Vulnerability Discovery

Dr. Edward J. Schwartz

eschwartz@cert.org

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

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Vulnerability Discovery Project

Increase **assurance** of 1st and 3rd party DoD software through **enhanced vulnerability discovery techniques**

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Team

Software Engineering Institute

- Edward Schwartz, PhD, CERT
- David Warren, CERT
- Allen Householder, CERT

Collaborators

∀.Secure

- David Brumley, PhD
- Thanassis Avgerinos, PhD
- Tyler Nighswander

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Agenda

Towards vulnerability discovery as a science

Intelligent fusion of vulnerability discovery techniques

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Towards Vulnerability Discovery as a Science

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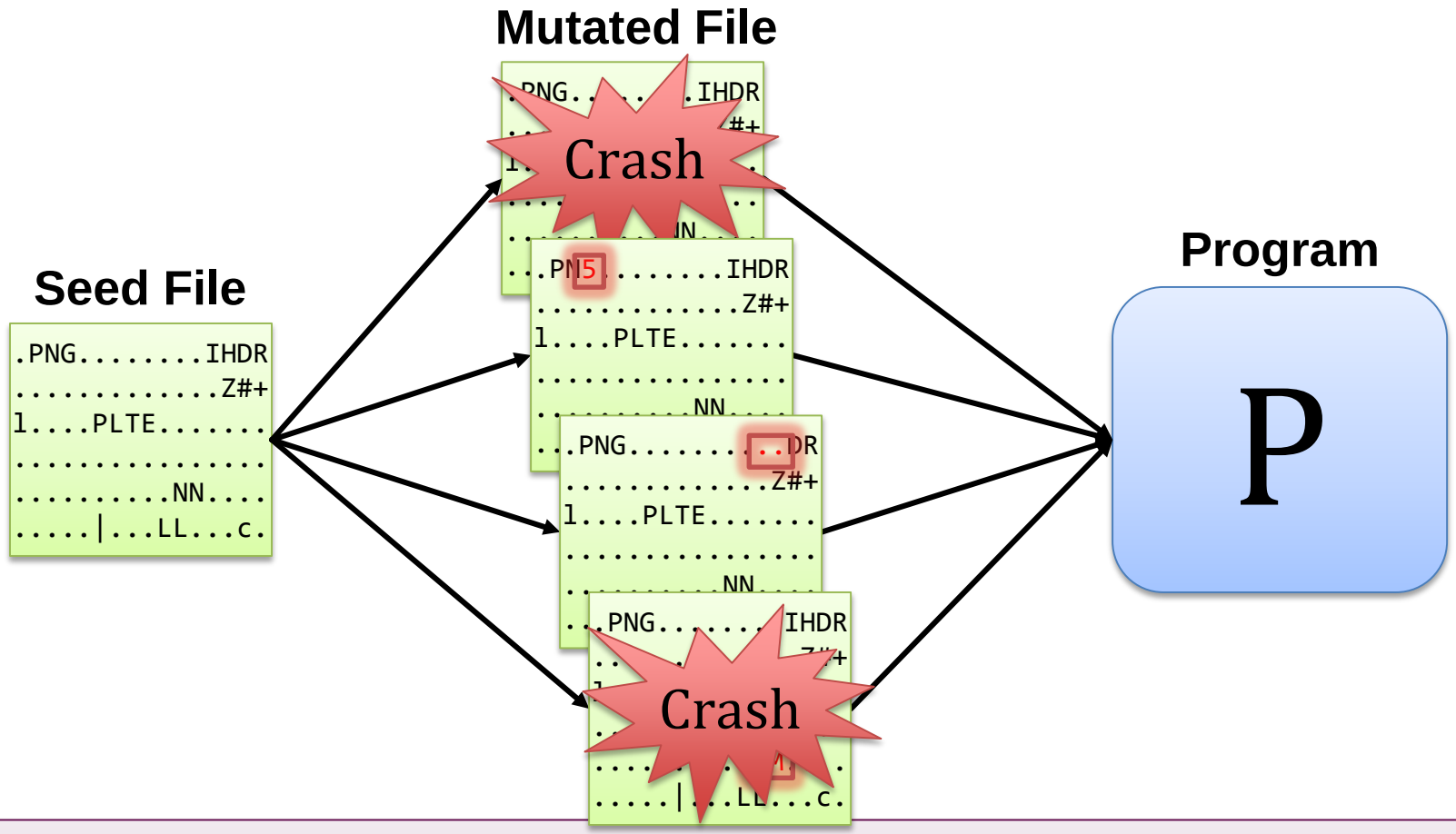
Background: Mutational Fuzzing of Software



Testing of programs by randomly mutating program inputs (seeds)

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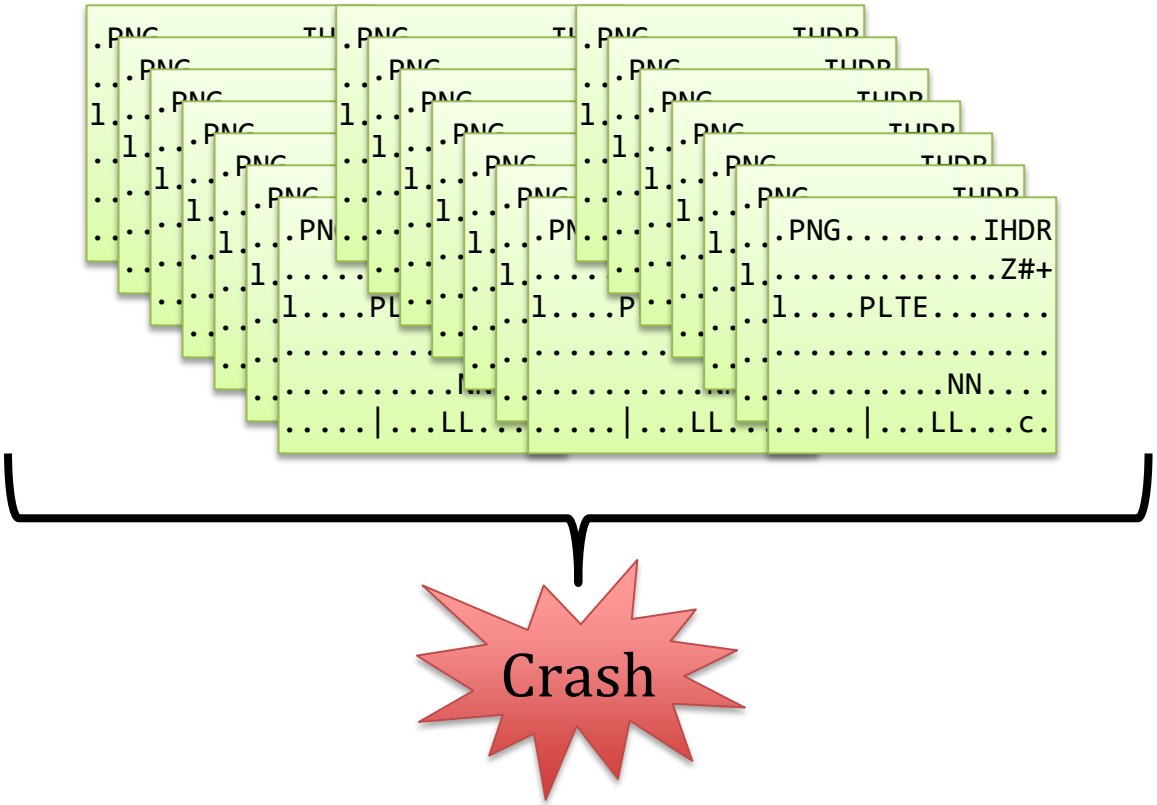
Challenge: How Many Software Vulnerabilities are There?



