Lecture 1:
Introduction and Overview

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8/16/2023

Software Becomes Inceasingly Sophiscated

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System Software Developed w/ Unsafe Languages

C was designed in 1970s

1. Less networked, less attacks
2. Favor performance and flexibility
3. Lack of security features
   - No automatic memory management
   - No strong typing
   - No bounds checks
   - No overflow checks

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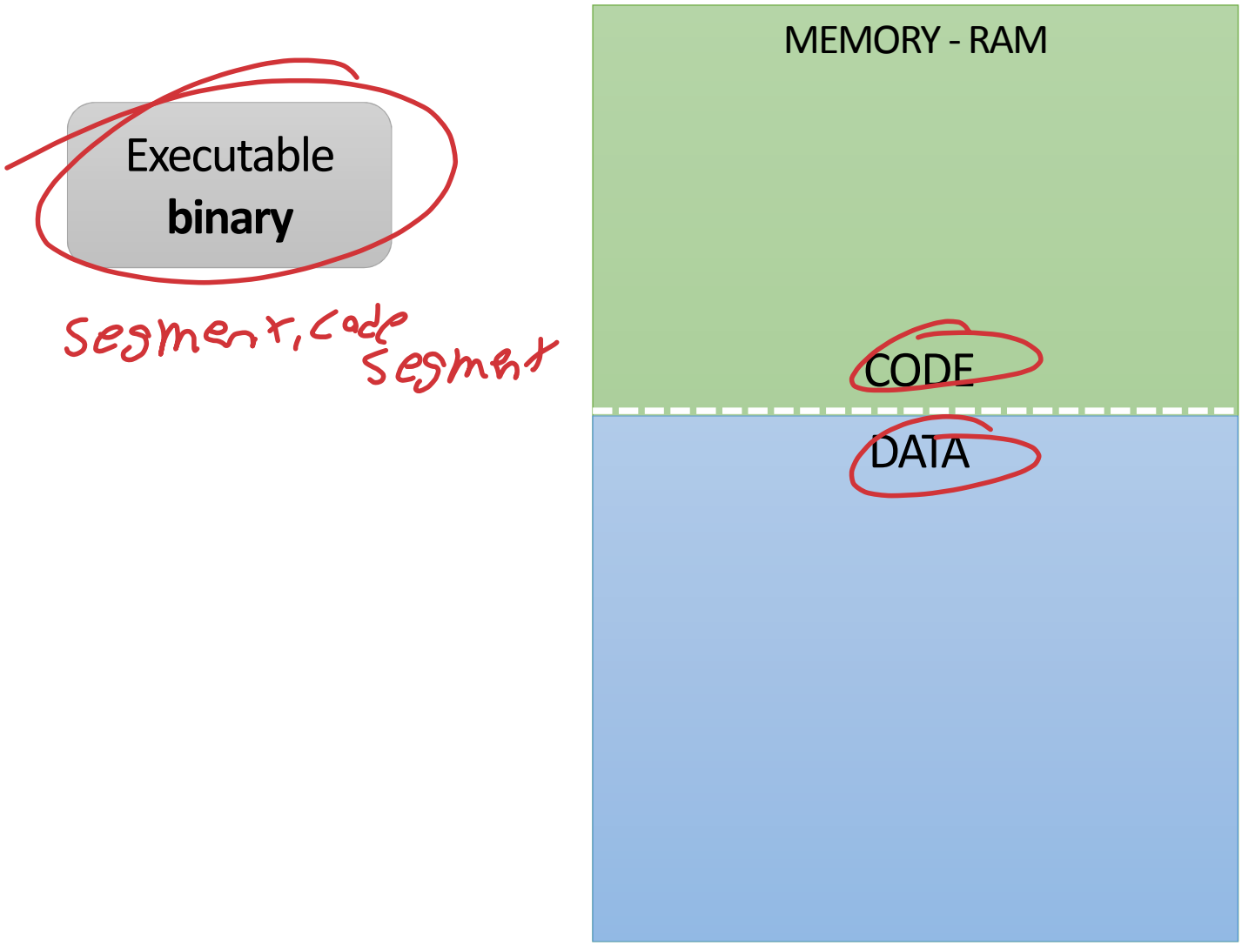
Why still being used?

1. Performance
   - C/C++/Object-C
   - Hand-written assembly
   - Optimal use of the hardware
2. Backwards-compatibility
   - Legacy systems
   - Most of them were developed in C

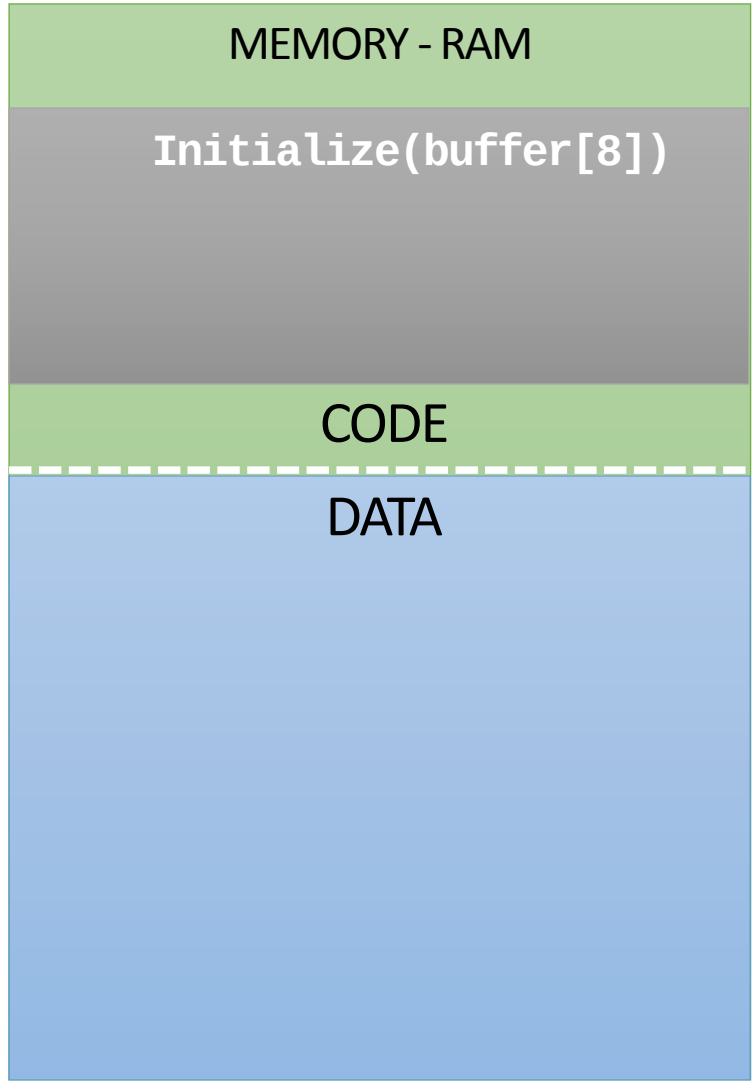
The Memory Corruption Vulnerability

mem corruption



The Memory Corruption Vulnerability

High level description



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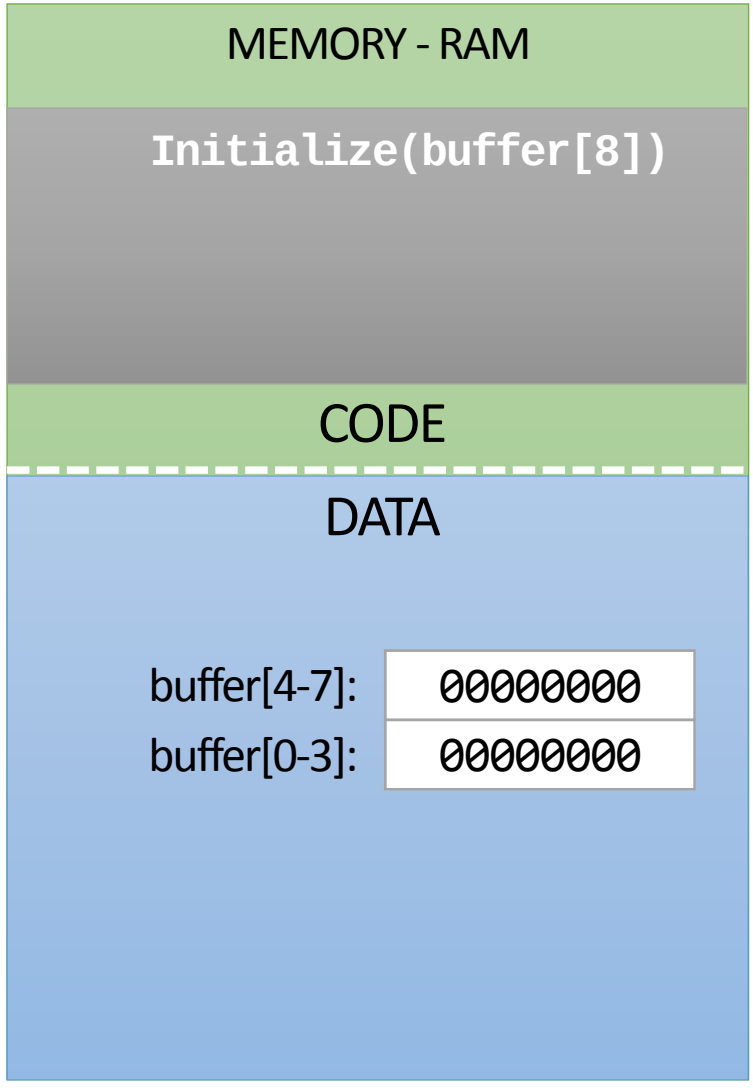

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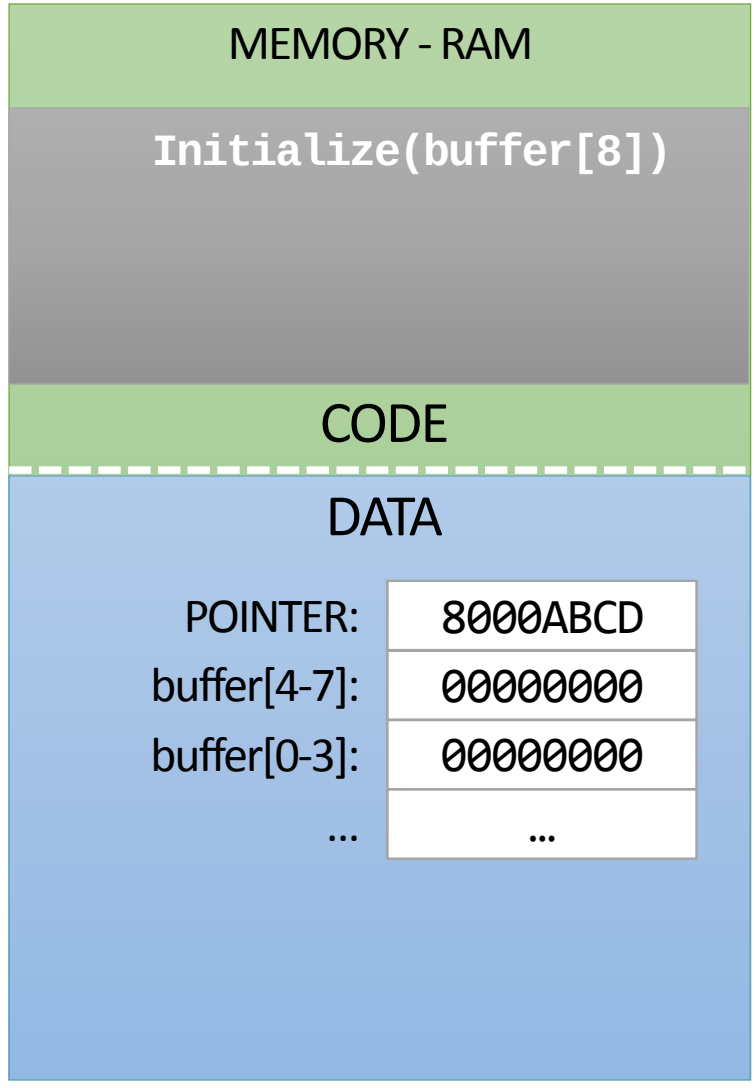

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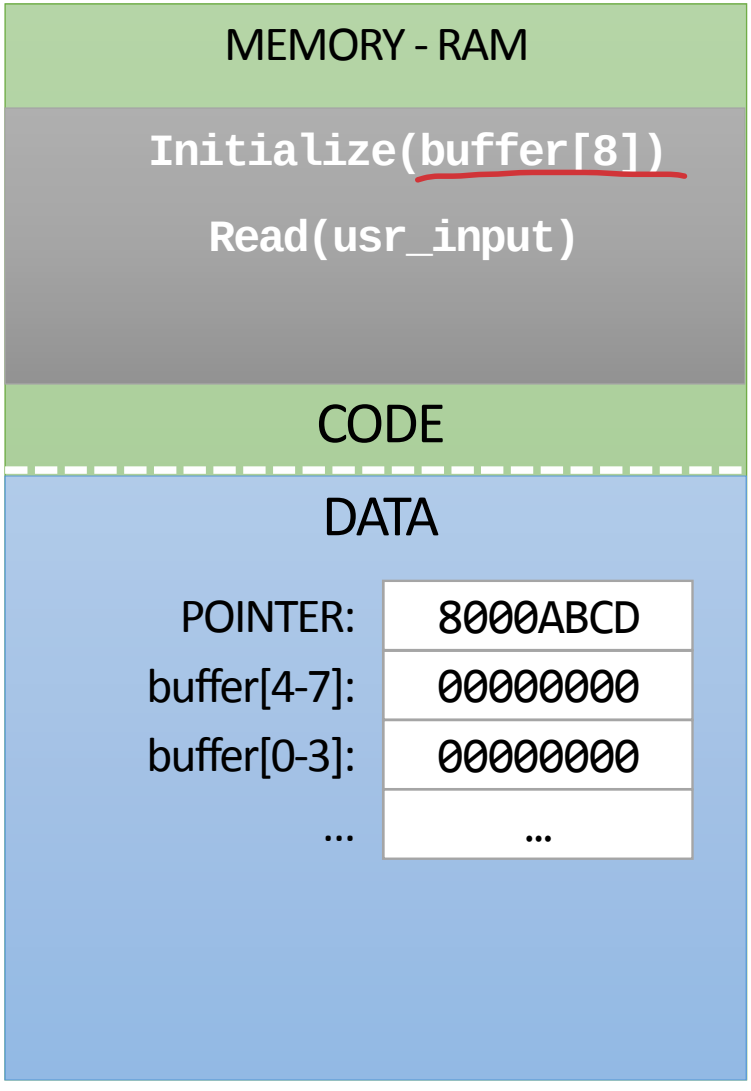

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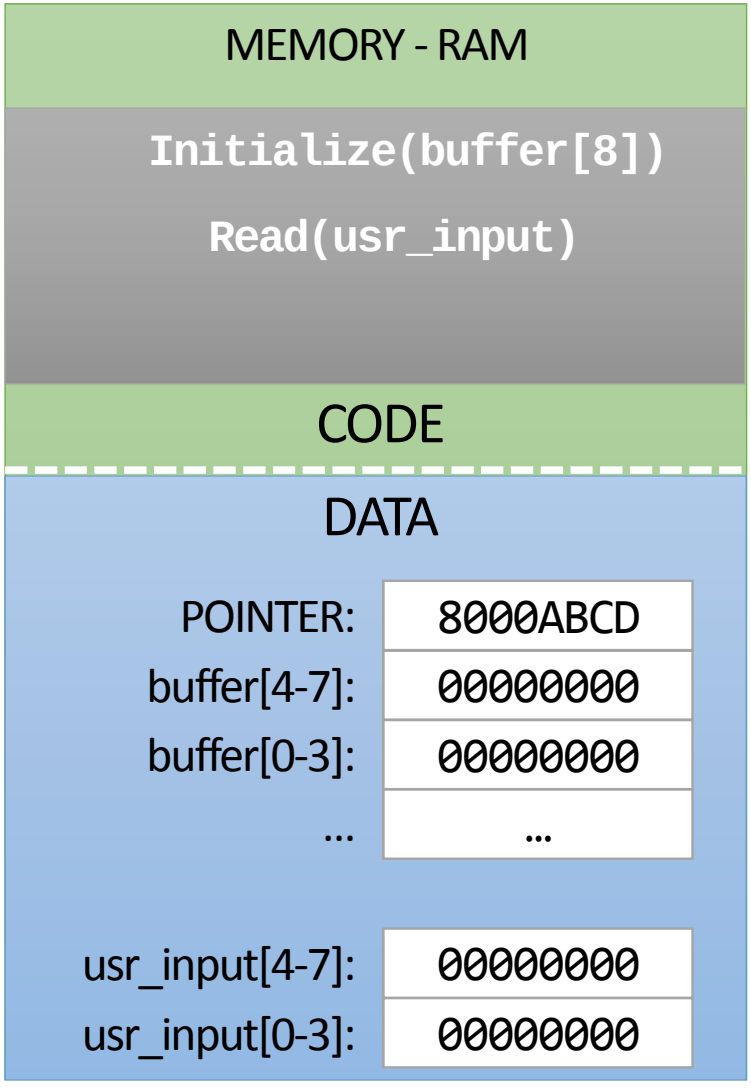

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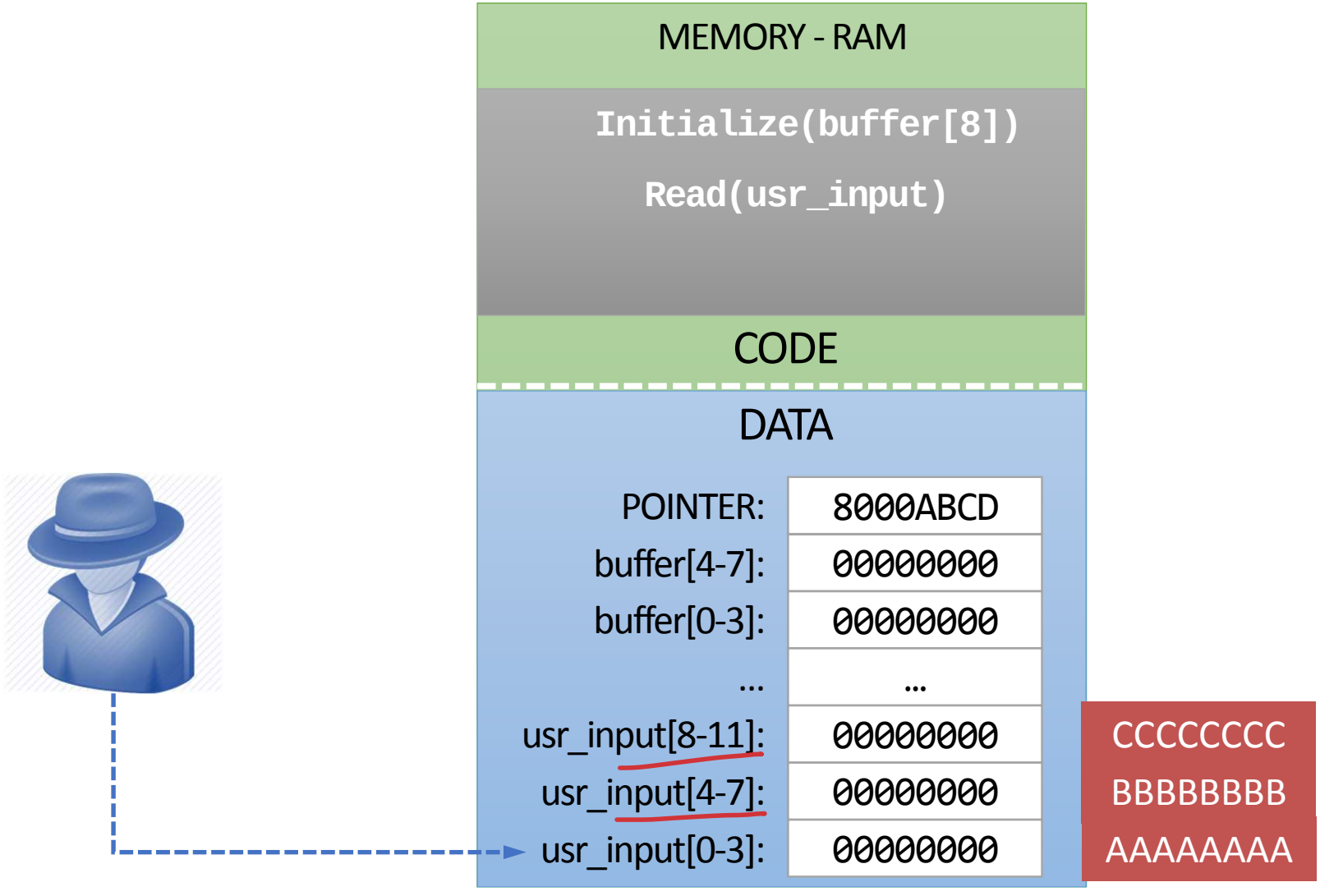

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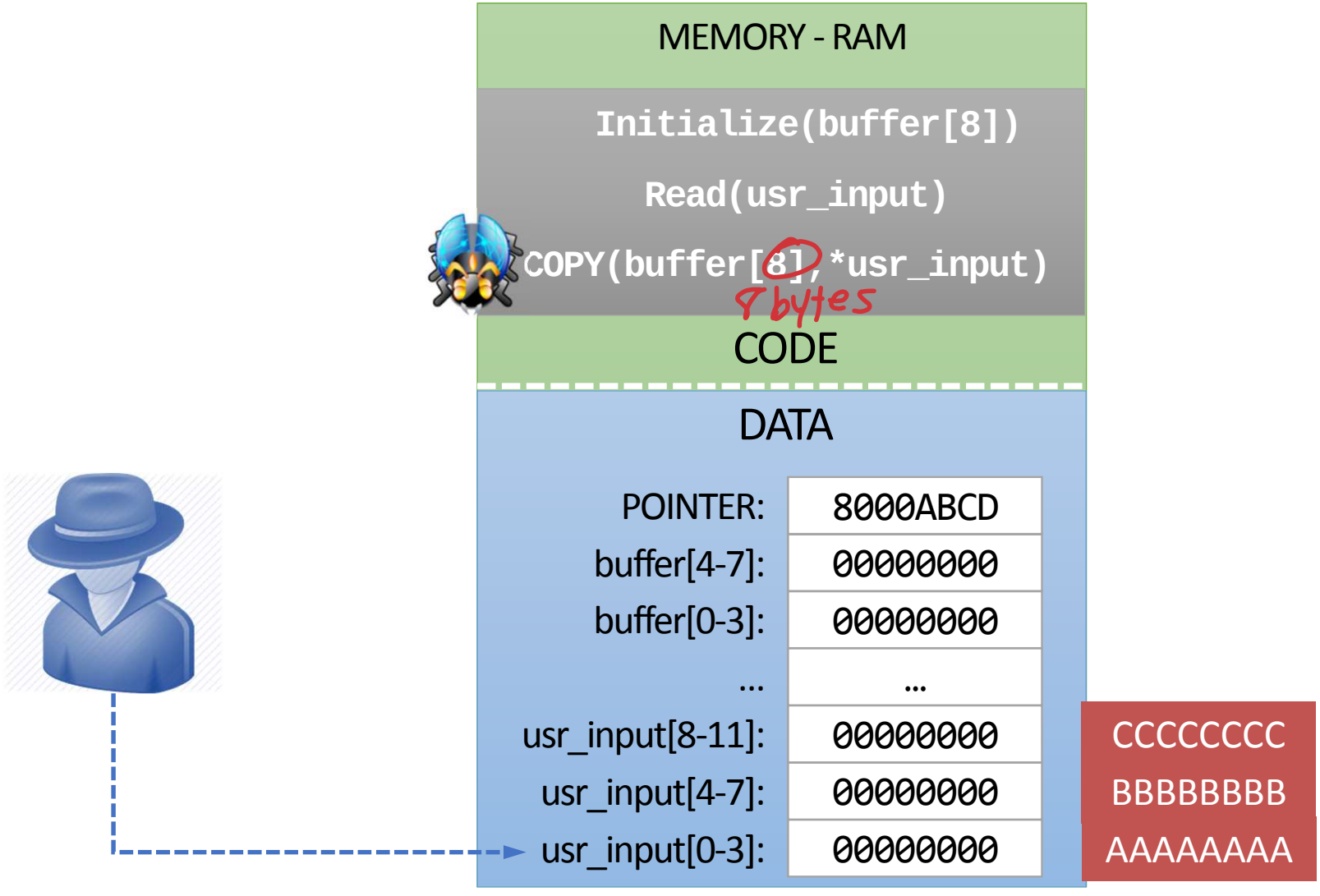

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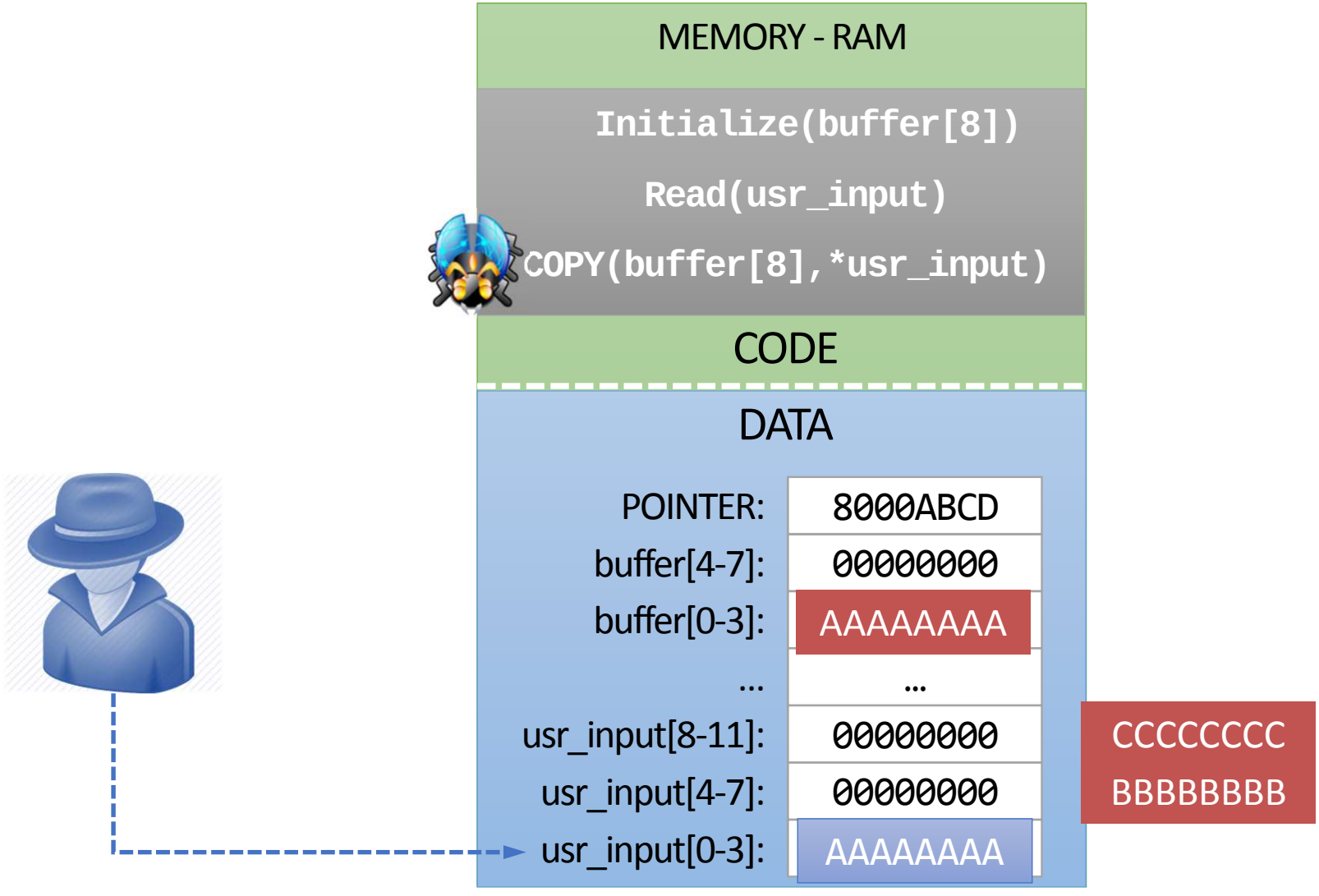

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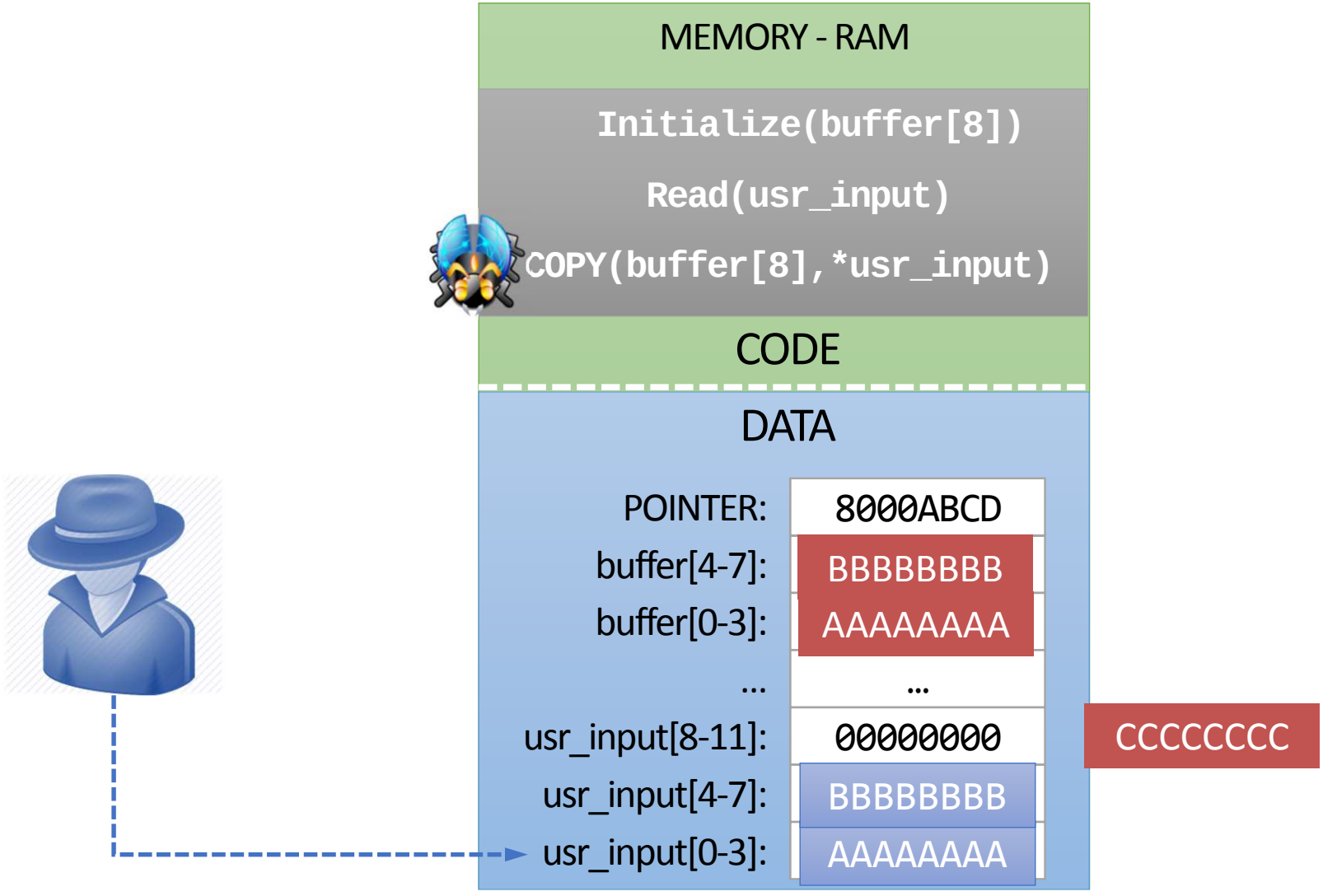

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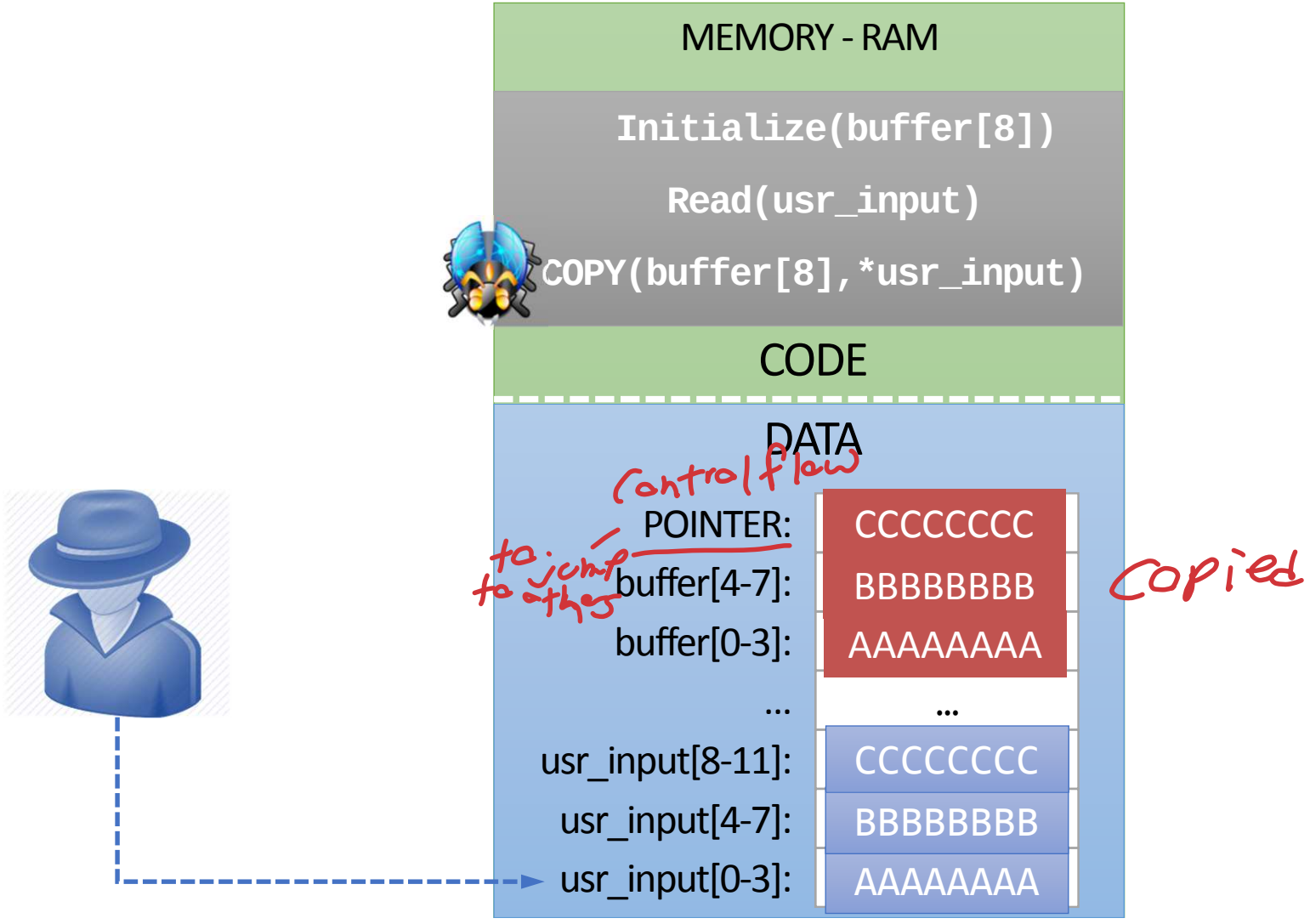

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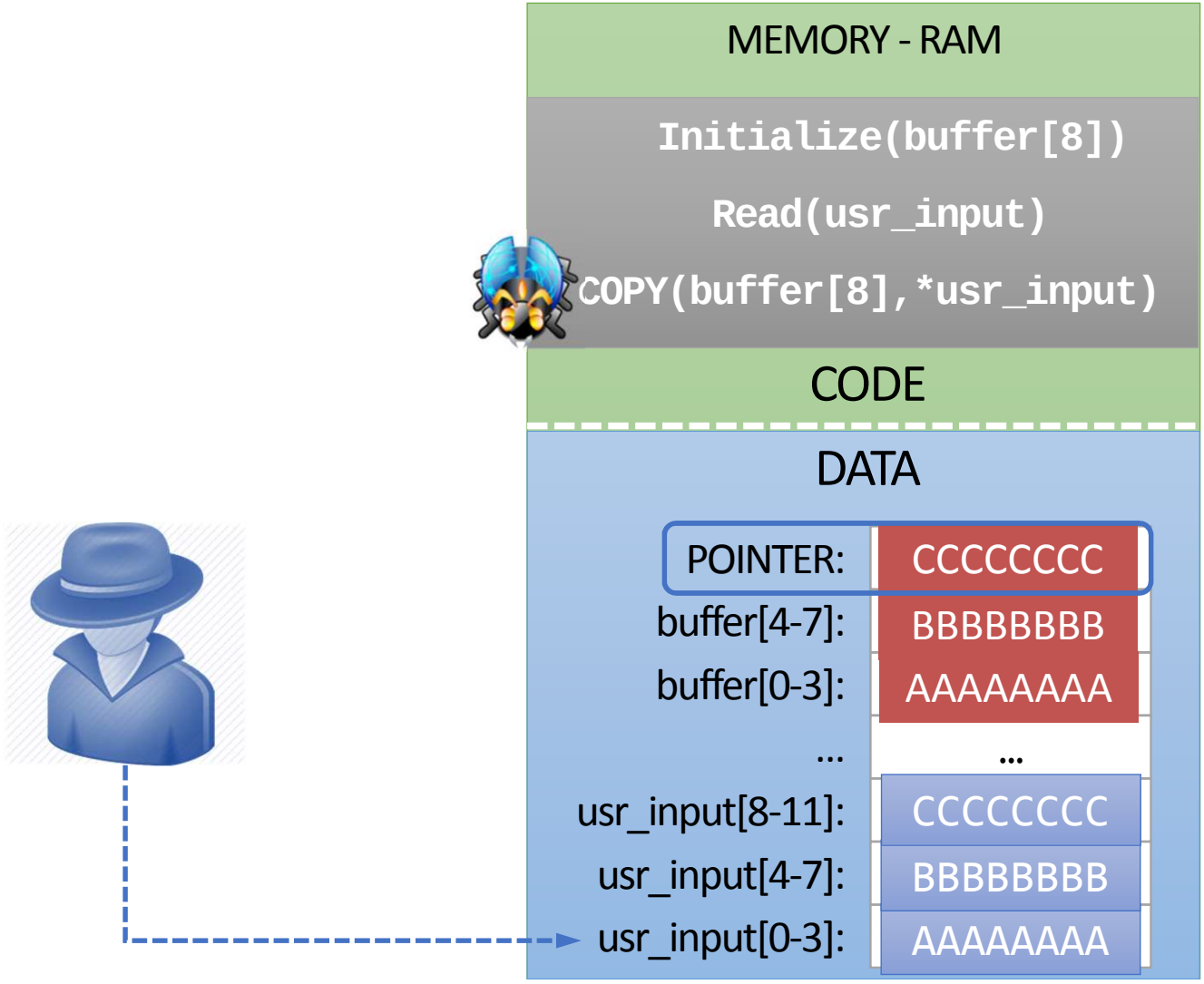

