SpecFuzz

Bringing Spectre-type vulnerabilities to the surface

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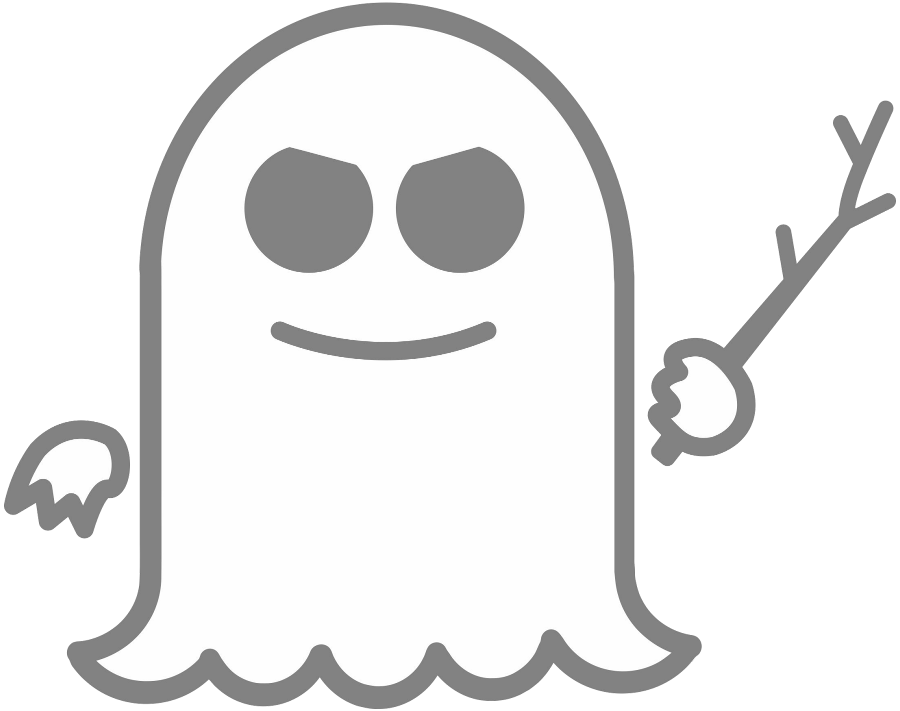
TECHNION Israel Institute of Technology



```
x = 100
...
if x < 10
    y = array[x]
```

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...
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```

⬅ False; Predict **True**

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if x < 10
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```