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Problem: Distinguishing One Vulnerability From Another

I don't know how to *specify* a vulnerability, but I know how to *fix* one

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The Idea: Patches Define Vulnerabilities

Any crash that is fixed by the patch is also affected by vulnerability V

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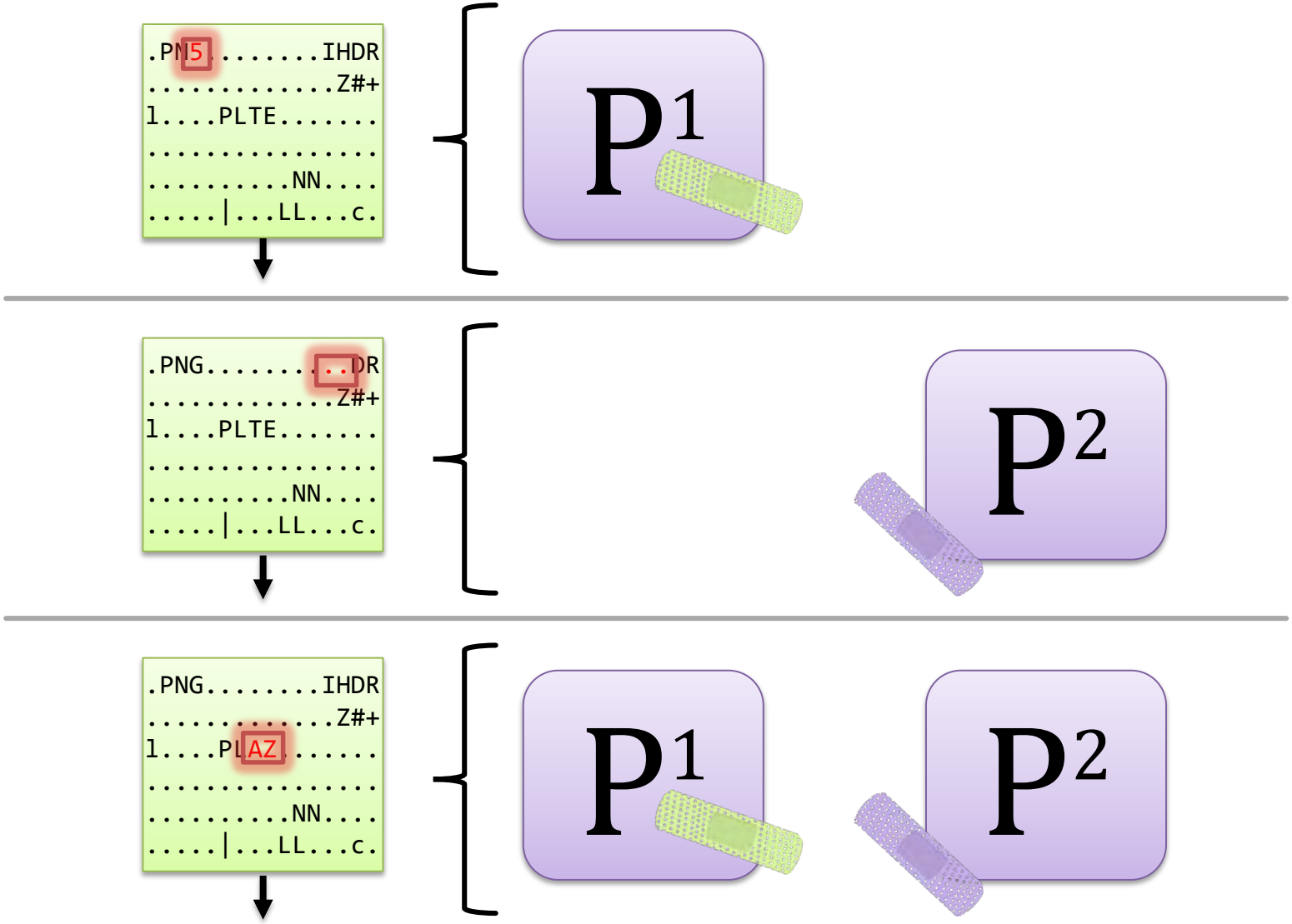
Example Ground Truth



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Patching ImageMagick

Fuzzed old ImageMagick with the CERT BFF fuzzer

- 1 week
- 130,000 crashes found

Manually patched all vulnerabilities

- Took approximately one month
- 31 patches/vulnerabilities

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Vulnerability Discovery Science

Analyze fuzzing parameters

- What mutators work best?
- When should we stop fuzzing?
- What effect do compiler settings have?
- …
- Paper submitted to NDSS 2016

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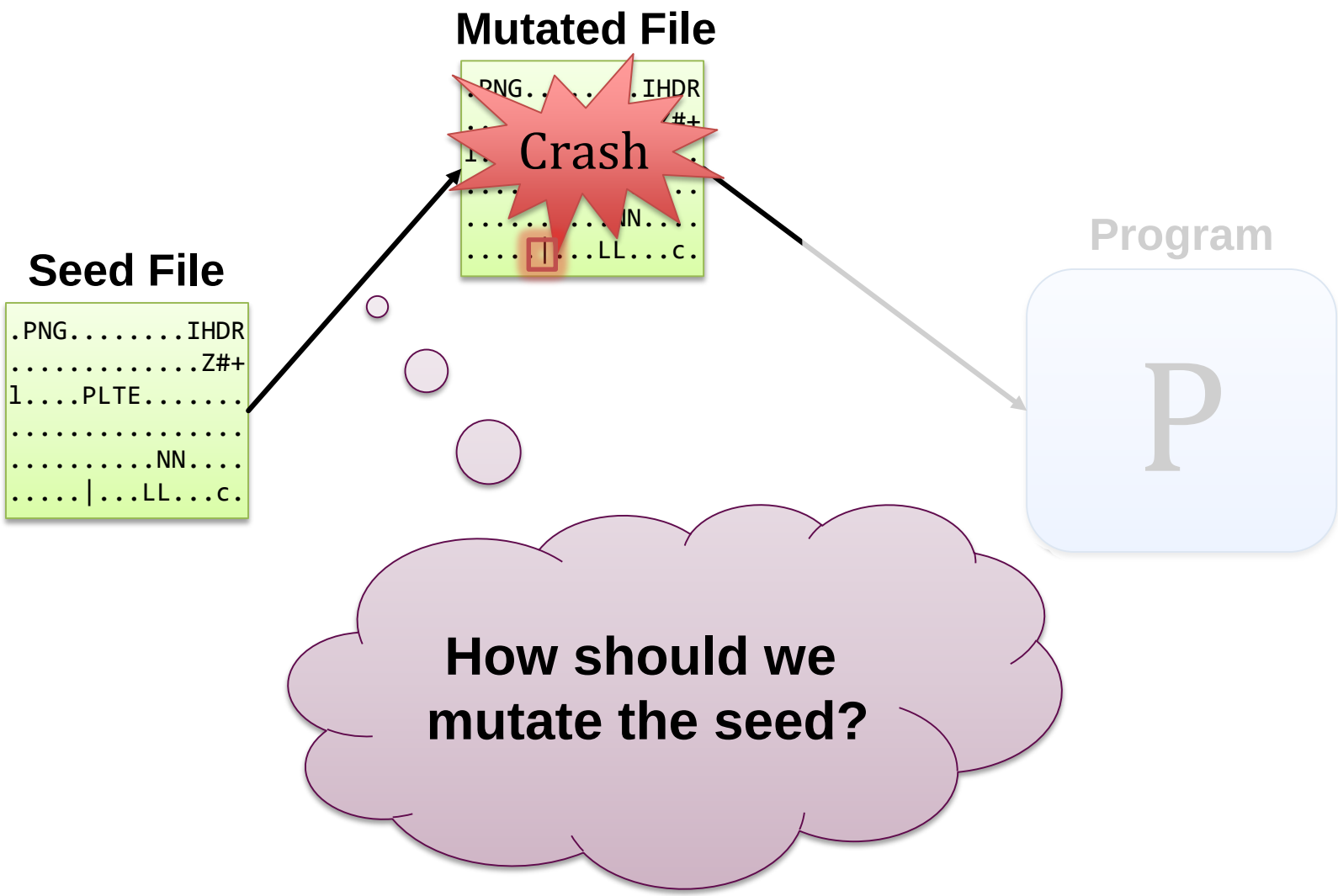