Why It Matters

Many High Impact Attacks

attack browser

1. Web browsers repeatedly exploited in pwn2own contests
2. Zero-day issues exploited in Stuxnet/Duqu
3. iOS jailbreak

Why It Matters

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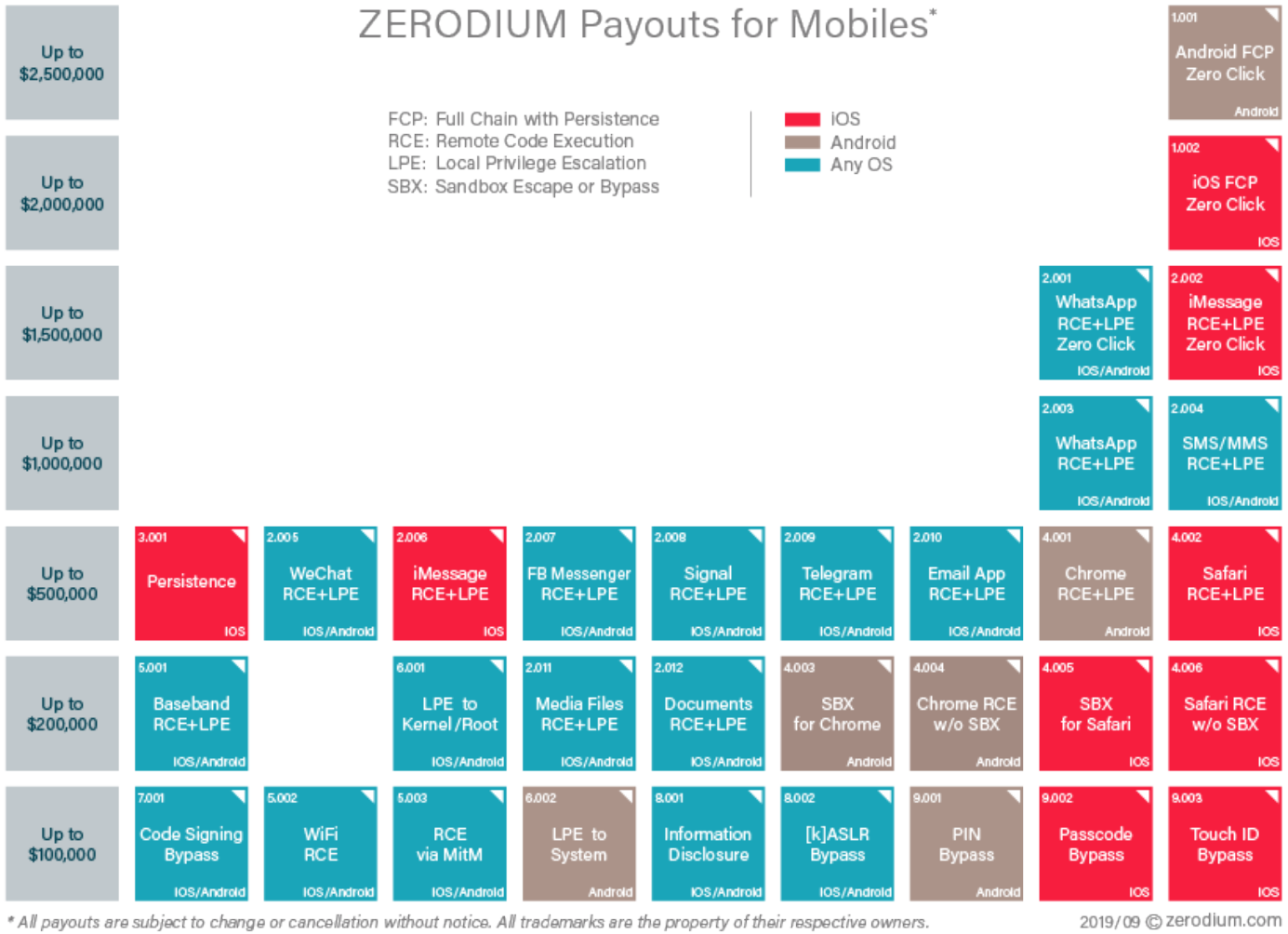
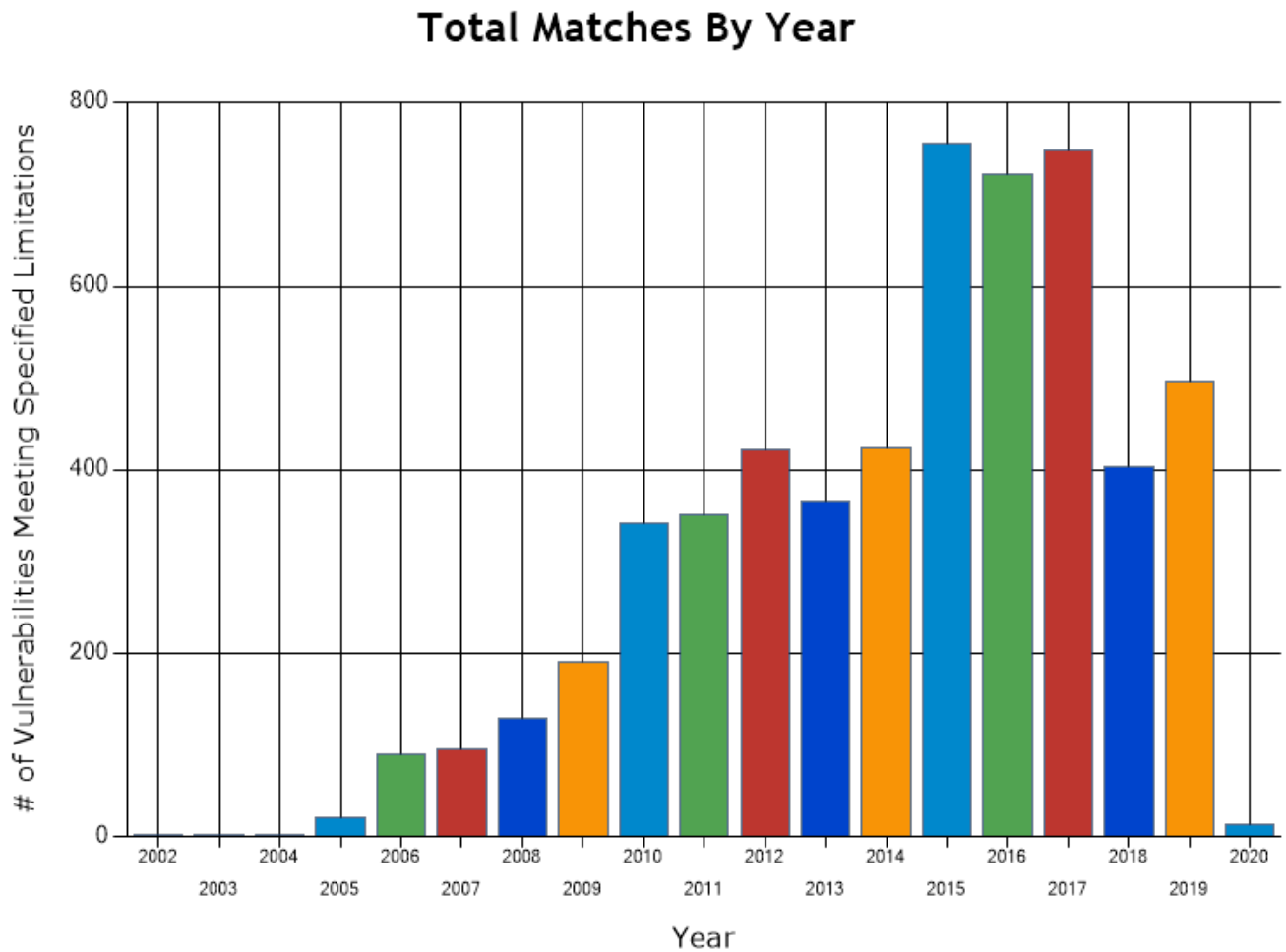


The Statistics of The Memory Corruption Vulnerabilities



https://nvd.nist.gov/vuln/search/statistics

The Arm Race (Attack and Defense) w/ Memory Corruptions

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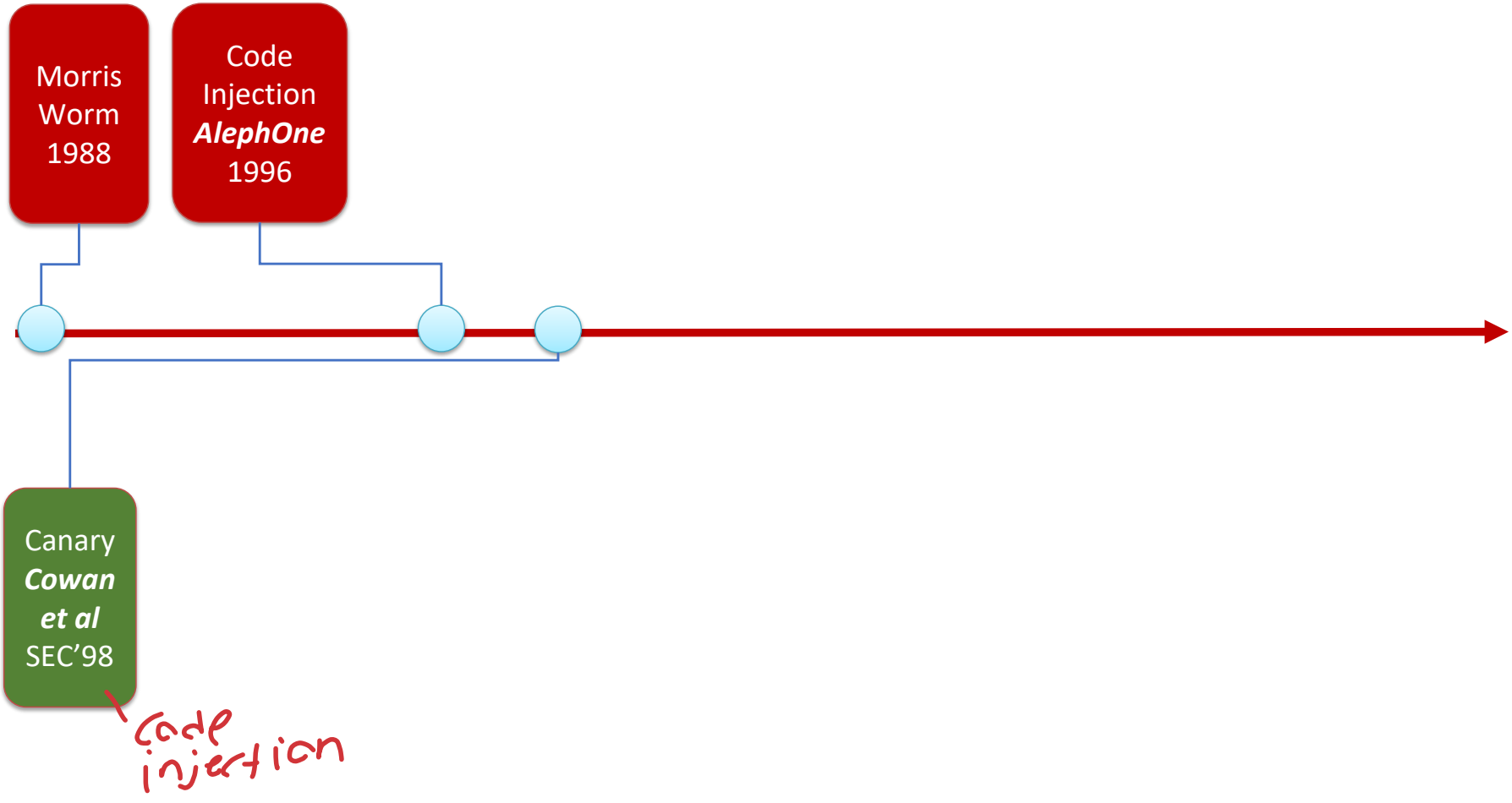

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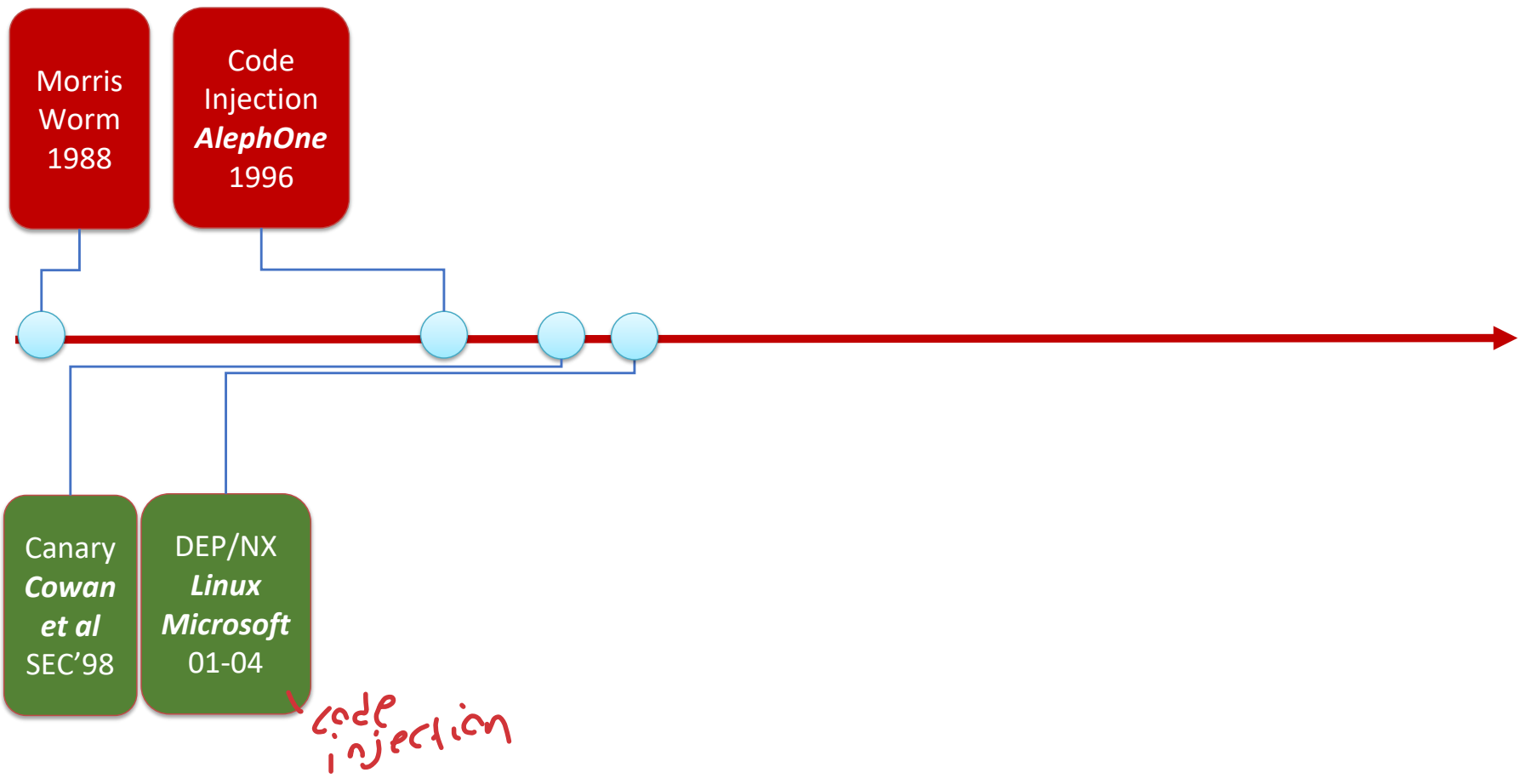

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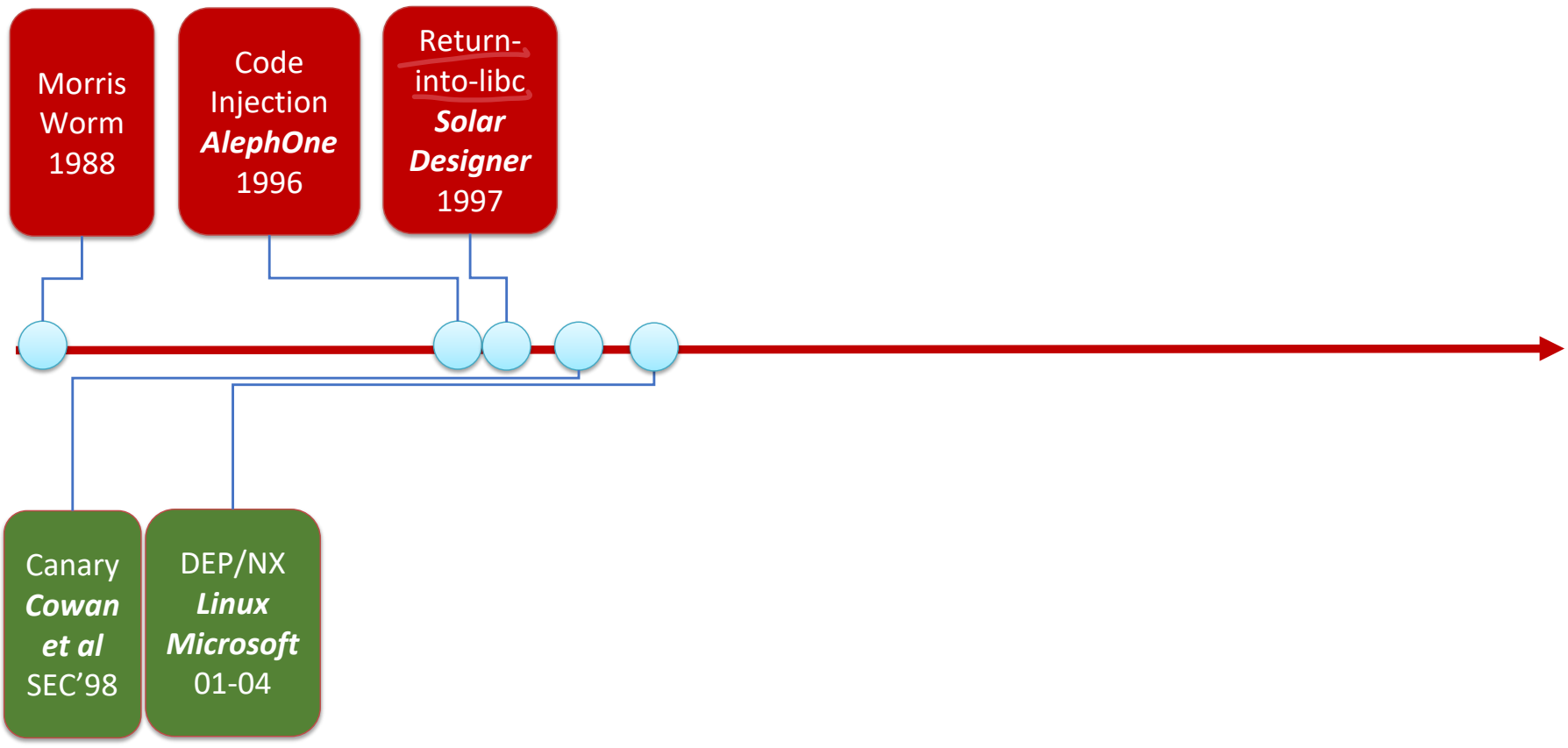

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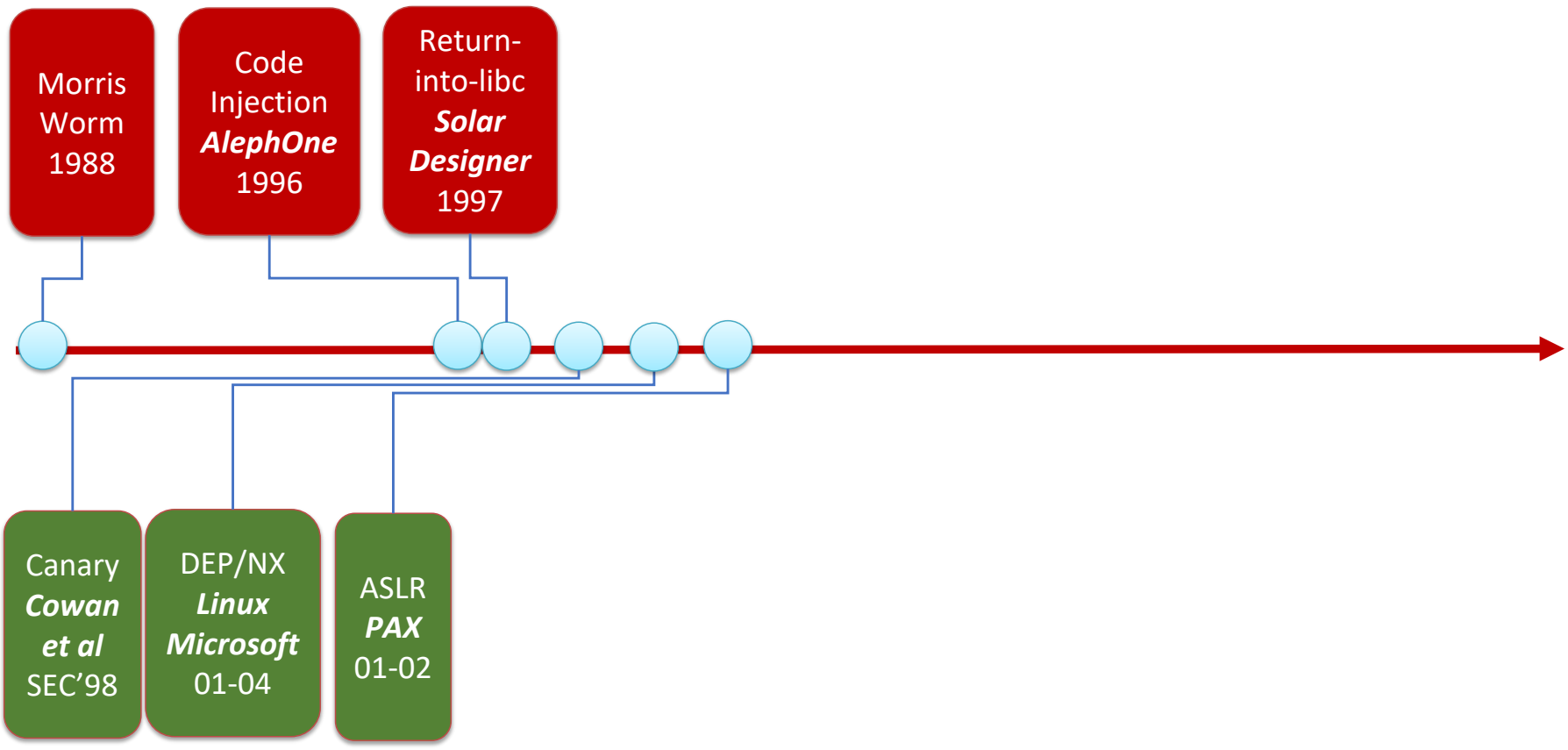

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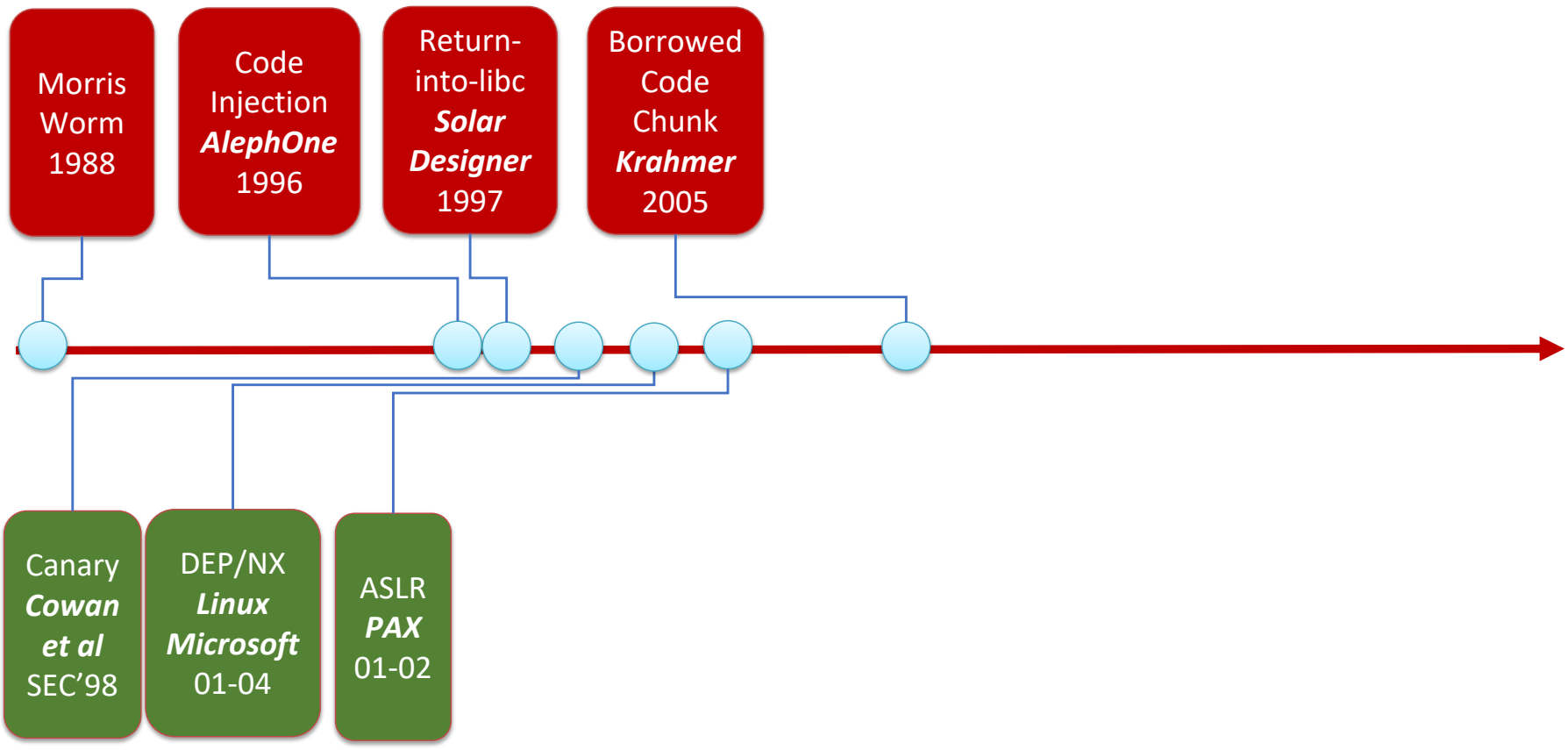

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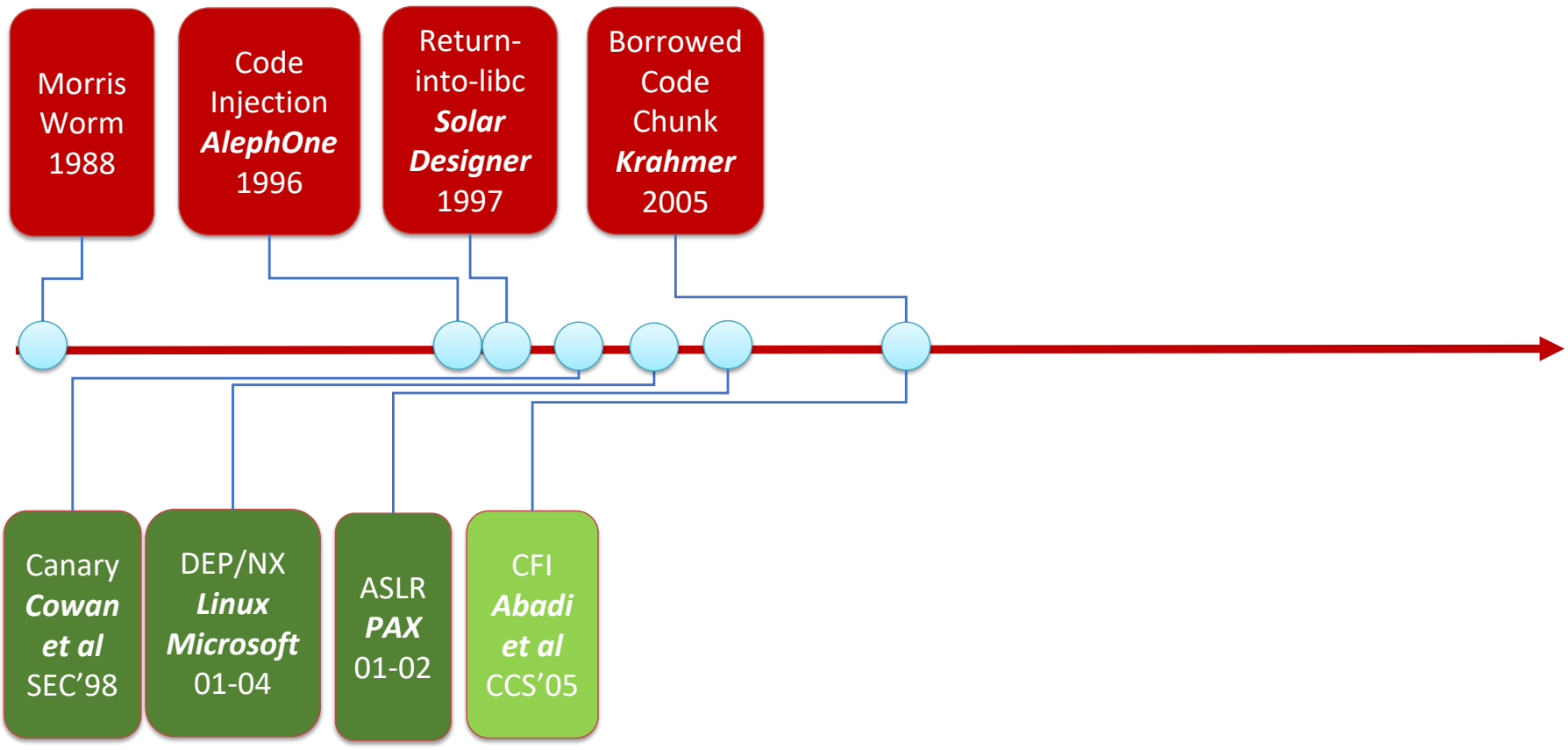

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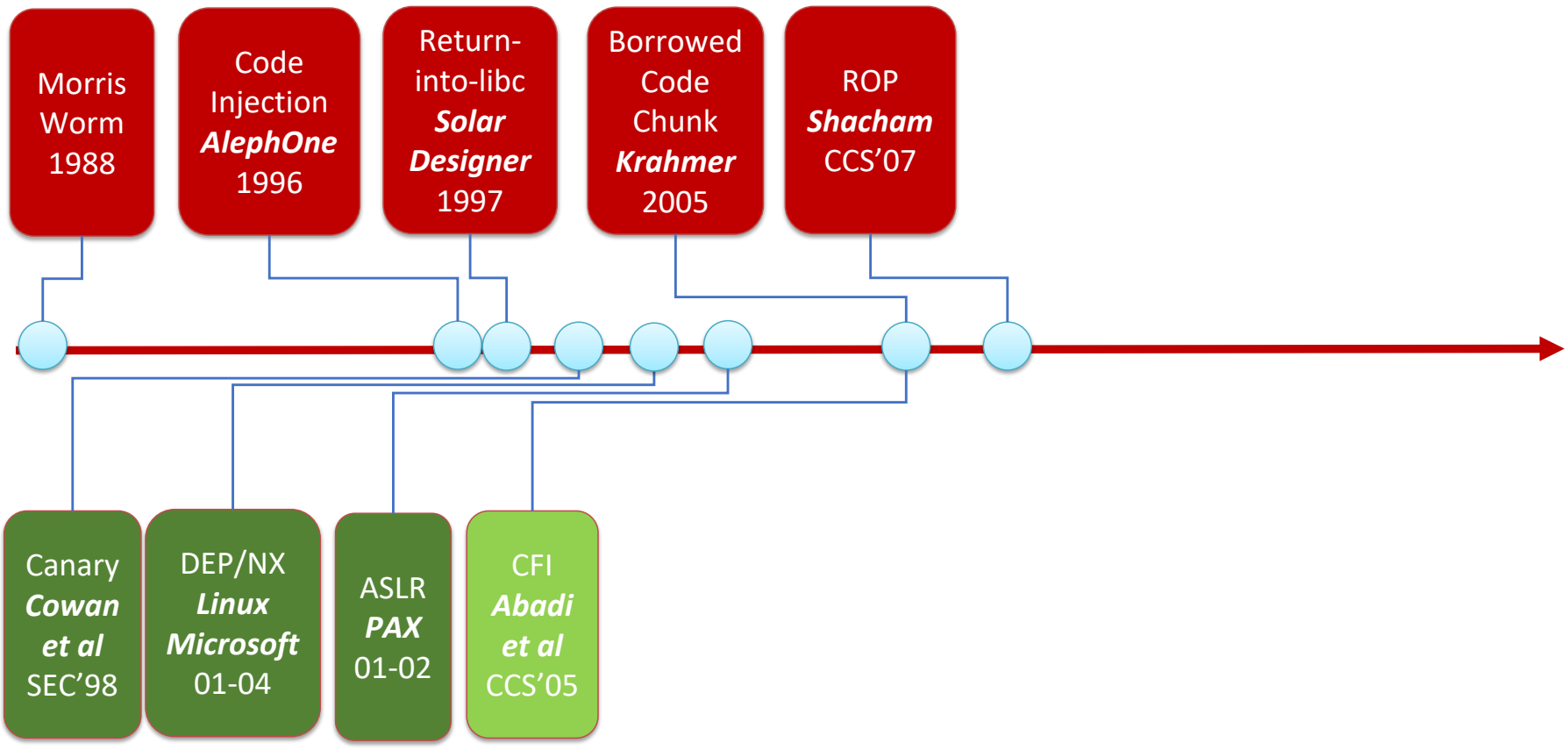

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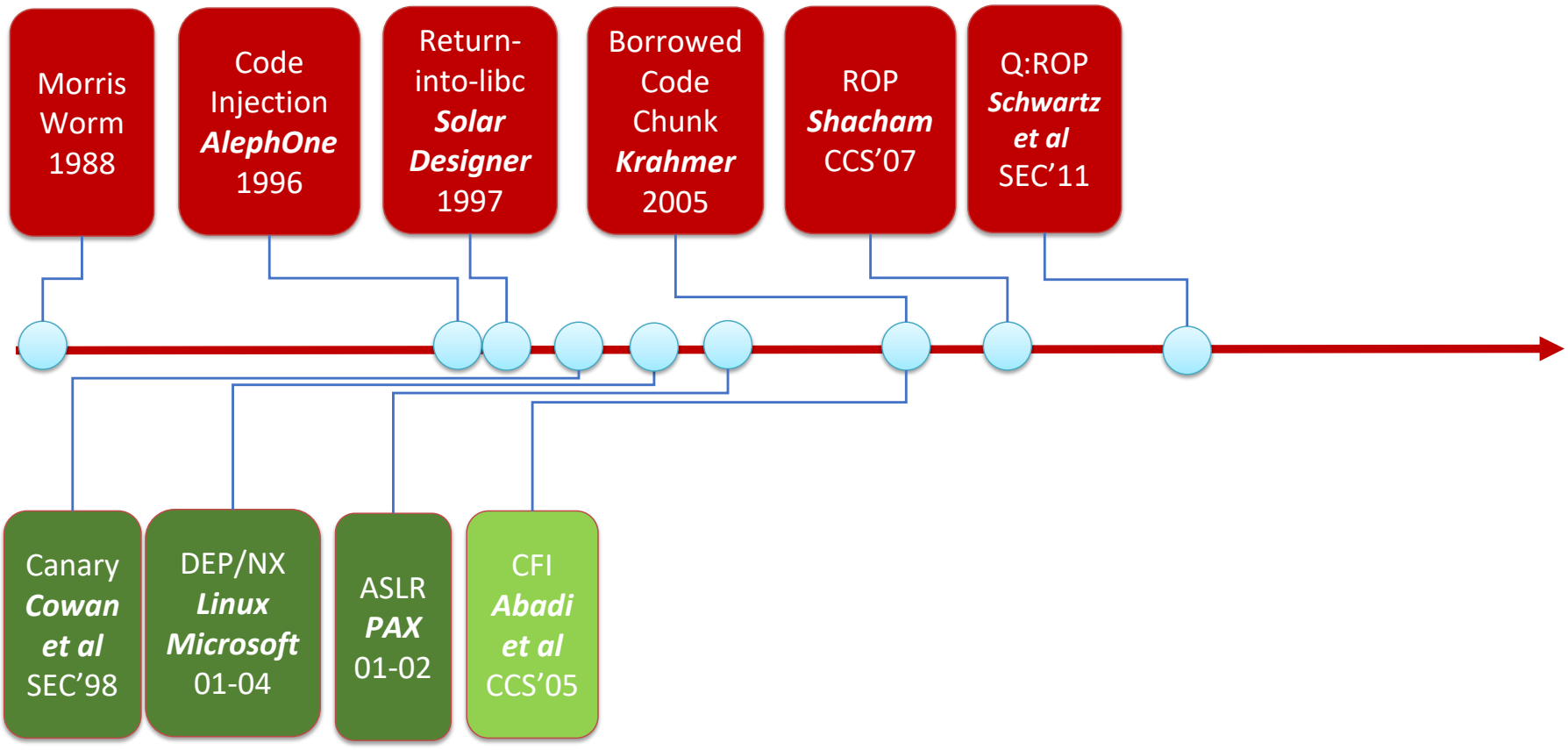

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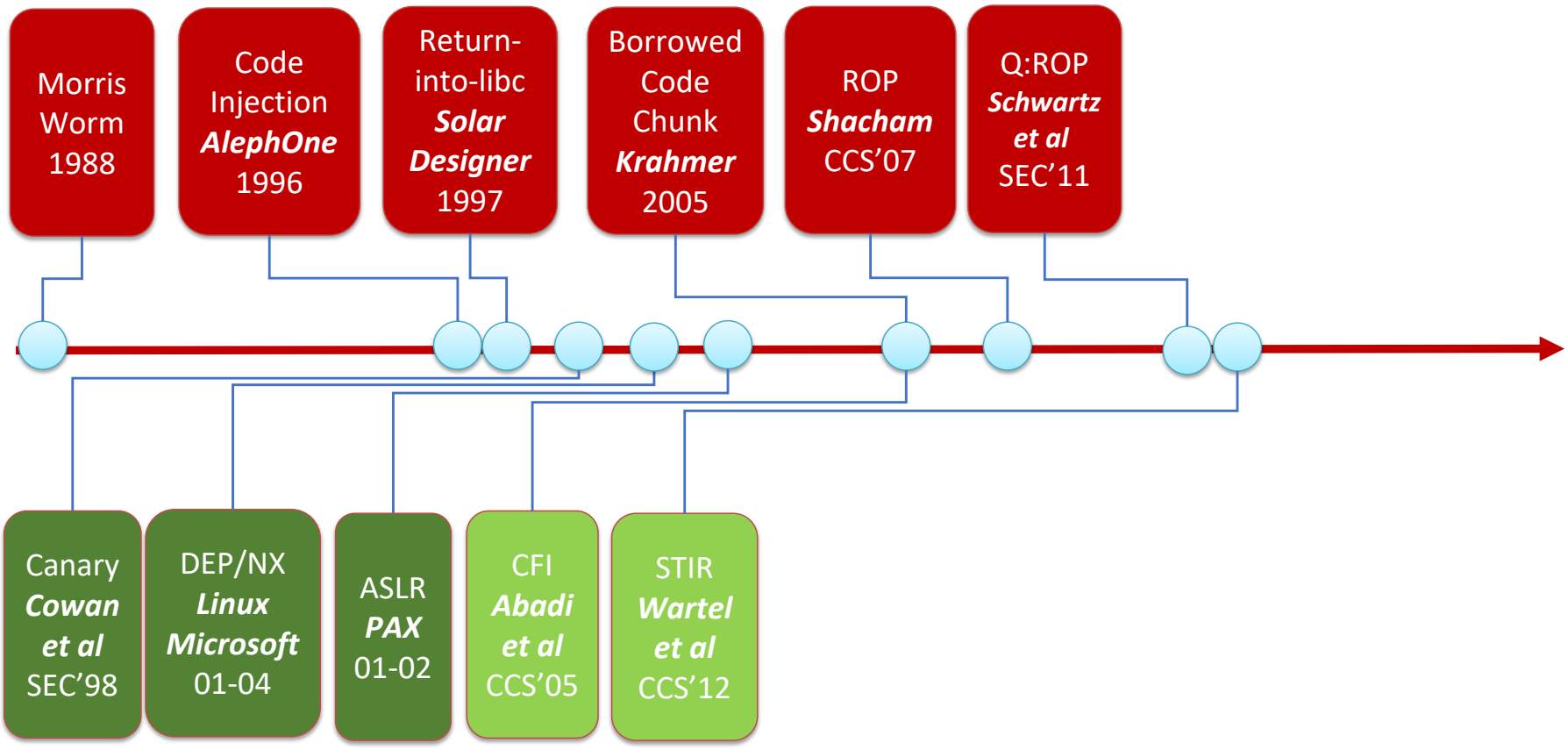