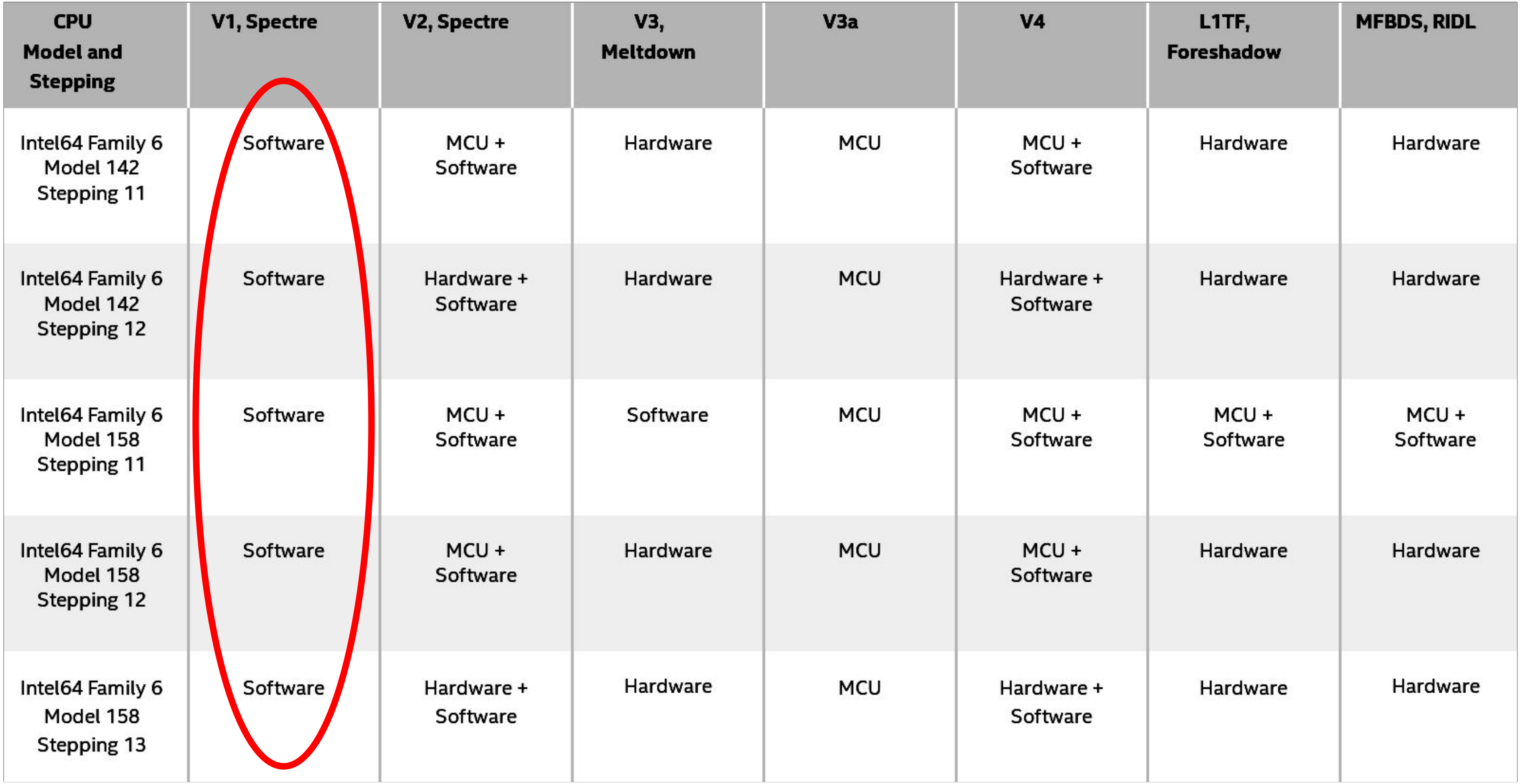
False; Predict True

⬅ **Execute speculatively**

```
x = 100
...
if x < 10                   False; Predict True
    y = array[x]            Execute speculatively
```

- **SW-invisible**
- **leaves HW traces**

Patches?



CPU Model and Stepping	V1, Spectre	V2, Spectre	V3, Meltdown	V3a	V4	L1TF, Foreshadow	MFBDS, RIDL
Intel64 Family 6 Model 142 Stepping 11	Software	MCU + Software	Hardware	MCU	MCU + Software	Hardware	Hardware
Intel64 Family 6 Model 142 Stepping 12	Software	Hardware + Software	Hardware	MCU	Hardware + Software	Hardware	Hardware
Intel64 Family 6 Model 158 Stepping 11	Software	MCU + Software	Software	MCU	MCU + Software	MCU + Software	MCU + Software
Intel64 Family 6 Model 158 Stepping 12	Software	MCU + Software	Hardware	MCU	MCU + Software	Hardware	Hardware
Intel64 Family 6 Model 158 Stepping 13	Software	Hardware + Software	Hardware	MCU	Hardware + Software	Hardware	Hardware

Source:
https://software.intel.com/security-software-guidance/processors-affected-transient-execution-attack-mitigation-product-cpu-model

Software	Defence Mechanism
Chrome	Site Isolation, Reduced Timer Precision, Sandboxing
Linux Kernel	Index masking (171 usages in v5.7.6)
OpenSSL	Outside the threat model [1]
Graphene SGX	None

[1] https://www.openssl.org/policies/secpolicy.html

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Why so little?

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High overhead

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Low risk

Our Goal?

Make Defences Affordable!

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Make Defences Affordable!

Our Solution?

Apply Fuzzing!

Problem

Speculation is invisible

Speculation Exposure

Speculation Exposure

Expose speculative execution…

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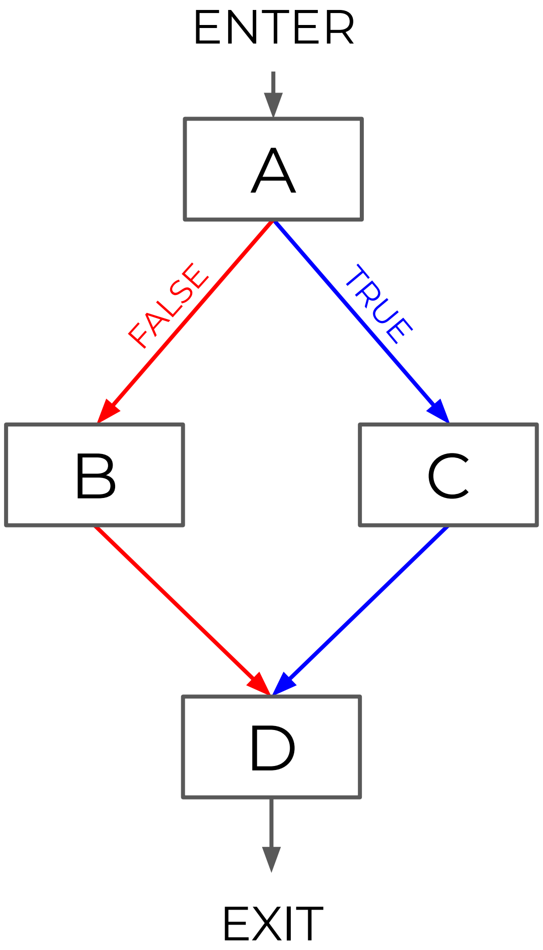
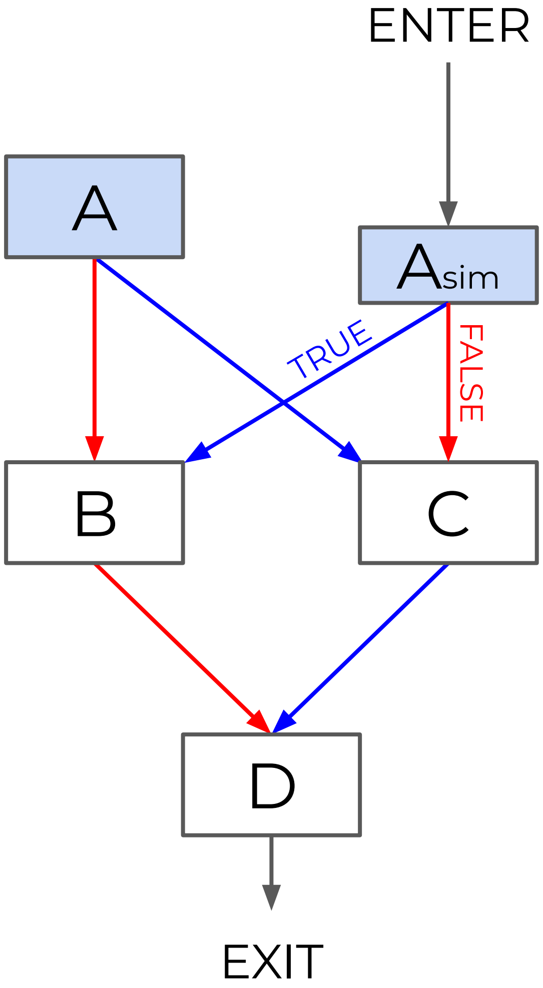
Expose speculative execution…