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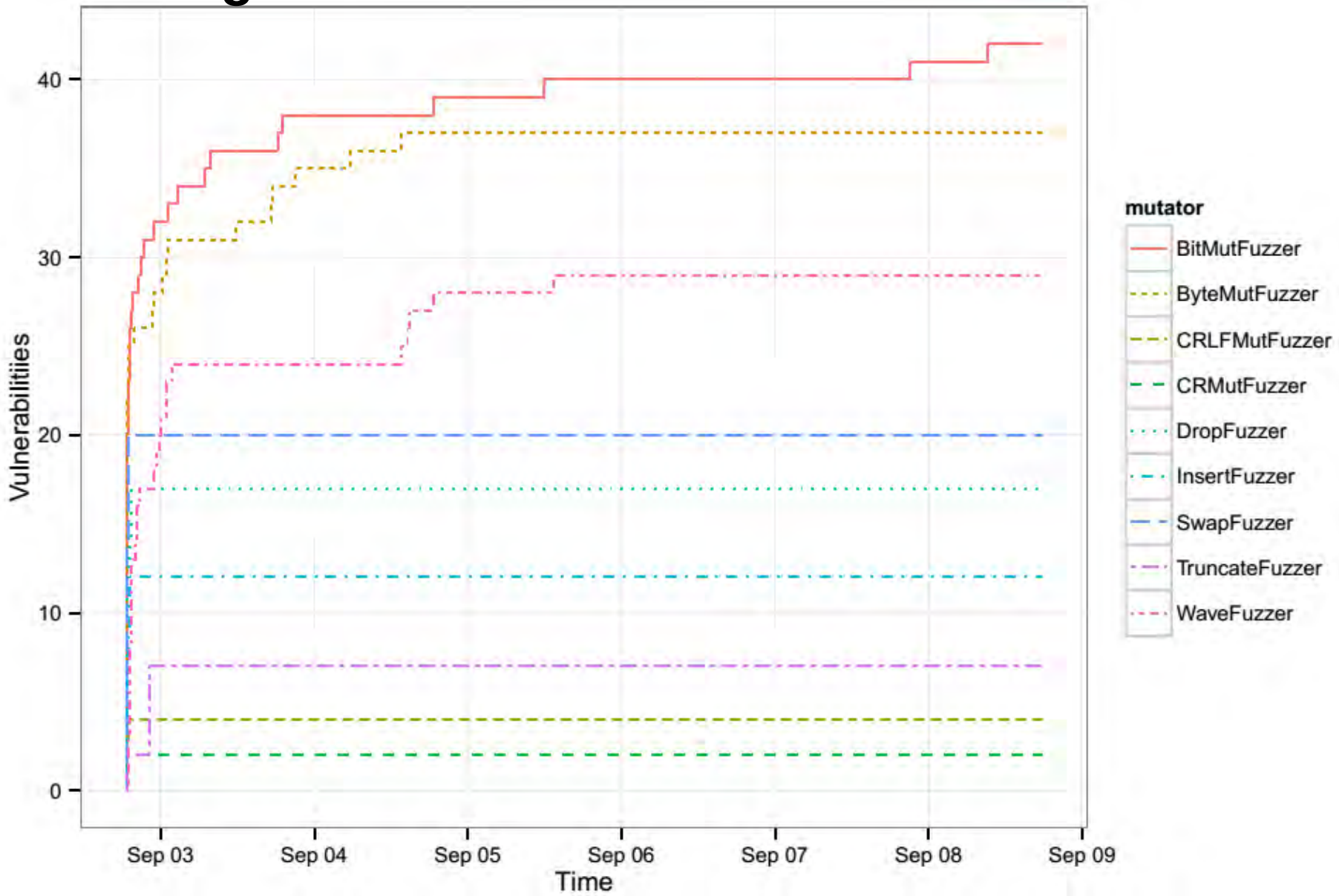
Fuzzing Mutators



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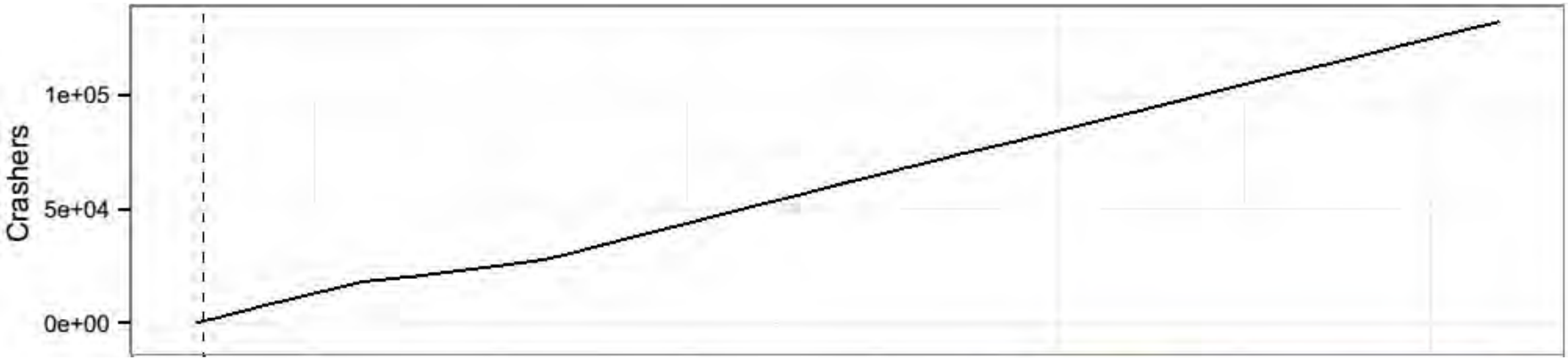
When to Stop Fuzzing?



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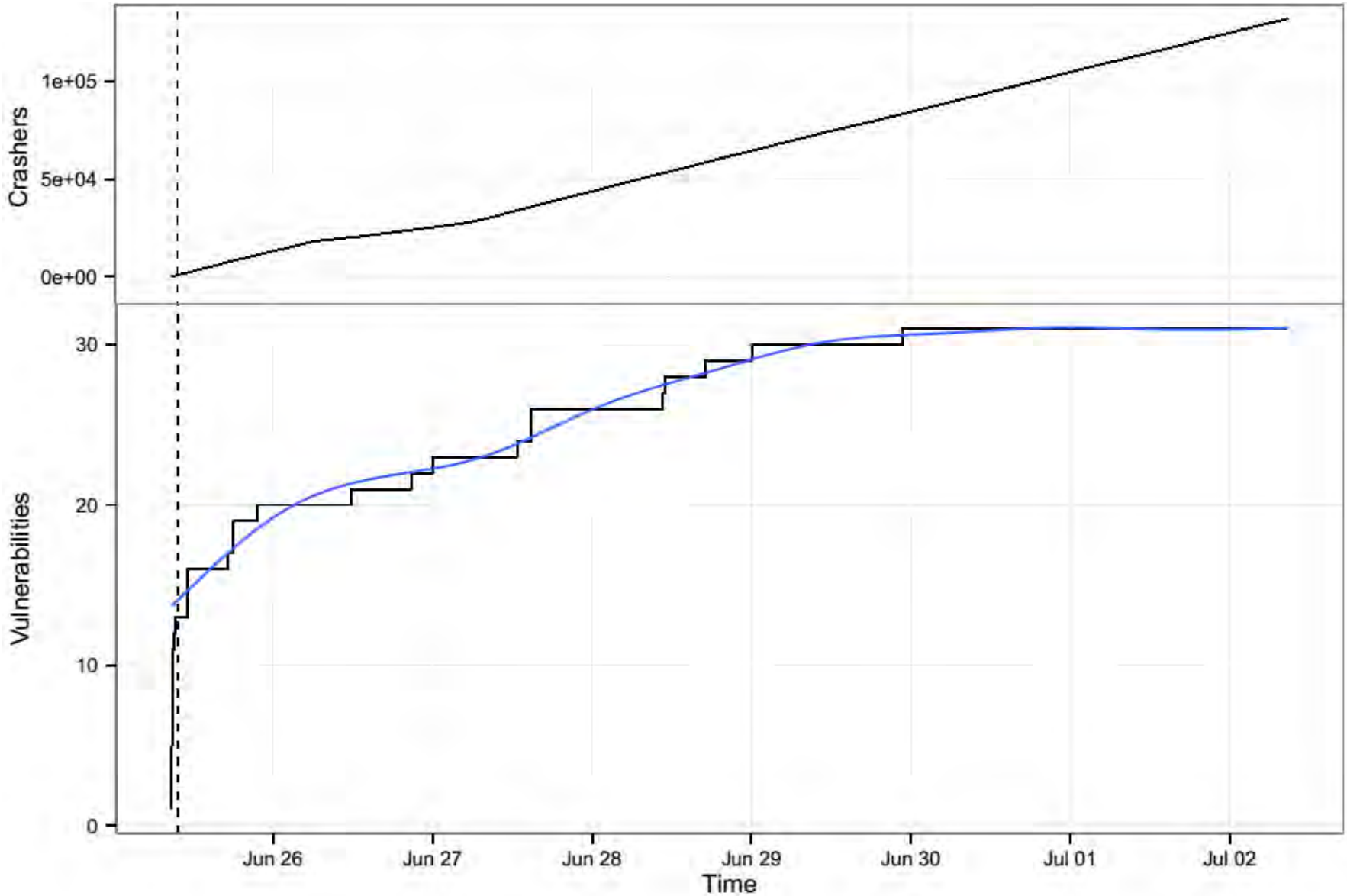
When to Stop Fuzzing?