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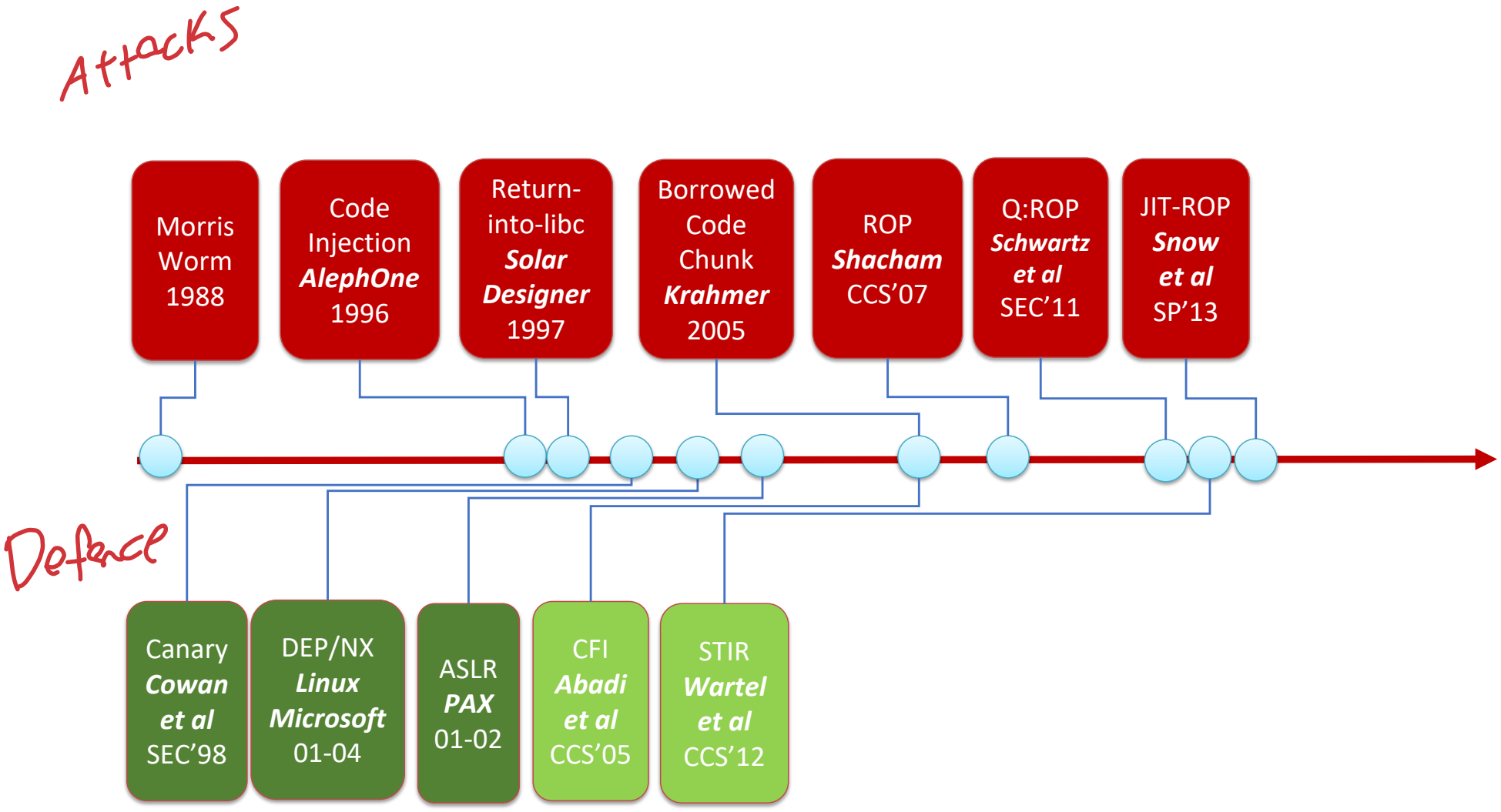

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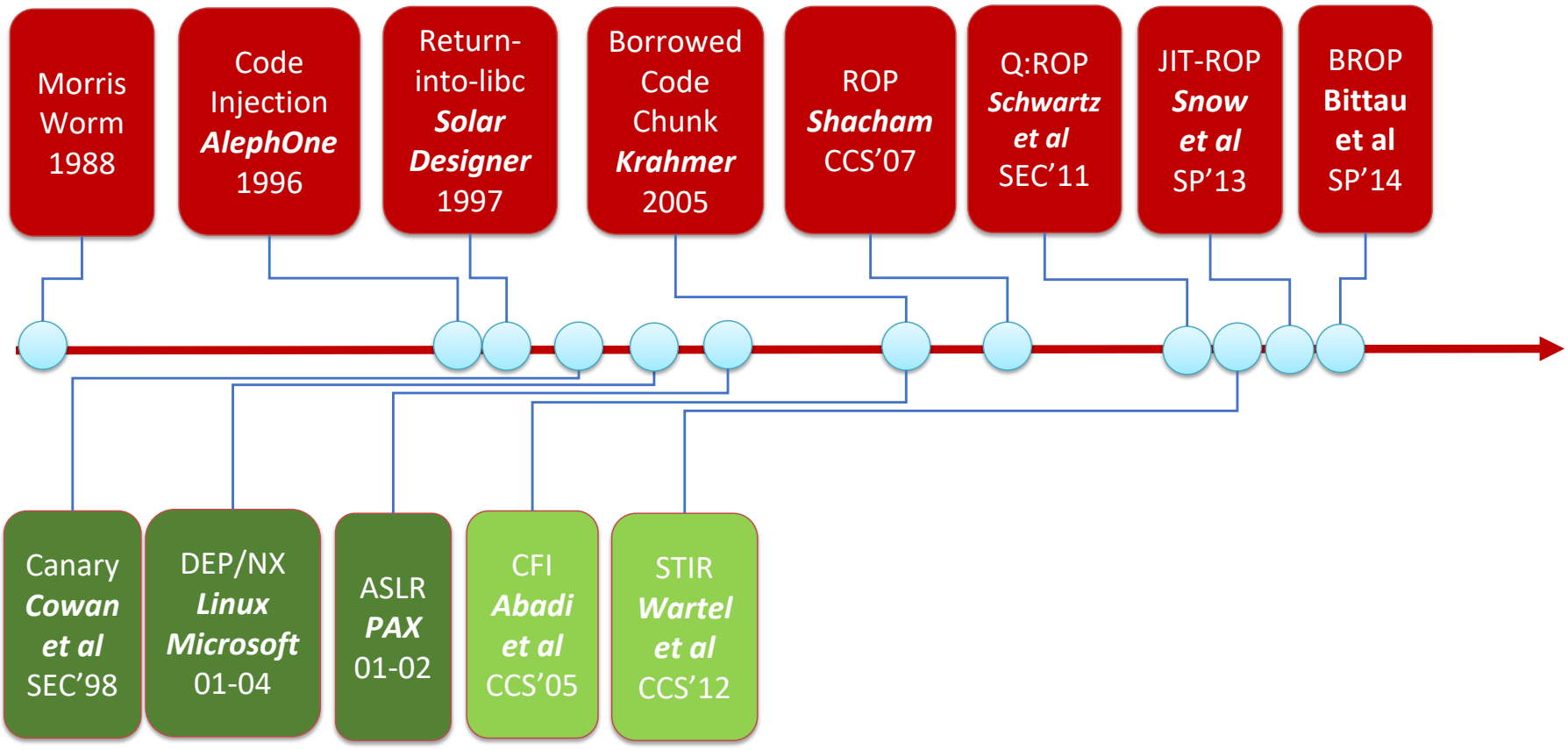

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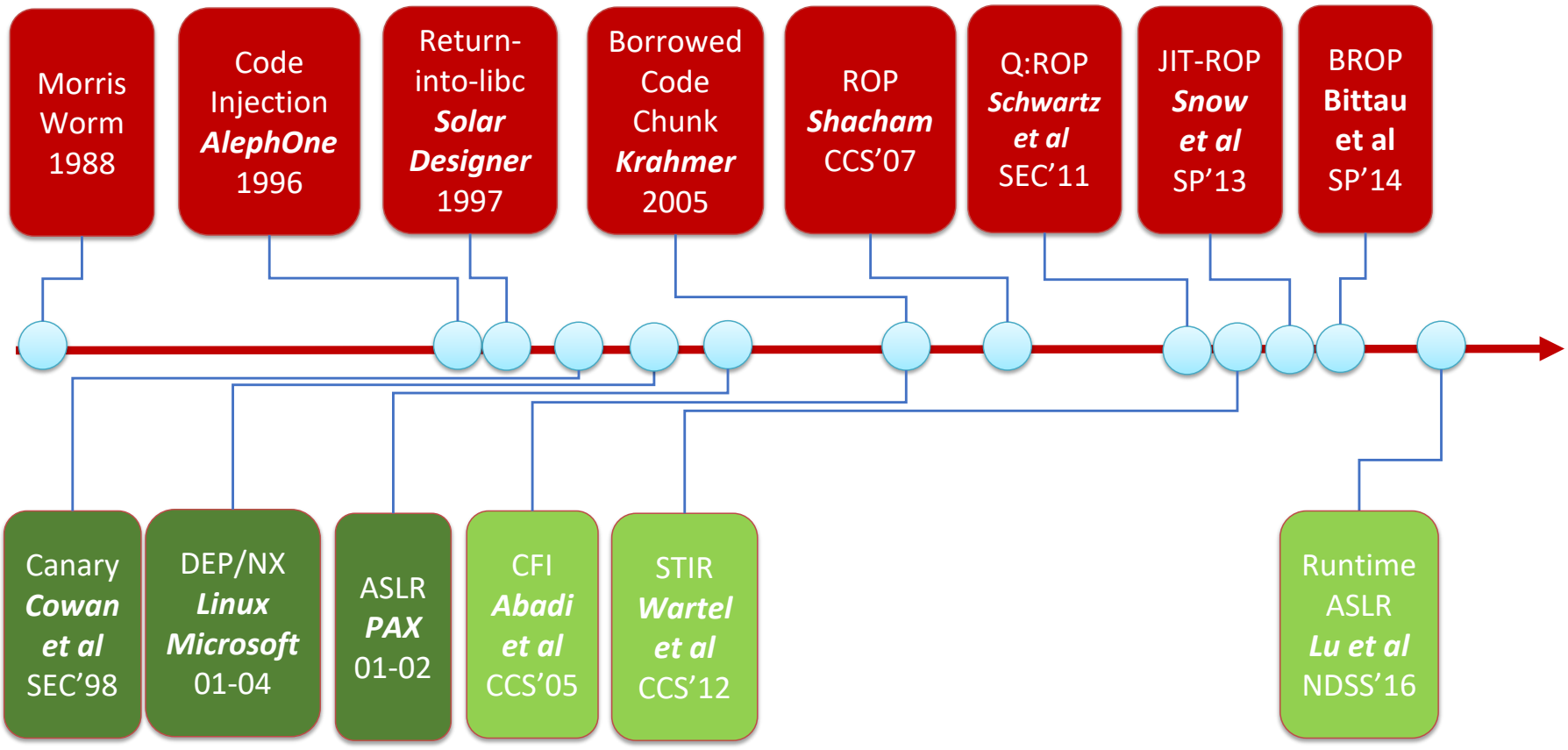

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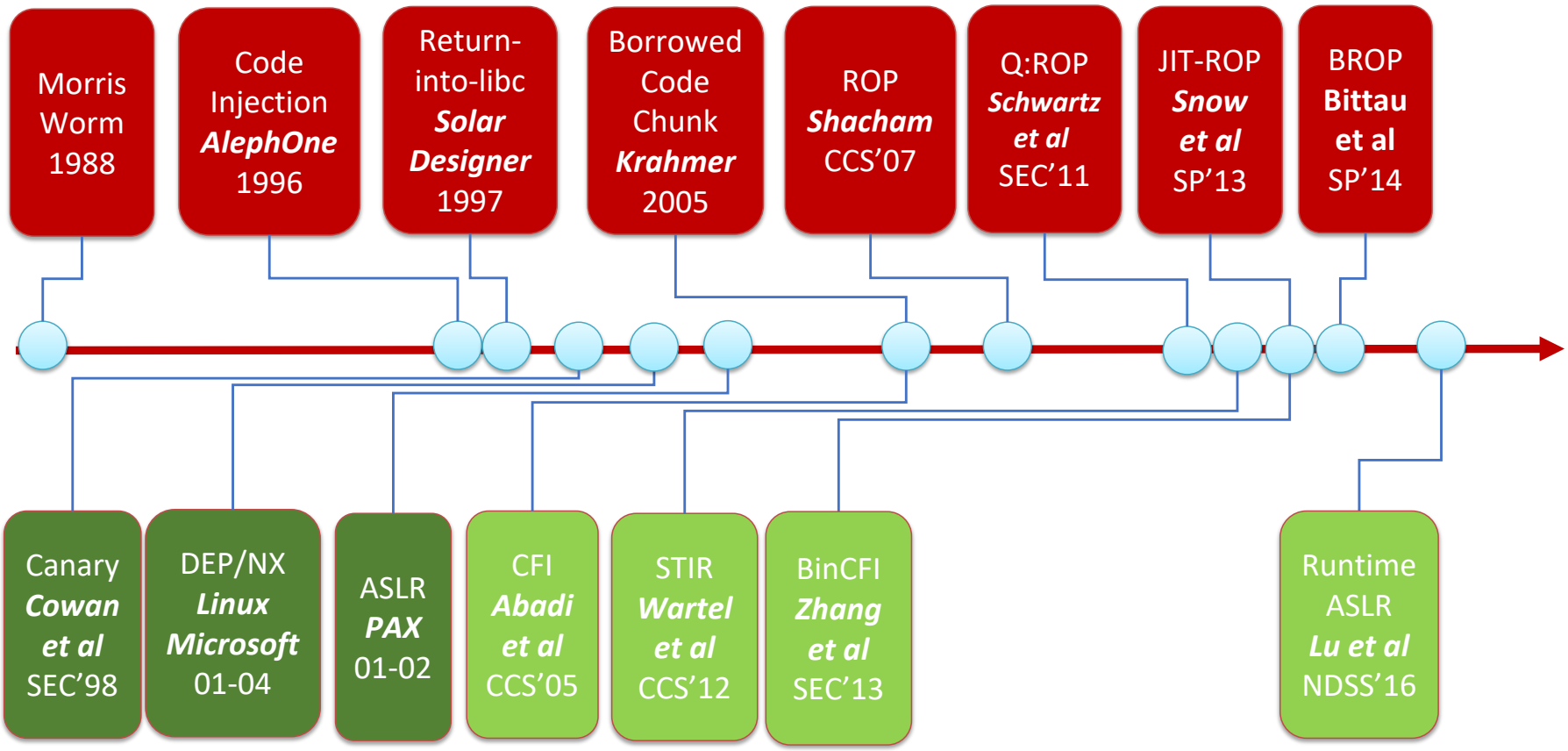

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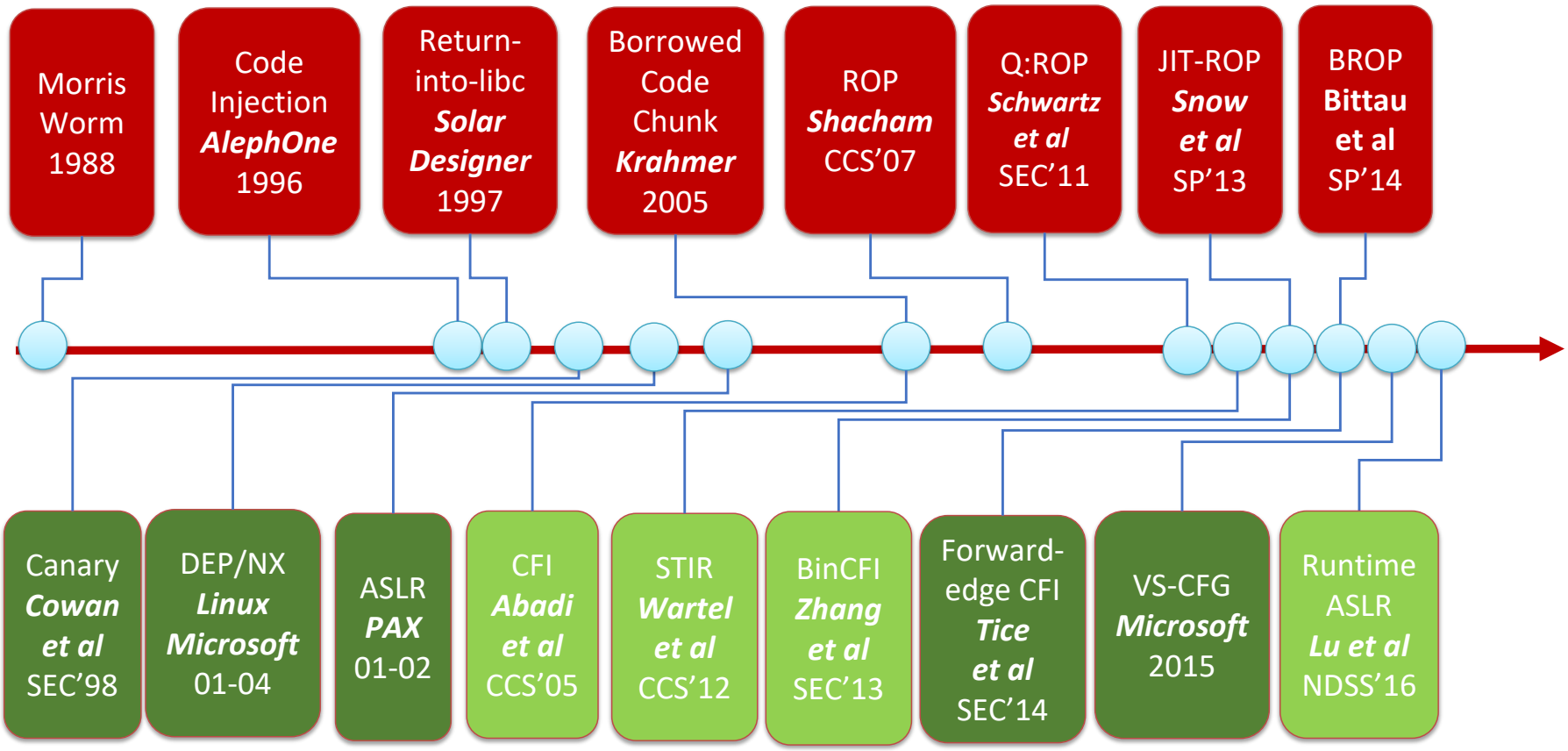

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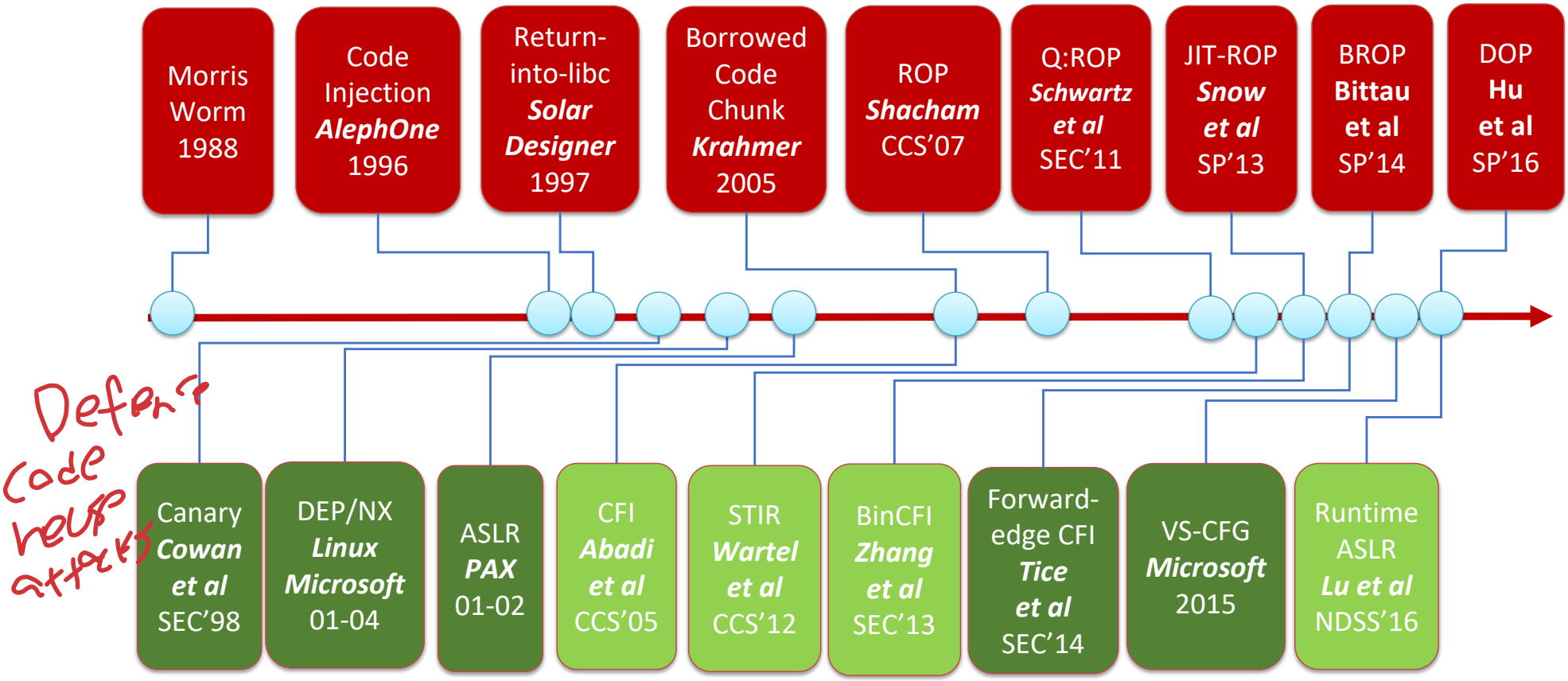

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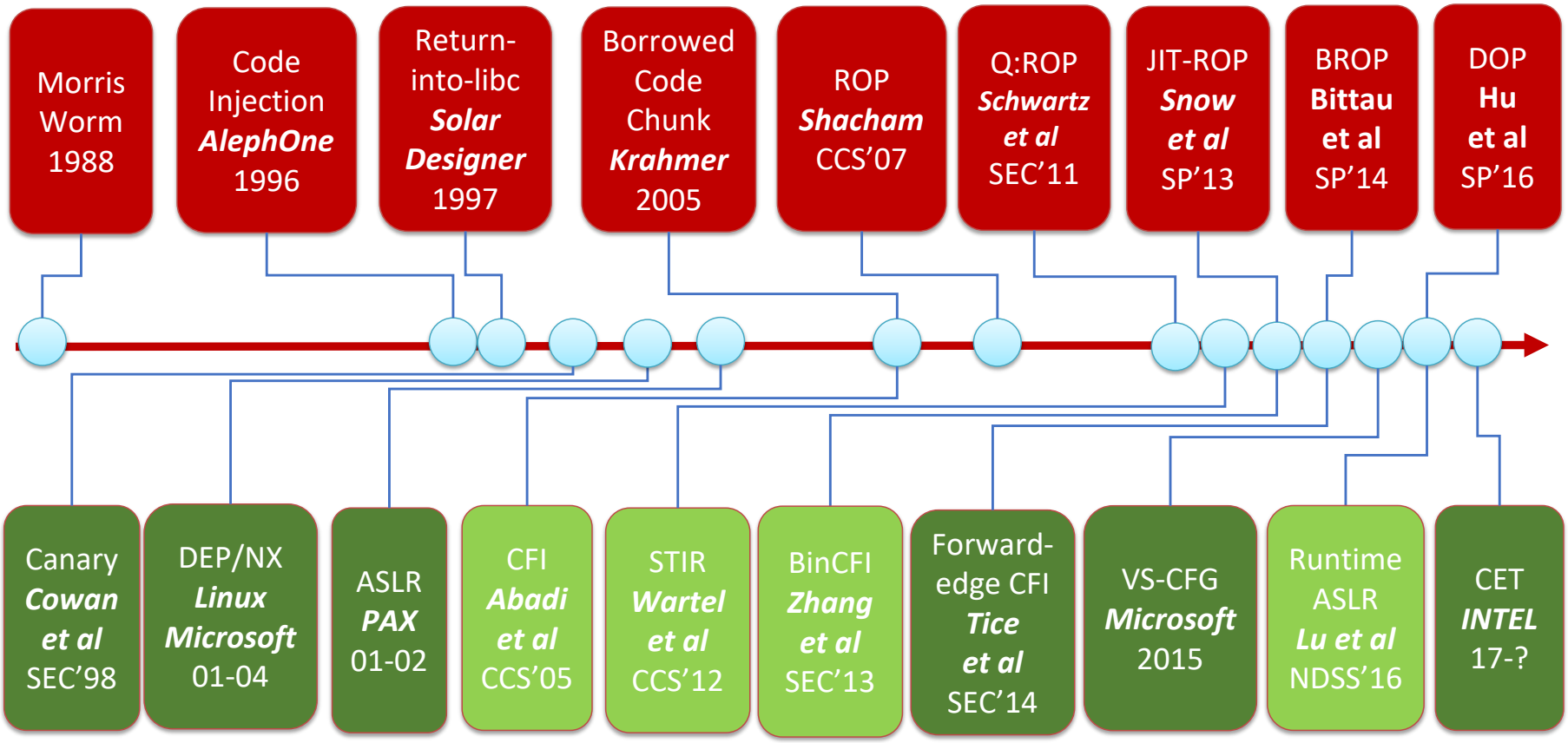

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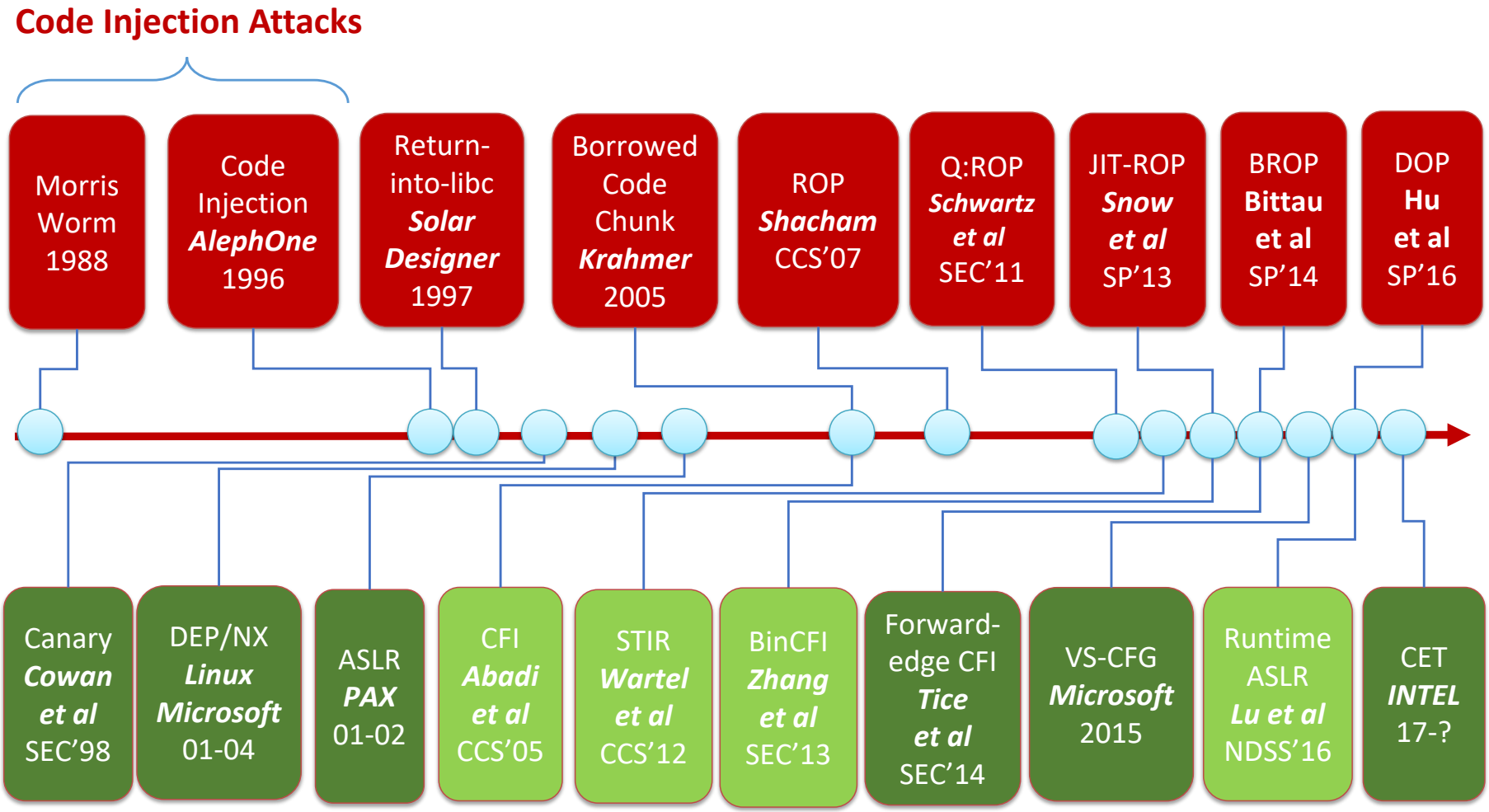

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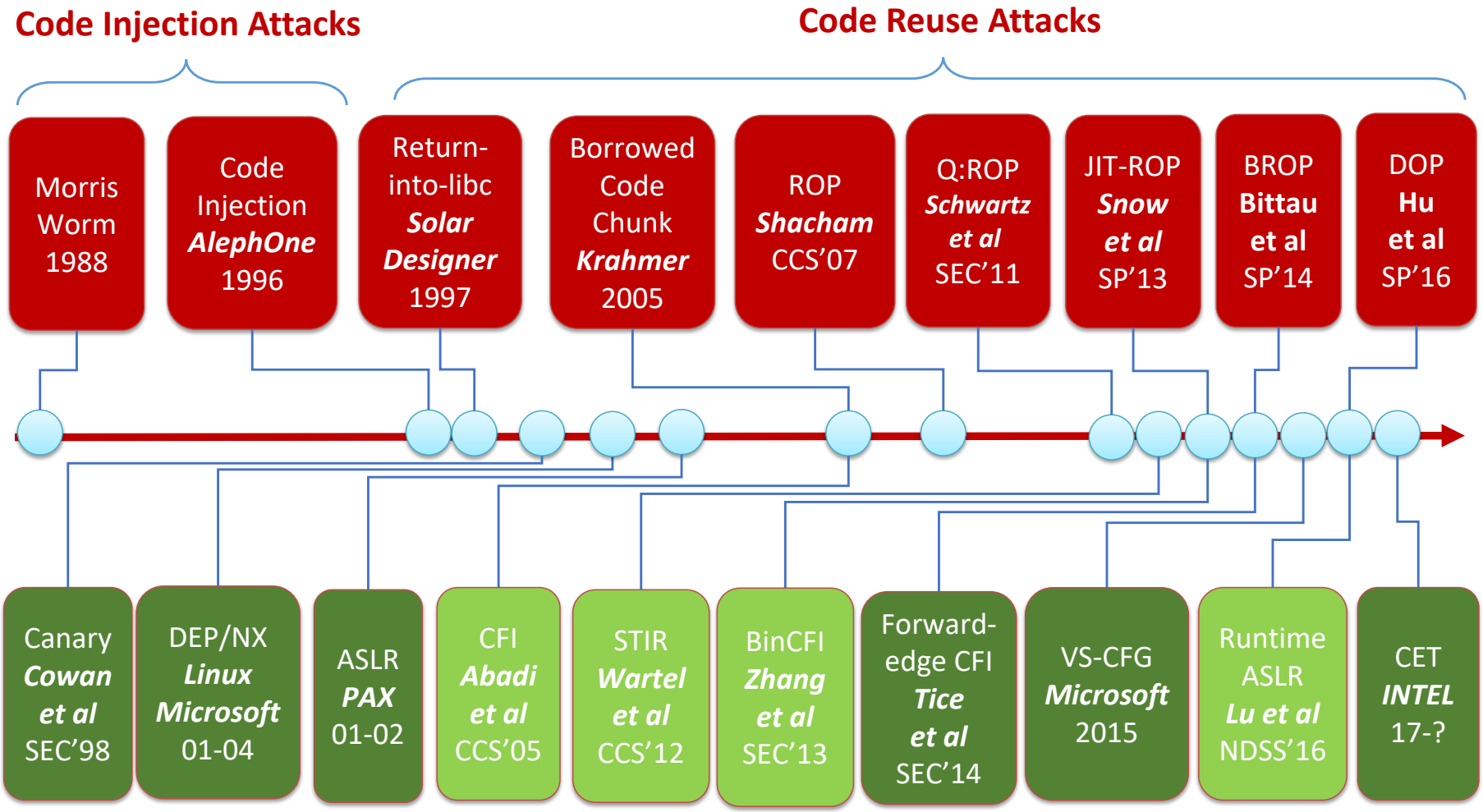
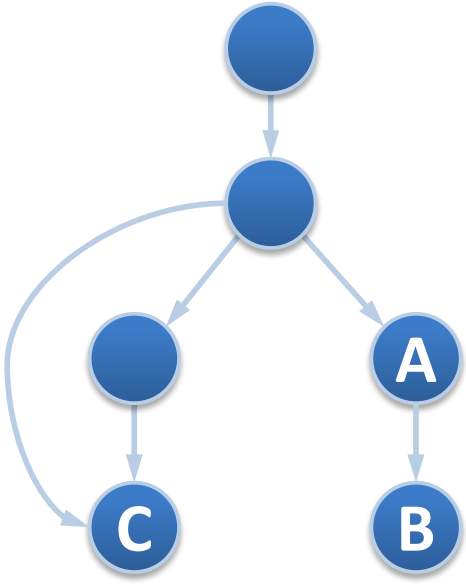


General Principle of **Code Injection Attacks**



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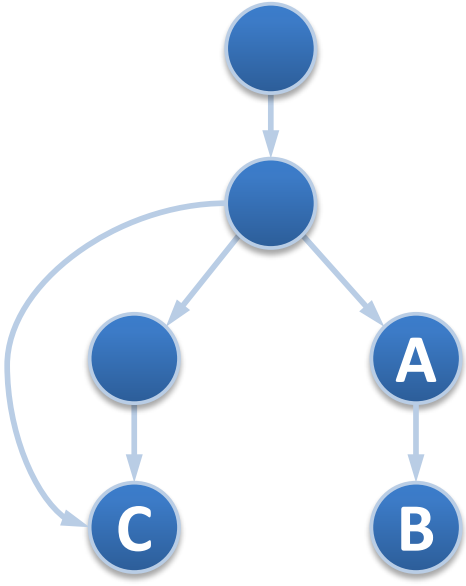

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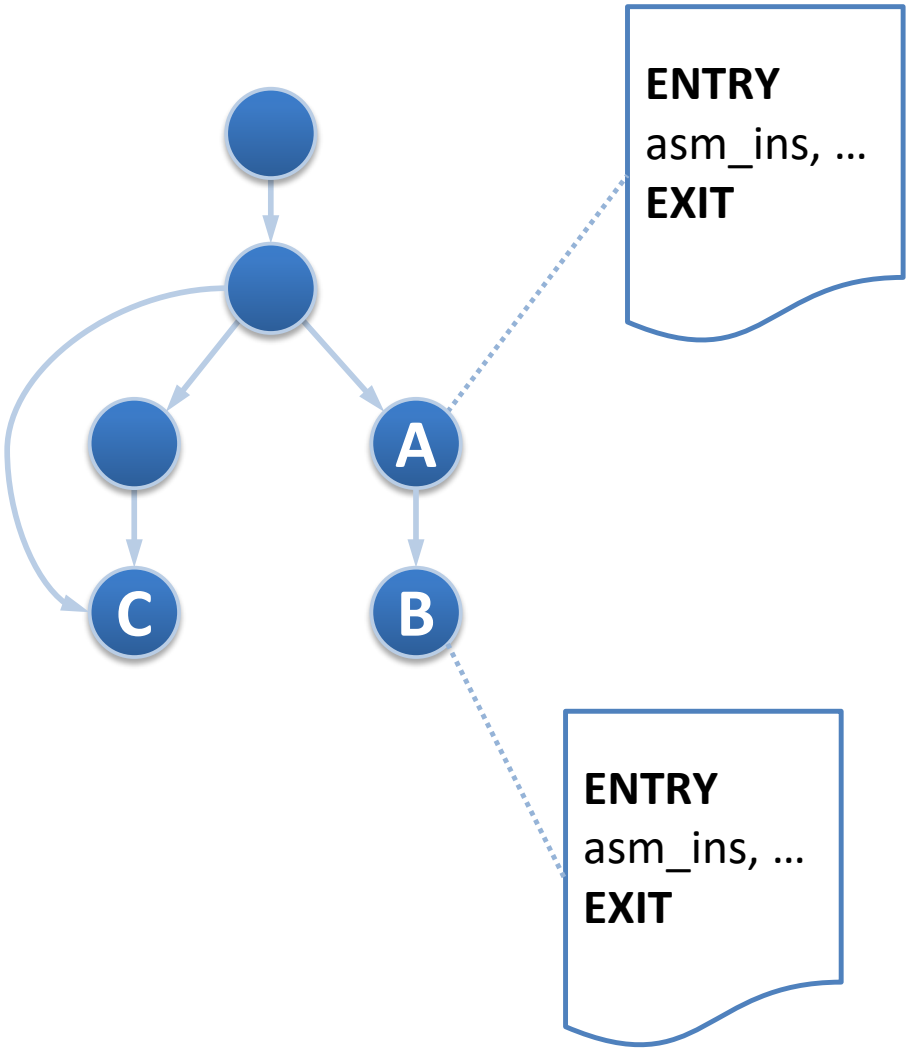