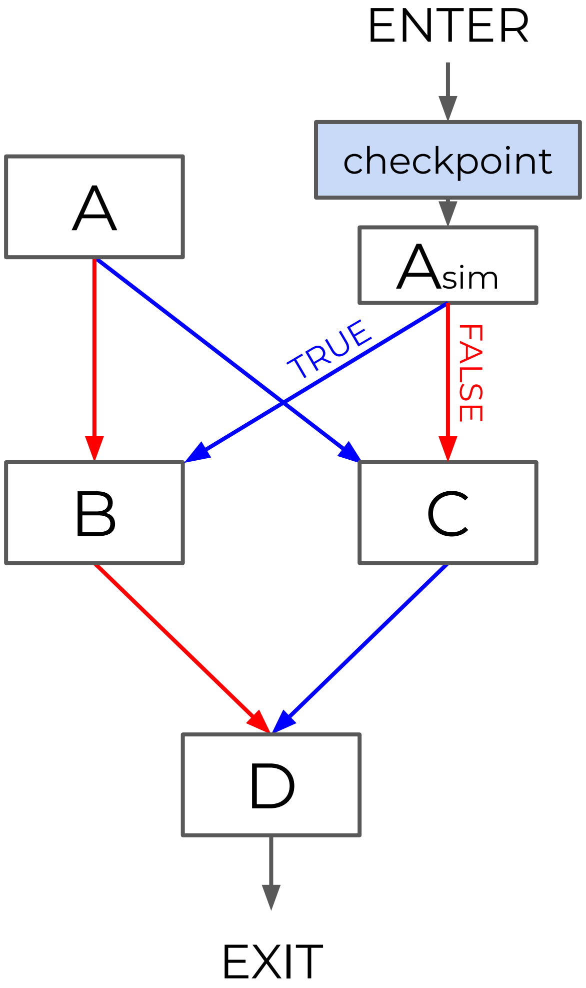
through a worst-case simulation…

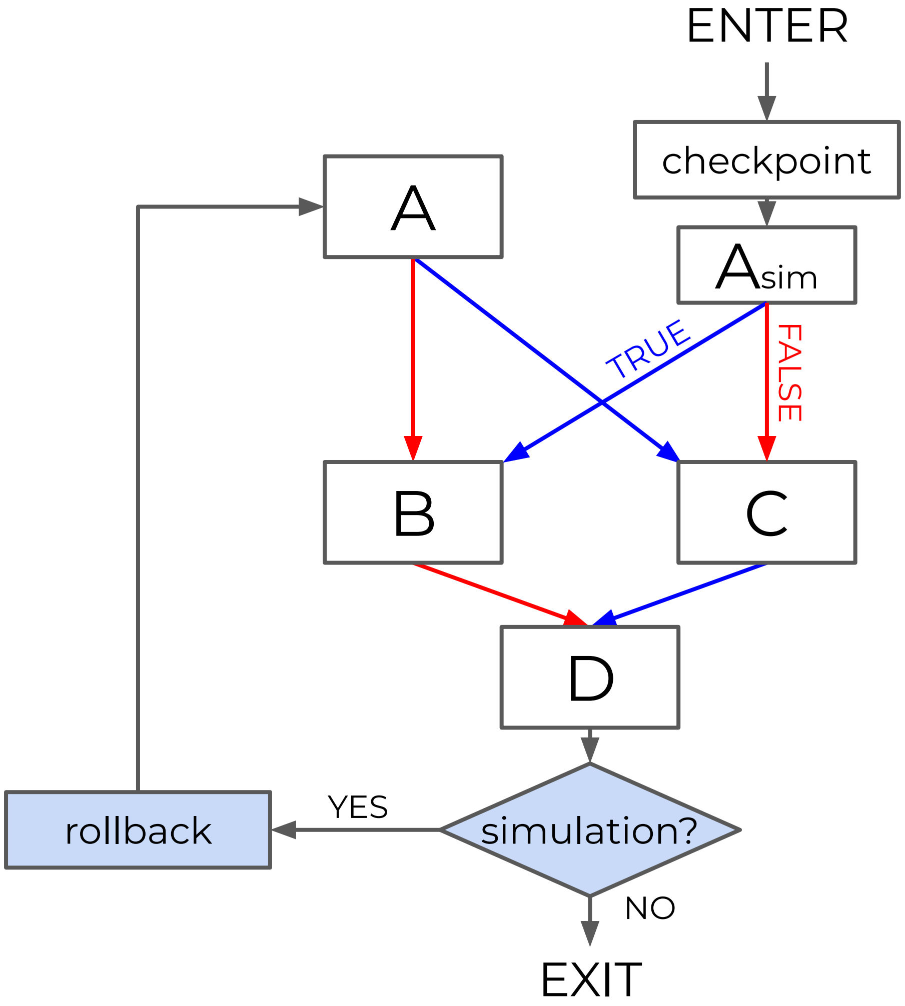
Speculation Exposure

Expose speculative execution…
through a worst-case simulation…
within the process


