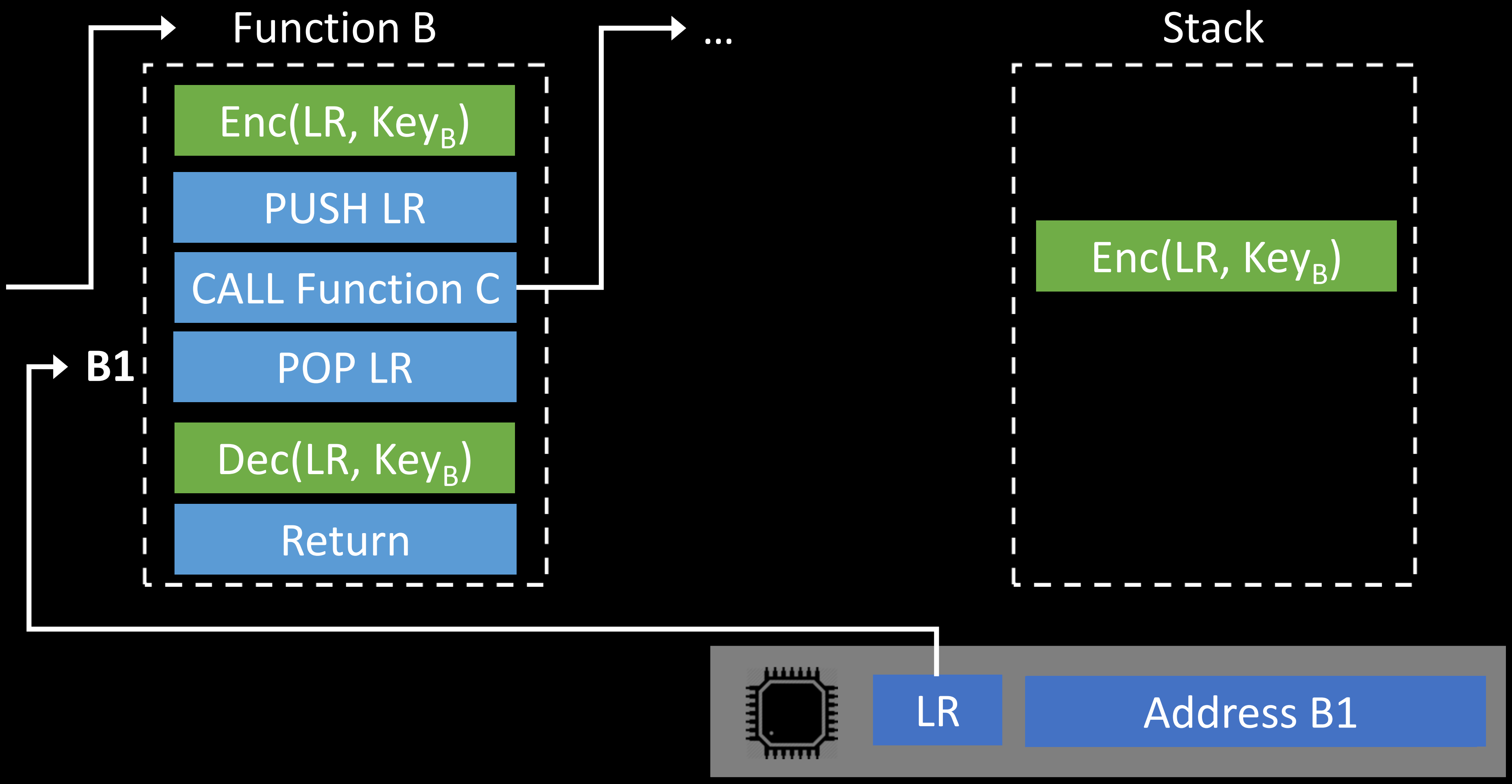


Sandboxing Reads: Optimizations

Optimizations: Loops

r0 <- address

For i <- 0 ; i < X ; ++i

Mask r0

r1 <- [r0]

Optimizations: Loops

r0 <- address

Mask r0

For i <- 0 ; i < X ; ++i

r1 <- [r0]