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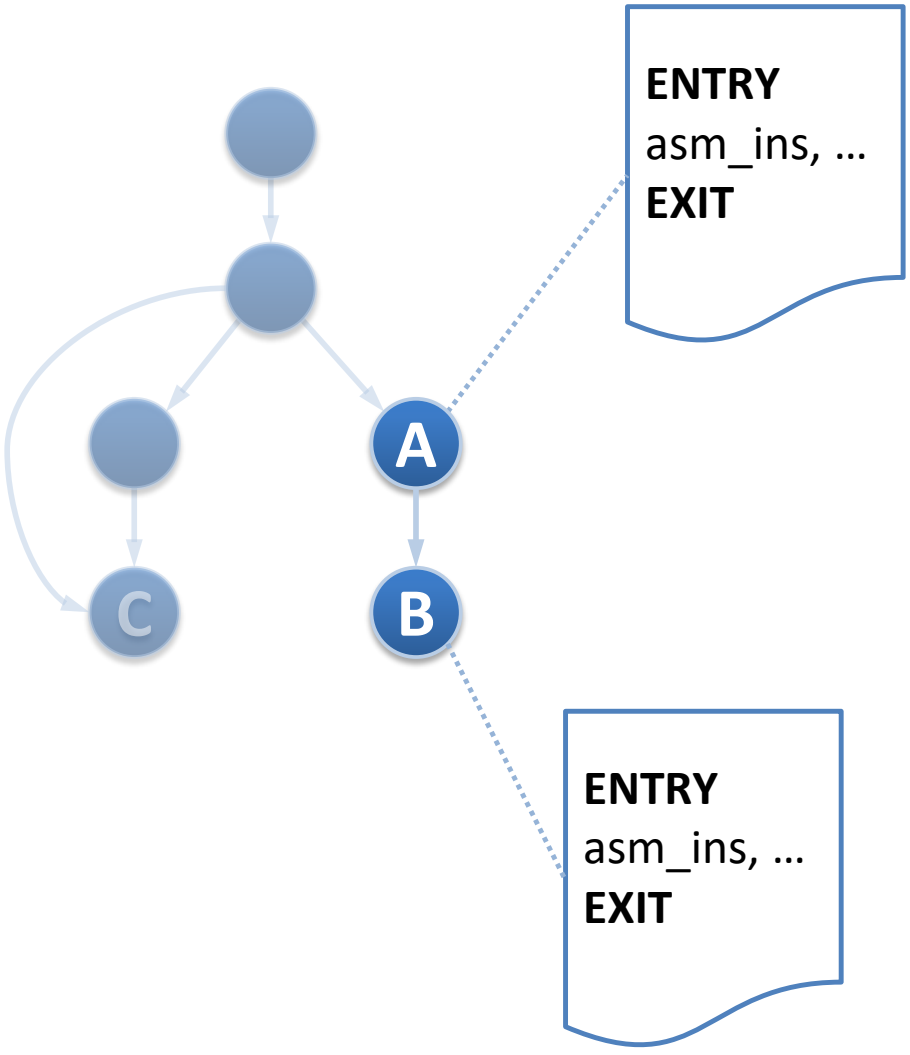

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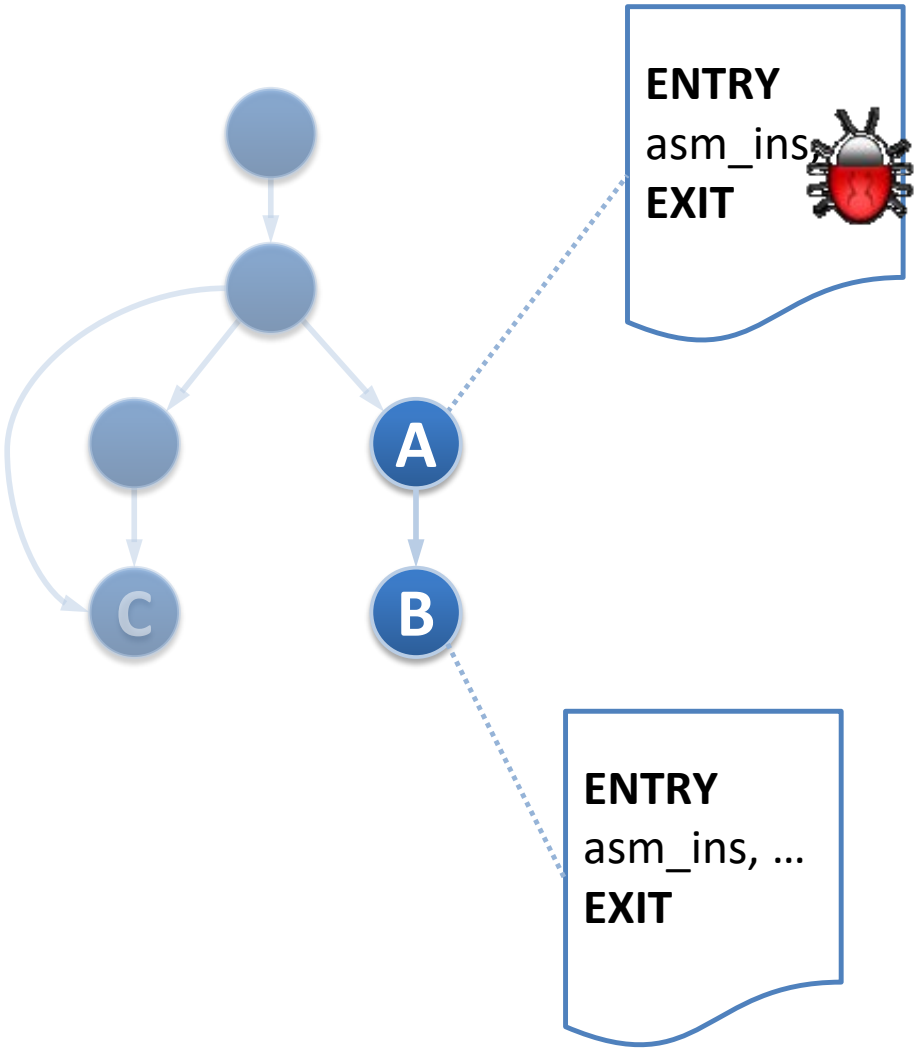

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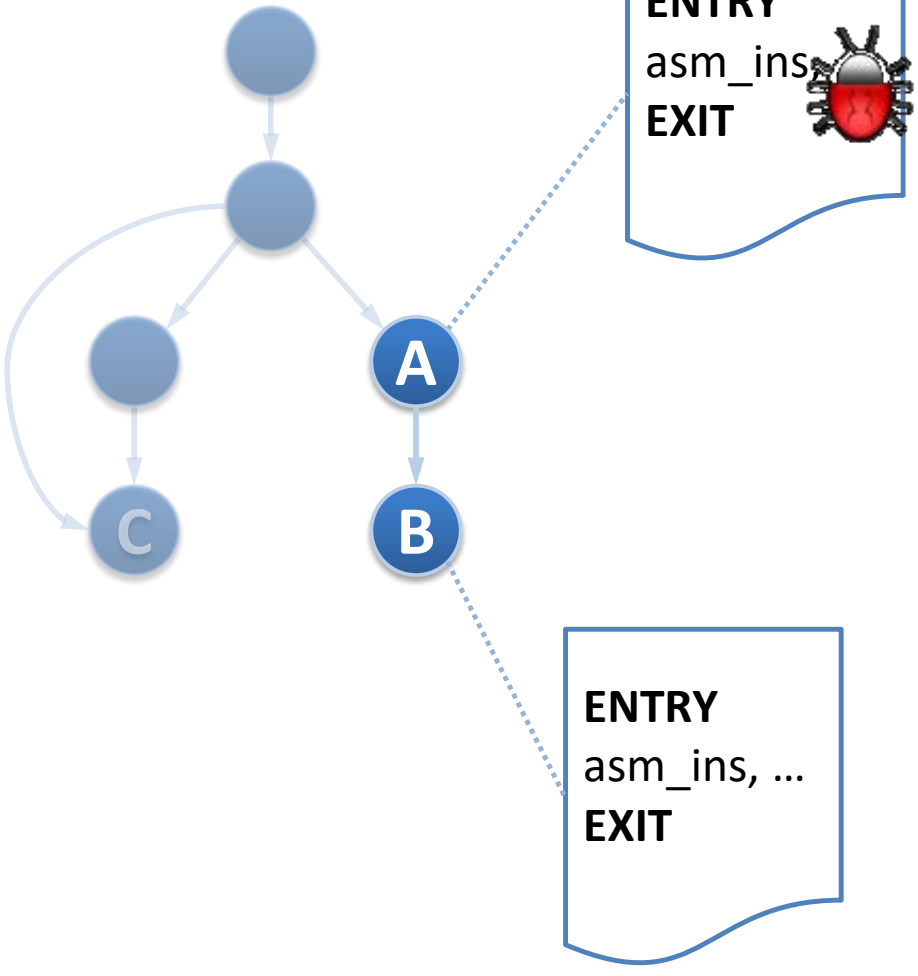

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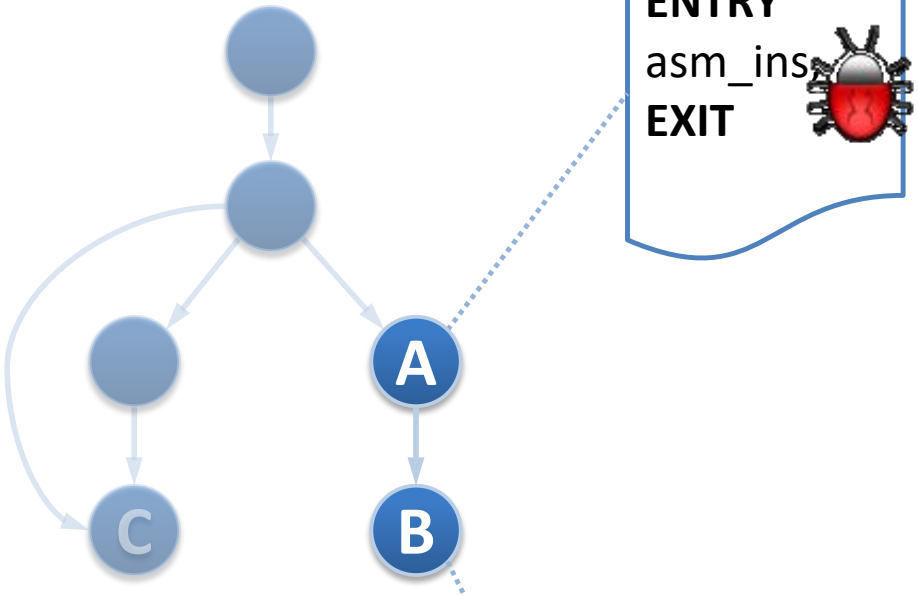

ENTRY
asm_ins
EXIT

ENTRY
asm_ins, ...
EXIT

Data flows
Program flows

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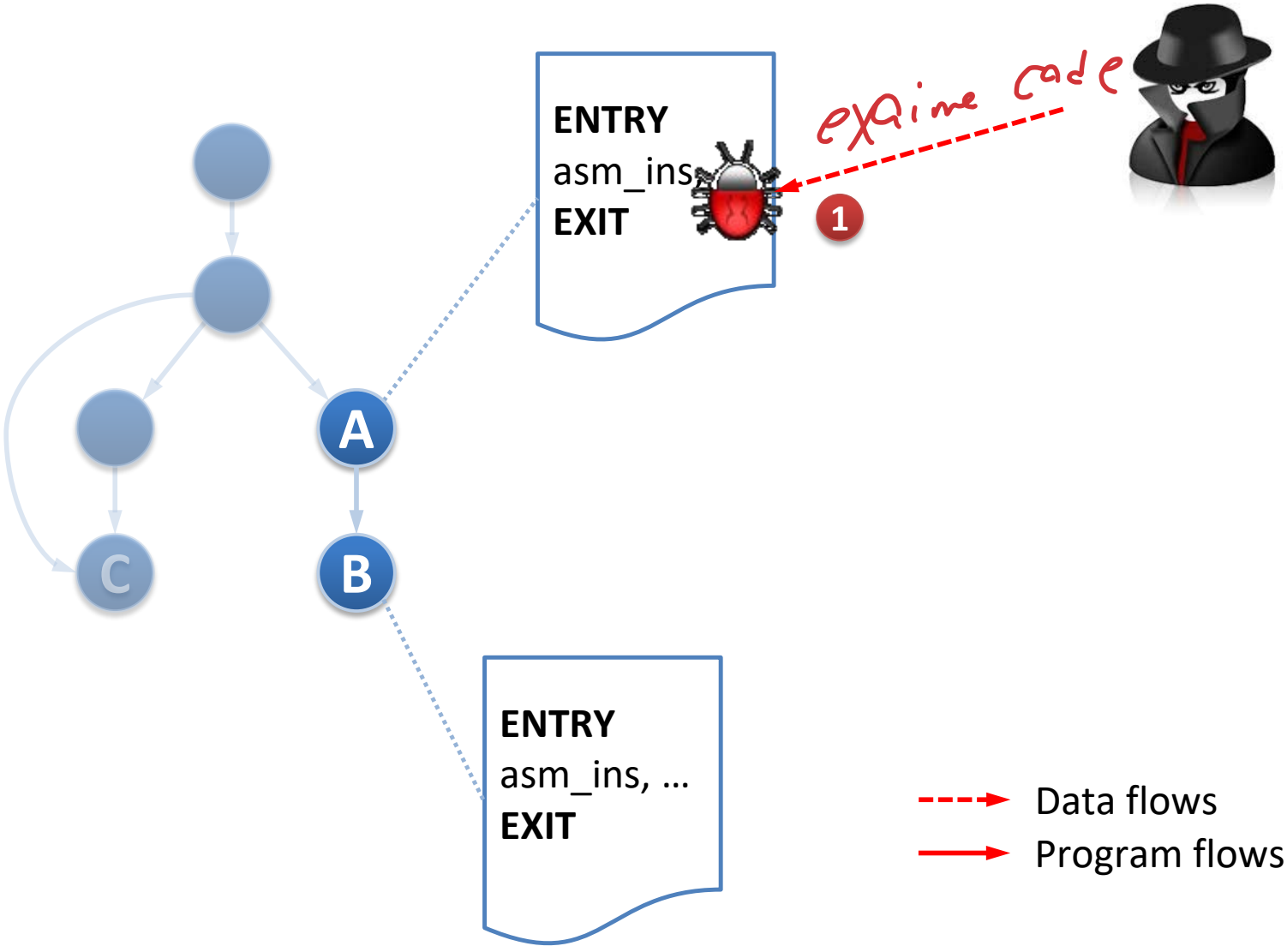

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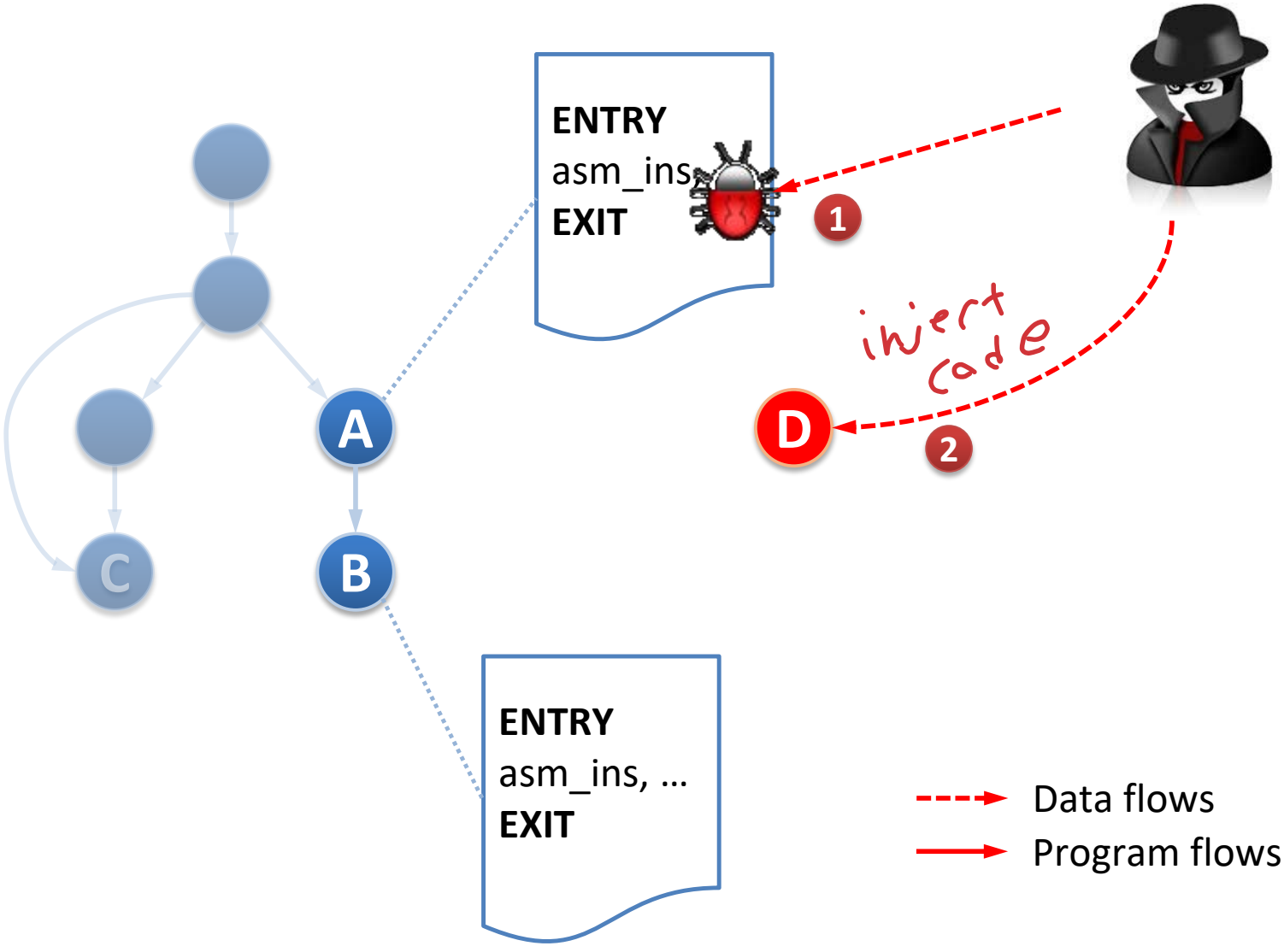

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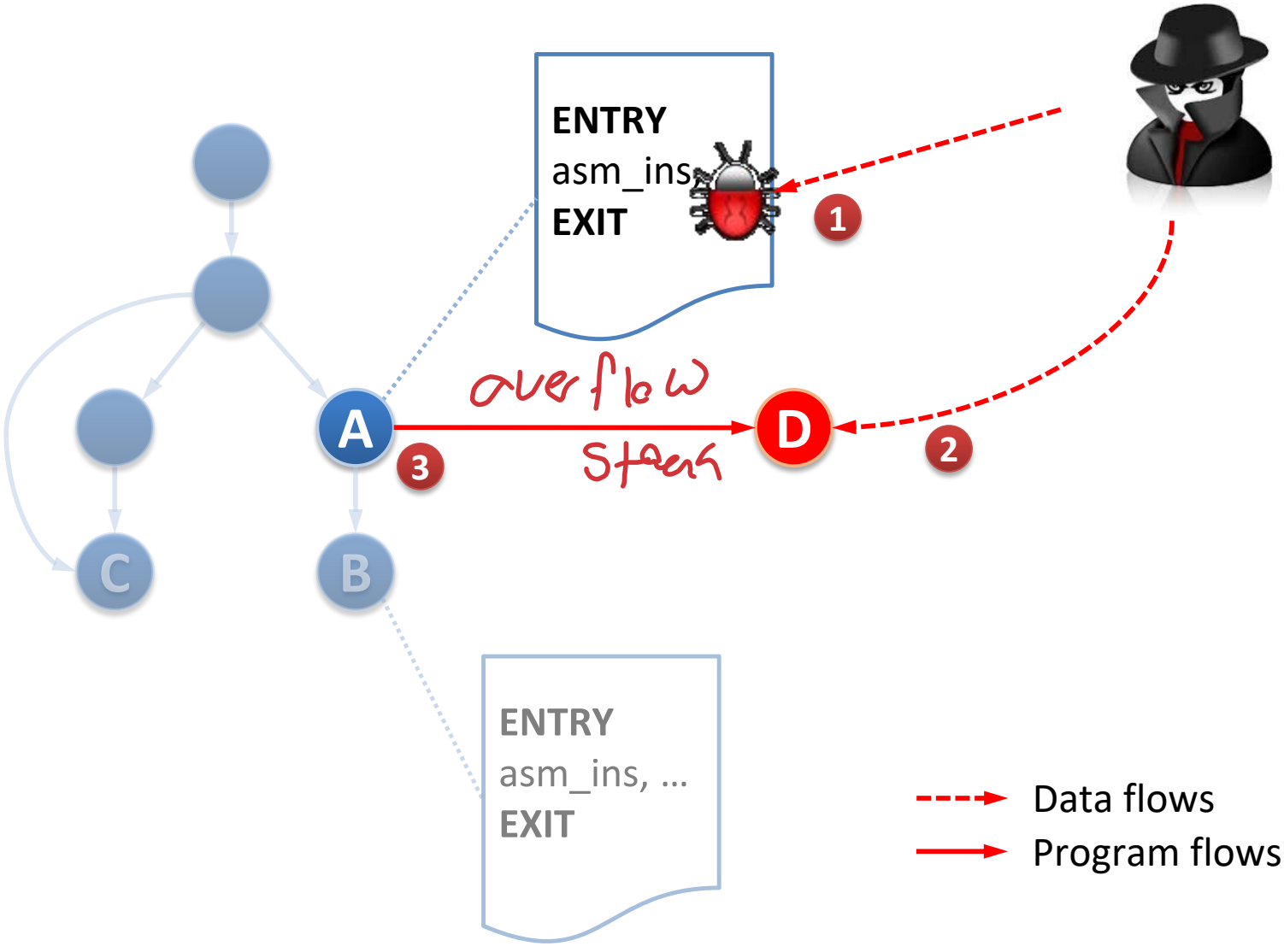

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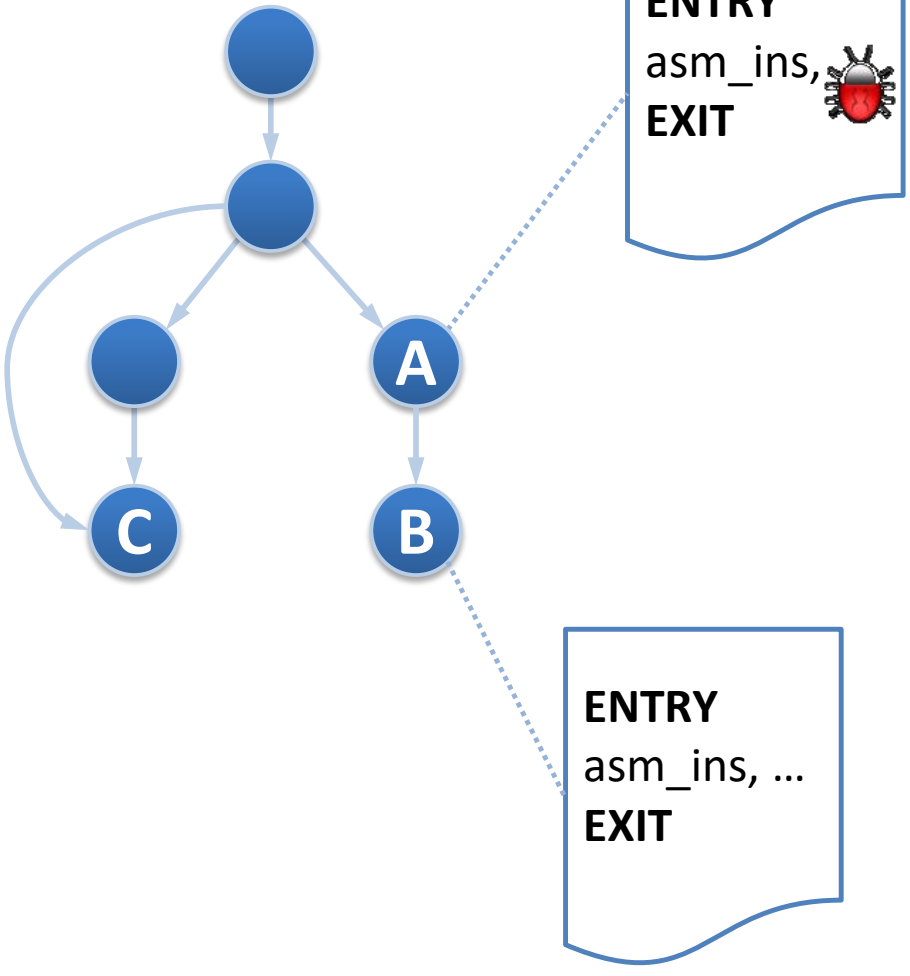

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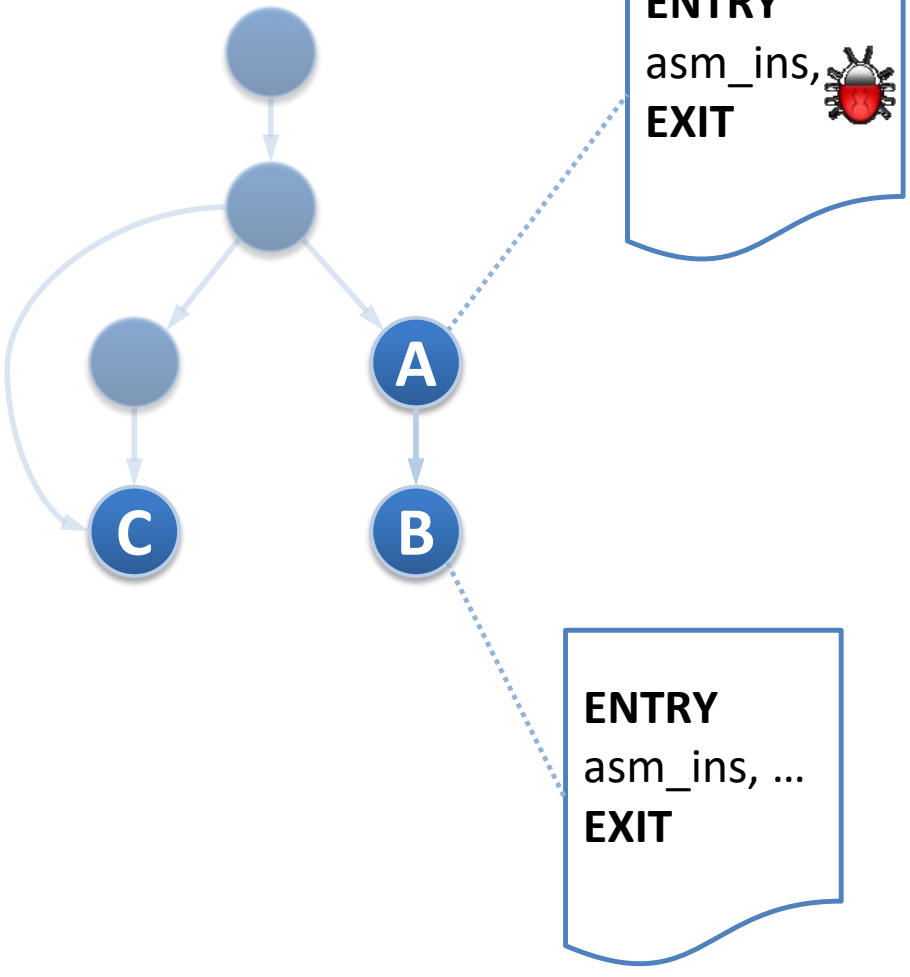

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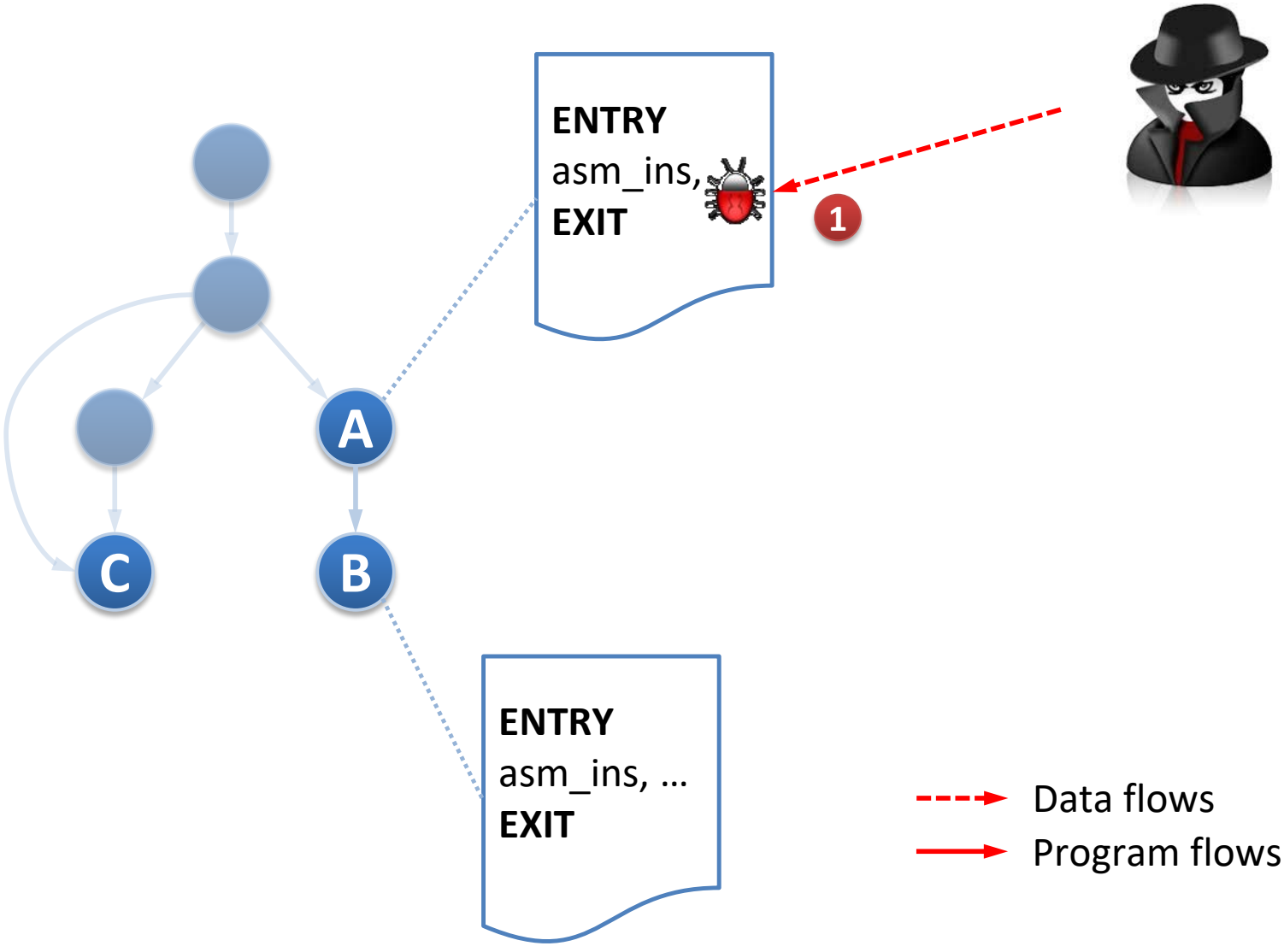

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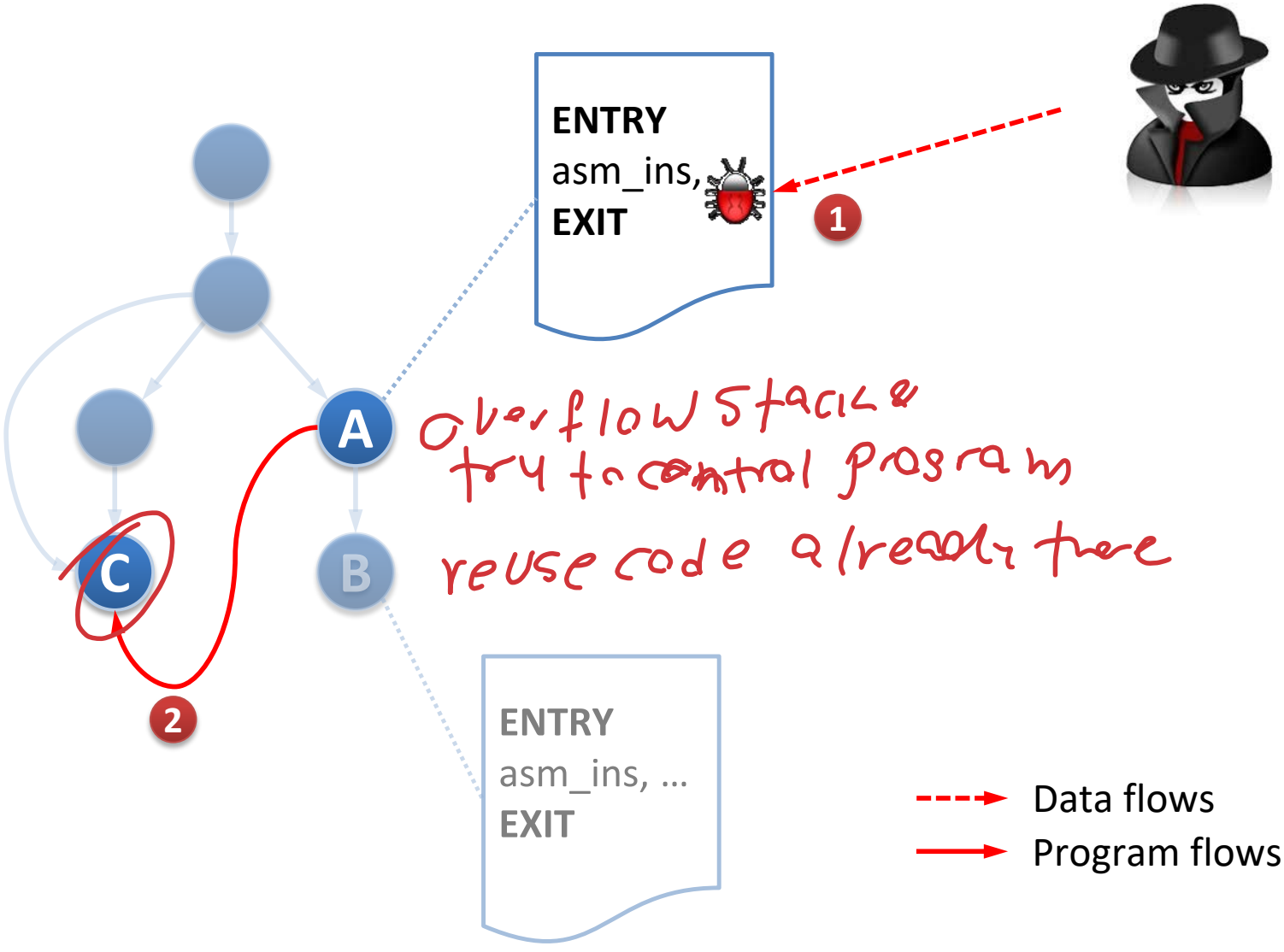


Memory Corruption → Control Flow Hijack

overwritten pointers

inject code here

buffer

computation + ***control***

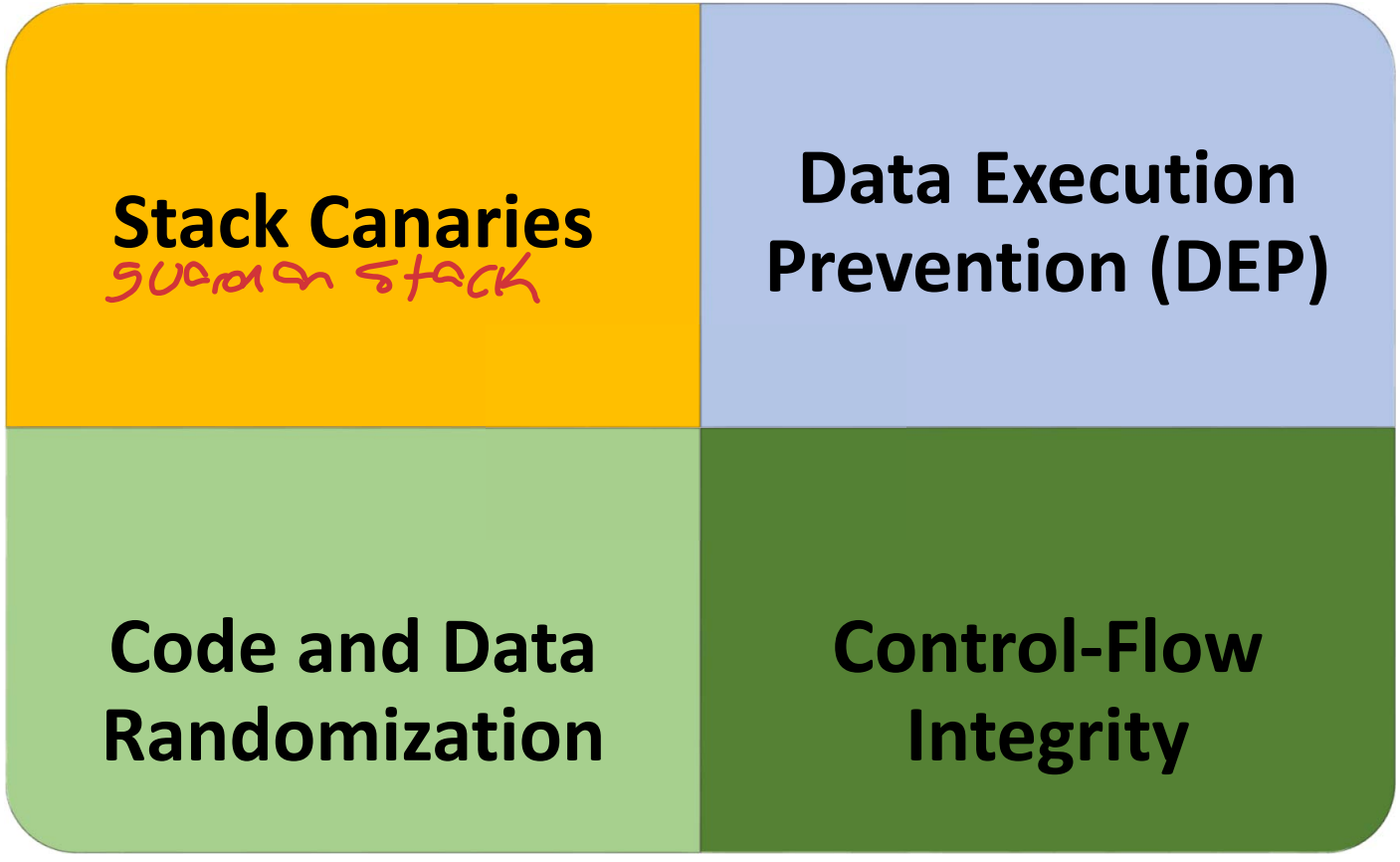
steps

1. Leveraging memory corruption **vulnerabilities**
2. Constructing special input (**exploit**):
   - Performing certain **computation**
   - Gaining the **control** of the program