ENTER
A
FALSE
TRUE
B
C
D
EXIT


ENTER
A
Asim
TRUE
FALSE
B
C
D
EXIT


ENTER
checkpoint
A
Asim
TRUE
FALSE
B
C
D
EXIT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checkpoint
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TRUE
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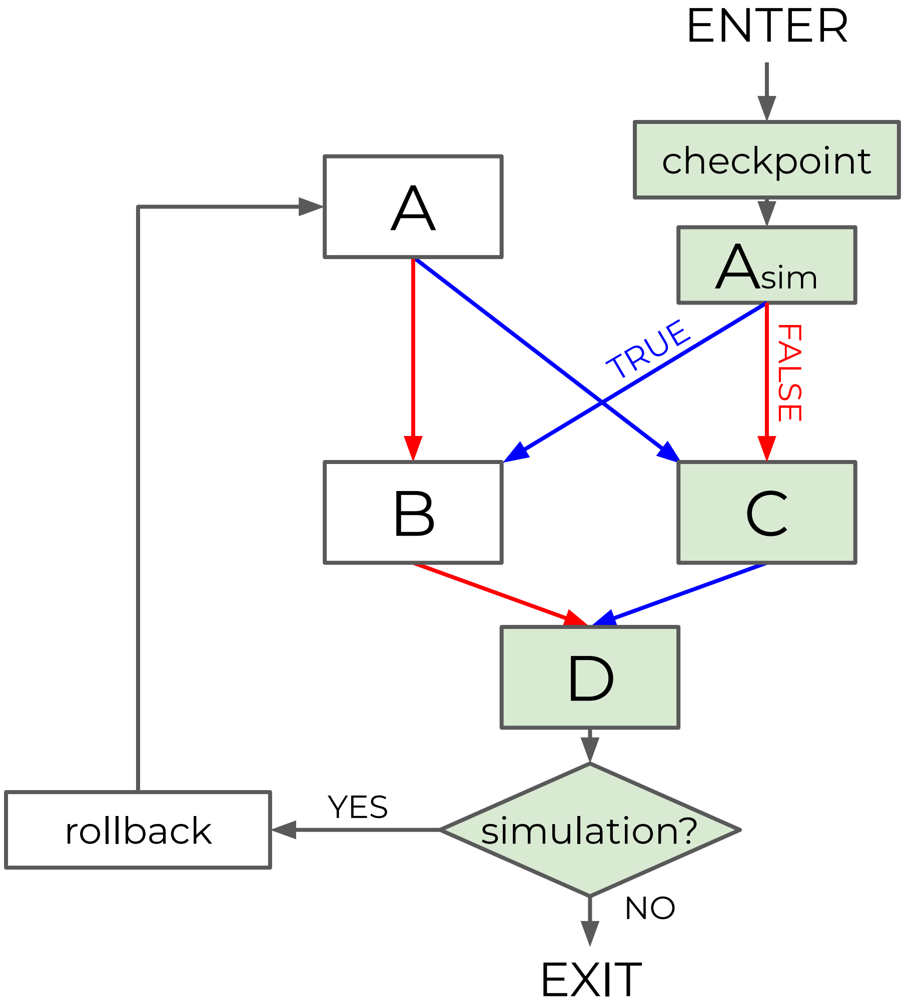