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Collaboration with ForAllSecure

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CMU Spinoff of David Brumley's research group

Dr. David Brumley

Dr. Thanassis Avgerinos

Alex Rebert

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Expertise

- Concolic execution
- Automatic exploitation
- Binary analysis
- Complements SEI's expertise in fuzzing

Previous collaboration

- With same group at CMU

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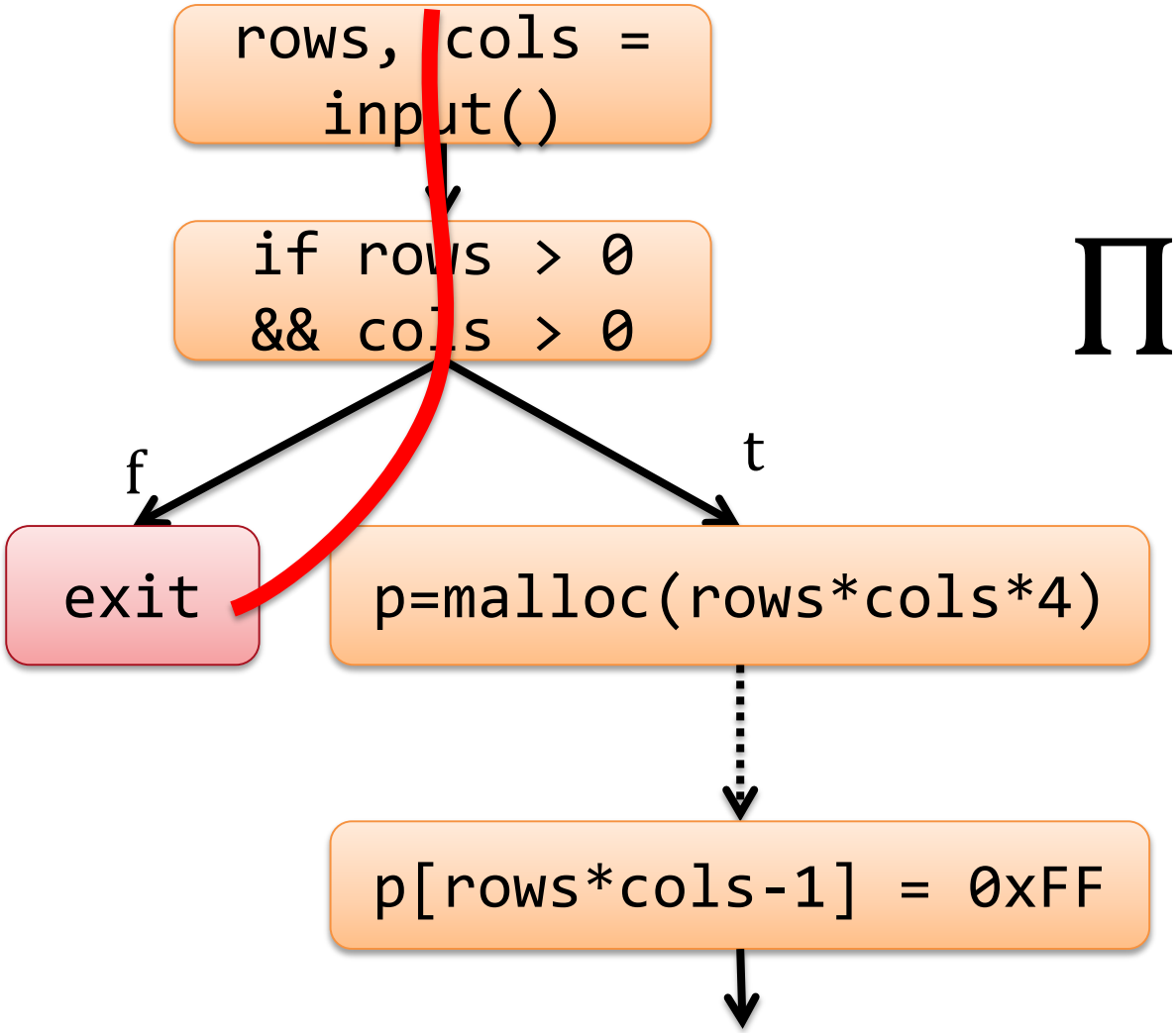
Background: Concolic Execution



Π

rows=0
cols=0

✖ (rows > 0 && cols > 0)

rows=5
cols=10

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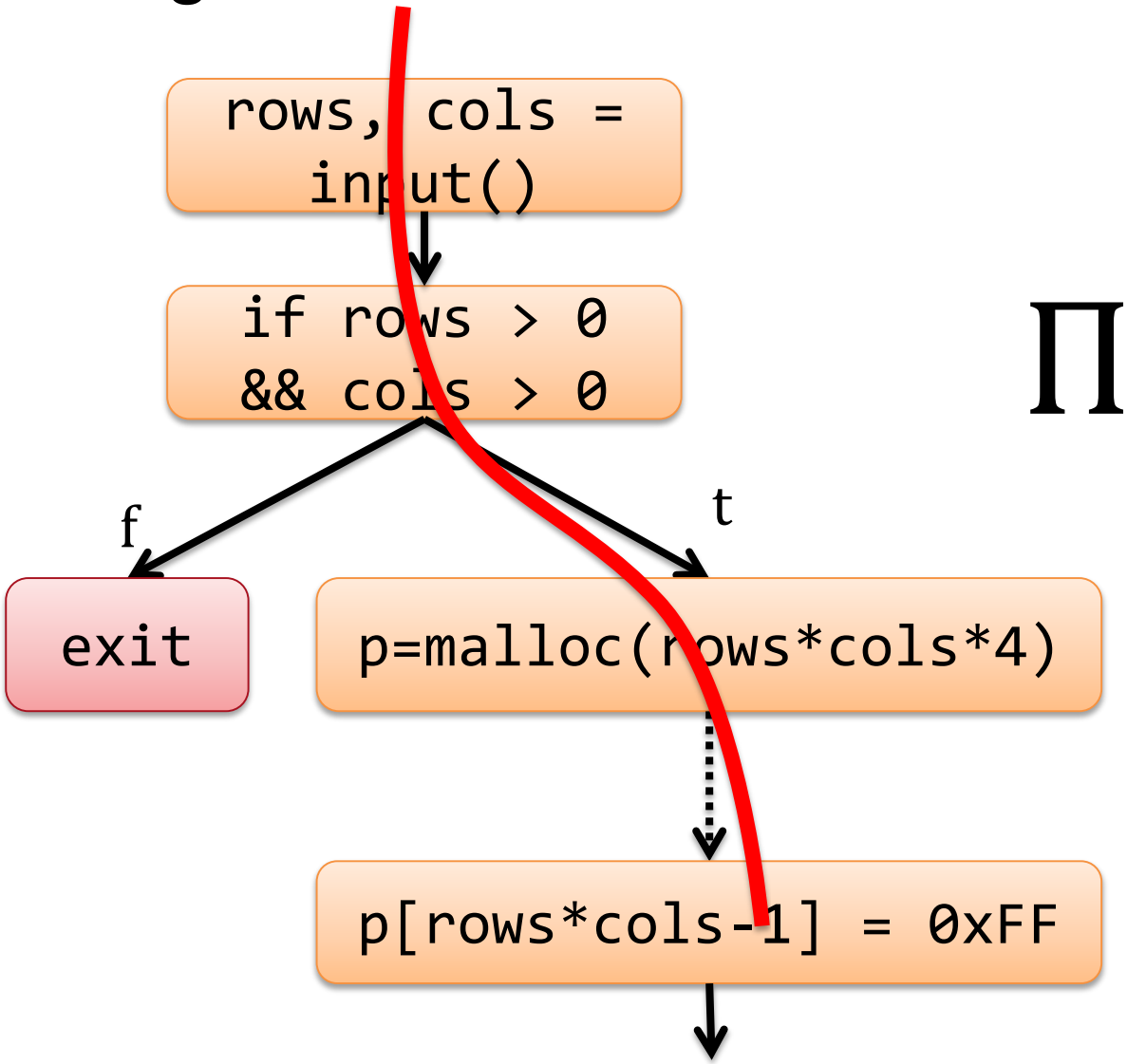
Background: Concolic Execution



Π

rows=0
cols=0

✖ (rows > 0 && cols > 0)

rows=5
cols=10

Overflow?

rows*cols-1 >= rows*cols*4

rows=0x11111112
cols=0x0000000f

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Background: Fuzzing

```
rows, cols =
input()
```

```
if rows > 0
&& cols > 0
```

f

t

```
exit
```

```
p=malloc(rows*cols*4)
```

```
p[rows*cols-1] = 0xff
```

Most mutations do not trigger the overflow vulnerability

```
rows=0x00000014
cols=0x00000014
```