Same principle, different mechanism

1. Code injection
2. Code reuse

The Run-time Defenses Against Memory Corruptions



Defense Against Code Injection

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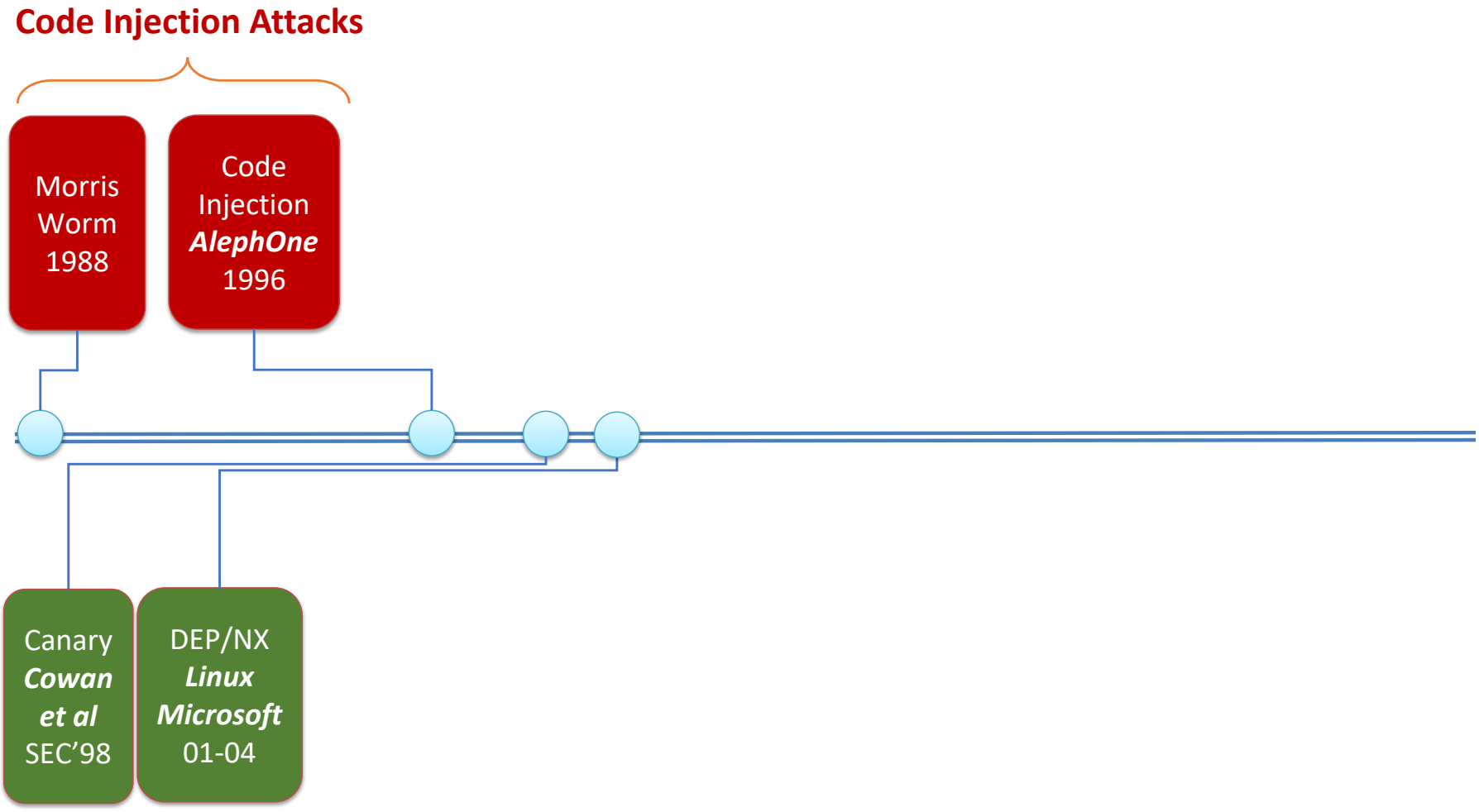
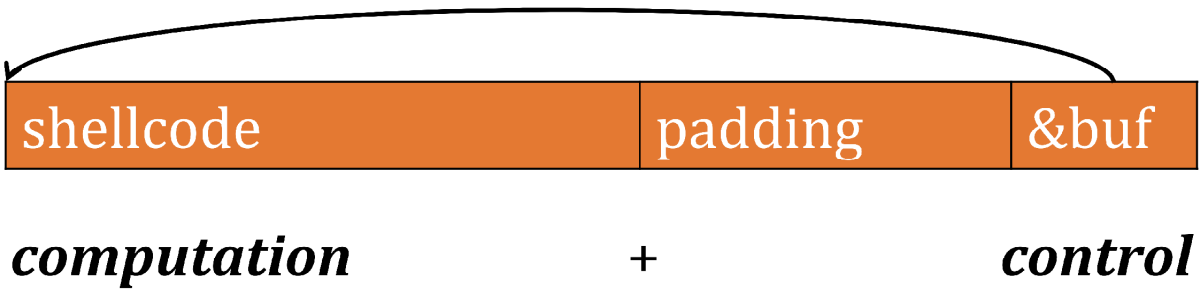
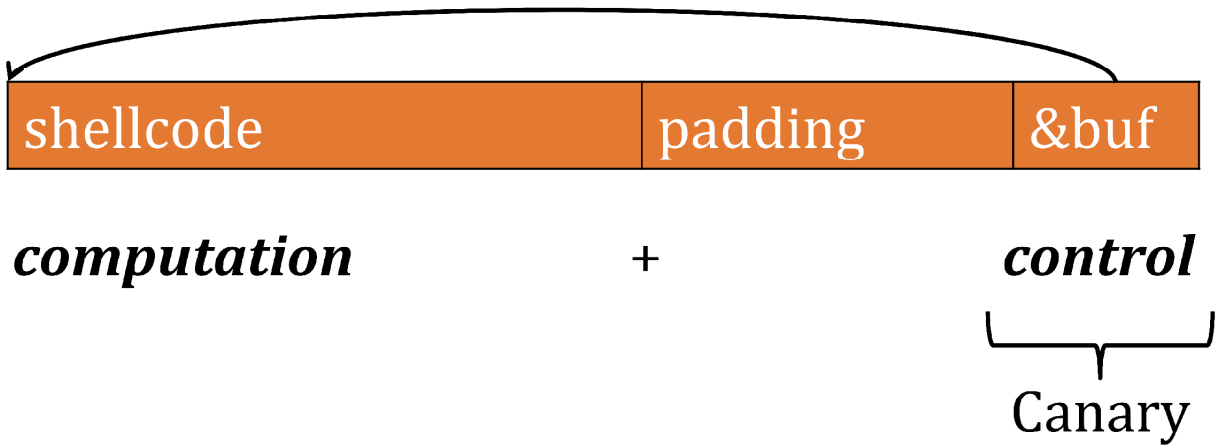


How Canary Defending Against Control Flow Hijacks

overflow buffer



How Canary Defending Against Control Flow Hijacks



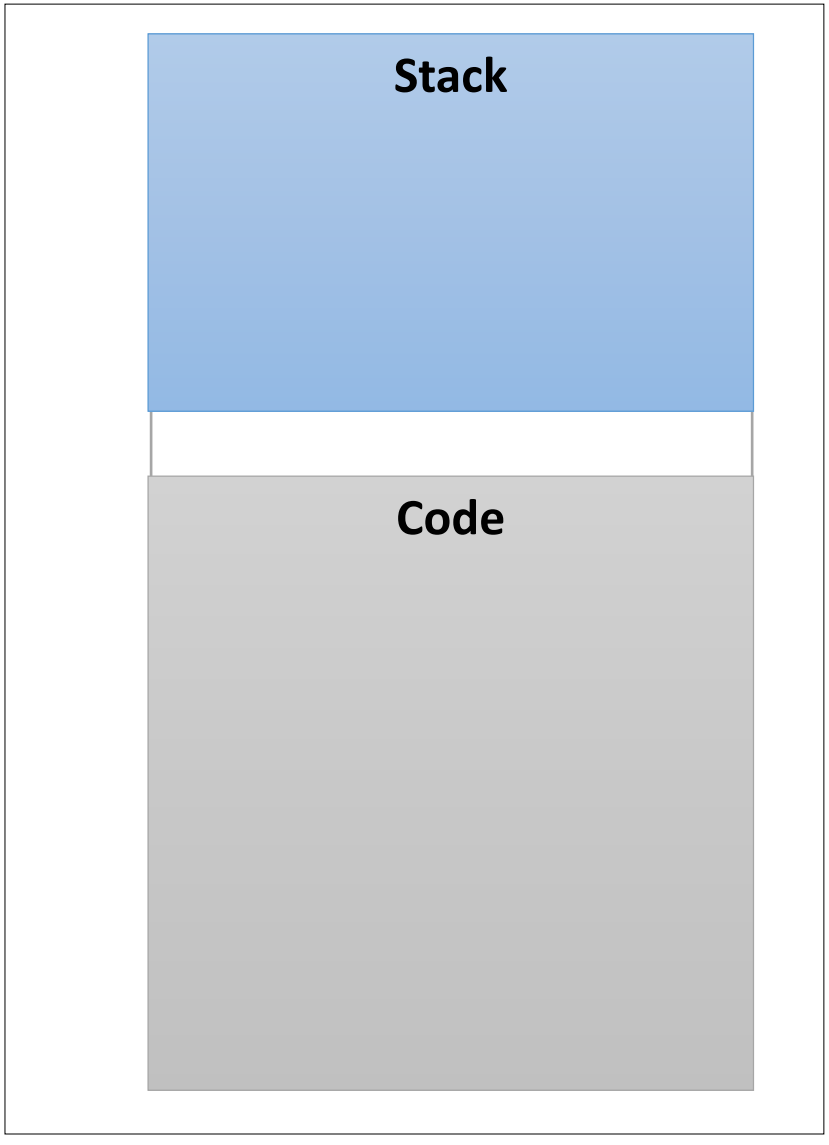
Canary Defense

Wikipedia: "the historic practice of using canaries in coal mines, since they would be affected by toxic gases earlier than the miners, thus providing a biological warning system."

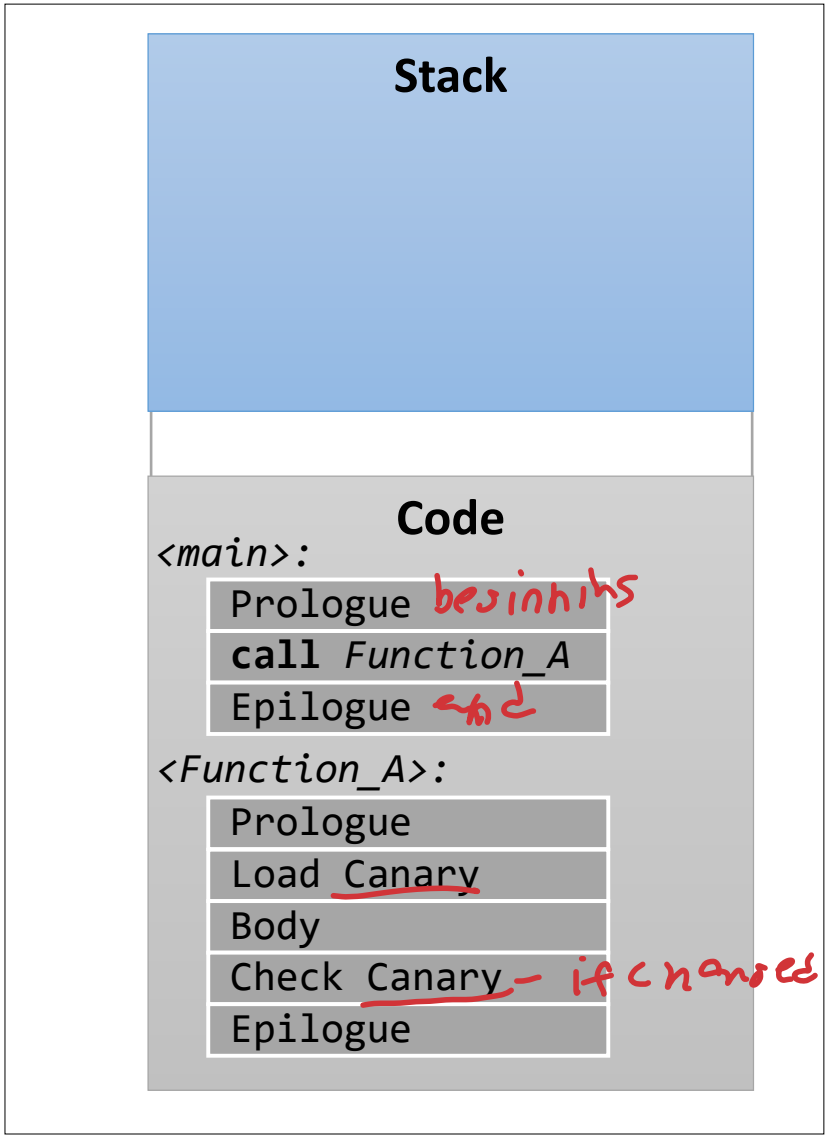
Canary / Stack Cookies

http://en.wikipedia.org/wiki/File:Domestic_Canary_-_Serinus_canaria.jpg

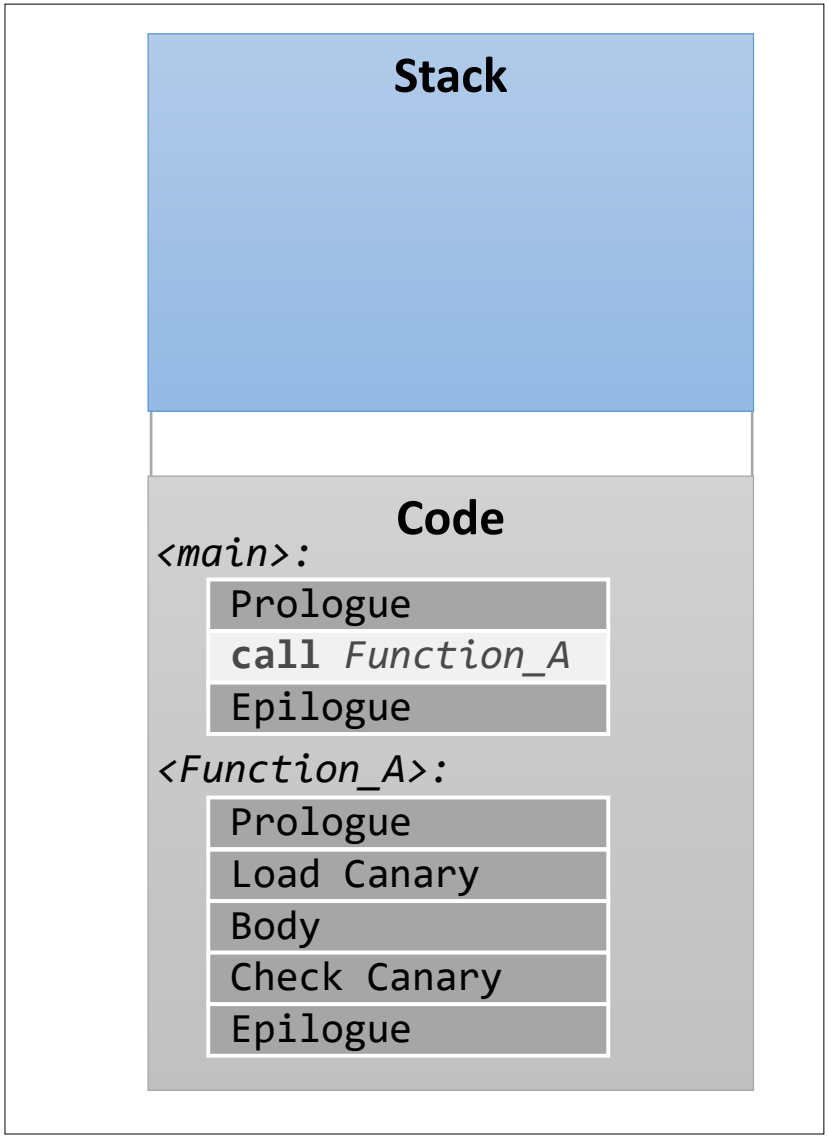
Canary Defense



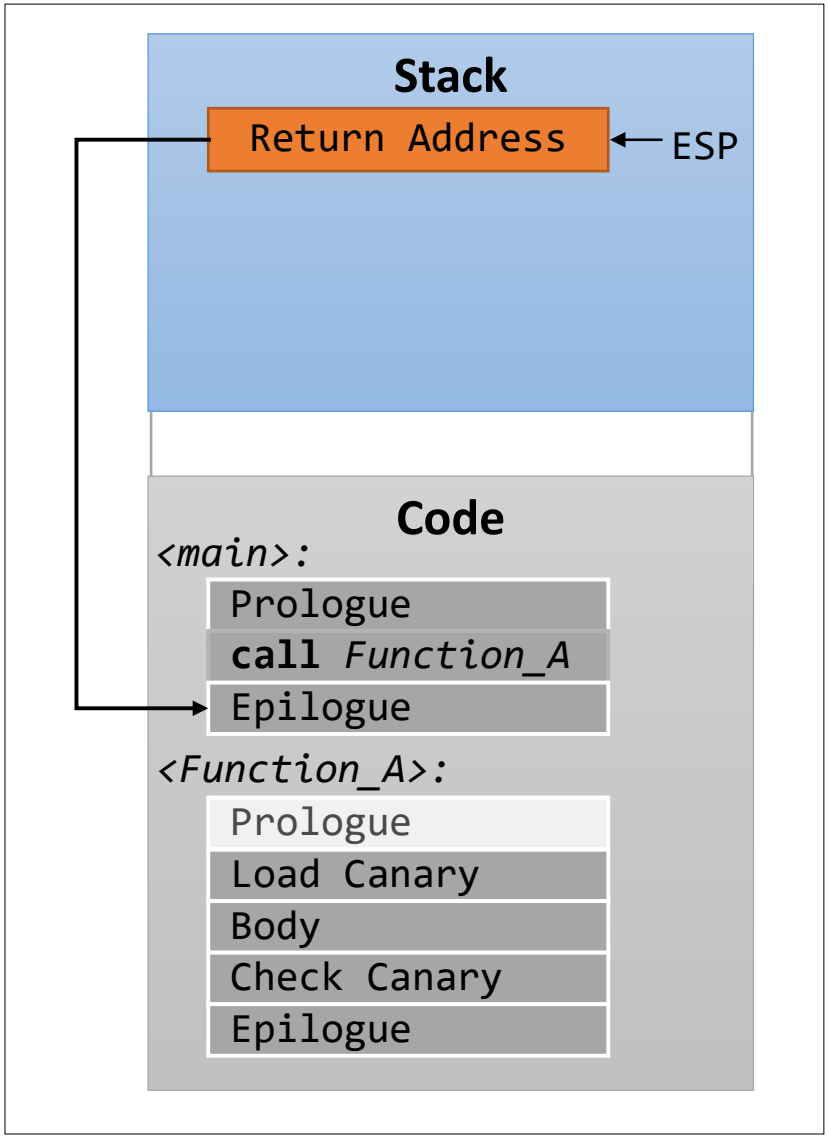
Canary Defense



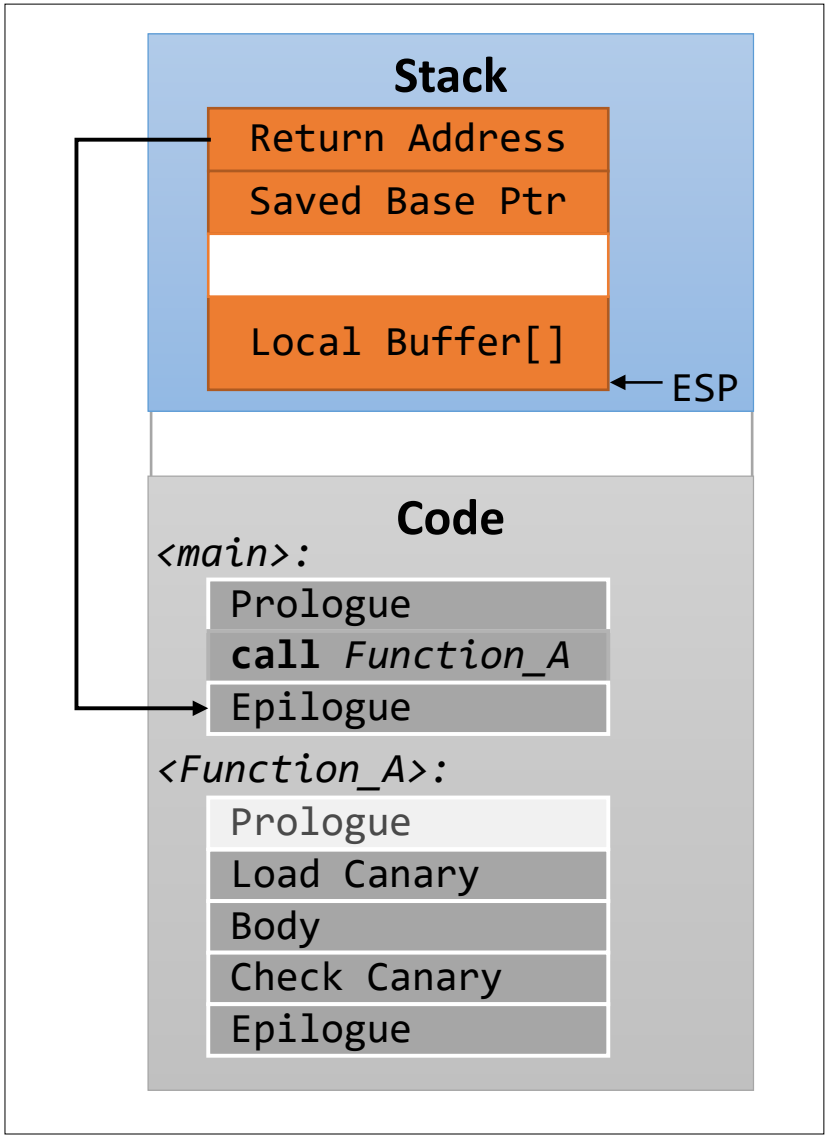
Canary Defense



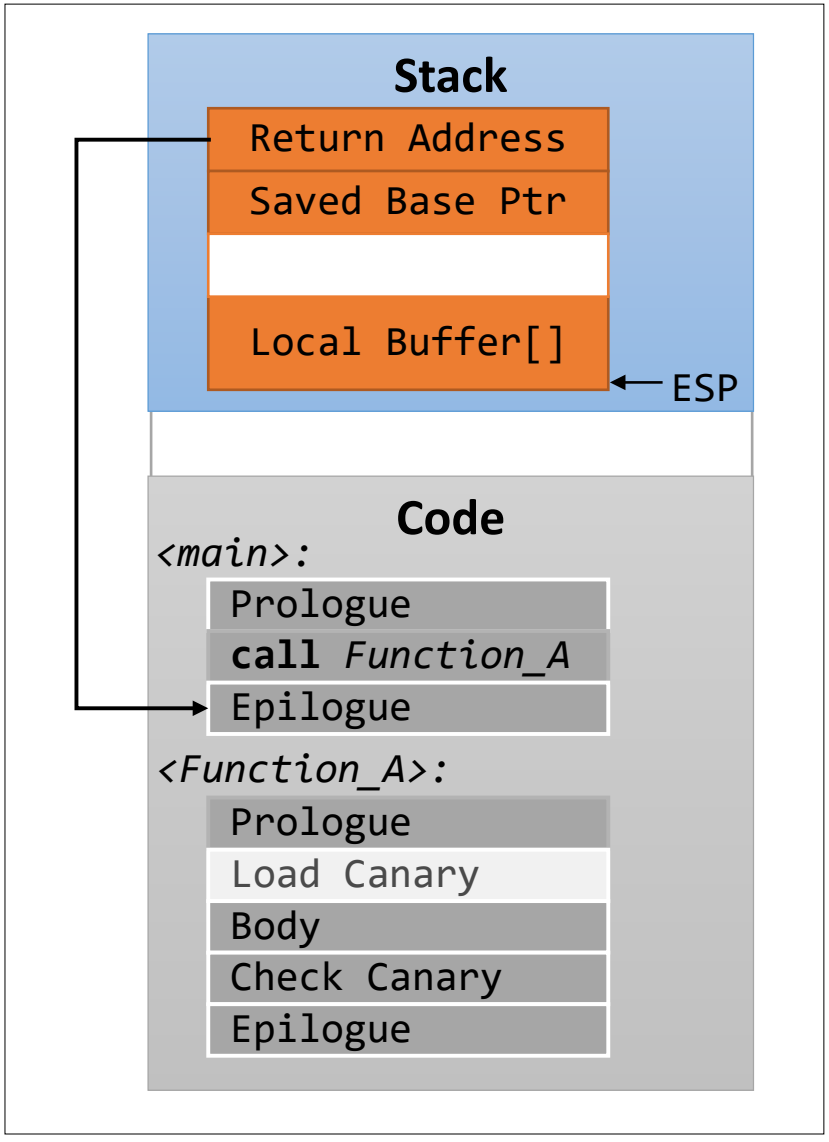
Canary Defense



Canary Defense



Canary Defense



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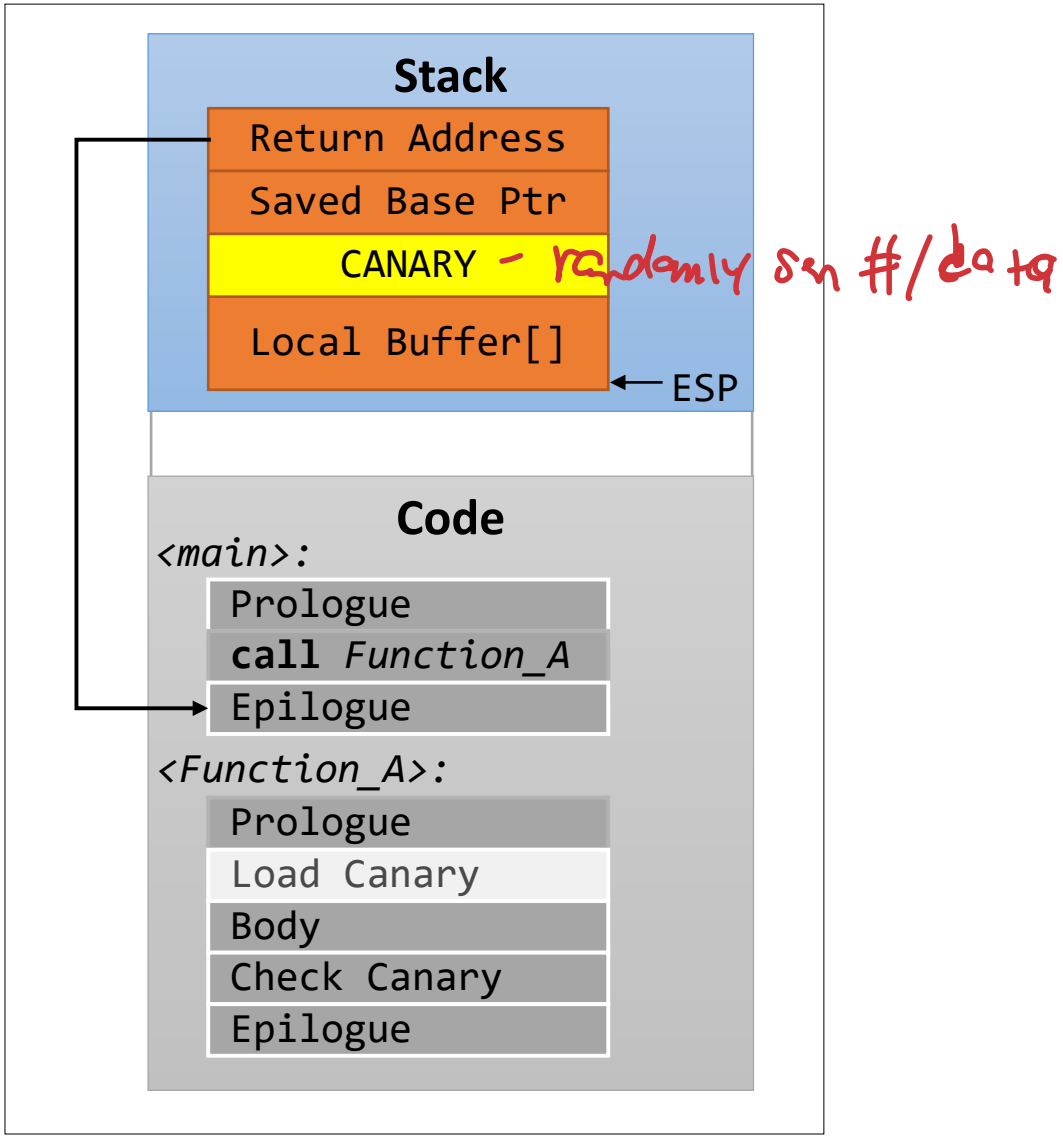
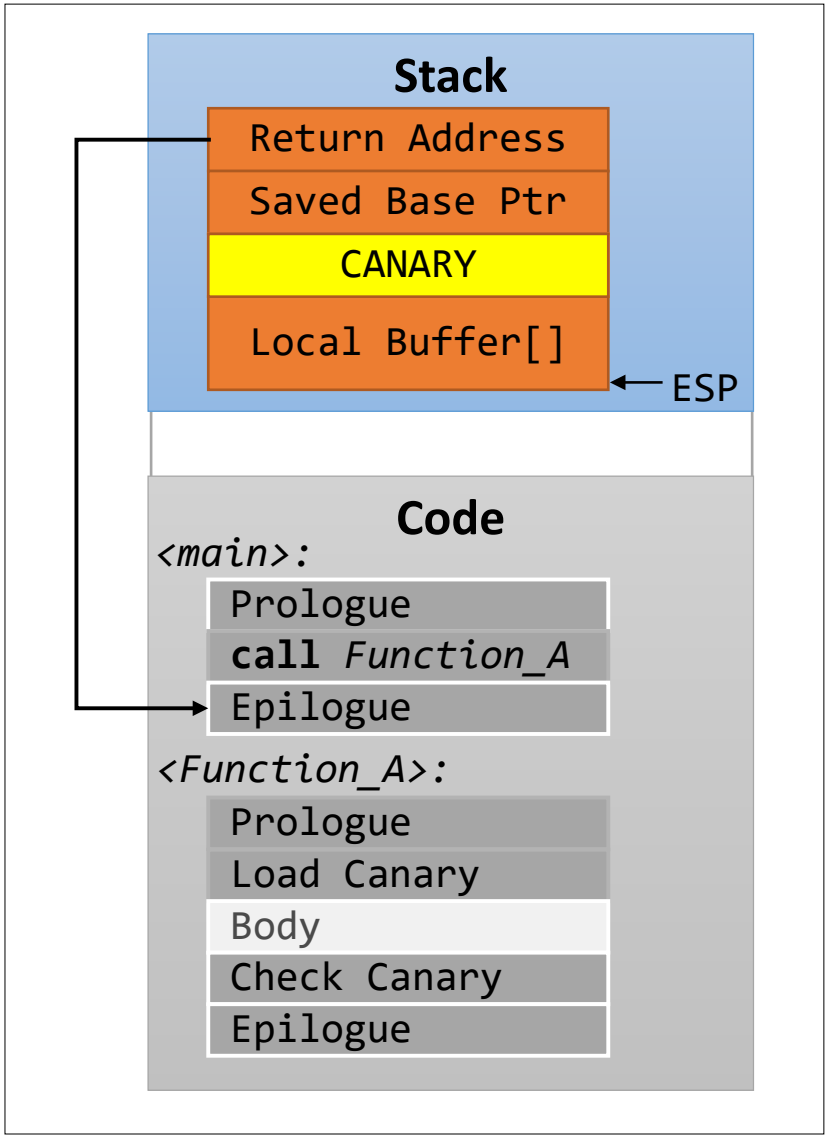
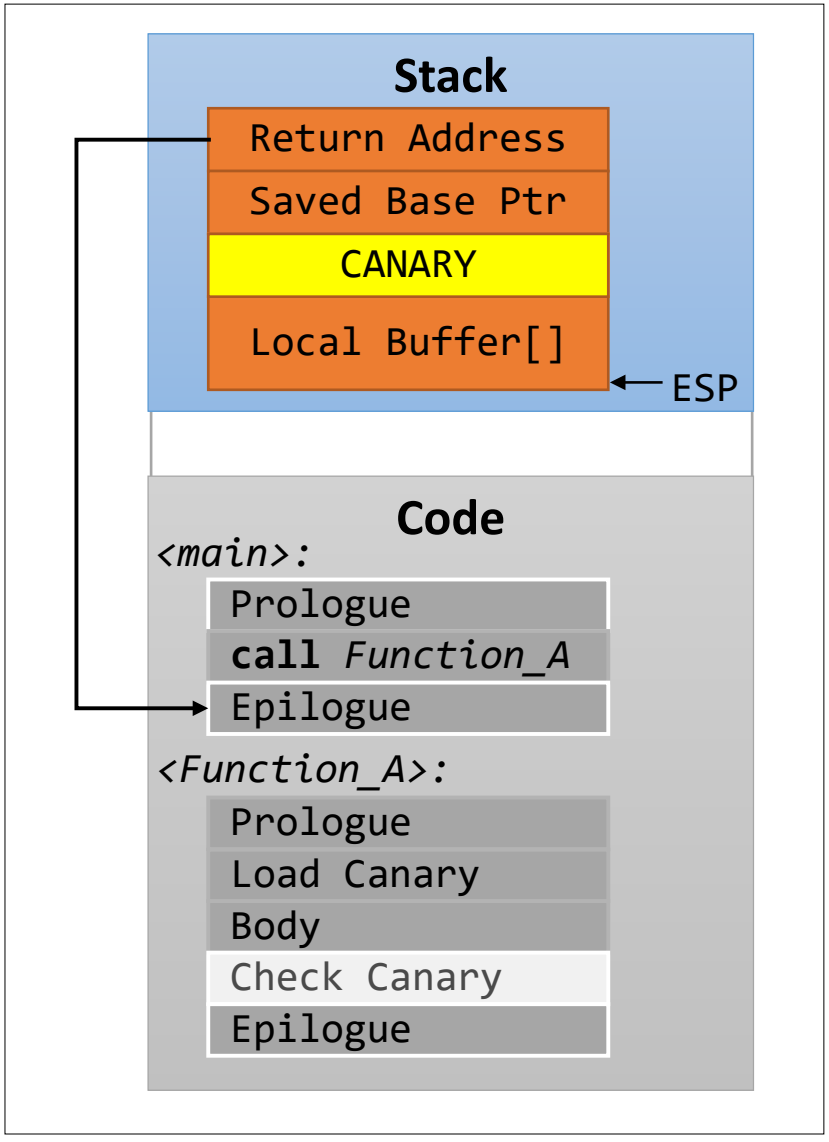


Canary Defense



B/C randomly generated if the attacker override the generated data the program will know

Canary Defense



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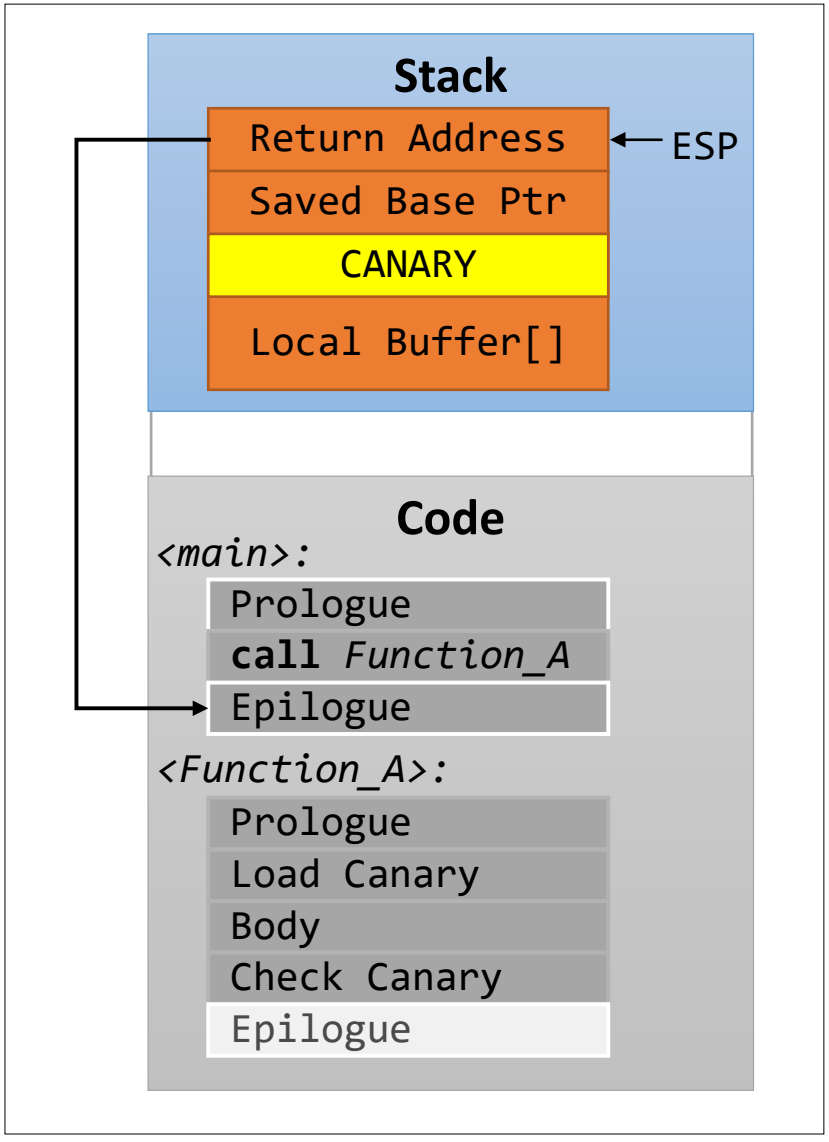
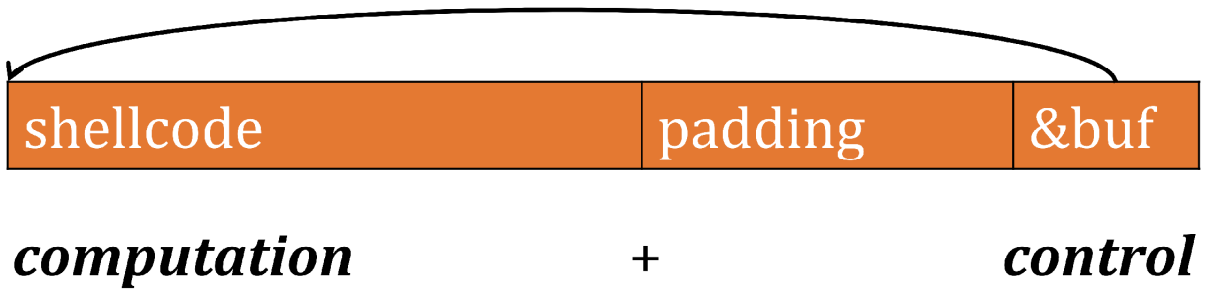