simulation?
YES
rollback
NO
EXIT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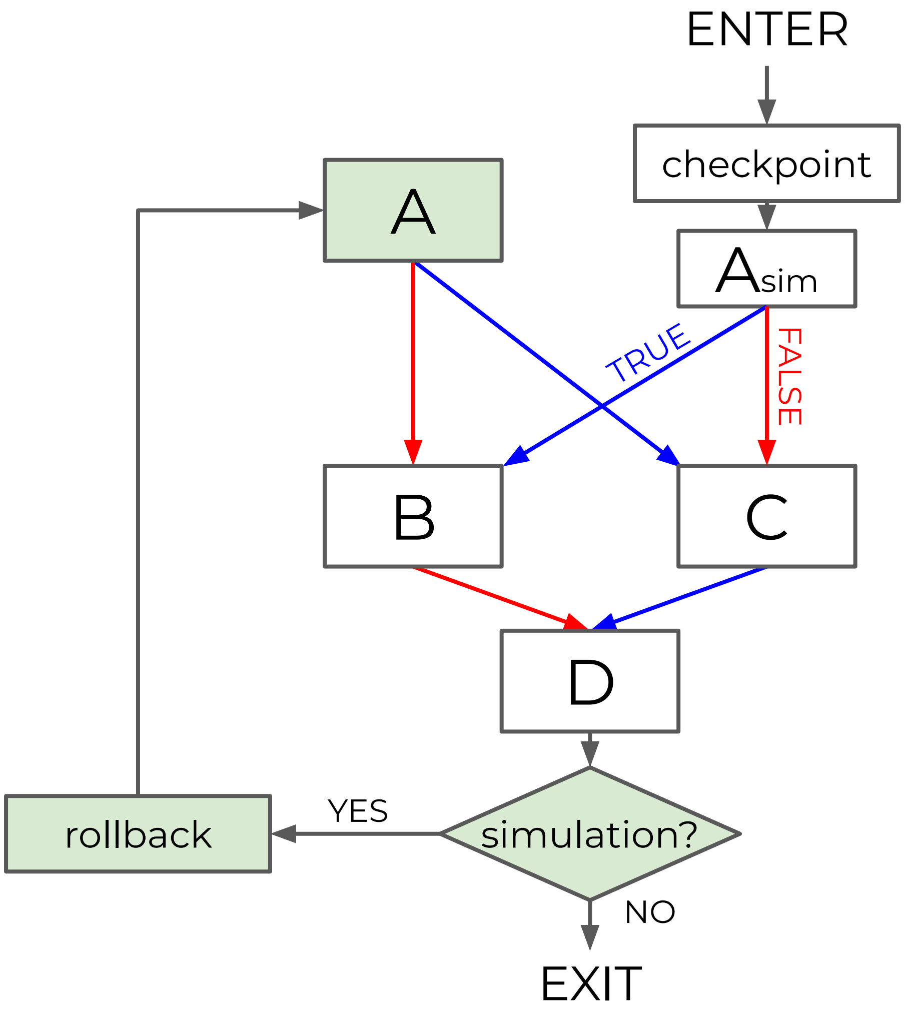
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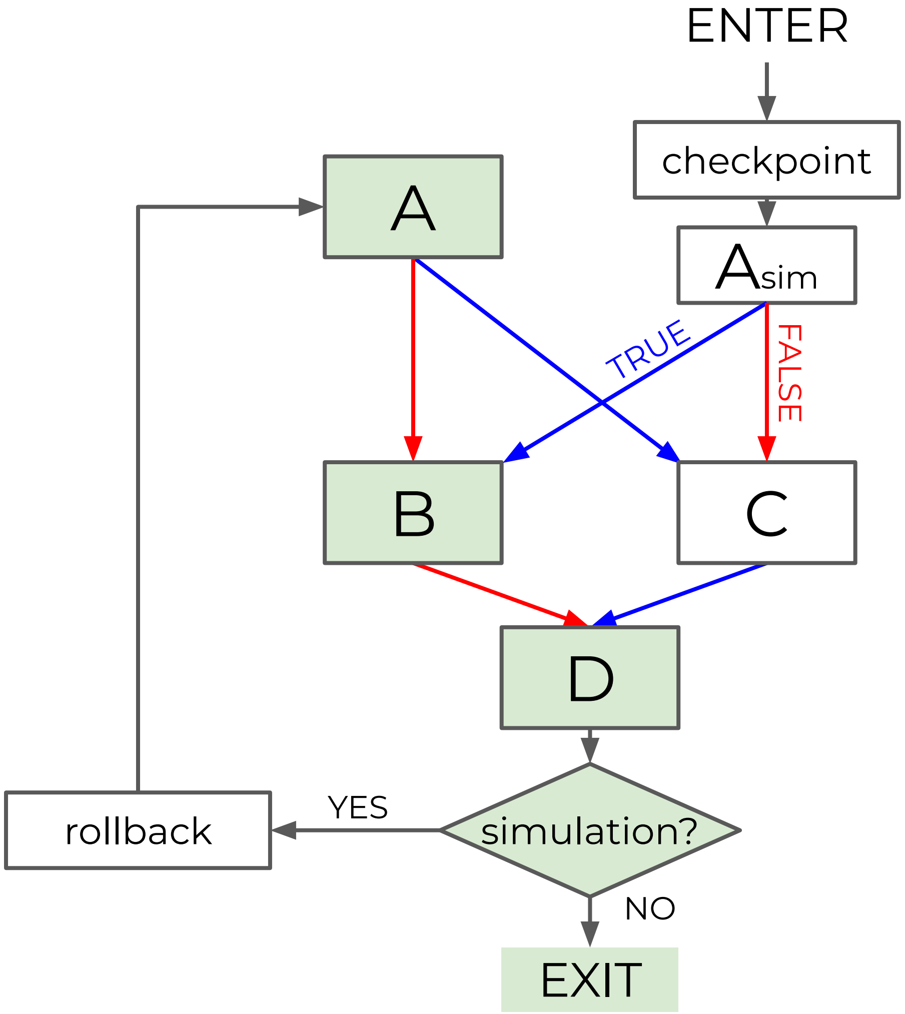
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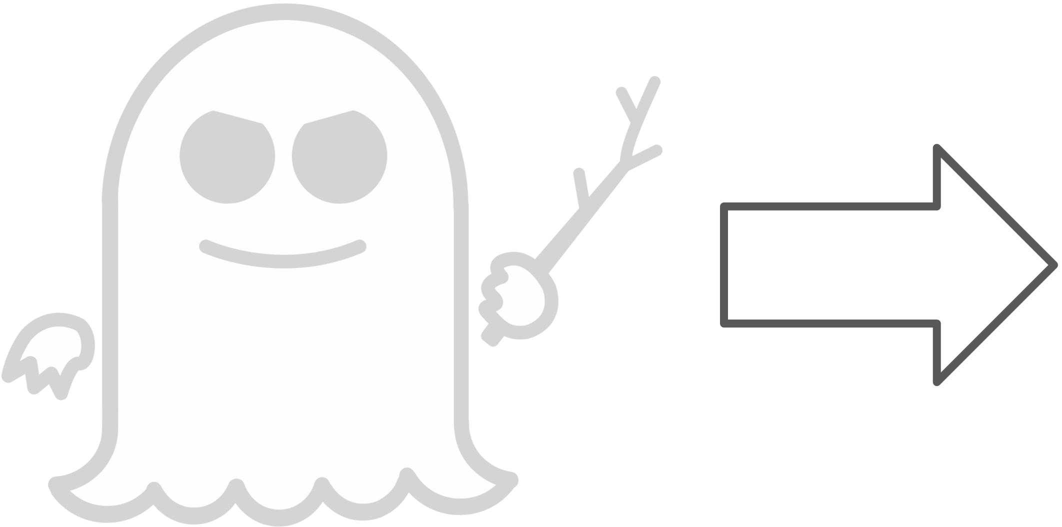
Speculation Exposure