Optimizations: Loops

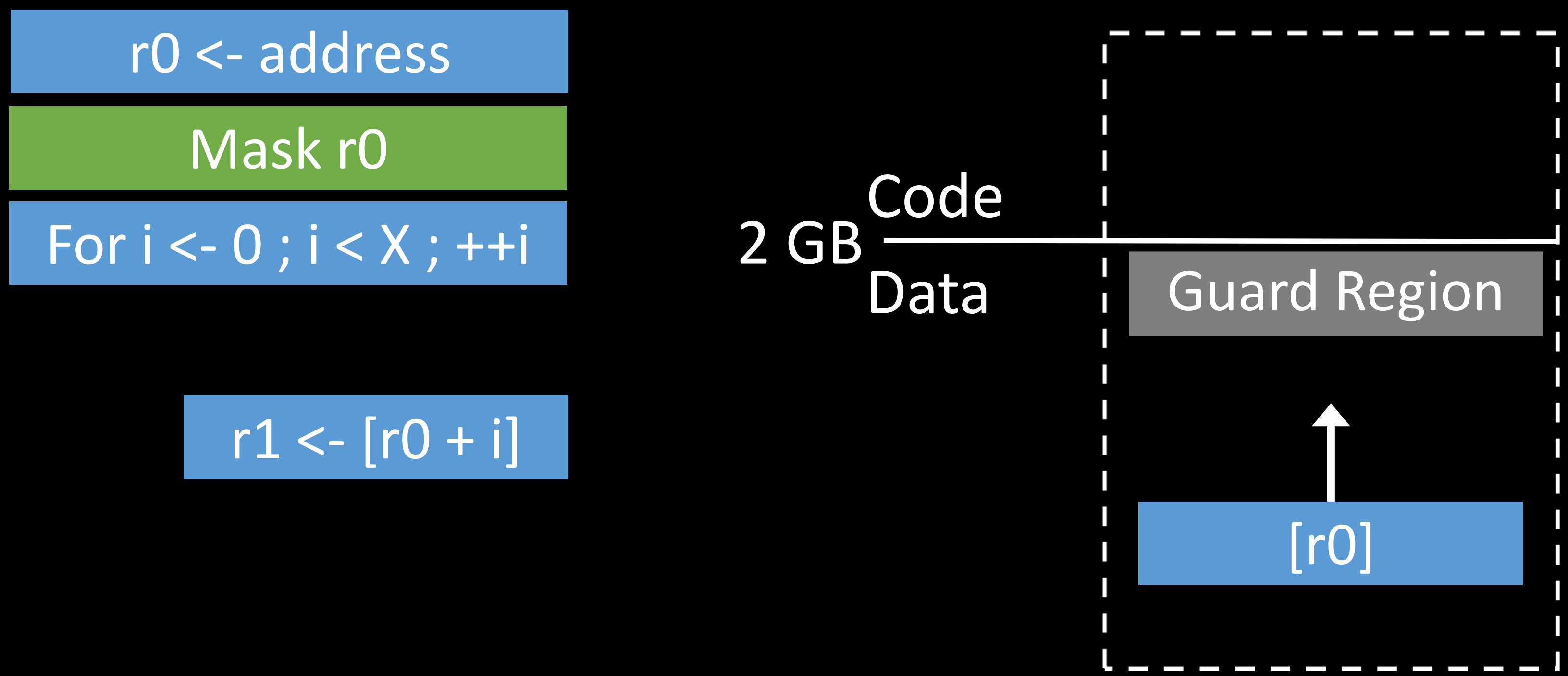
r0 <- address

Mask r0

For i <- 0 ; i < X ; ++i

r1 <- [r0 + i]