How to defending against control flow hijacks



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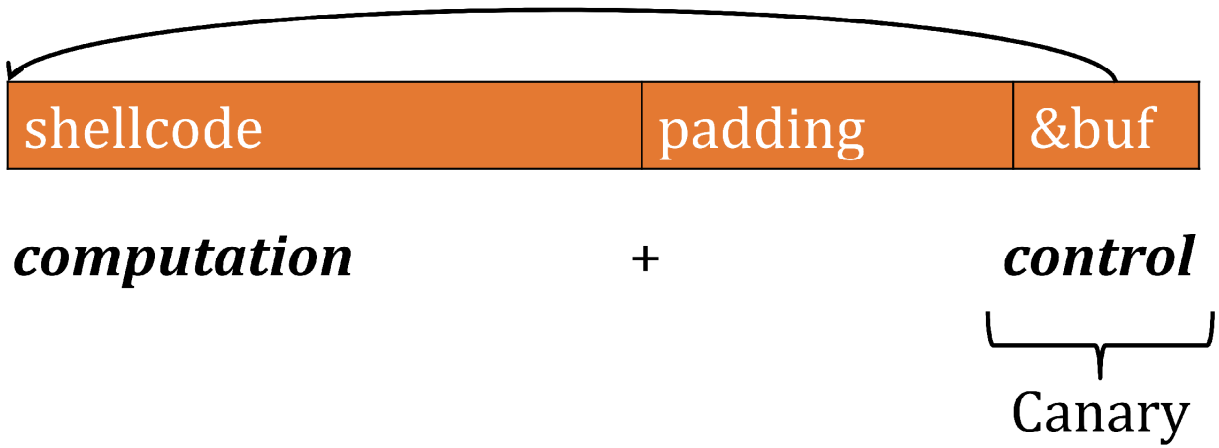
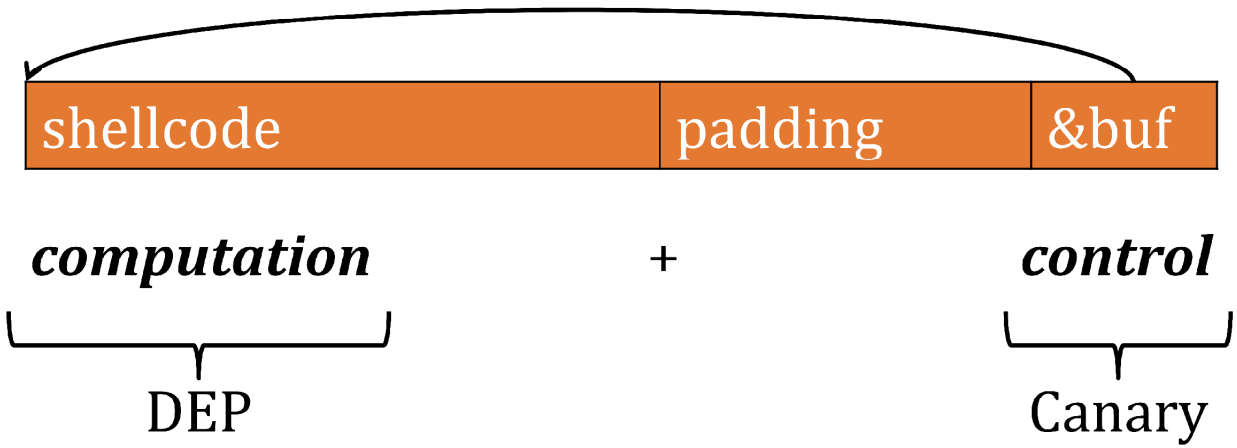


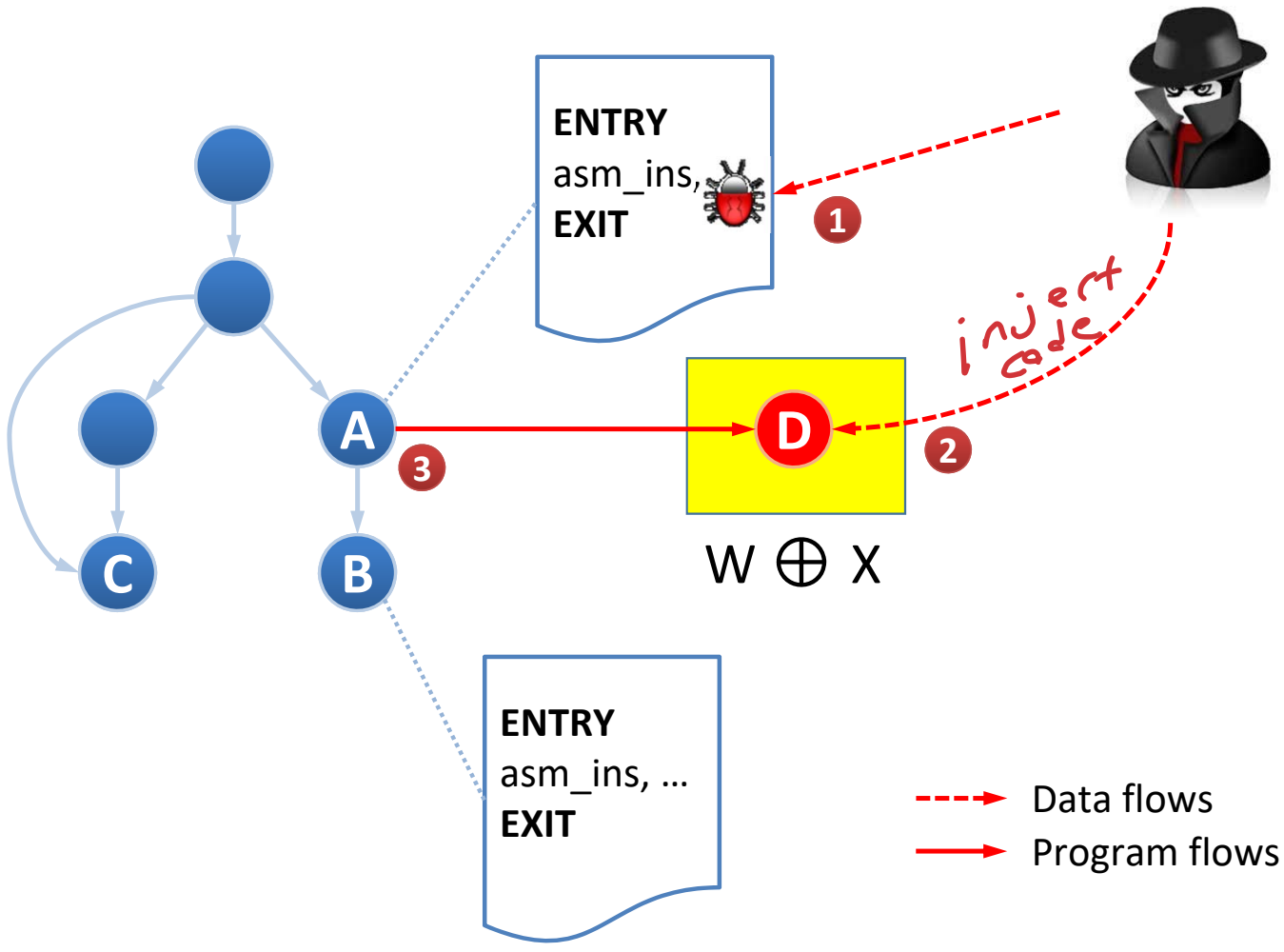
How to defending against control flow hijacks

We can stop people injecting code into mem

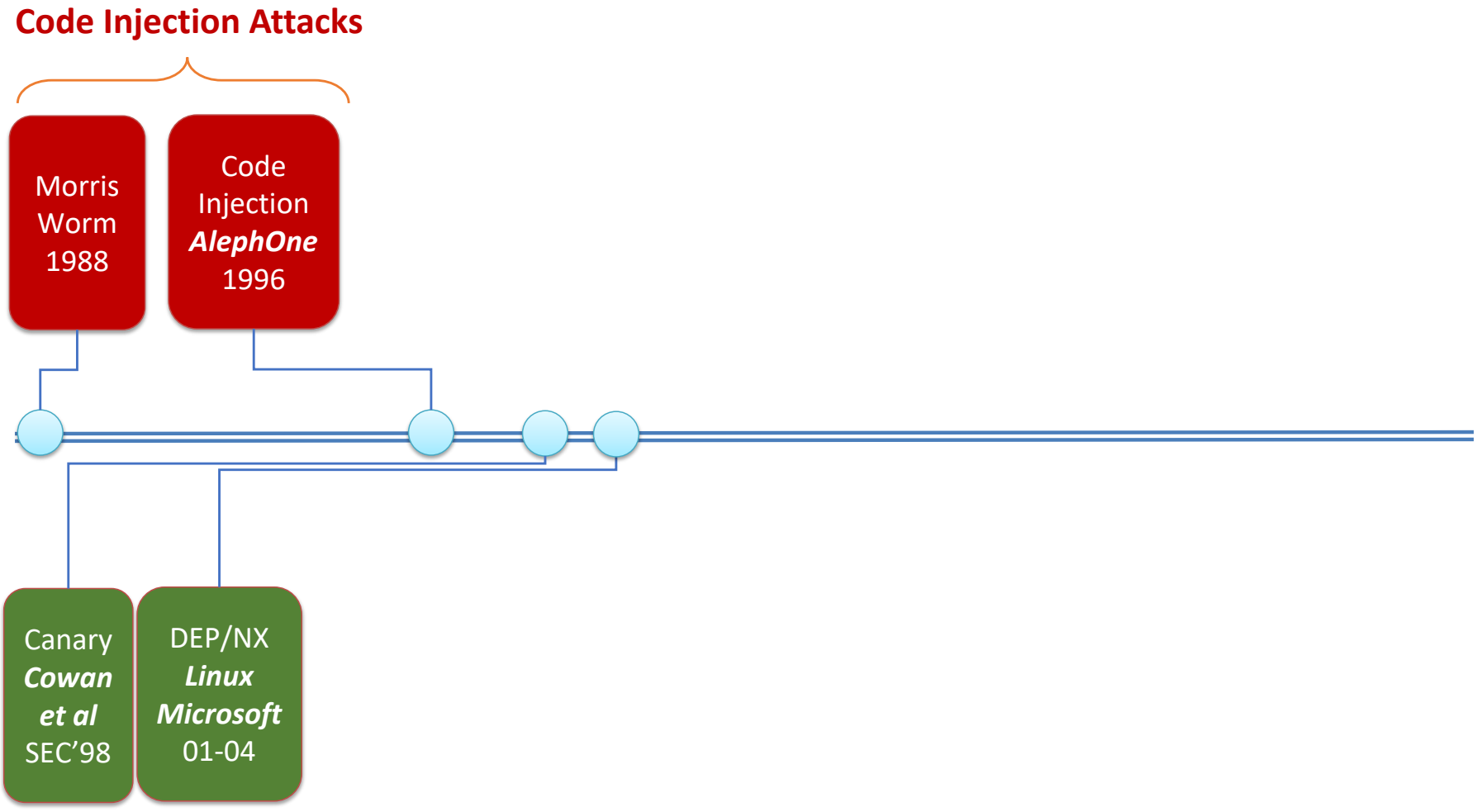
Data execution Proveation



Data Execution Prevention



Defense Using Randomization



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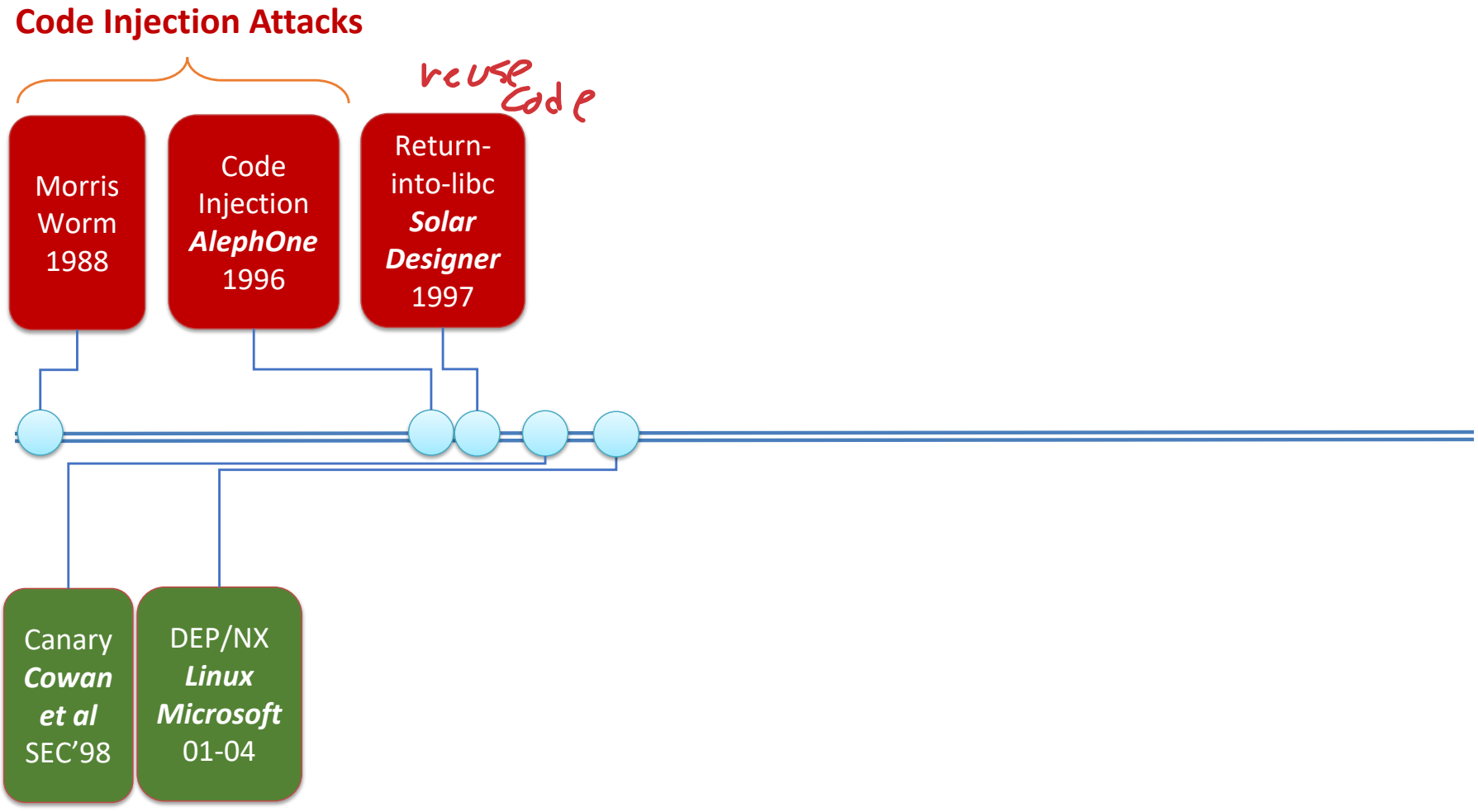

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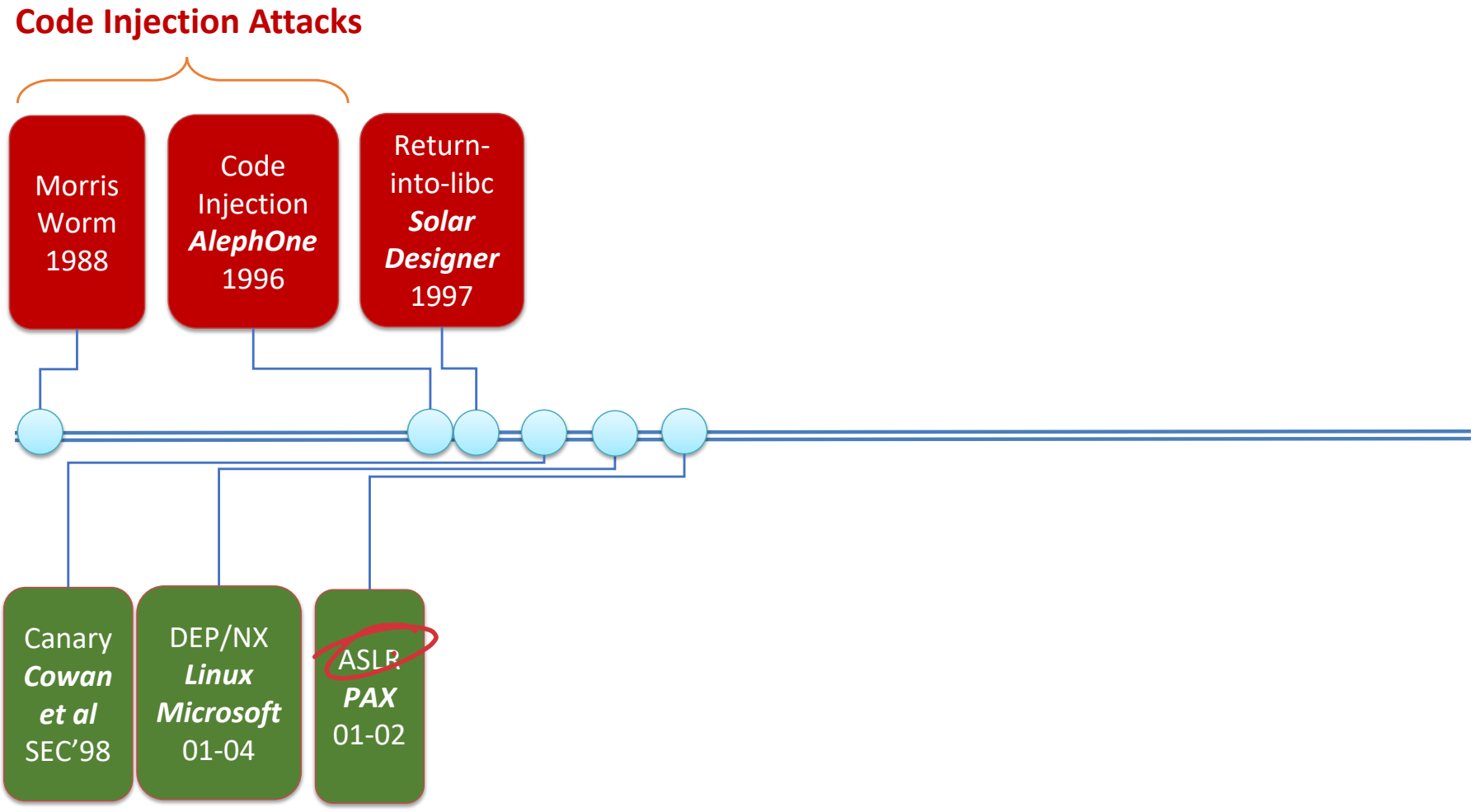
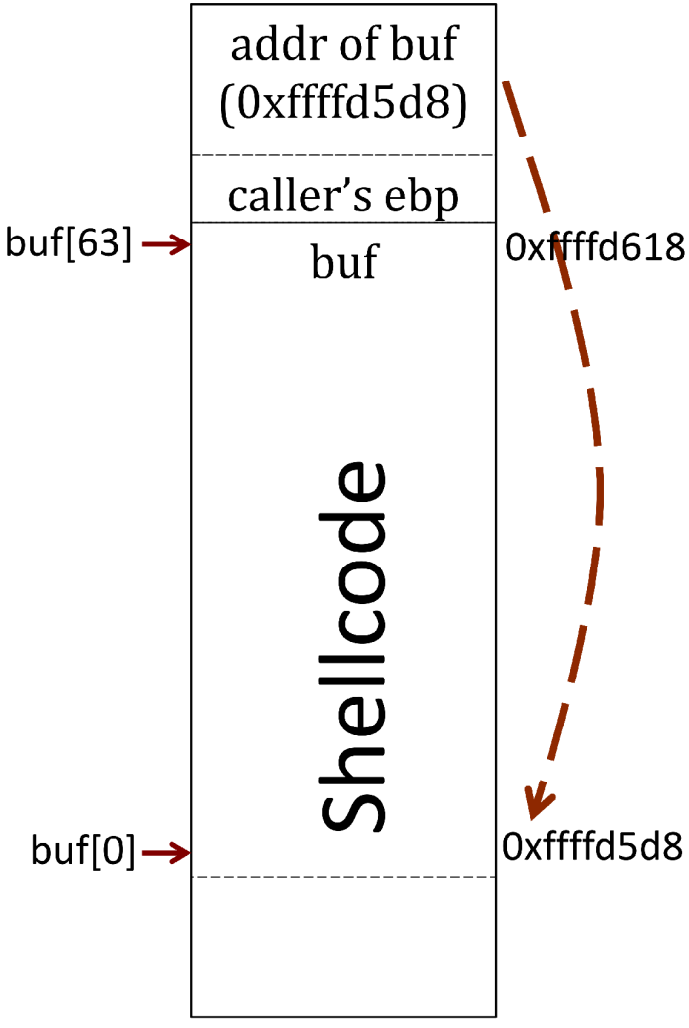


Address Space Layout Randomization (ASLR)



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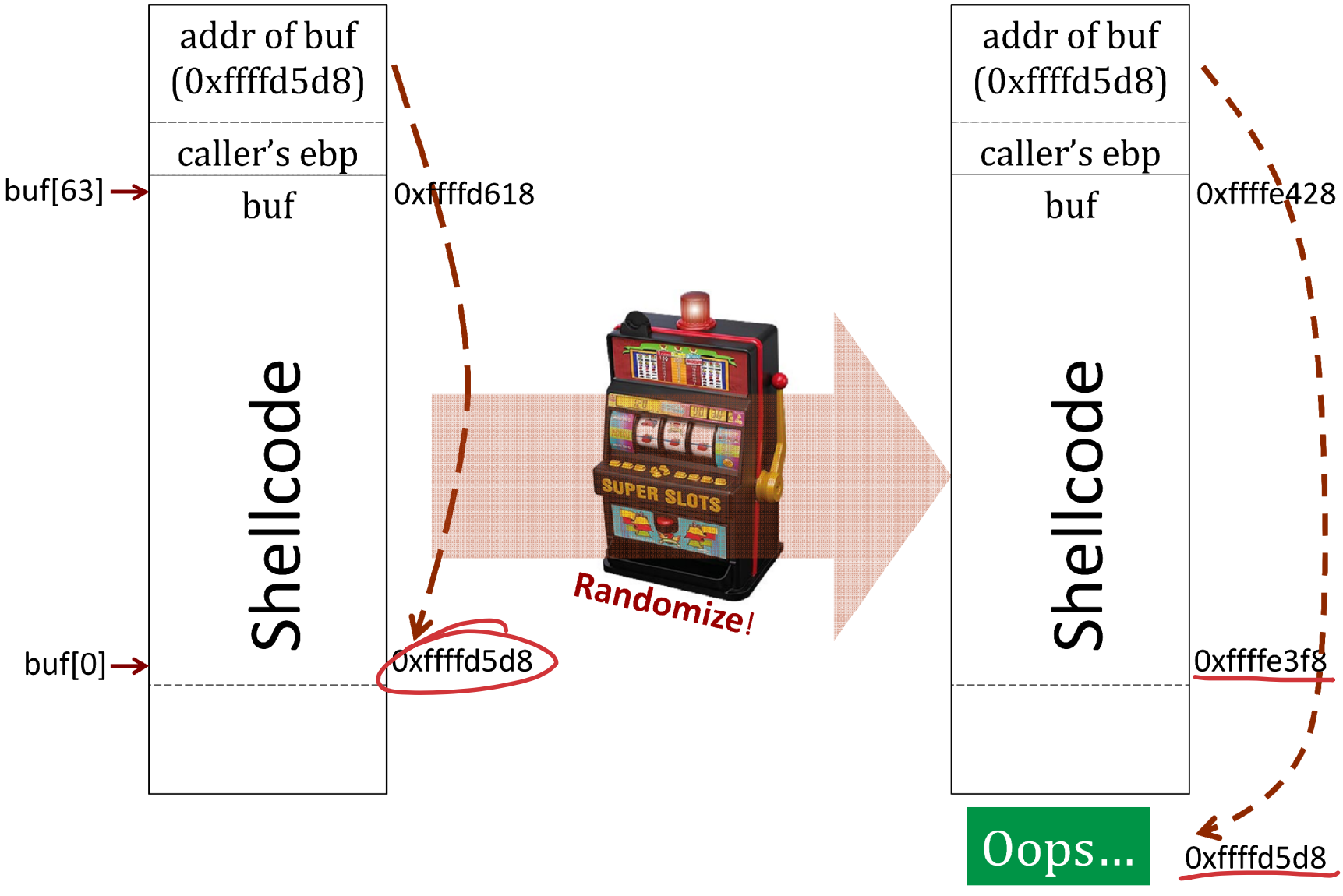

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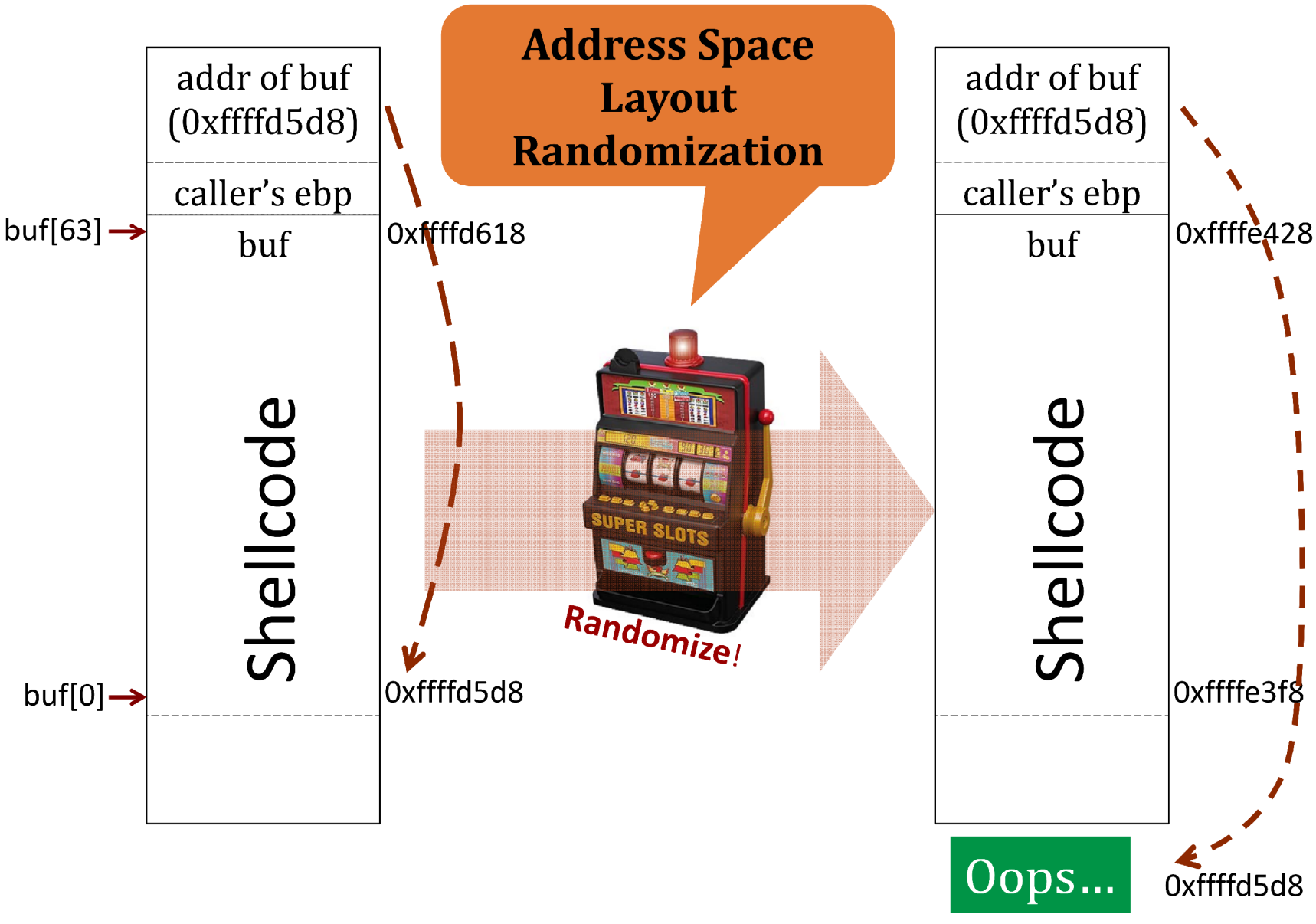
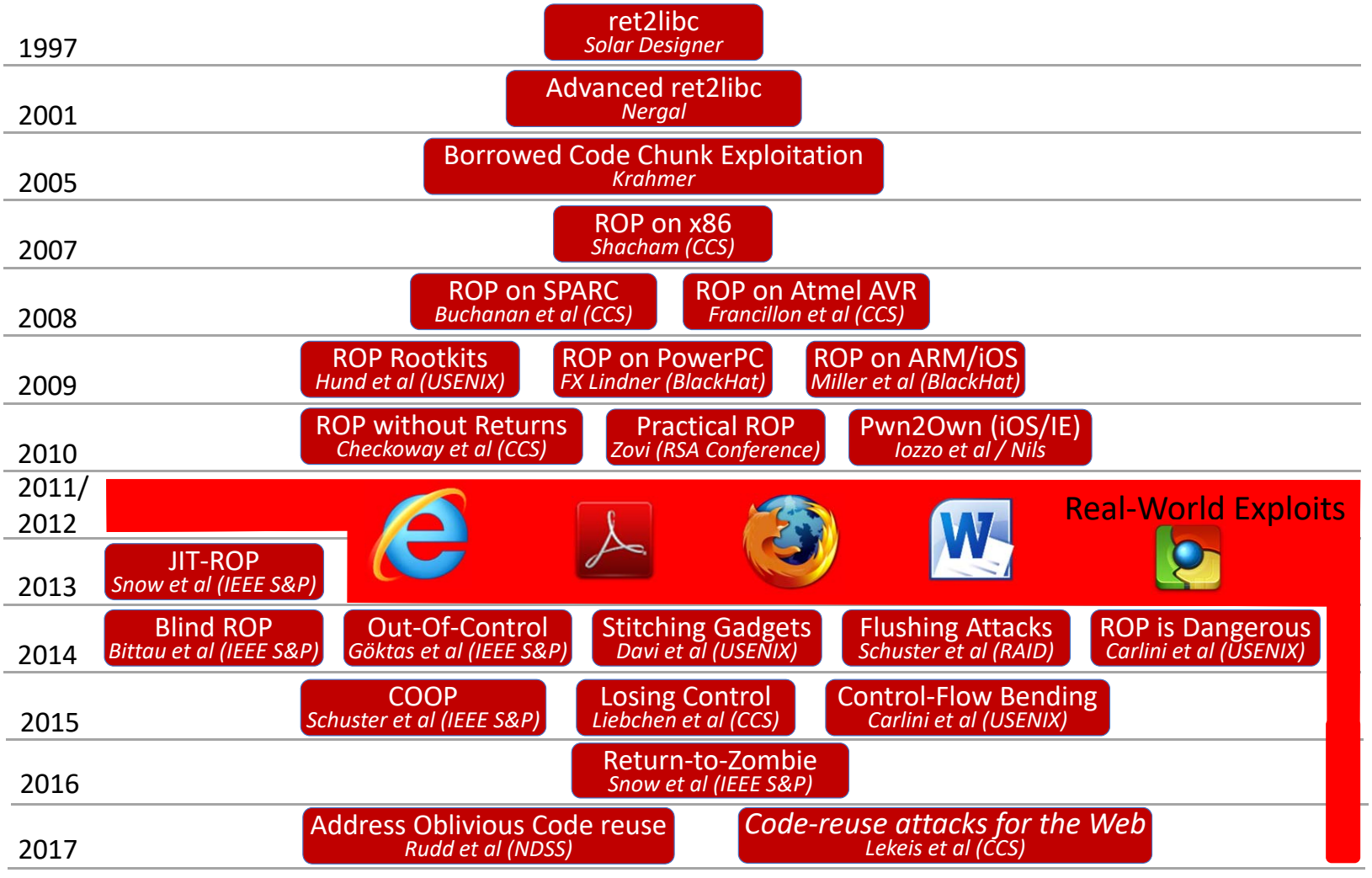


Recent Efforts on Code Reuse Attack



Return Oriented Programming (ROP)

The New Yo

Saturday, January 6, 2007

Daily Blog Tips awarded th

Last week Darren Rowse, from the famous Problogger blog, announced the winners of his latest Group Writing Project called "Reviews and Predictions". Among the Daily Blog Tips is attracting a vast audience of bloggers who are looking to improve their blogs. When asked about the success of his blog Daniel commented that

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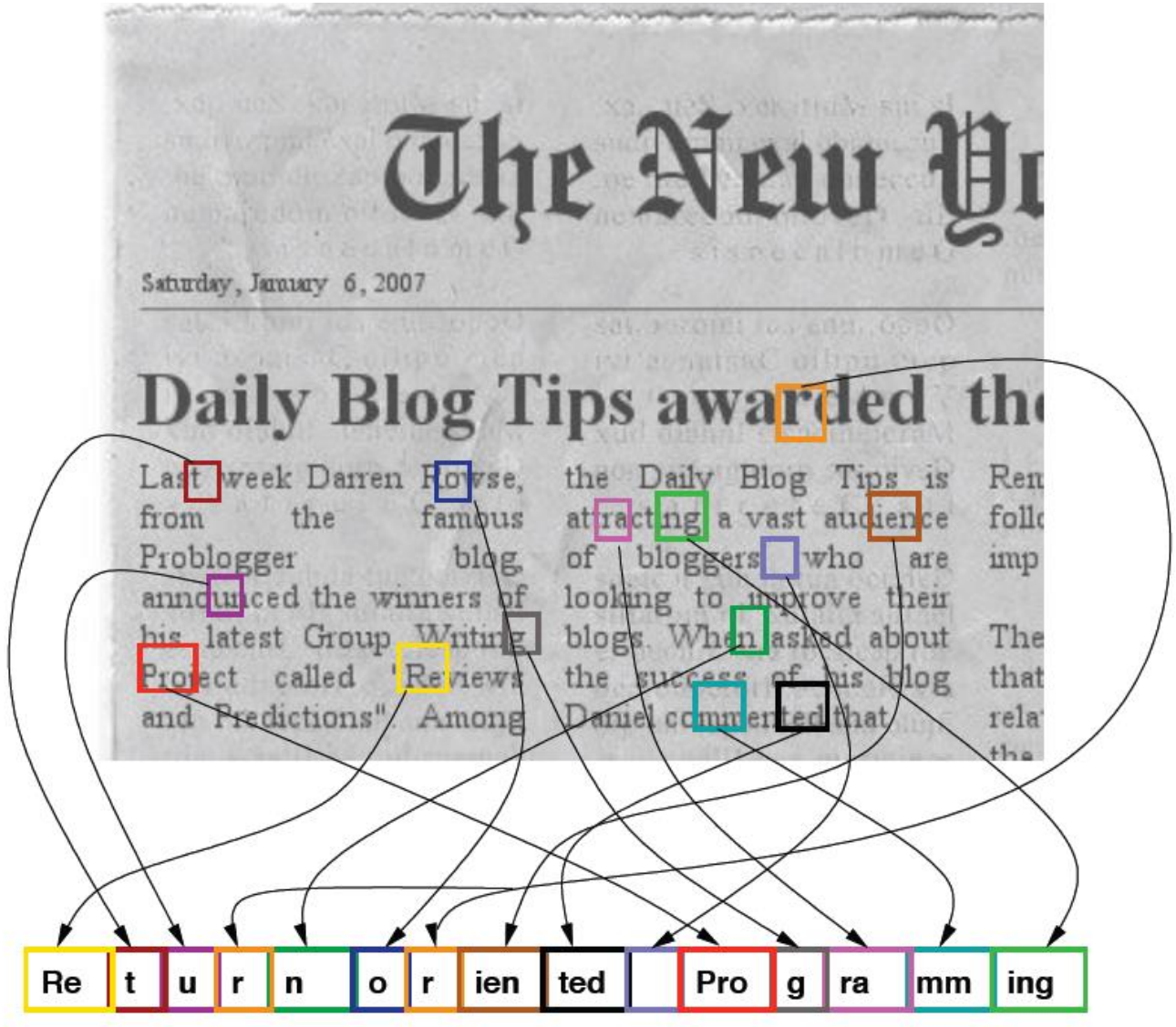
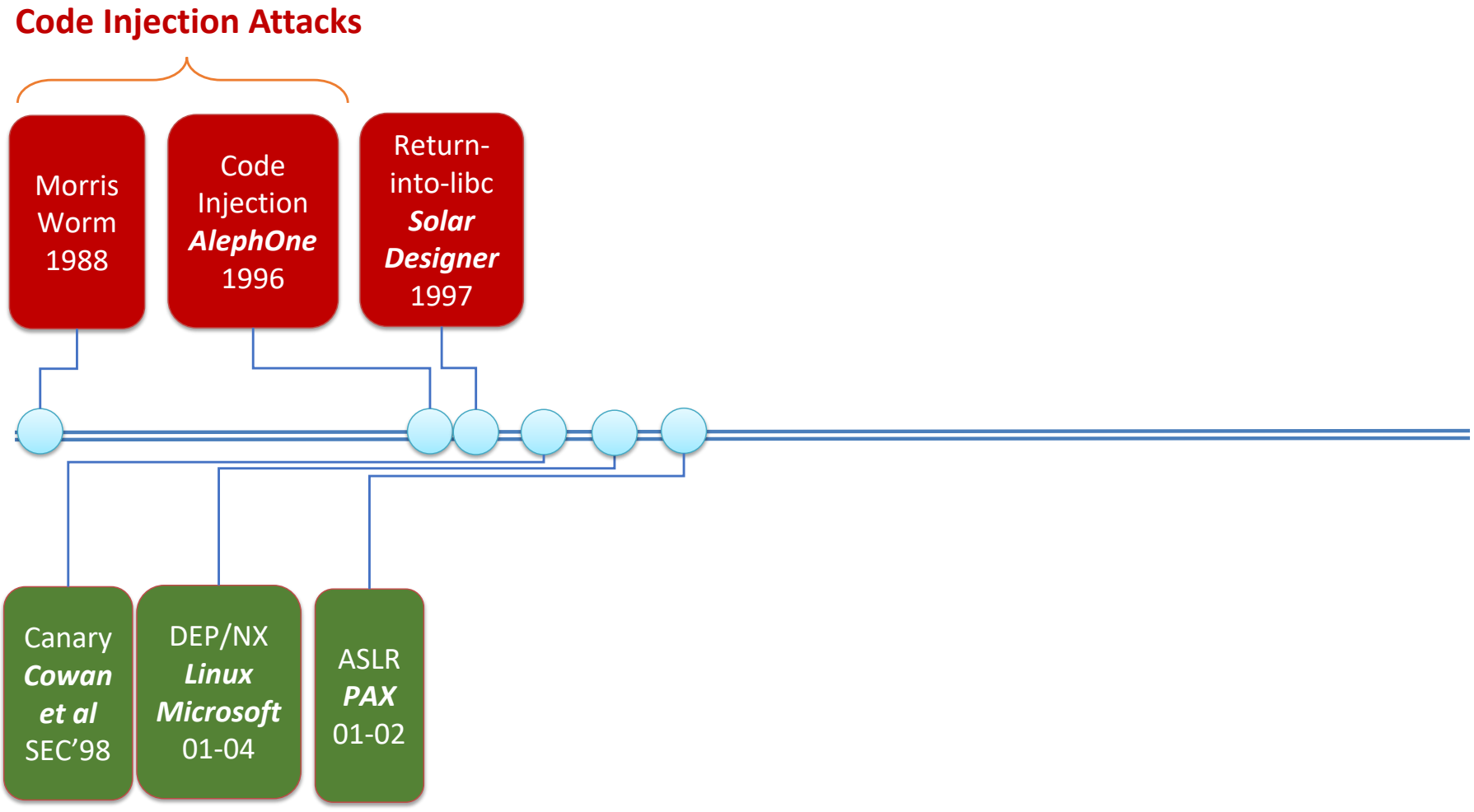