Buffer Overflow

SpecFuzz:

Speculation Exposure
(LLVM pass + library)
+ ASan

Technical Challenges

- Nested Speculative Exposure
- External Calls
- Coverage
- Efficient checkpoint-rollback
- Fault Recovery
- Interaction with external libraries
- Speculative control-flow errors

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Technical Challenges

- Nested Speculative Exposure
- External Calls

See The Paper

- Fault Recovery
- Interaction with external libraries
- Speculative control-flow errors

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Speculative Memory Violations

Type	JSMN	Brotli	HTTP	libHTP	libYAML	OpenSSL
Code	0	2	1	2	3	16
Controlled	16	68	9	91	140	589
Uncontrolled	34	36	6	222	49	1127
Unknown	0	4	0	29	59	423

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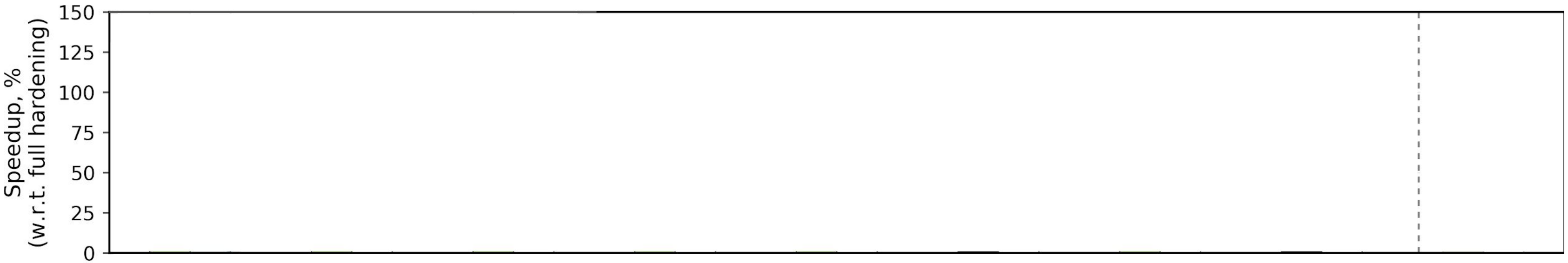
Automatic Patching

