# Bypassing memory safety mechanisms through speculative control flow hijacks

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Northeastern University

IBM Research

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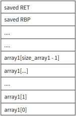

saved RET

saved RBP

....

....

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....

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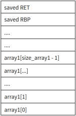

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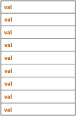

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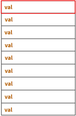

val
val
val
val
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val
val
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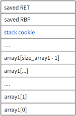

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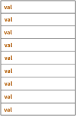

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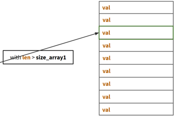

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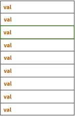

**Fast forward 2018 - speculative execution attacks**

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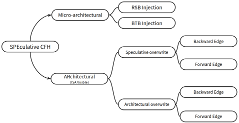
# Research Question

**Are current** memory corruption **mitigations** still **valid**

**in** the context of **speculative execution attacks**?

# SPEculative ARchitectural control flow hijacks (SPEAR)



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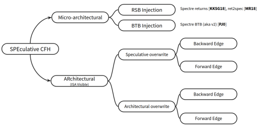

SPEculative CFH

Micro-architectural

RSB Injection

Spectre returns [**KKSG18**], ret2spec [**MR18**]

BTB Injection

Spectre BTB (aka v2) [**PJ0**]

ARchitectural
(ISA Visible)

Speculative overwrite

Backward Edge

Forward Edge

Architectural overwrite

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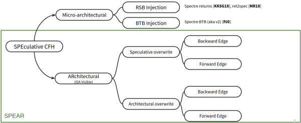

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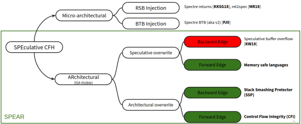

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Speculative buffer overflow [**KW18**]

Forward Edge

**Memory safe languages**

Architectural overwrite

Backward Edge

**Stack Smashing Protector (SSP)**

Forward Edge

**Control Flow Integrity (CFI)**

SPEAR

# Does SSP fully mitigate buffer overflows?

```
func:
    mov rbx, QWORD[fs:0x28]
    mov QWORD[stack_cookie], rbx
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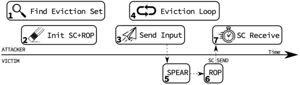
**We demonstrate SSP can be bypassed with a SPEAR**

# Bypassing SSP with SPEAR: CVE-2004-0597



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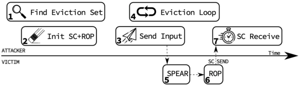

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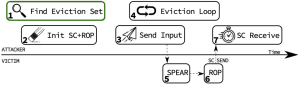

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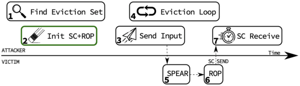

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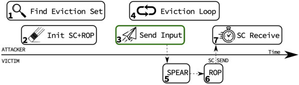

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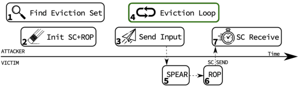

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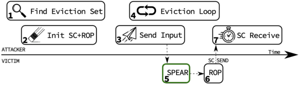

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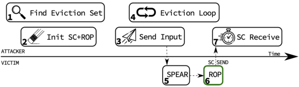

1 Find Eviction Set

2 Init SC+ROP

3 Send Input

4 Eviction Loop

7 SC Receive

ATTACKER

Time

VICTIM

5 SPEAR

6 ROP

SC SEND

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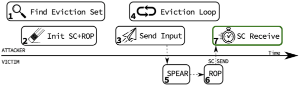

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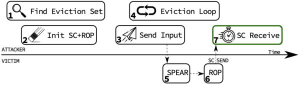

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**Impact**: arbitrary read from victim program

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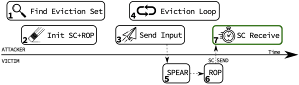

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Leakage 0.3 bytes x second

**Impact**: arbitrary read from victim program

# Other use cases

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Memory safe languages are also affected (Golang, Rust)

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Control flow integrity (LLVM-CFI, GCC-VTV)

**=> LLVM-CFI NOT vulnerable due to design**

# Conclusion

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SPEAR attacks bypass mitigations and memory safety to leak confidential data

=> **new and old mitigations must be analyzed and possibly modified to withstand SPEAR attacks**

These attacks are complex but practical

=> **with new tools to aid building each attack stage, they could become more practical**

**Speculative ROP is possible and eases the task of finding a spectre v1-like side channel send gadget**

SEAs are a significant research and industry challenge for the next decade (tools, attacks and defences)