More Defenses Using Randomization



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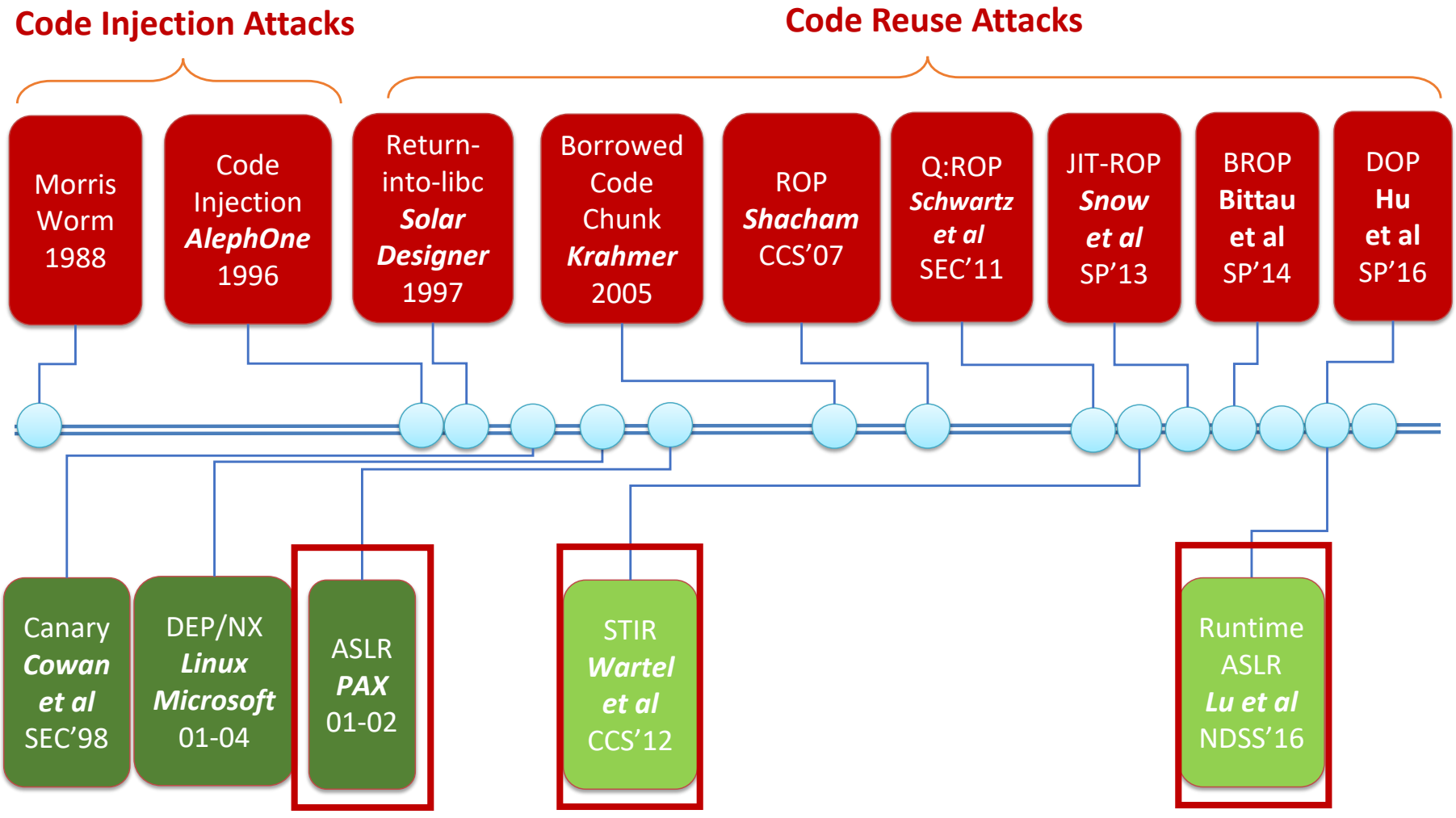
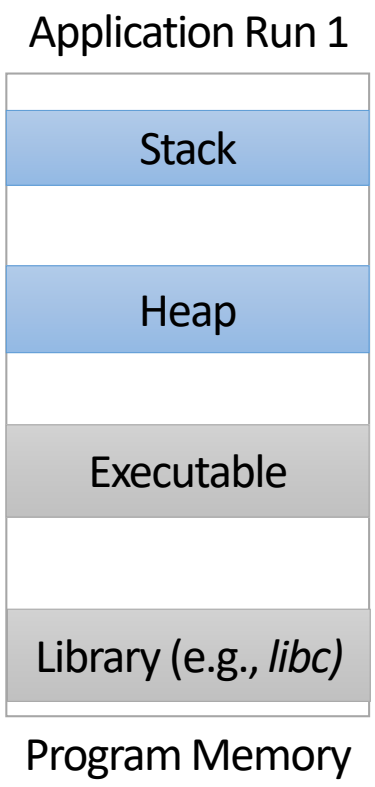


From Coarse-Grained to More Fine-Grained ASLR



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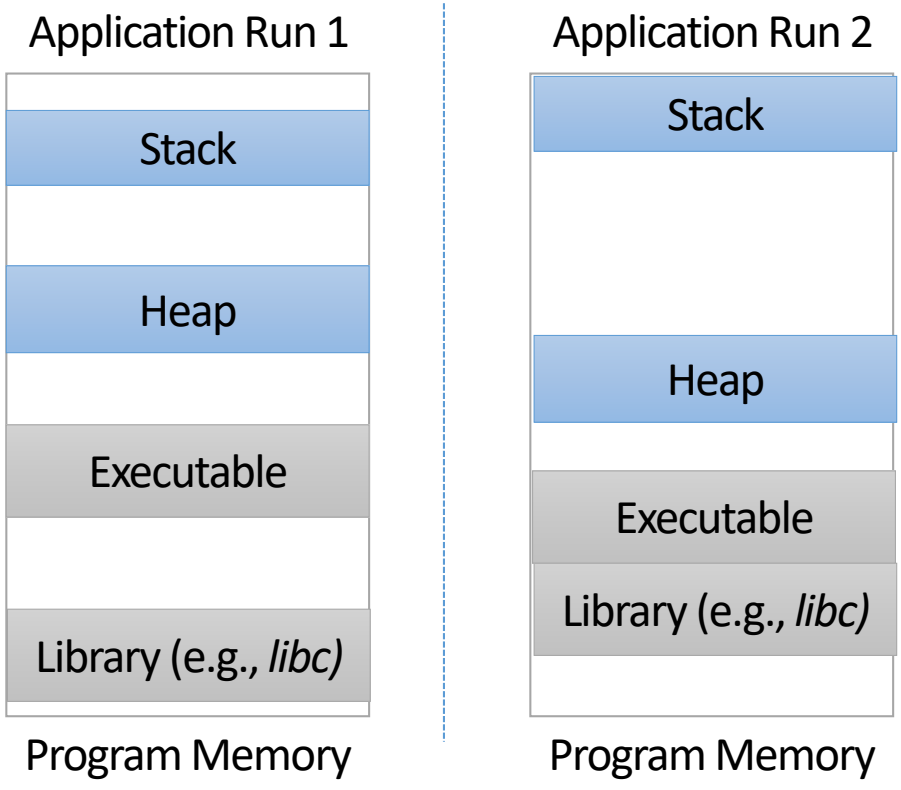

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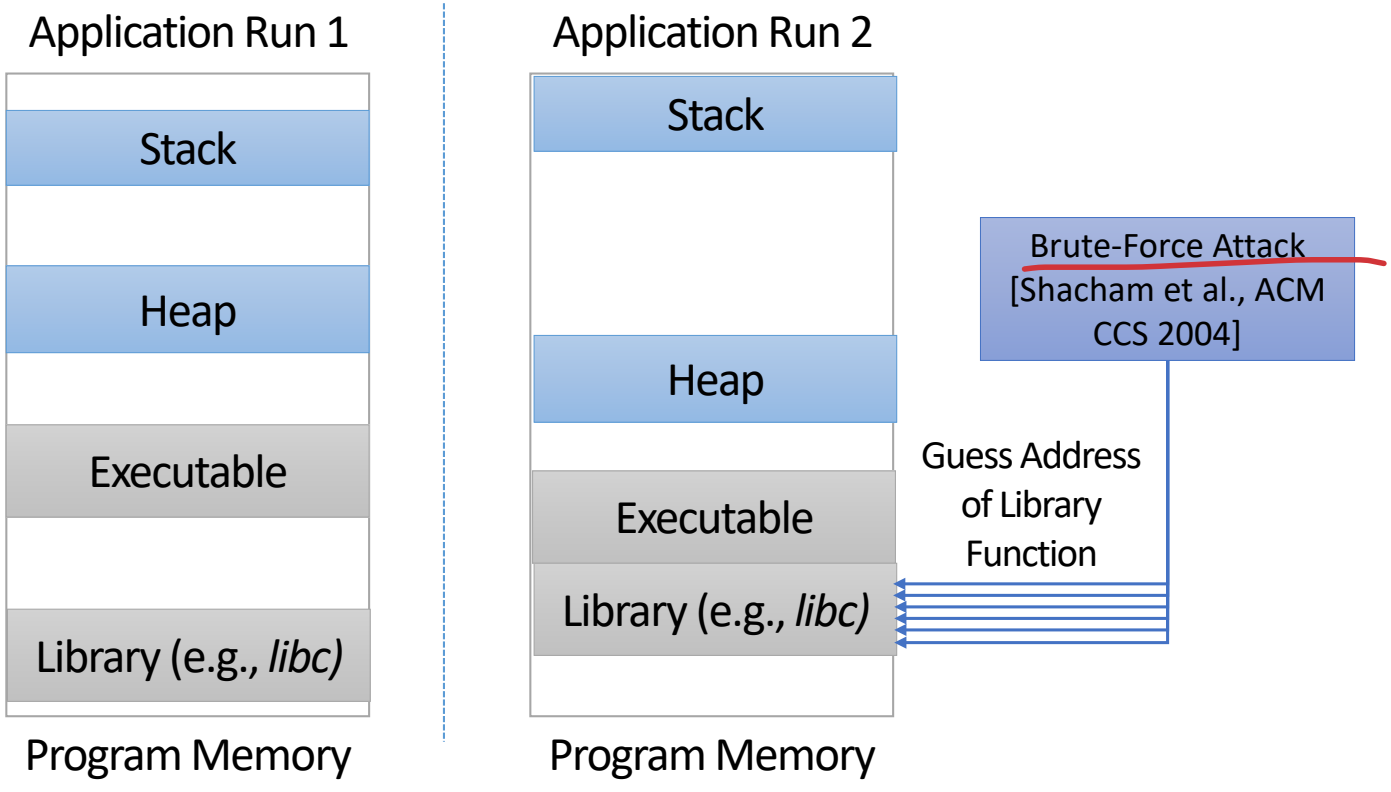
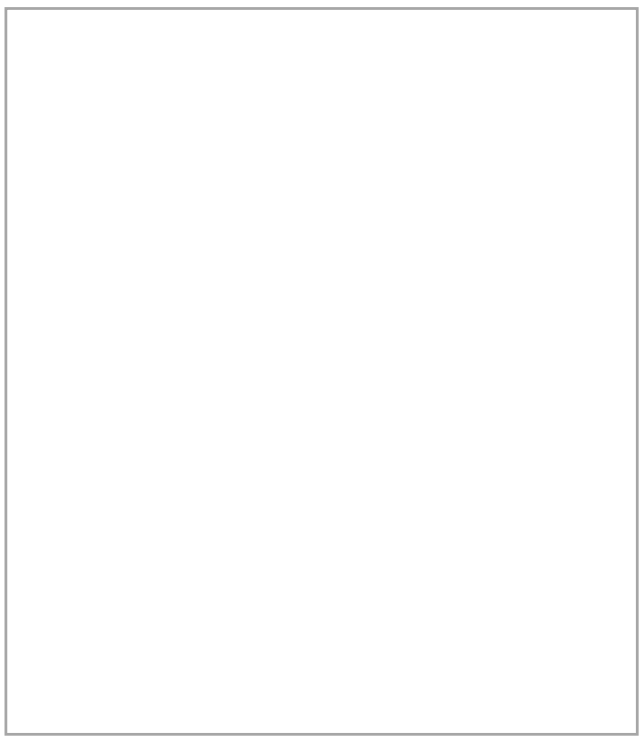
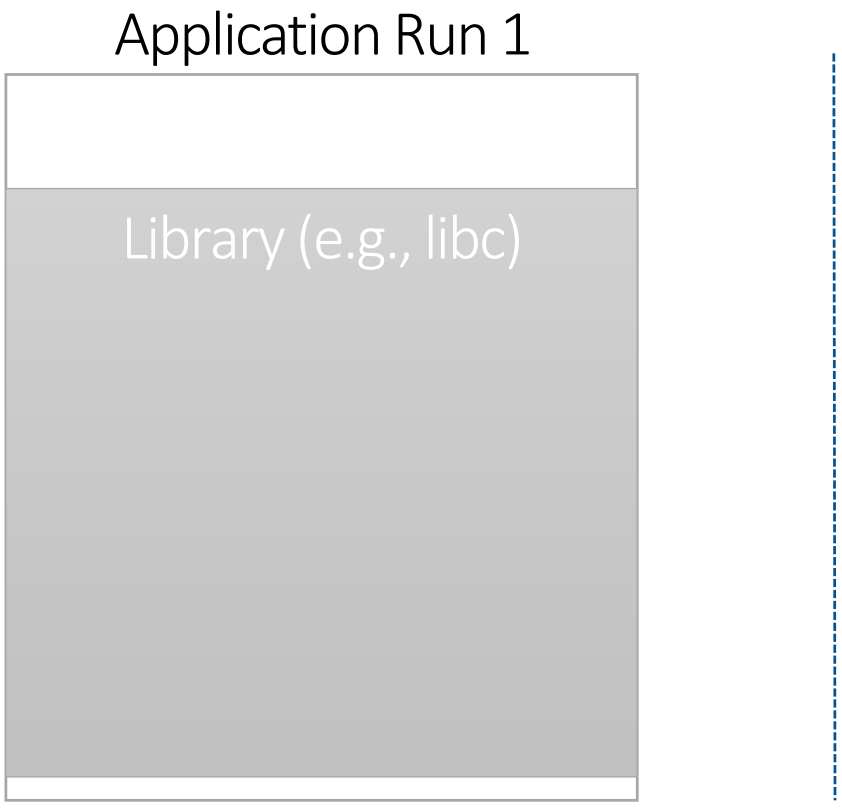


From Coarse-Grained to More Fine-Grained ASLR

Application Run 1



From Coarse-Grained to More Fine-Grained ASLR



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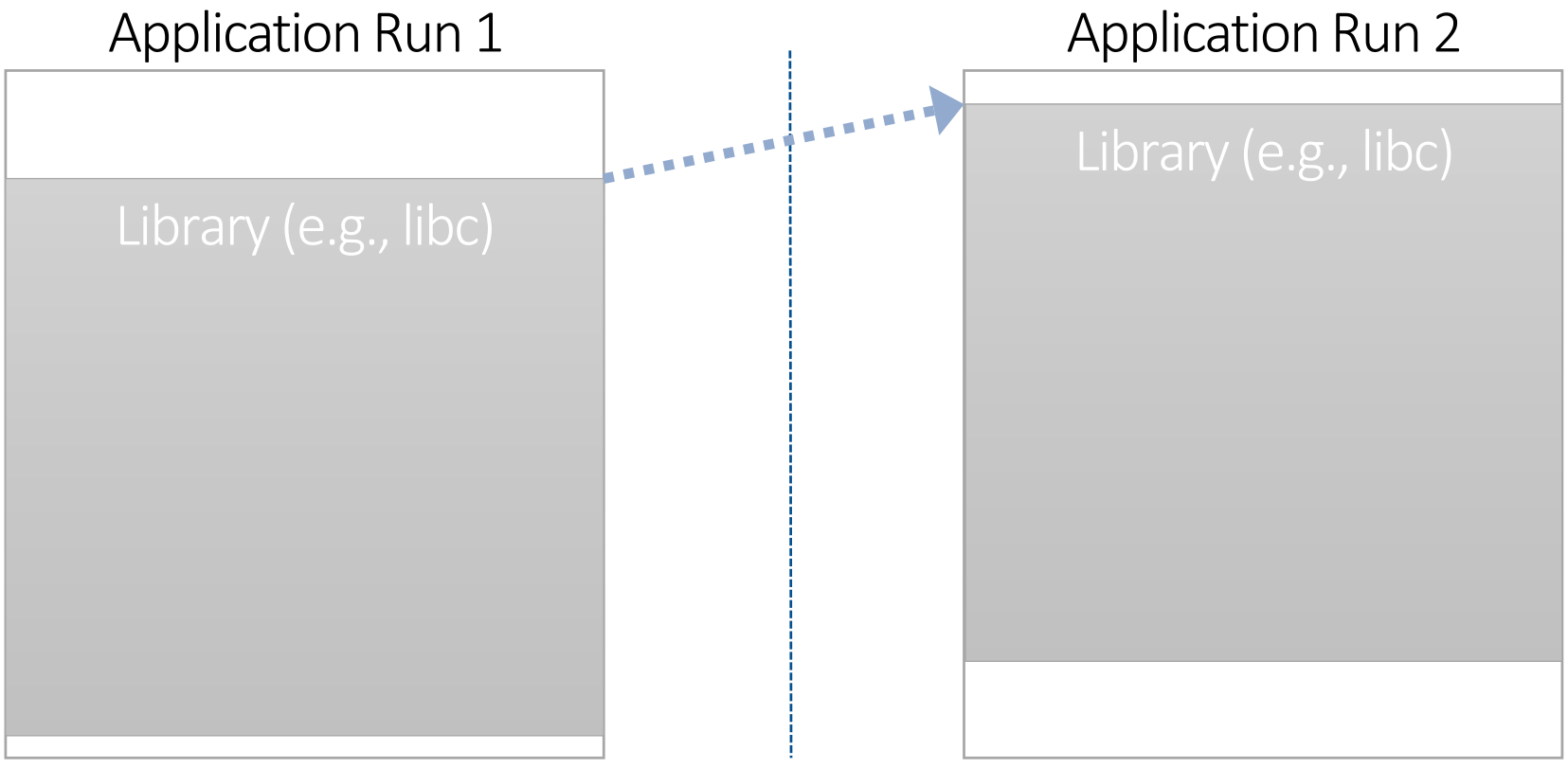
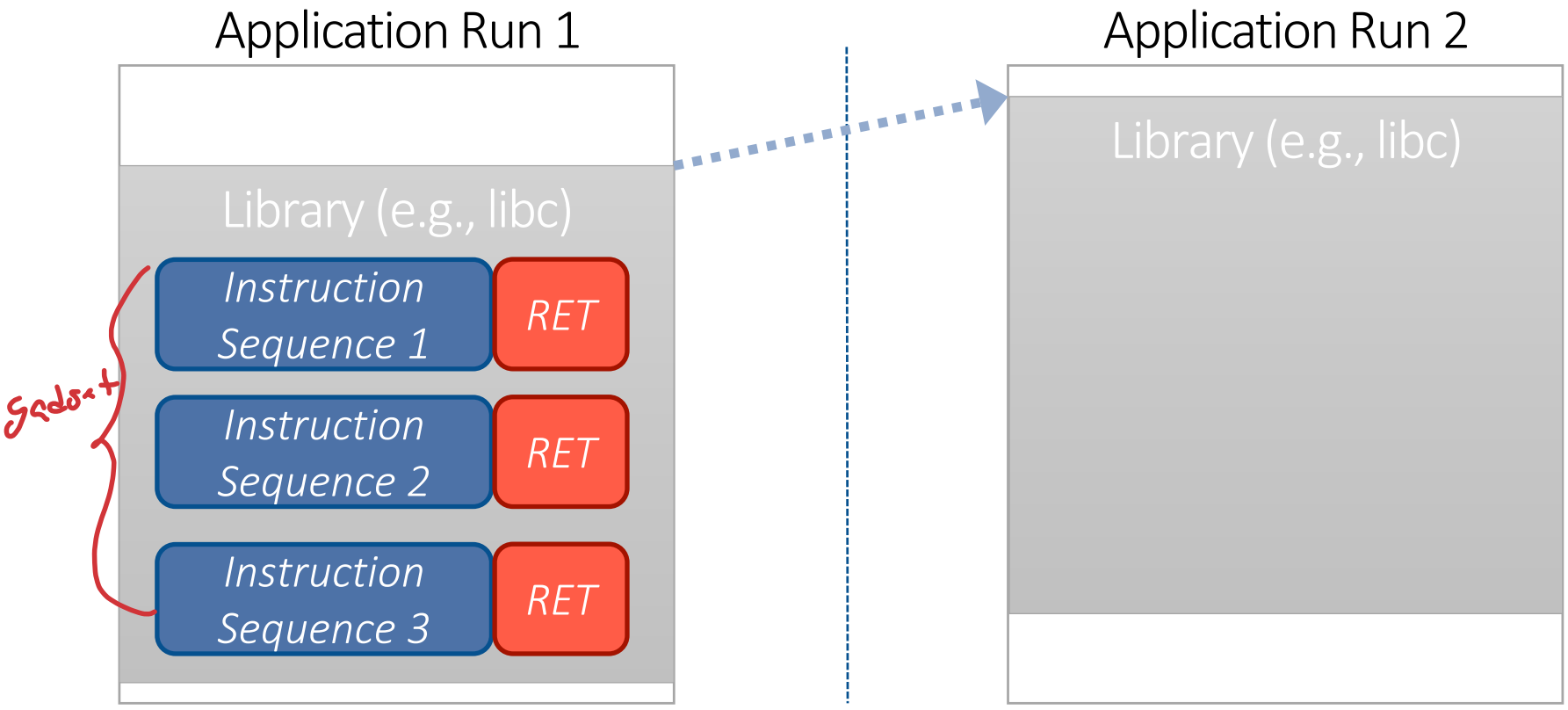
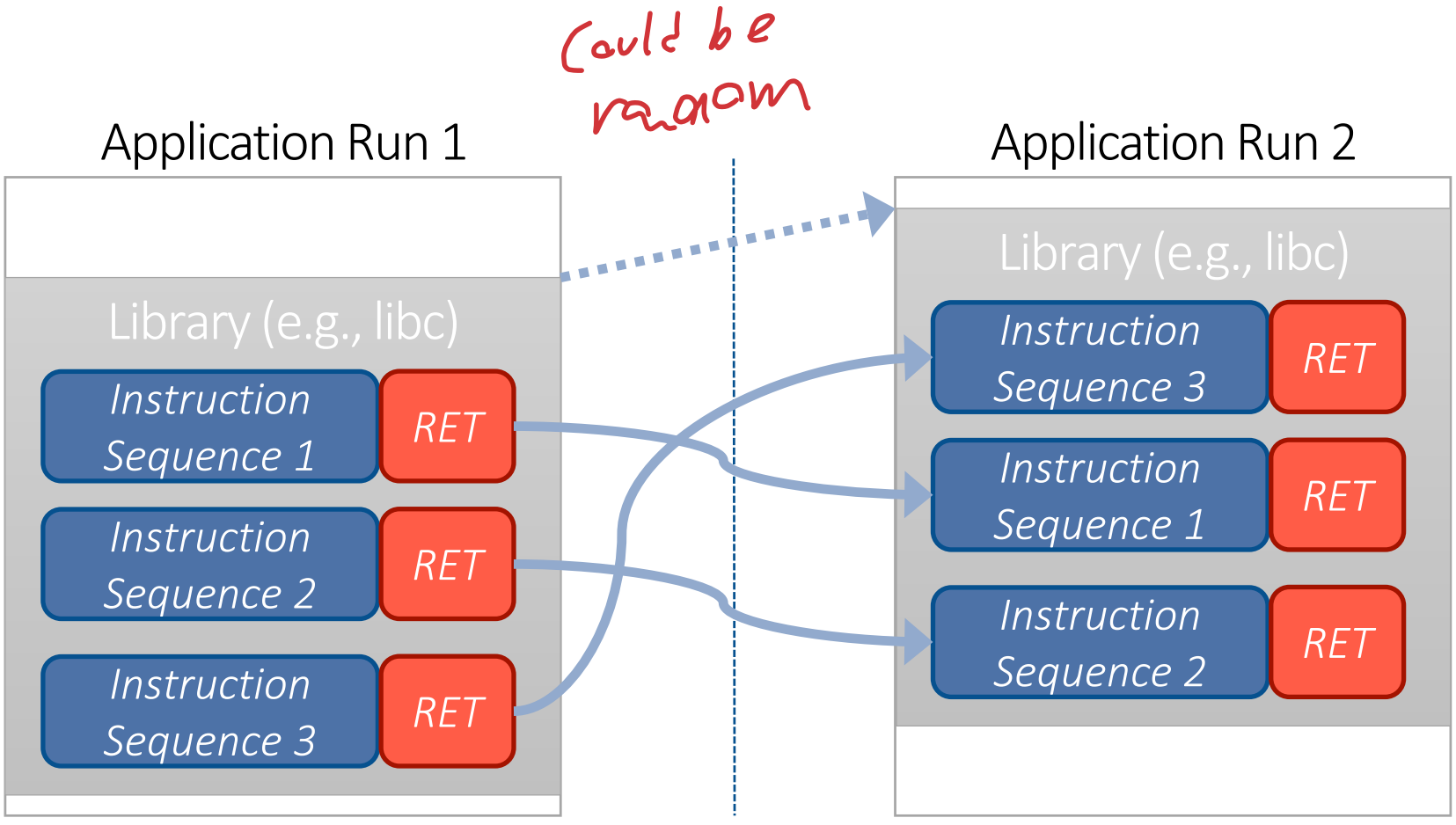


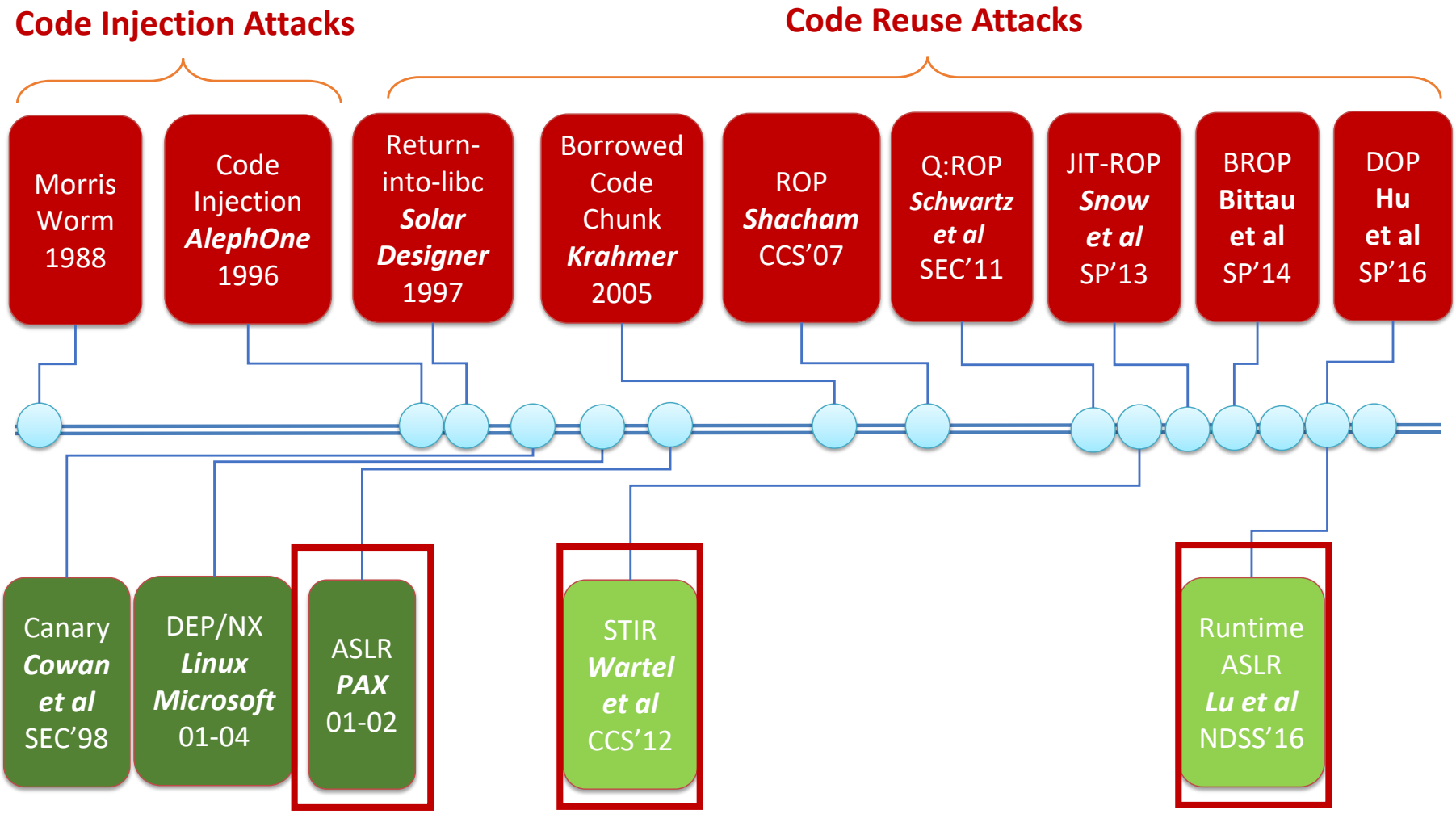
From Coarse-Grained to More Fine-Grained ASLR



From Coarse-Grained to More Fine-Grained ASLR



Defense Using Control Flow Integrity



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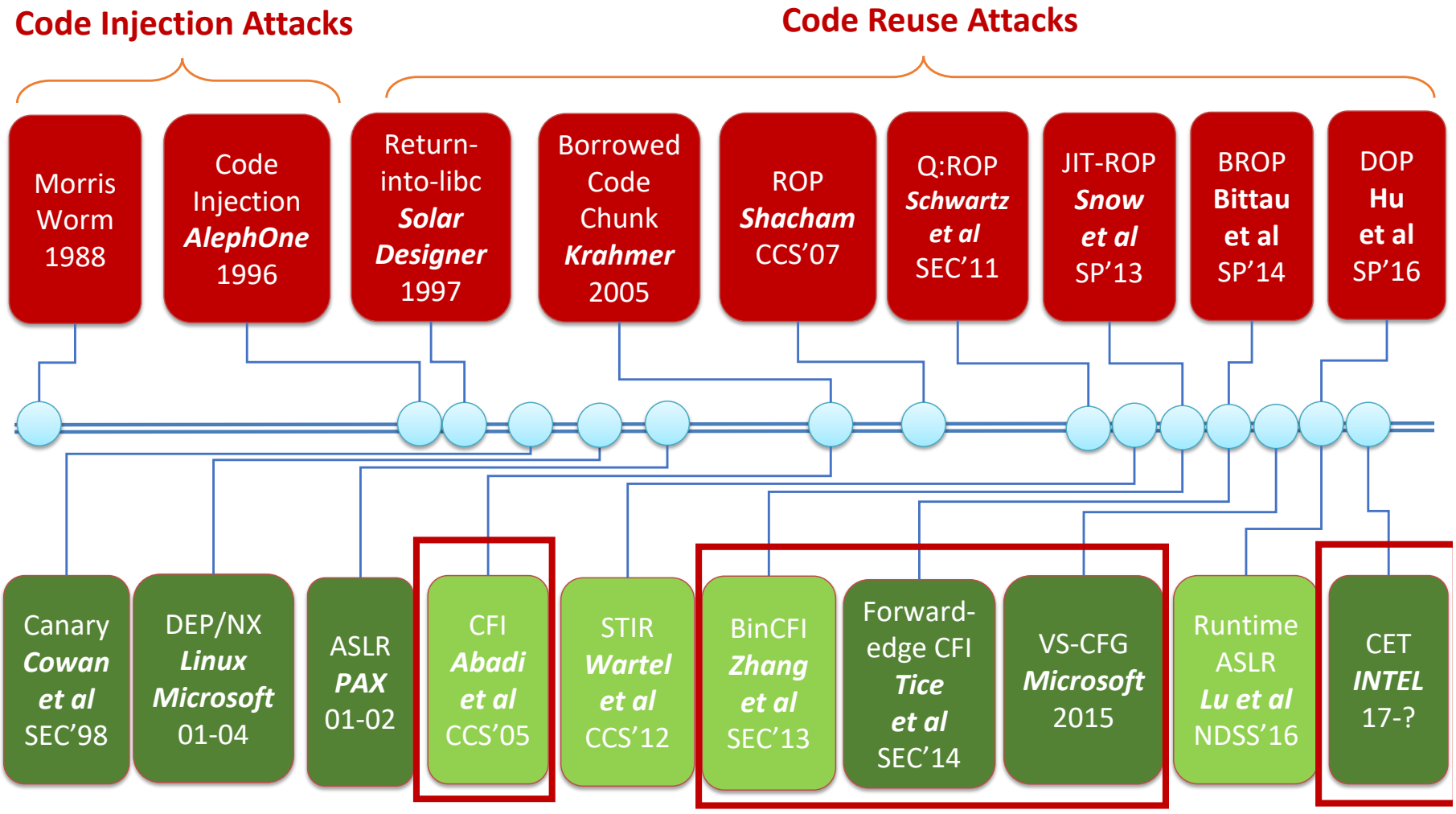


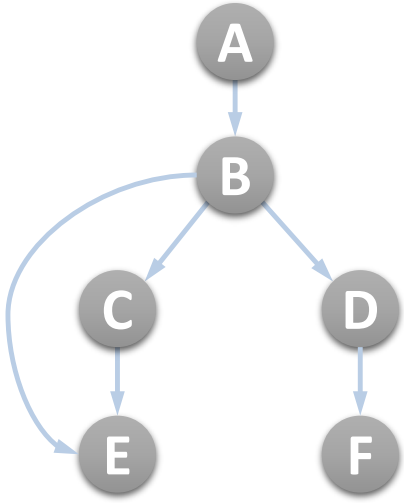
ASLR and CFI

(Fine-grained) Code Randomization

Control-Flow Integrity (CFI)

ASLR and CFI

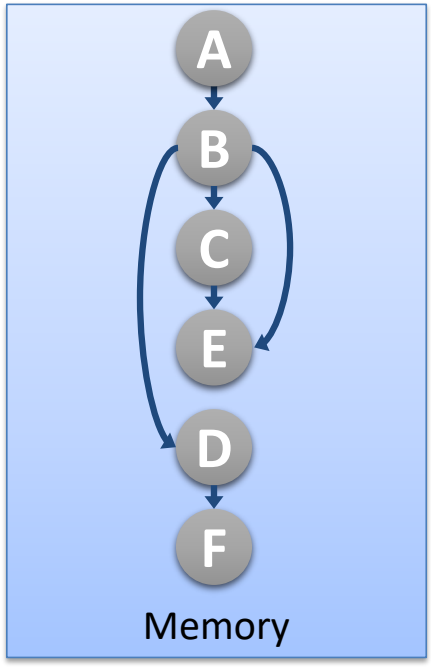
(Fine-grained) Code Randomization



Control-Flow Integrity (CFI)

ASLR and CFI

(Fine-grained) Code Randomization



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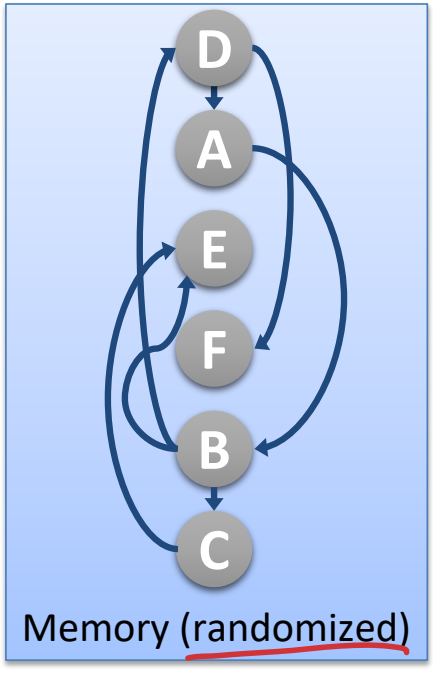

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ASLR and CFI

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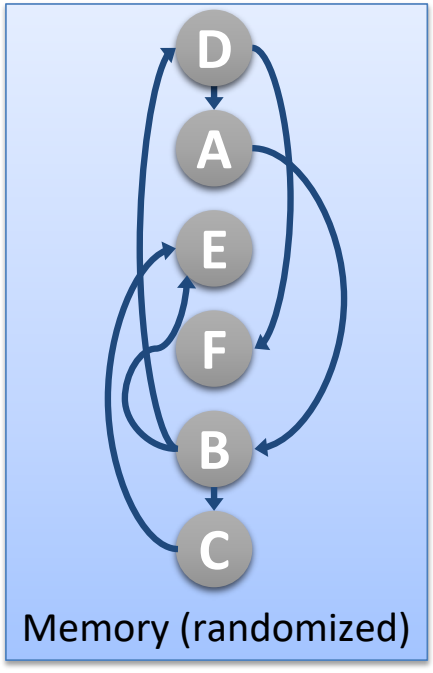

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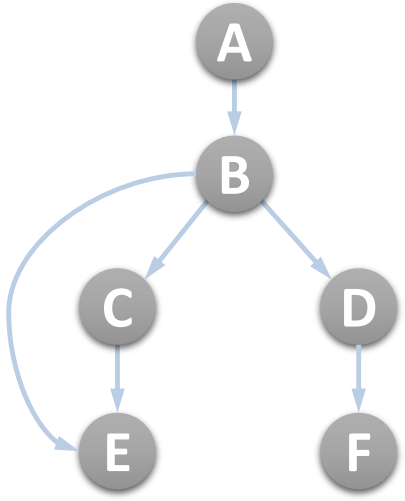

ASLR and CFI

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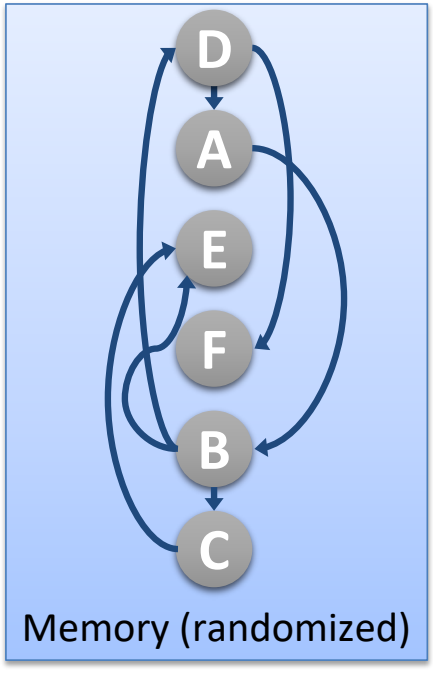

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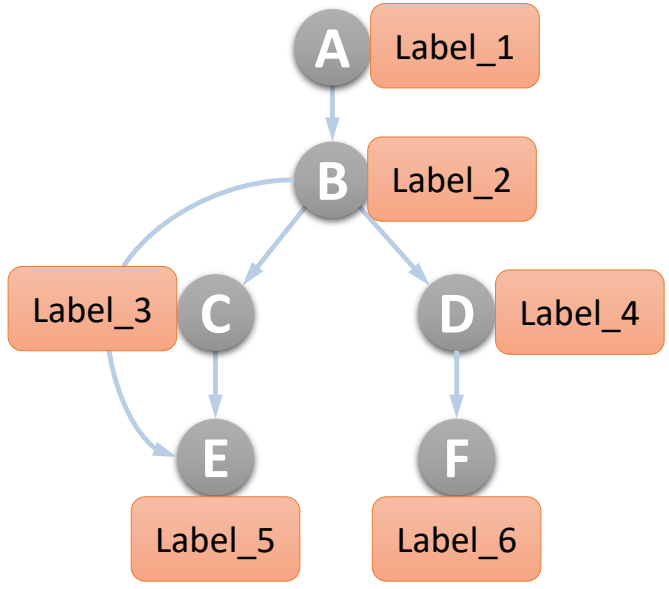