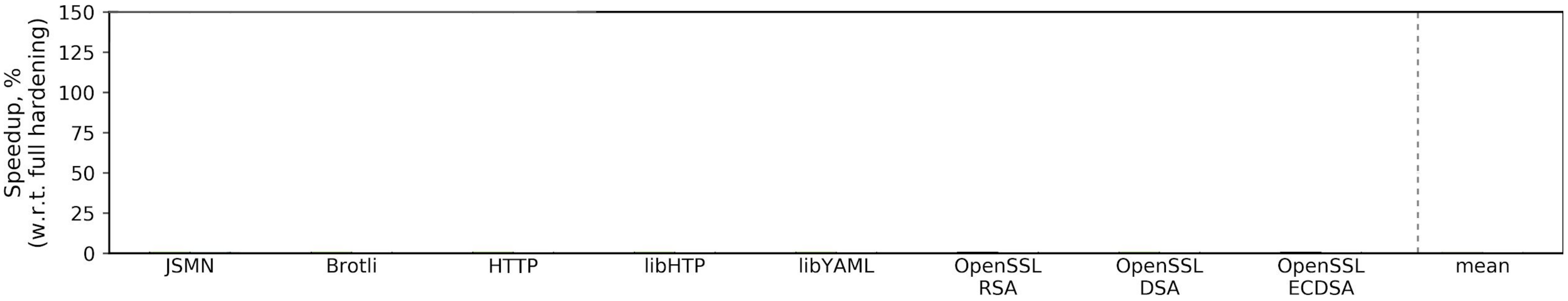
Remove hardening from
"seemingly benign" branches

Speedup



Higher
is better

Speedup



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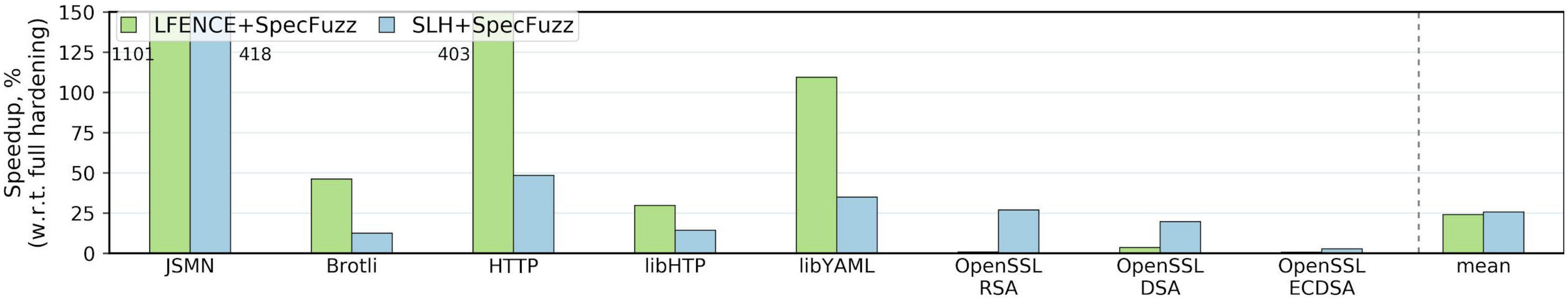
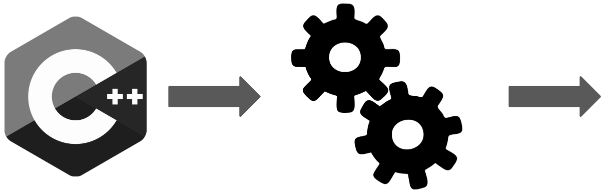


Higher is better

Summary

Summary

SpecFuzz



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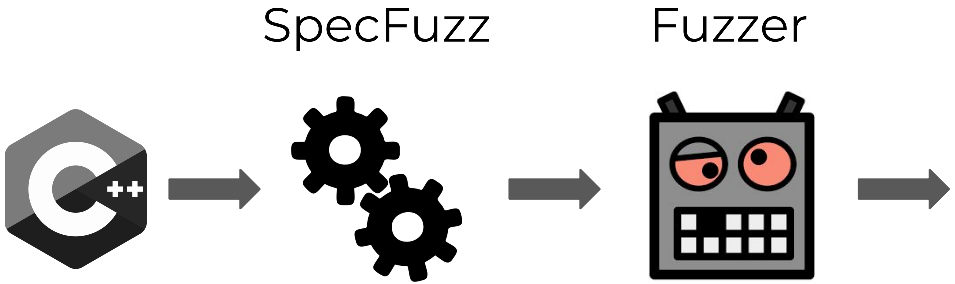
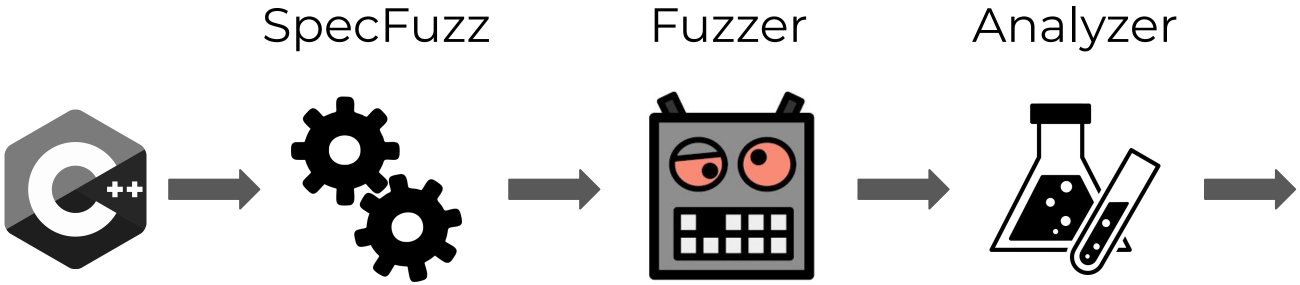