Overflow?

```
0xd040f >=
0x341040
```

No

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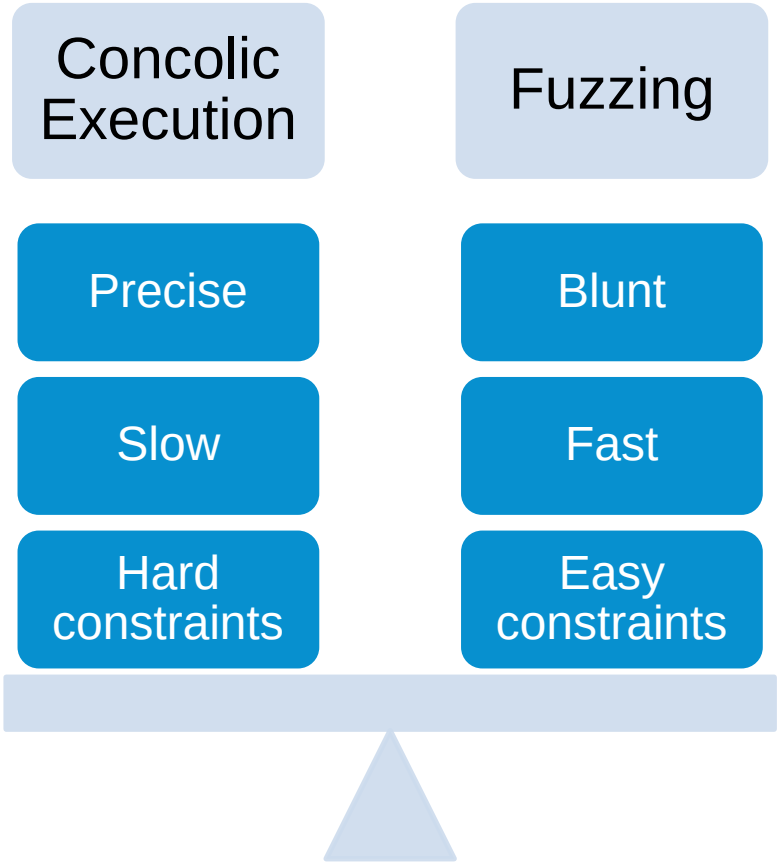
Concolic Execution vs. Fuzzing



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SMART

The Synergistic Mayhem AFL Research Tool

- Concolic execution: Mayhem (ForAllSecure+SEI)
- Fuzzing: AFL
- Periodically synchronize seed files between them

Challenges

1. Where to go?
   - We don’t know the location of vulnerabilities
2. How much should we use concolic execution?
   - ~10^4 times slower than fuzzing
   - Brute force vs. high cost

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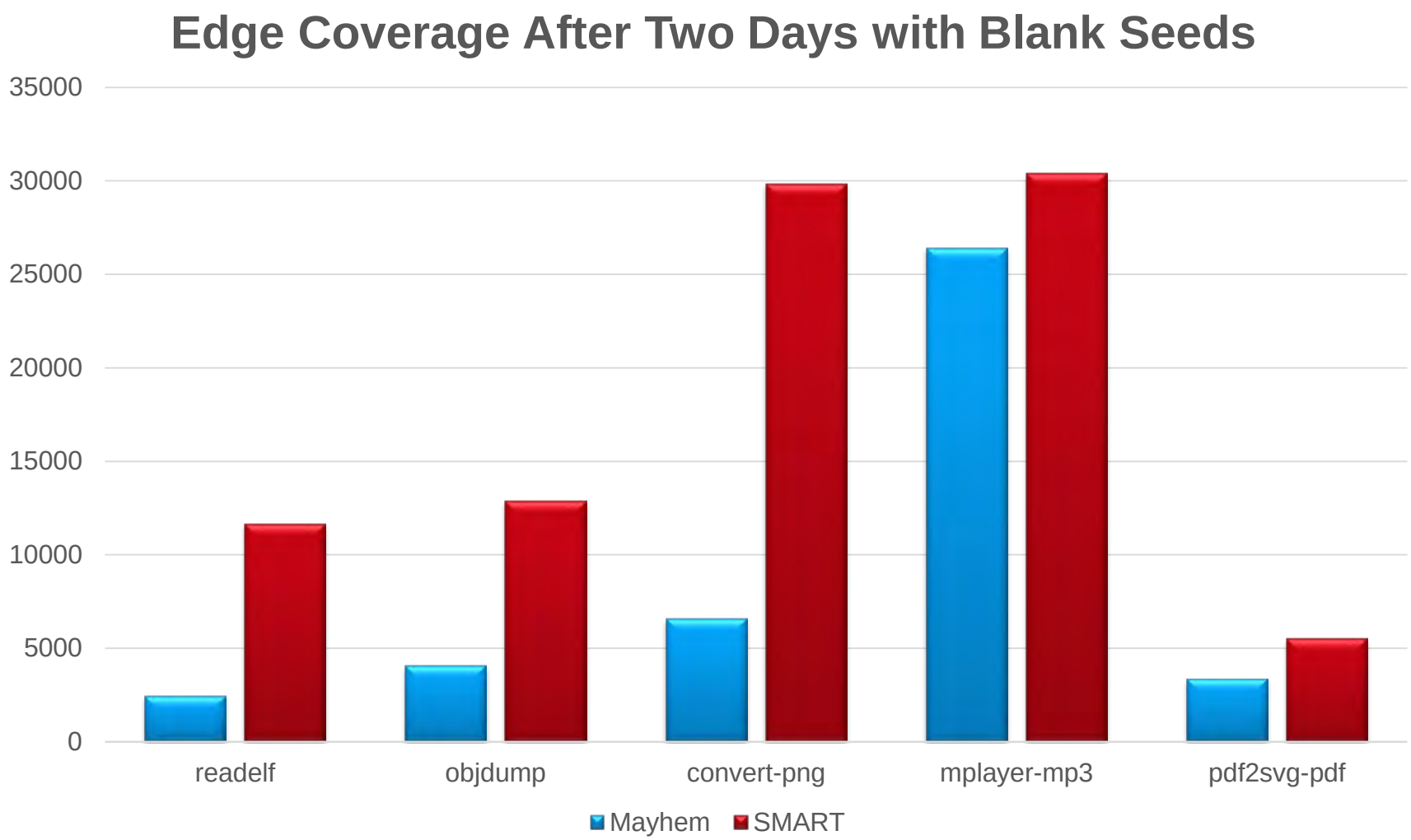
SMART Evaluation



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Summary

- Developing new techniques for discovering and mitigating vulnerabilities in the DoD
- Developed vulnerability uniqueness model and used ground truth to explore the effect of fuzzing parameters
- ForAllSecure: Hybrid fuzzing and concolic tester

Team Members

- Edward Schwartz, PhD, CERT
- David Warren, CERT
- Allen Householder, CERT

ForAllSecure, Inc.:

- David Brumley, PhD
- Thanassis Avgerinos, PhD
- Tyler Nighswander

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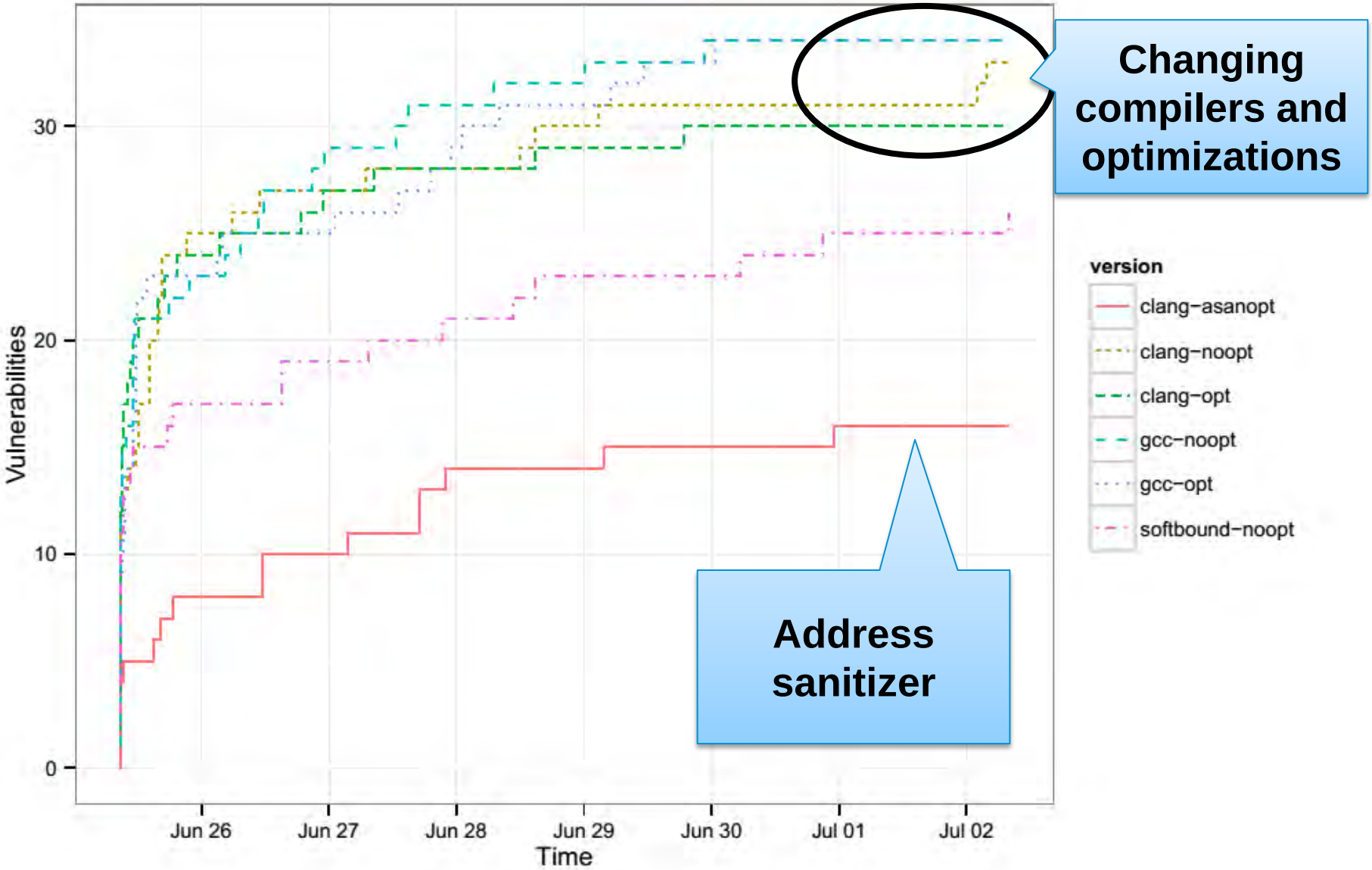
Compiler Flags and Settings