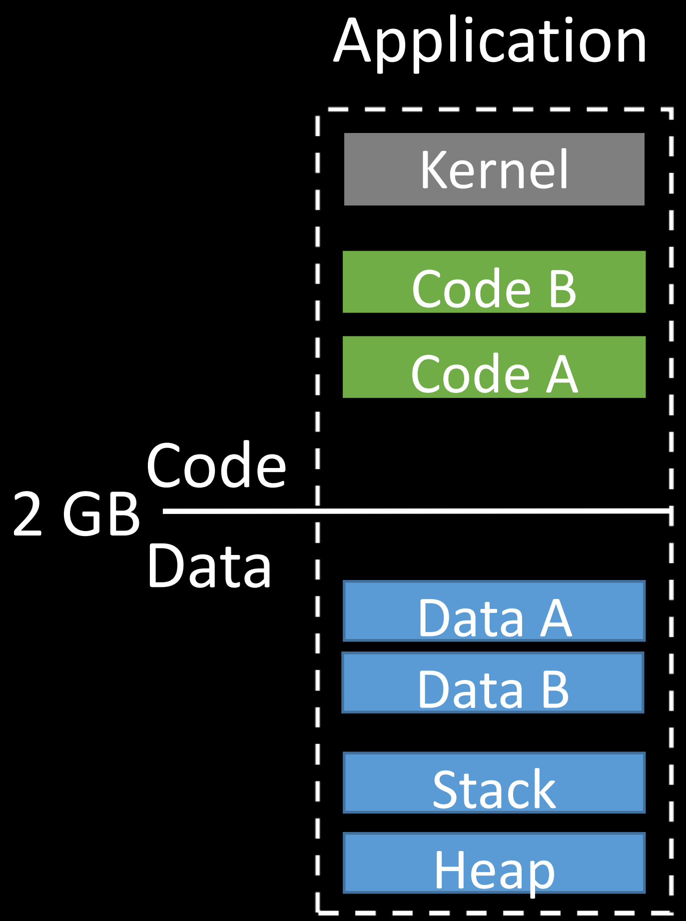
Optimizations: Loops



Implementation

Implementation

- Kernel
  - Stack and Heap Allocations
- Loader
  - Code and Data Sections
- Compiler
  - Sandbox Read Instructions