SpecFuzz

Fuzzer

Summary

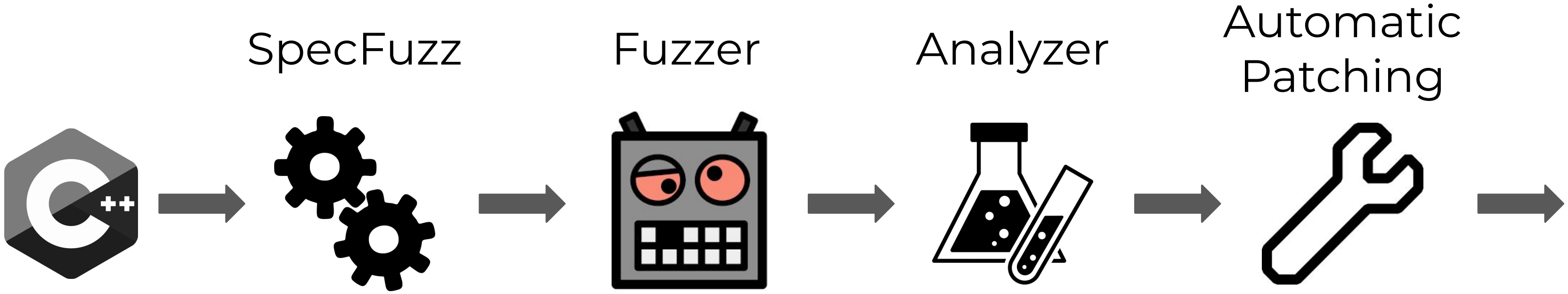


SpecFuzz

Fuzzer

Analyzer

Summary



SpecFuzz

Fuzzer

Analyzer

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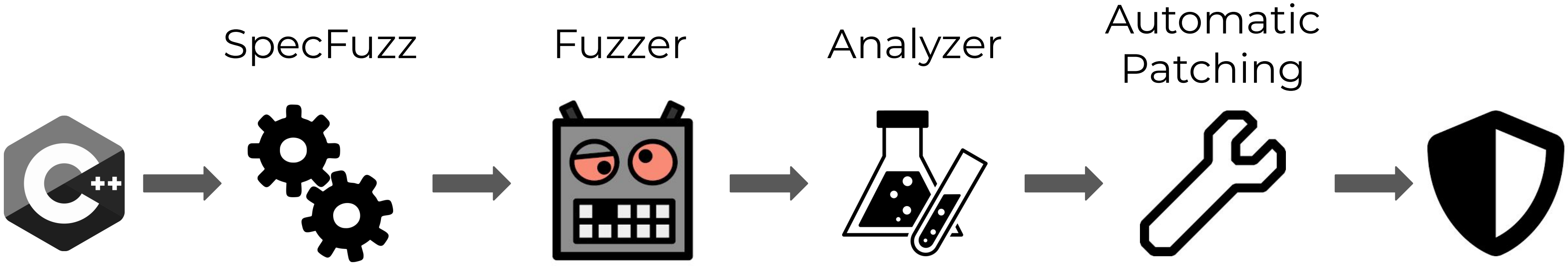

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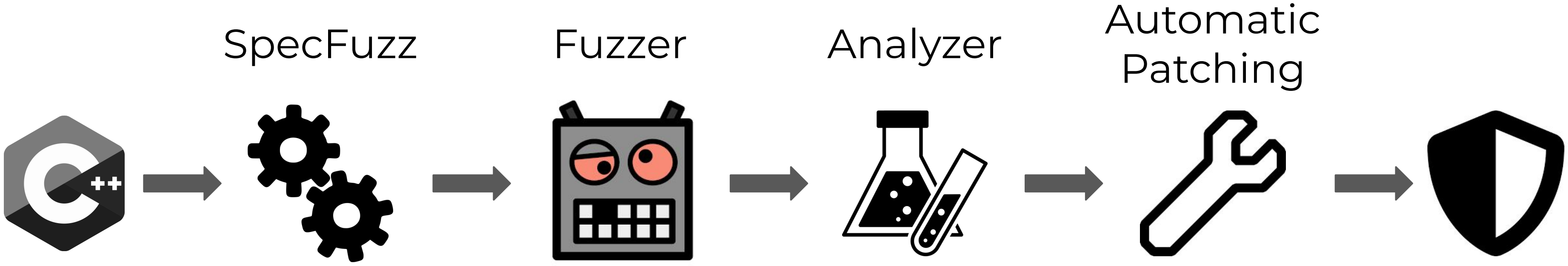

SpecFuzz

Fuzzer

Analyzer

Automatic Patching

https://github.com/tudinfse/SpecFuzz

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