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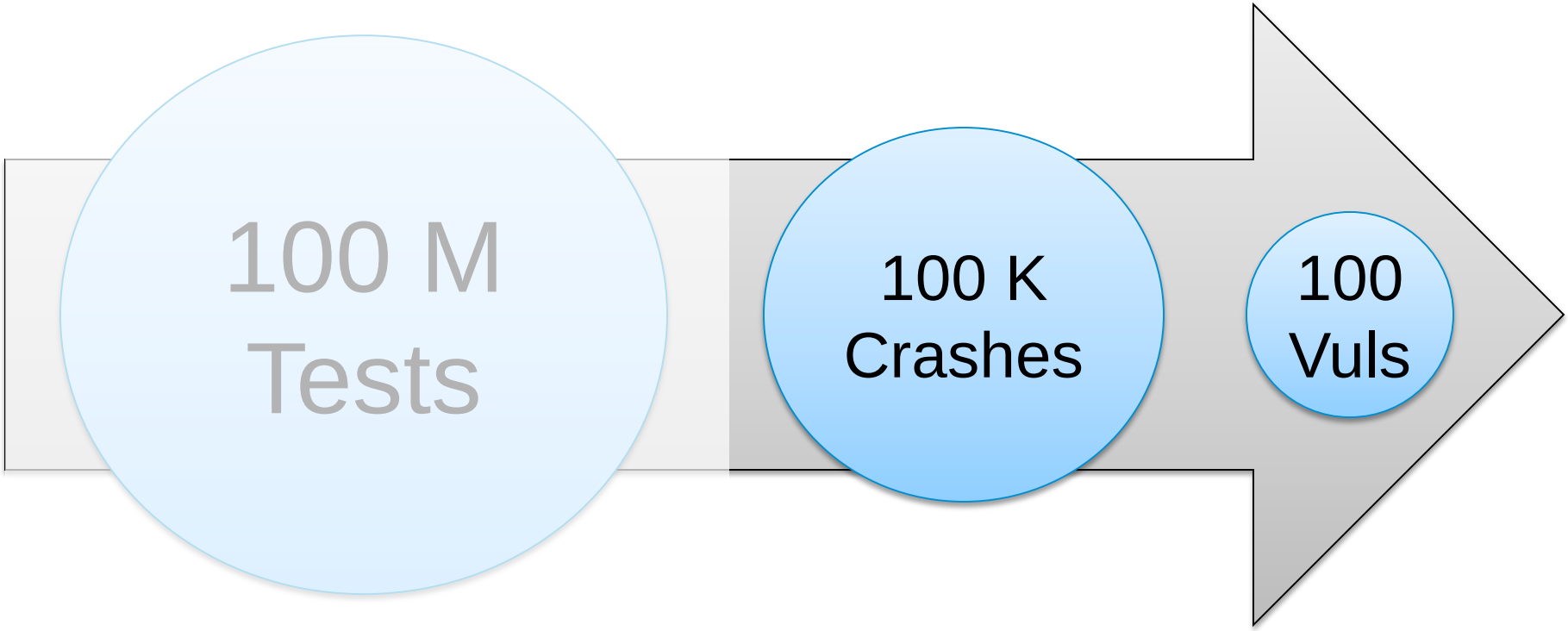
The Crash Uniqueness Problem



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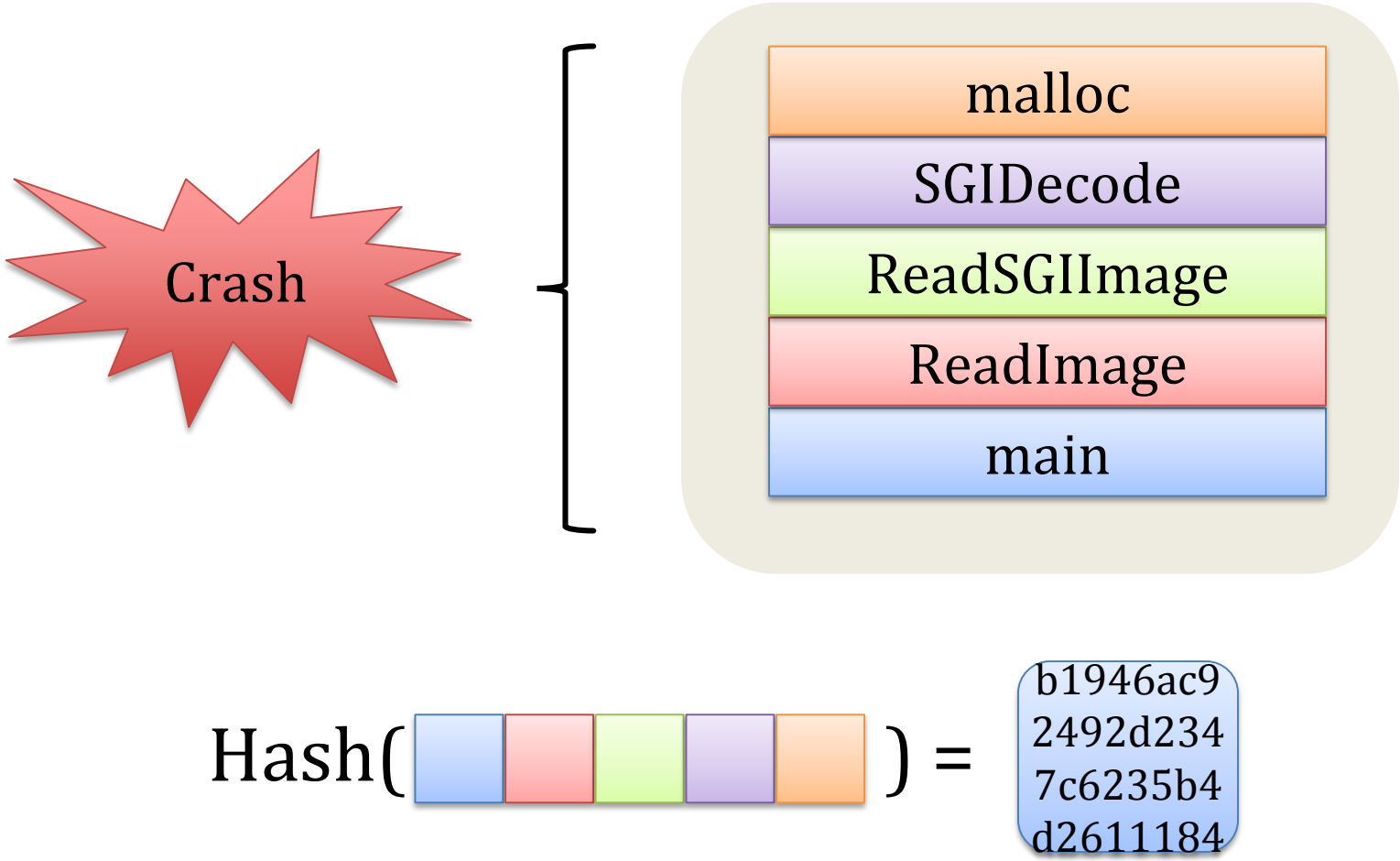
The State of the Art: Stack Hashing