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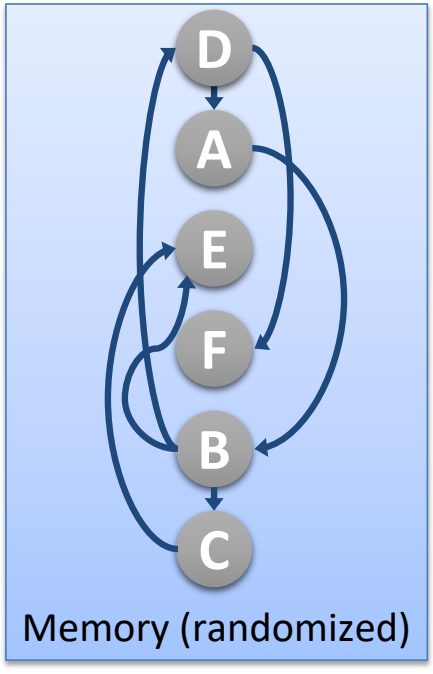

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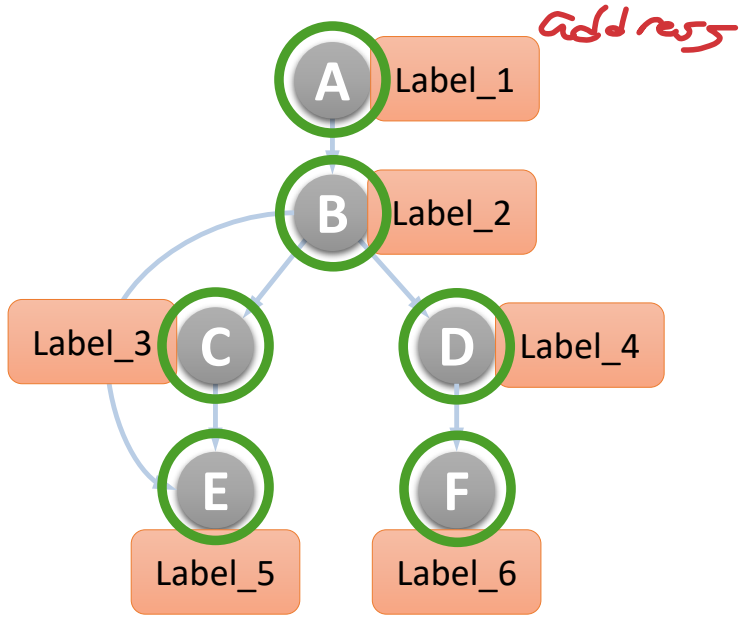

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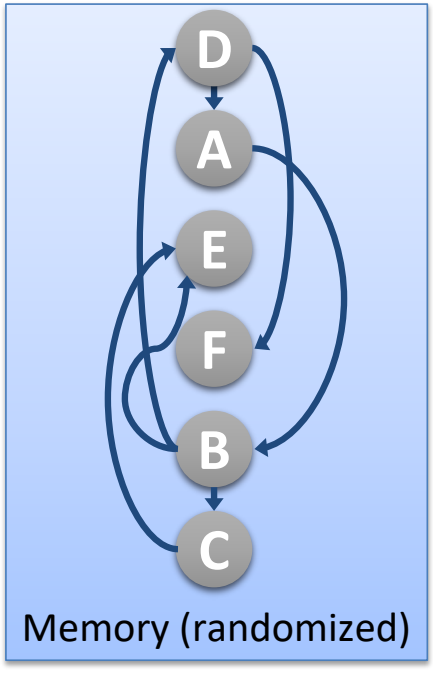
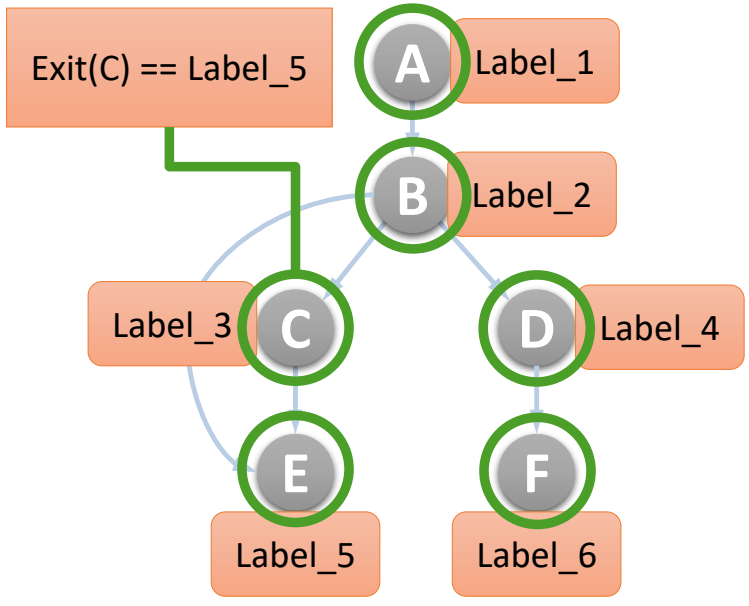
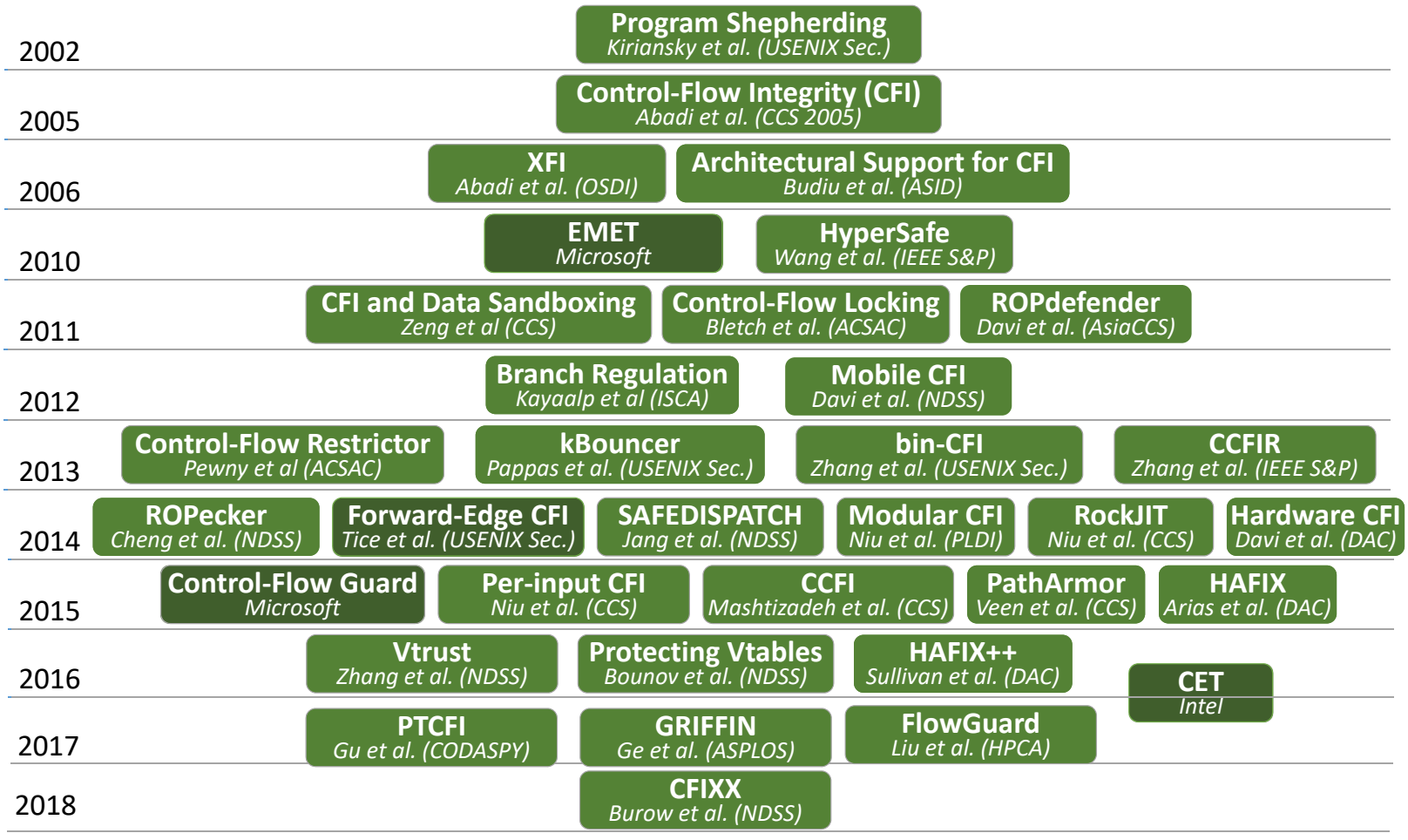


Control-Flow Integrity (CFI)

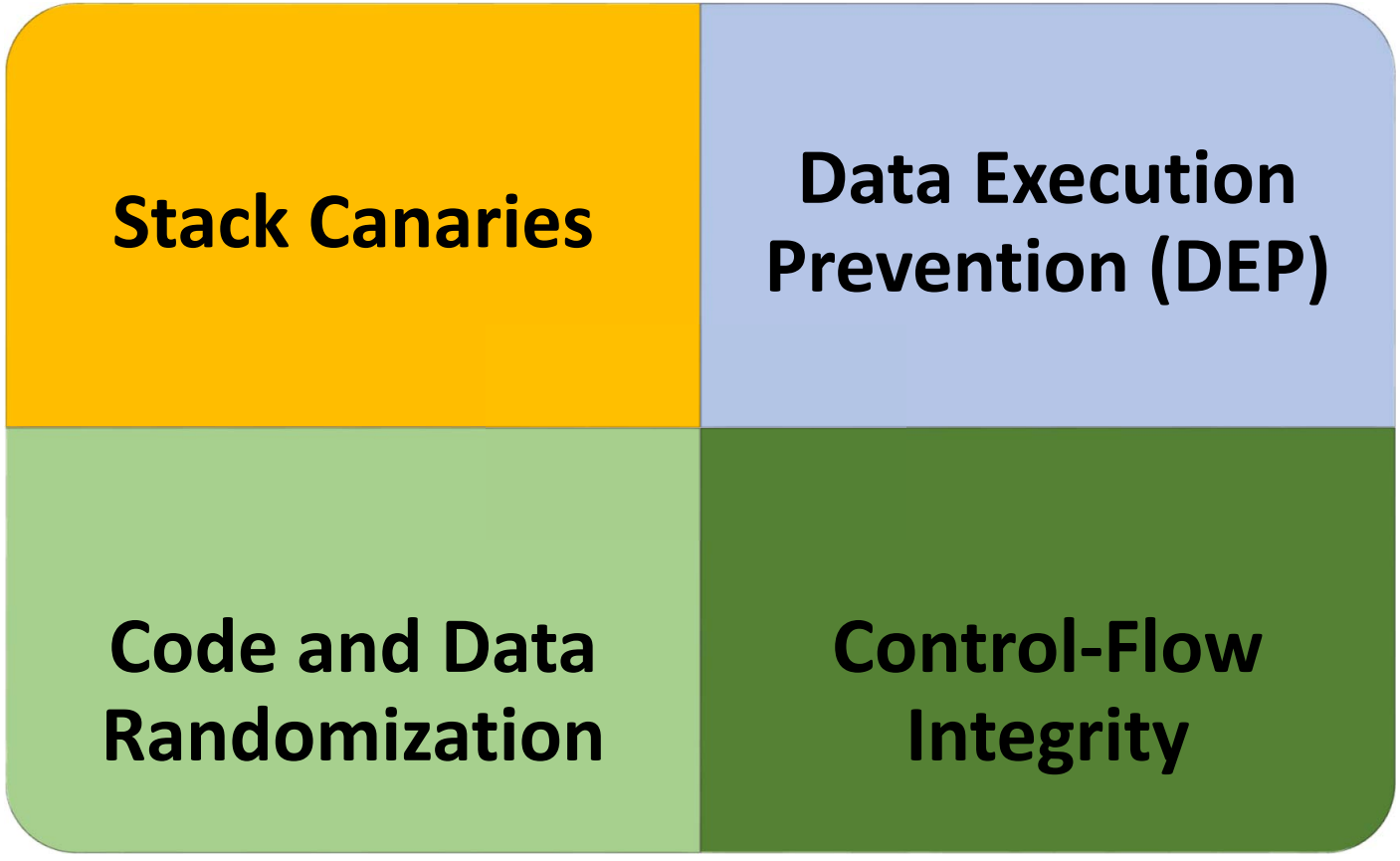
integrity checked



Recent Efforts on CFI Research



The Practical Run-time Defenses Against Memory Corruptions



How to Implement the Defense Mechanisms (or Software in General)

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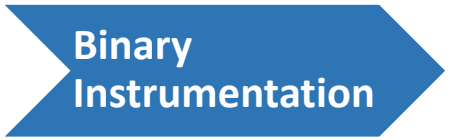

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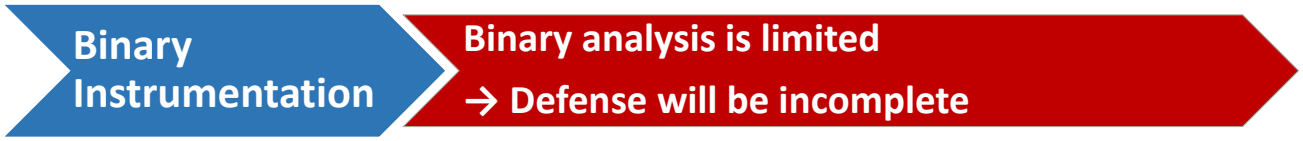

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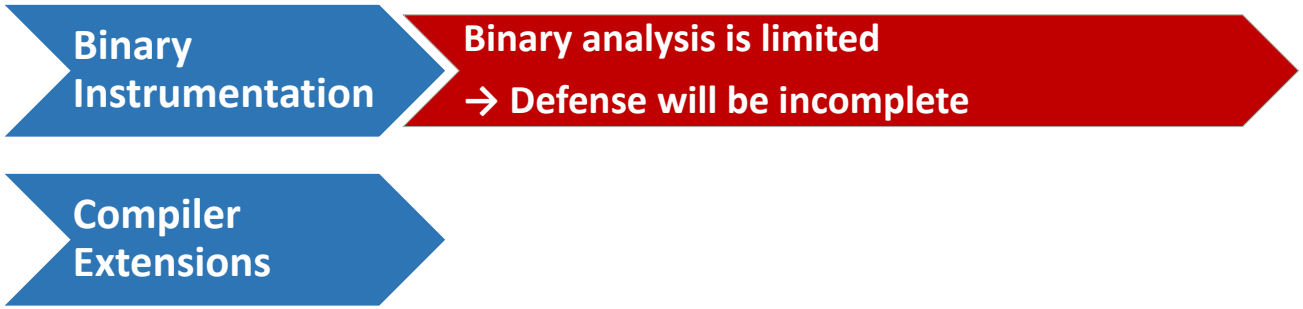

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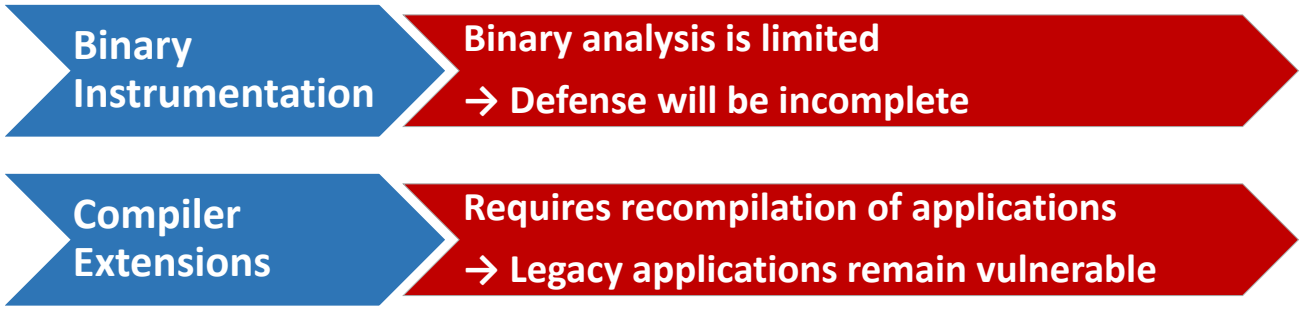

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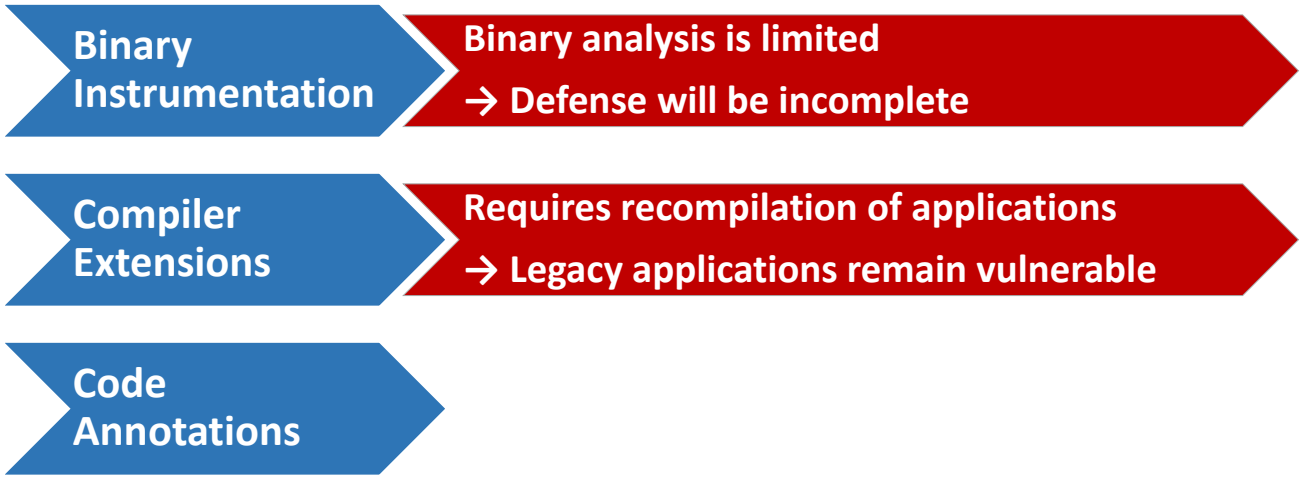

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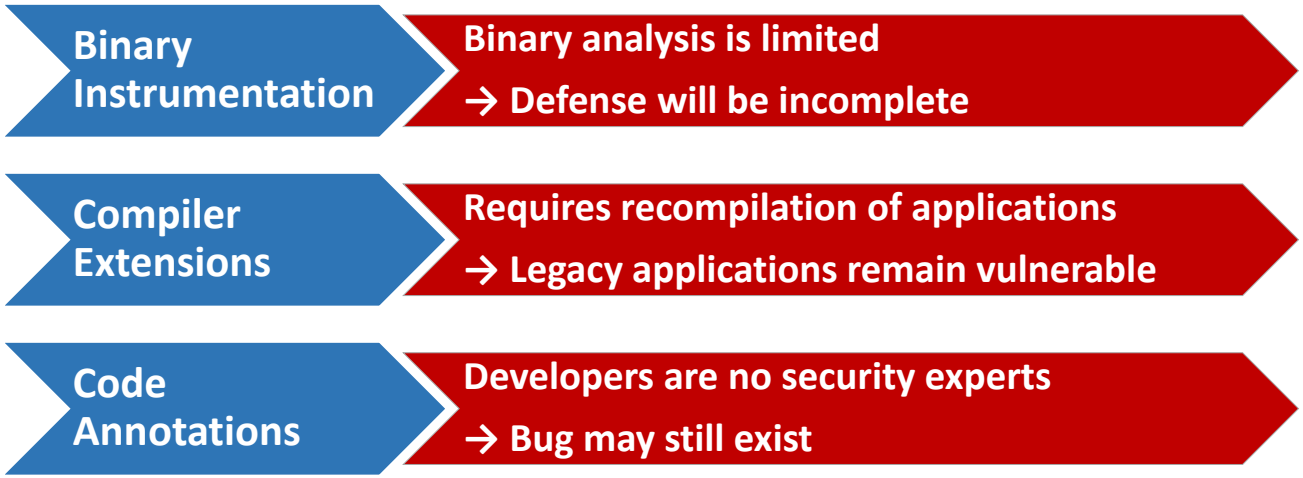

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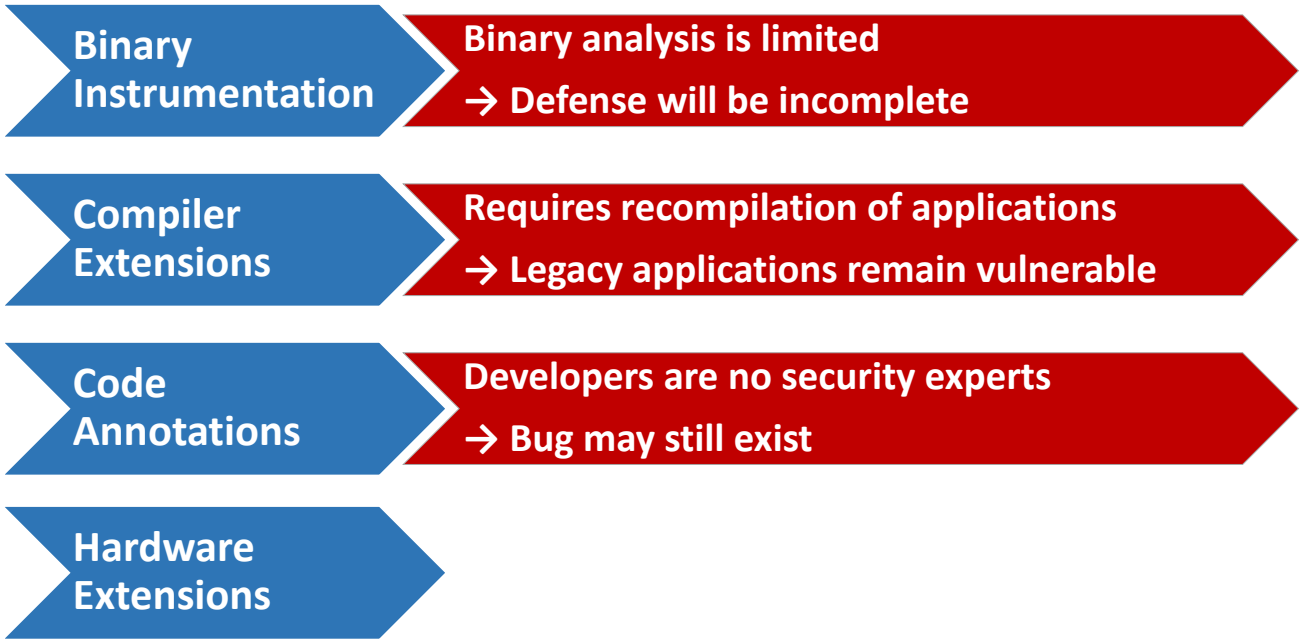

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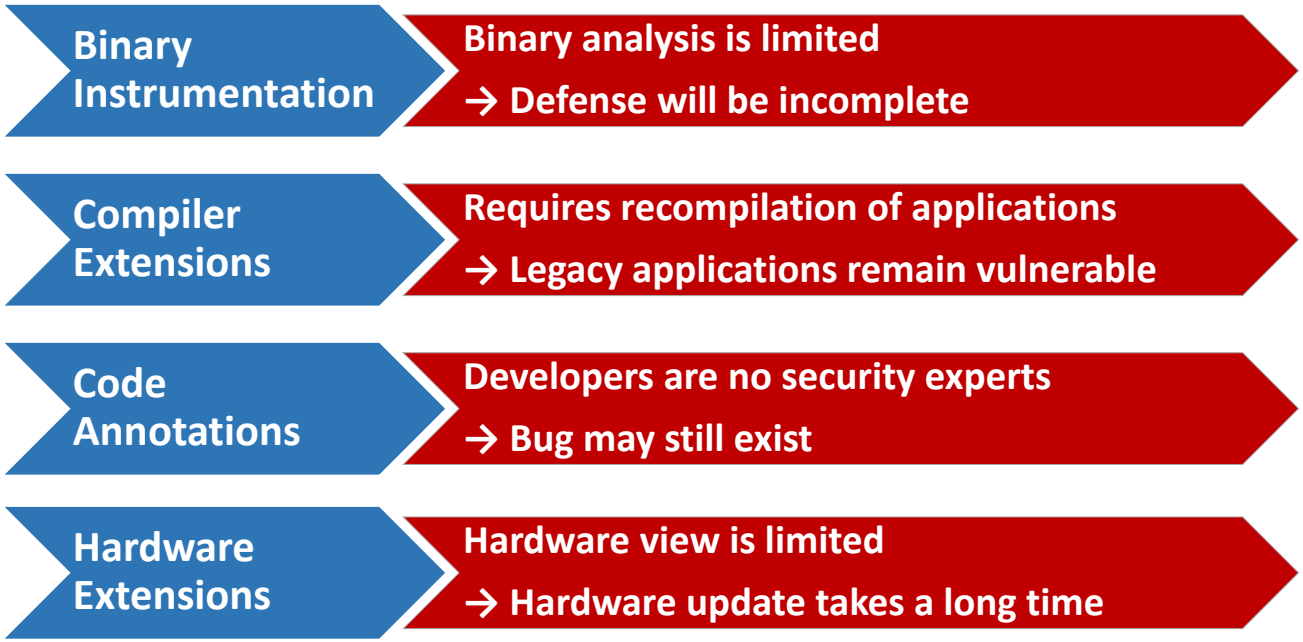

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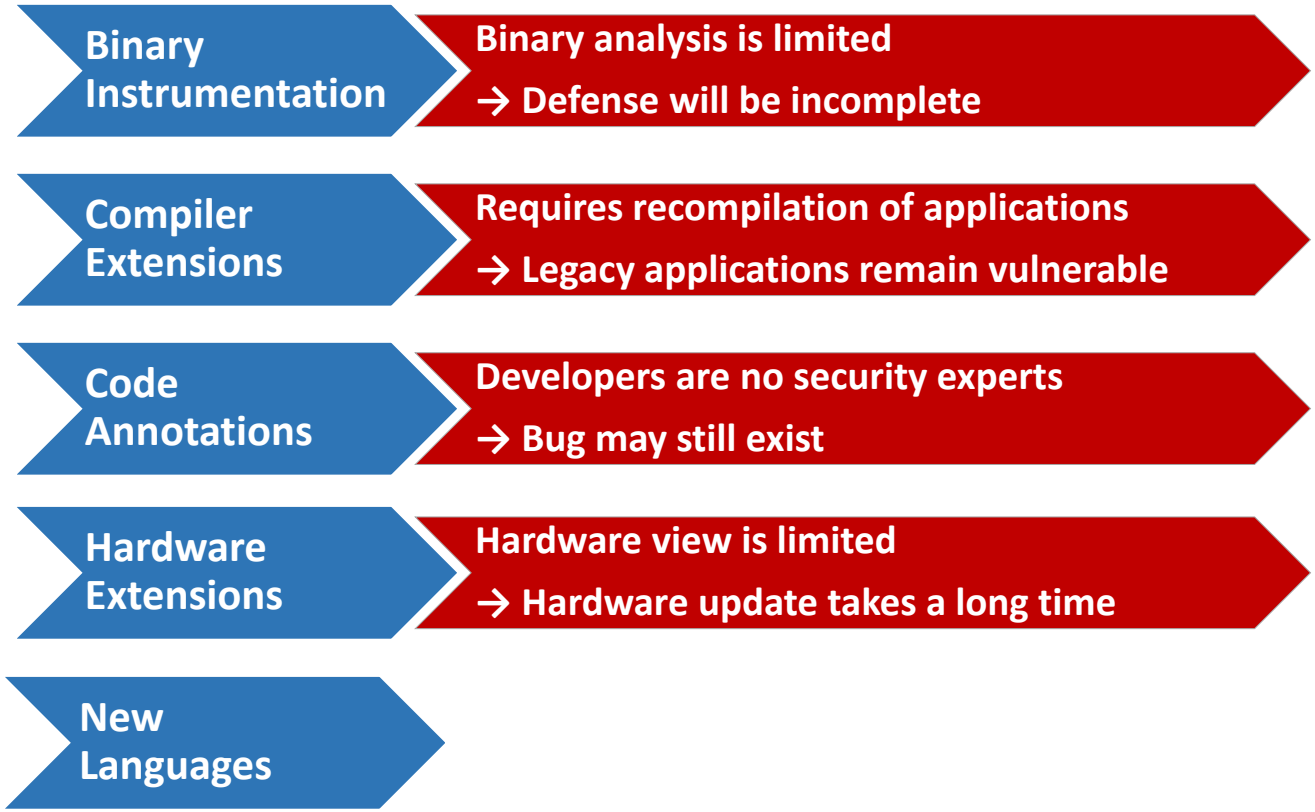

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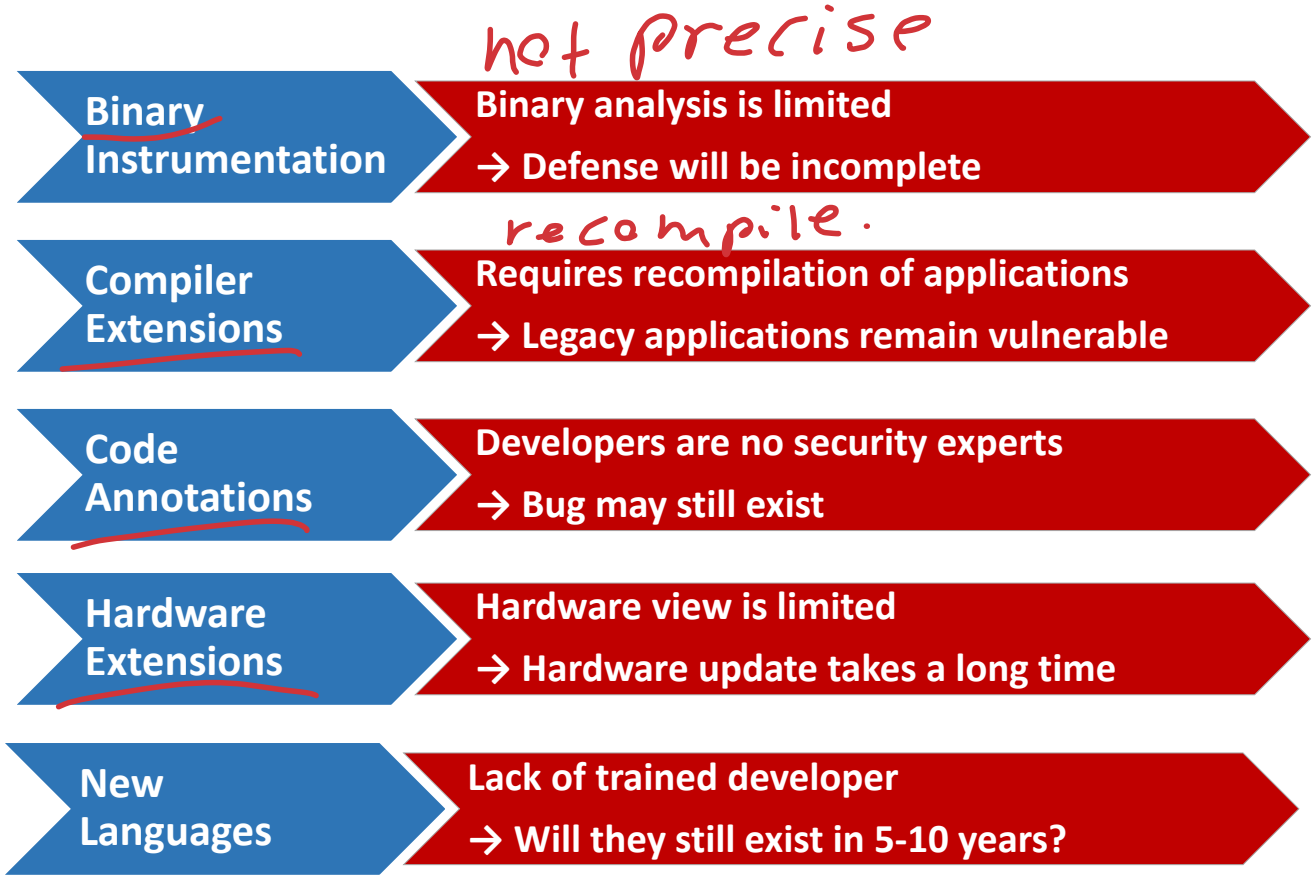

Other Approaches: Proactive Vulnerability Identification

Fuzzing

1. Identifying vulnerabilities before attackers
   - Blackbox (dumb) fuzzing
   - Generational aka grammar-based fuzzing
   - Whitebox fuzzing with SAGE
     - Looking at symbolic execution of the code
   - Evolutionary fuzzing with afl
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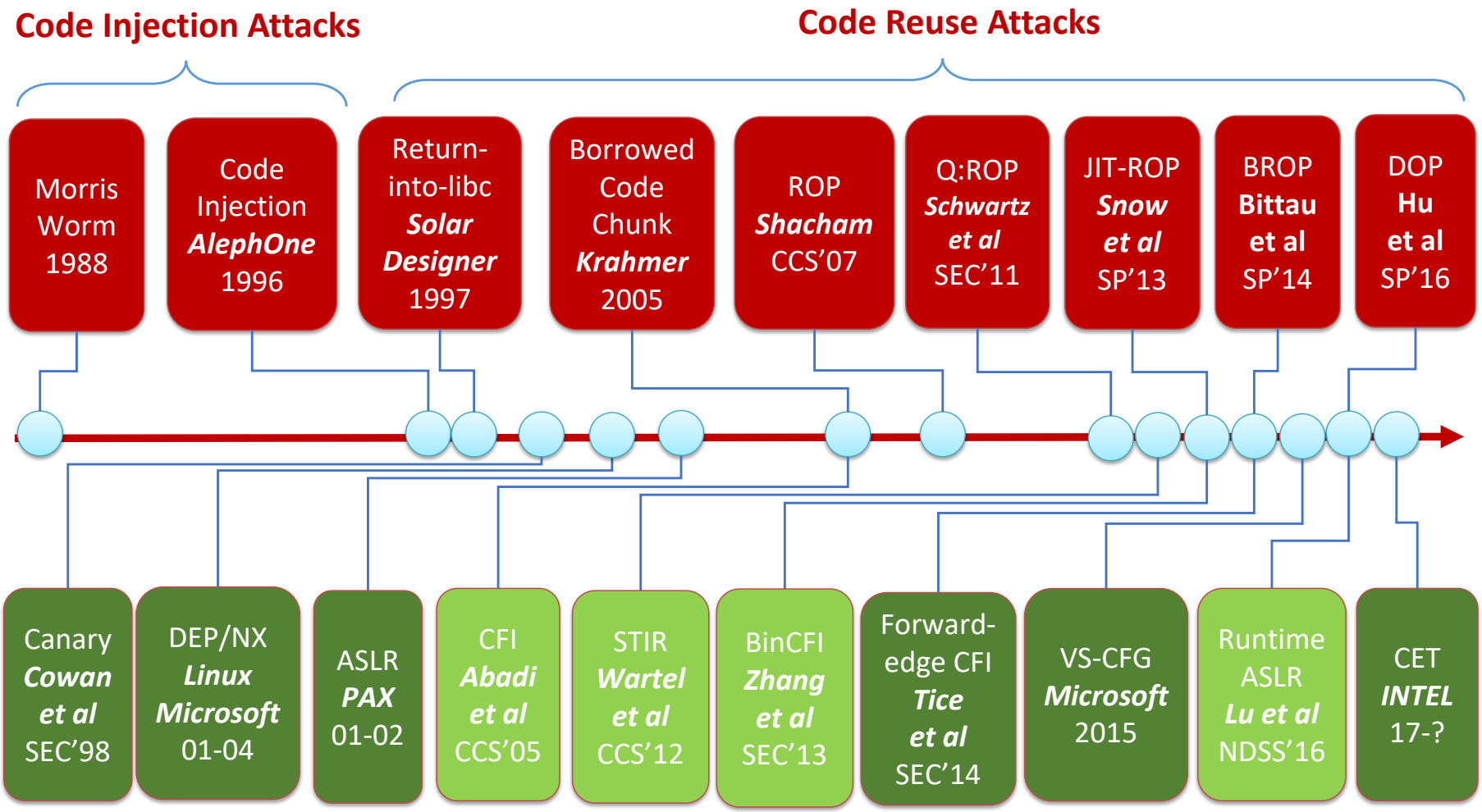
AFL (American Fuzzy Lop)

1. Support software w/
   - Source code (using a compiler flag)
     - C/C++/Object-C
     - Hand-written assembly
   - Binary (executed in an emulator)
2. Identified many 0-day vulnerabilities
3. Highly practical

The Arm Race Between Offense and Defense



Practical Defenses

When Developing New Software

1. Turnning on compiler flag
   - Canary (/gs, -fstack-protector)
   - CFI (/cfg, -fsanitize=cfi-icall)
   - CET (gcc 8.0)
   - ASLR (-pie -fPIE)
2. Using type safe language
   - Rust

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When Deploying Old Software

1. Turnning on kernel DEP
2. Turnning on ASLR
   - Load-time
   - Microsoft EMET
3. Keeping software patched
4. Penetration testing
   - Using fuzzing

Software Security

Software is Not Secure

1. Memory unsafe code (written in C/C++, asm, ...)
2. Prevalent software defects
   - Stack/Heap smashing
   - Format string bugs
   - Pointer errors

Defenses

1. Stack/Heap Canaries
2. ASLR, DEP, CFI
3. RELRO, BIND_NOW
4. BPF_SECCOMP, FORTIFY_SRC

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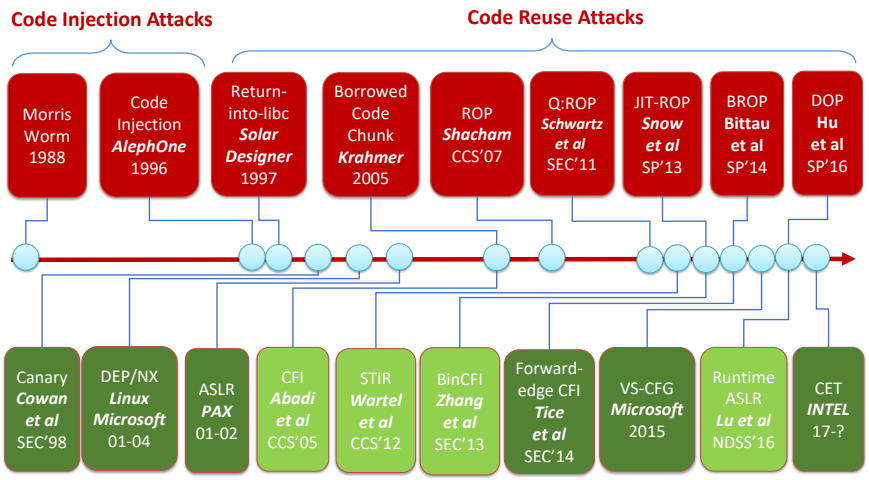
Offenses

1. Code injection
2. Code Reuse
   - Return-to-libc (ret2libc)
   - Return-oriented prog. (ROP)
   - Just-In-Time ROP (JIT-ROP)

Thank You



1

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[1] Instructor appreciates the help from Prof. Zhiqiang Lin.