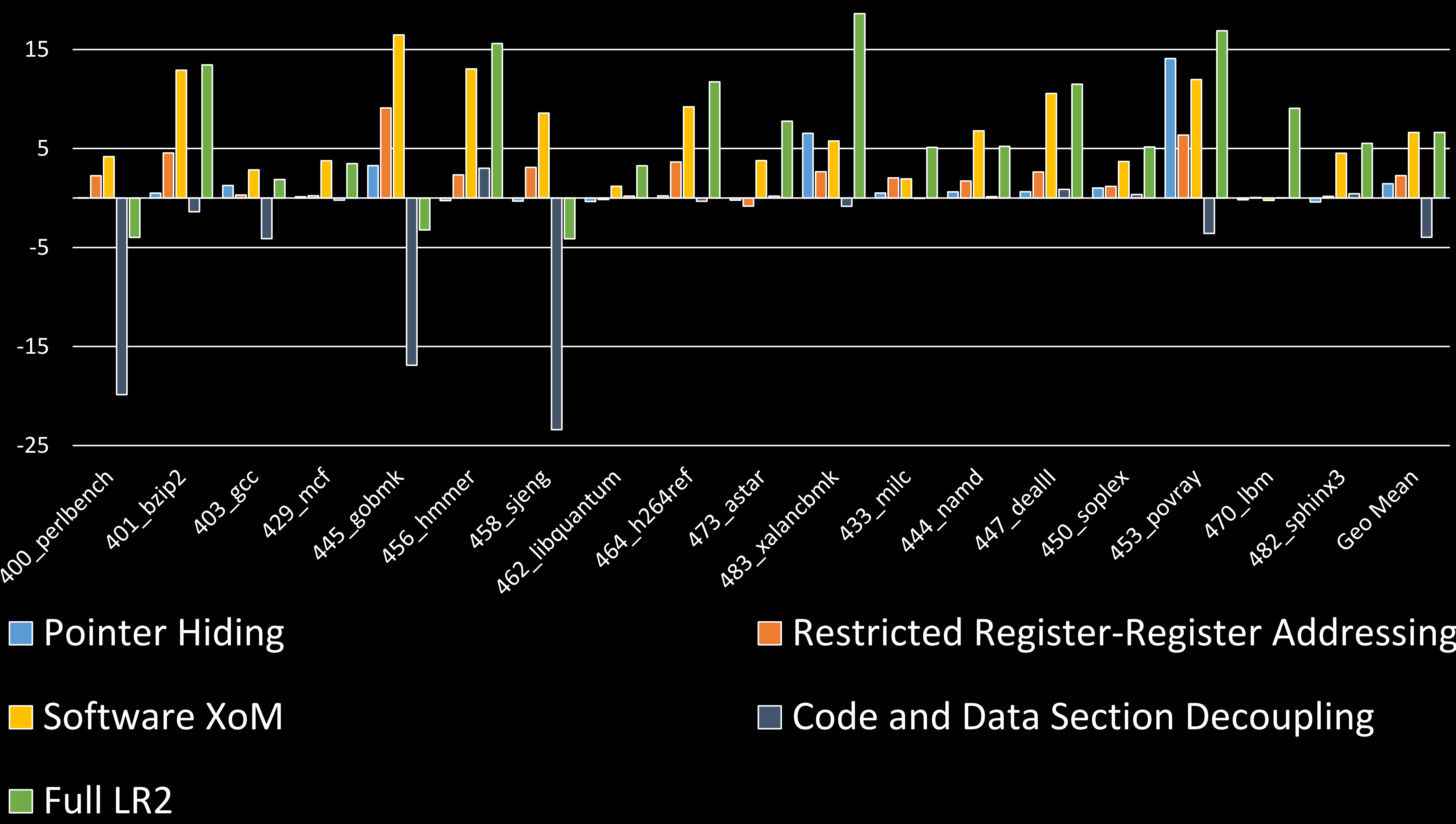


Evaluation

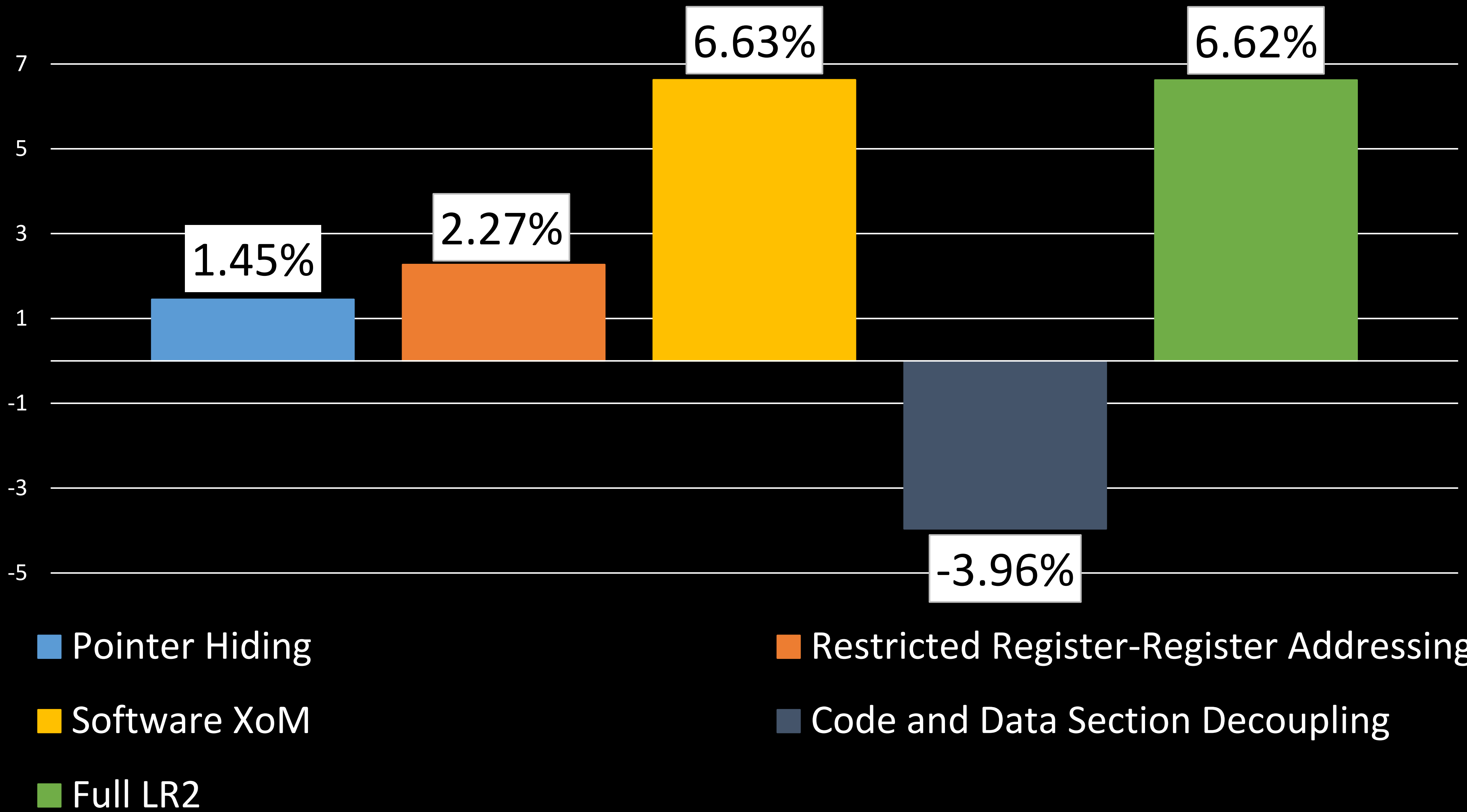
- Security:
  - Code-Reuse Attacks: Function Permutation
  - Direct disclosure: Execute-only Memory
  - Indirect disclosure:
    - Code-pointer Hiding
    - Code/Data section decoupling

- CPU: Nvidia Tegra Logan K1
- Performance:
  - 6.6% run-time overhead
  - 5.6% space overhead

SPEC CPU 2006



SPEC CPU 2006 Geometric Mean



LR^2 and Software Fault Isolation (SFI)

- Different Threat Models
  - SFI isolates untrusted code
  - LR^2 protects trusted code
- LR^2 can protect multiple load instructions by masking one address
- SFI sandboxes write and branch instructions

Conclusion

- First pure software execute-only memory technique
- Optimized return address protection scheme
- Performance and security matches state-of-the-art solutions requiring special, high-end hardware