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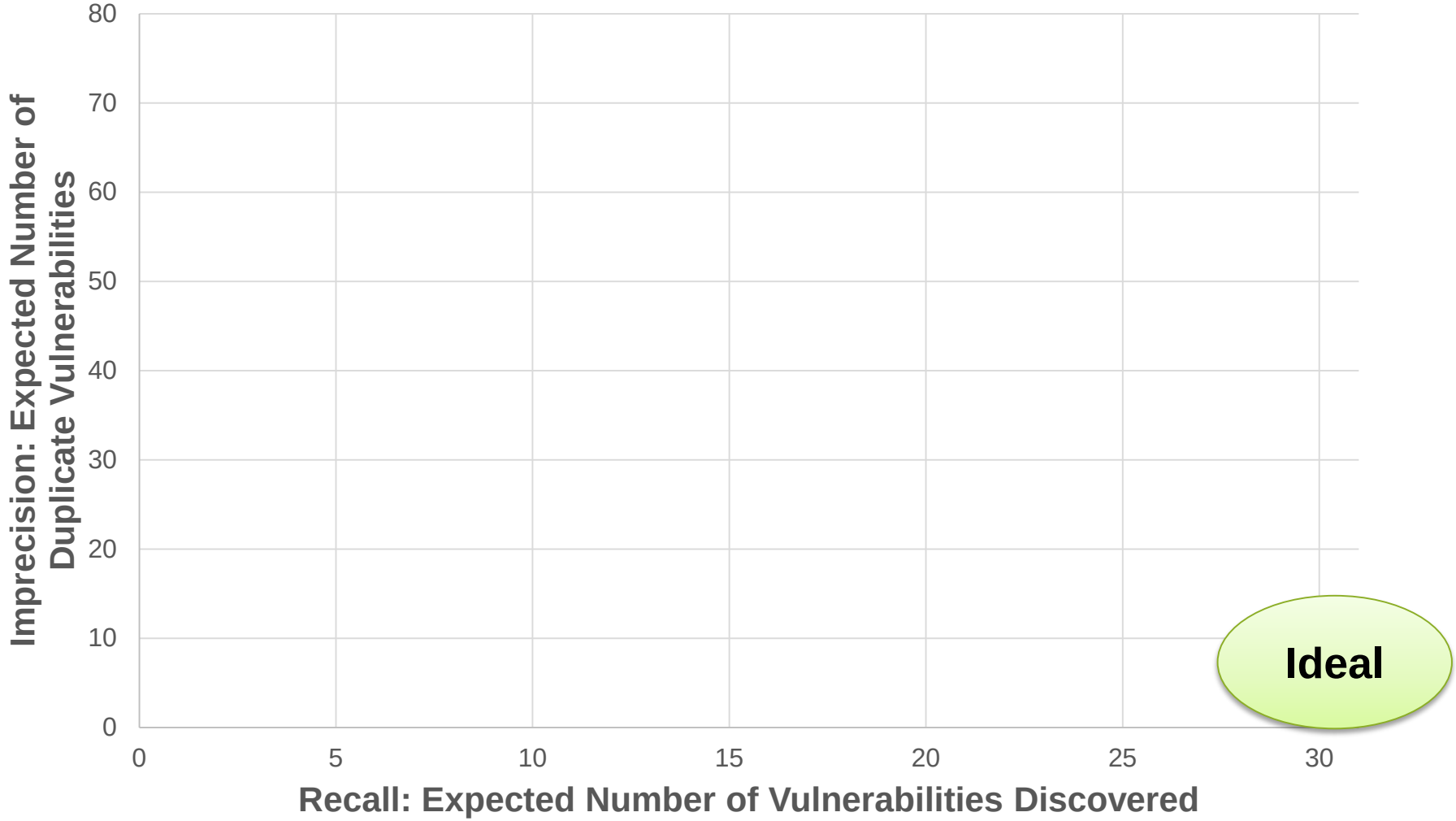
Does Stack Hashing Work?



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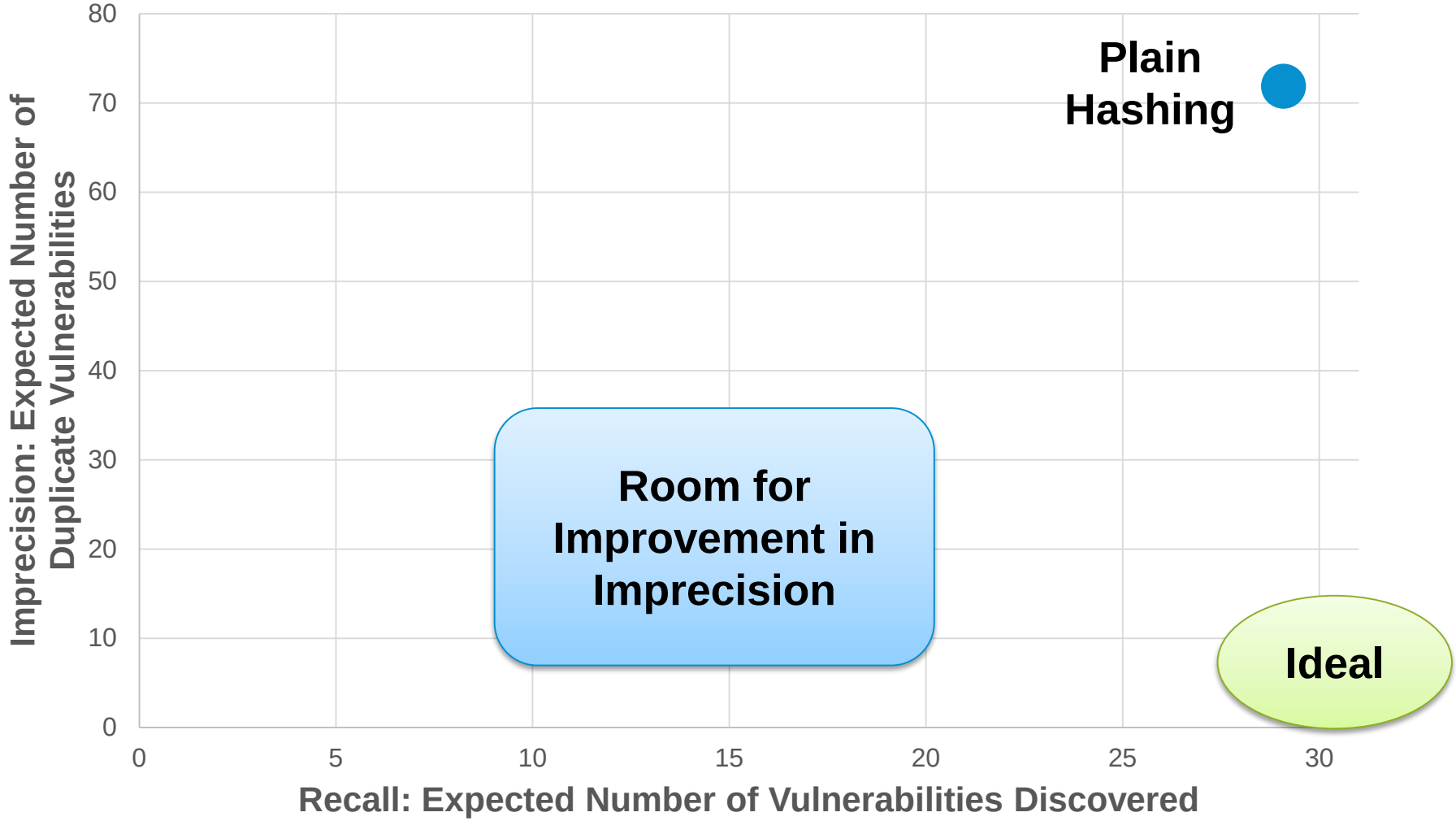

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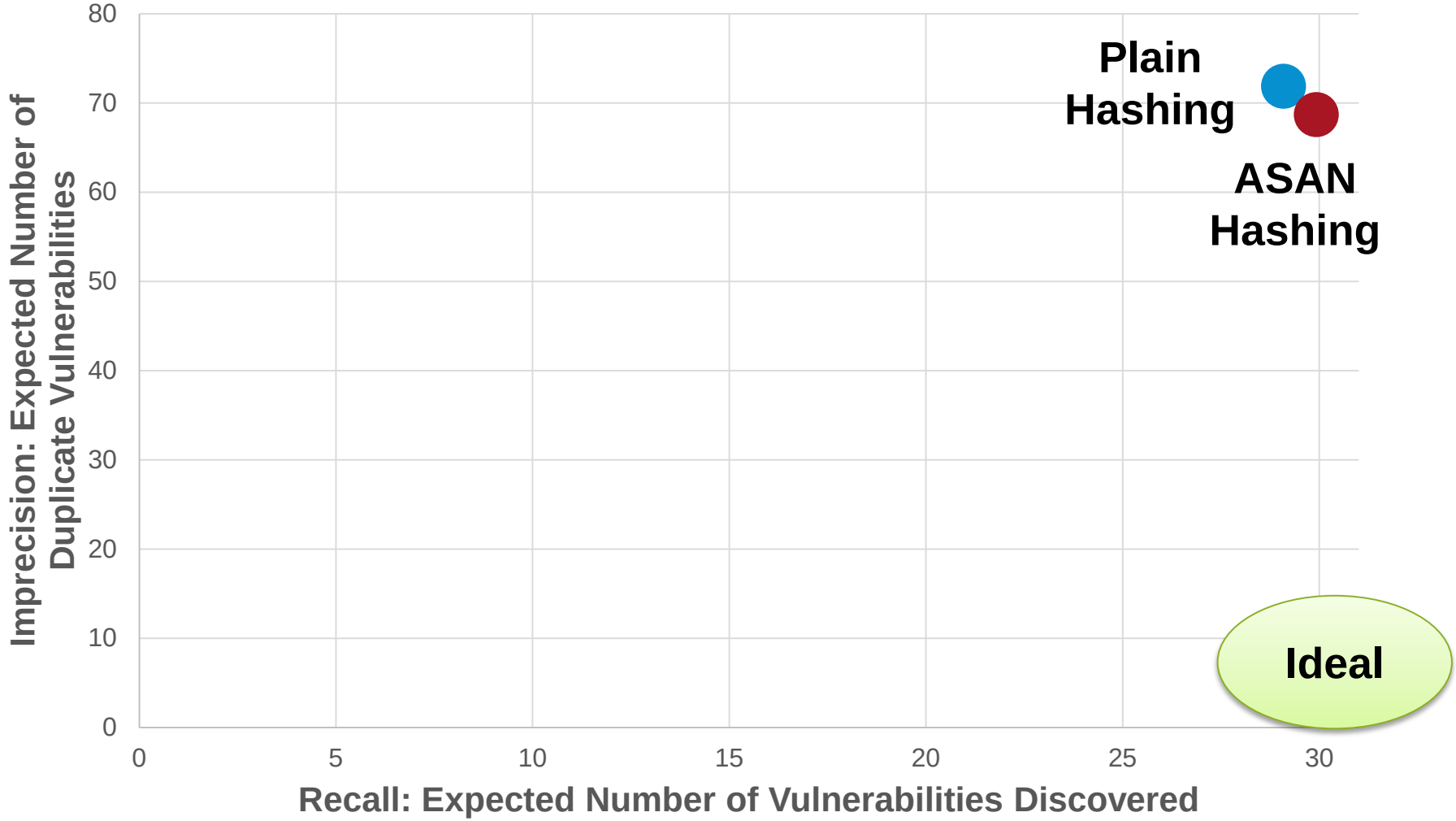

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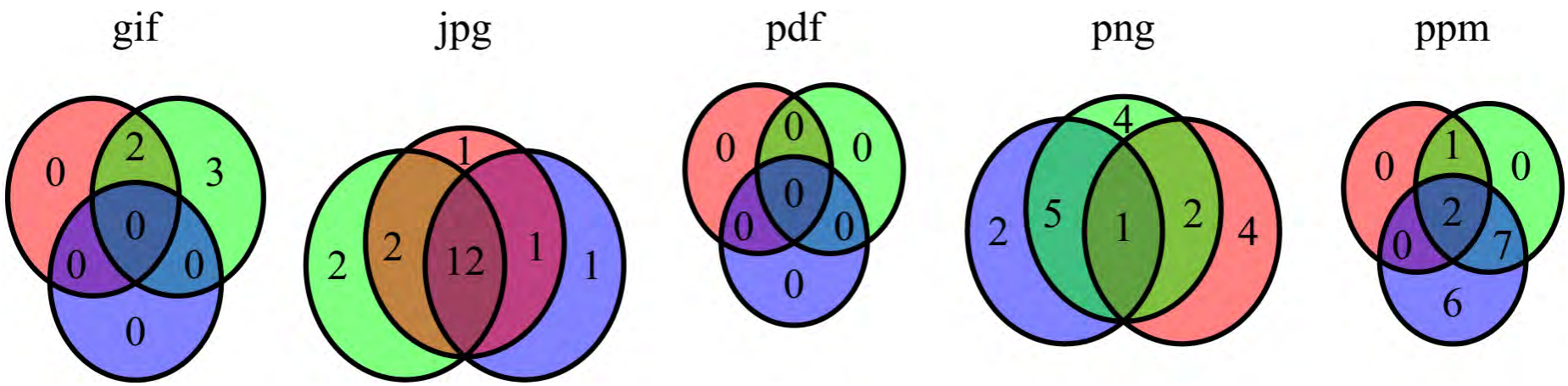
Importance of Seed Selection



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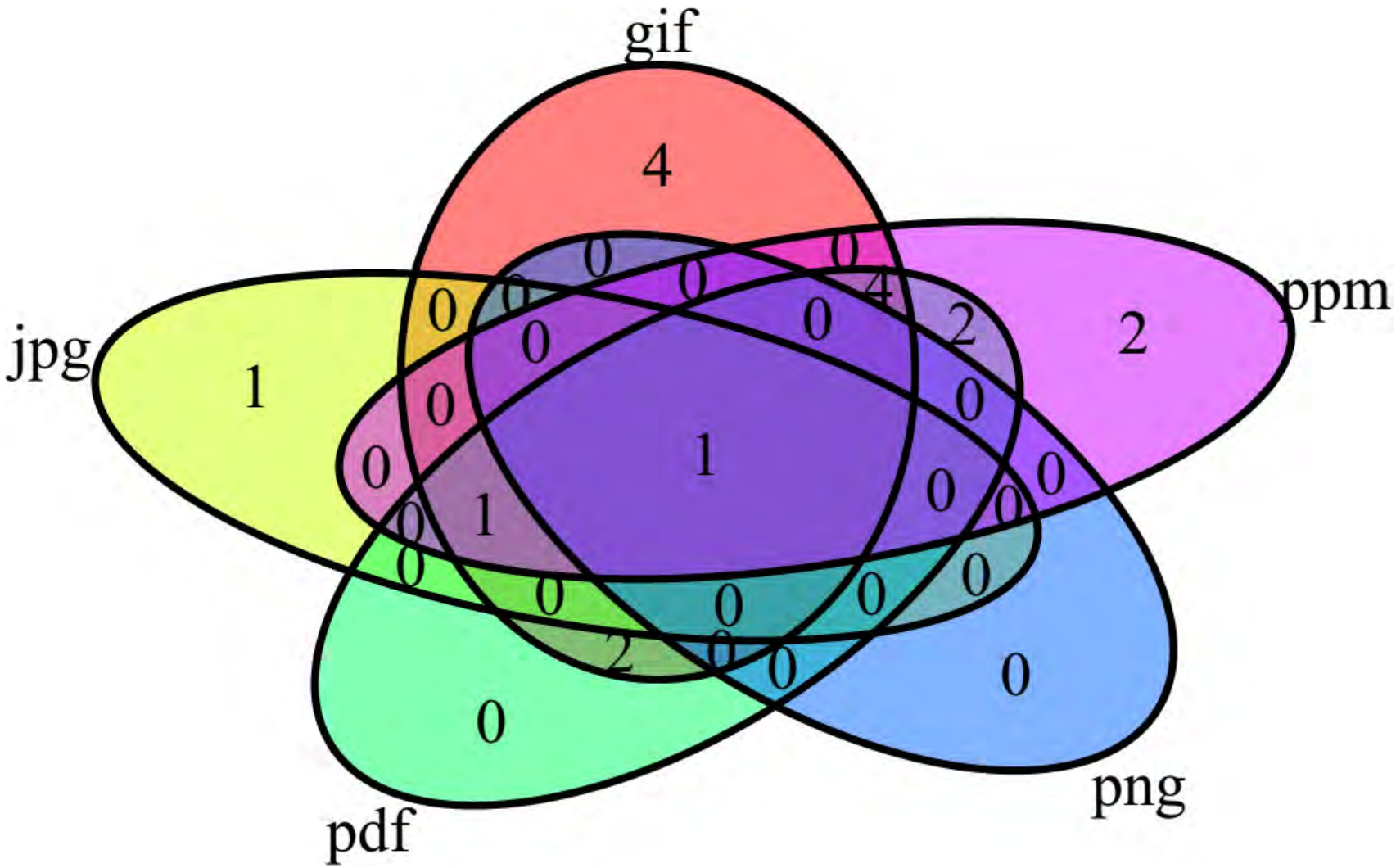
Importance of Seed Selection



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Challenge: Multiple Vulnerabilities

```
int main(int argc, char* argv[]) {
  int x = atoi(argv[1]);
  if (x&1) vulA(1);
  if (x&2) vulB(1);
}
```

Which vulnerability causes `main(3)`?

Vuls	1	2	3	4	5
Crashes	45859	**79626**	6860	21	1

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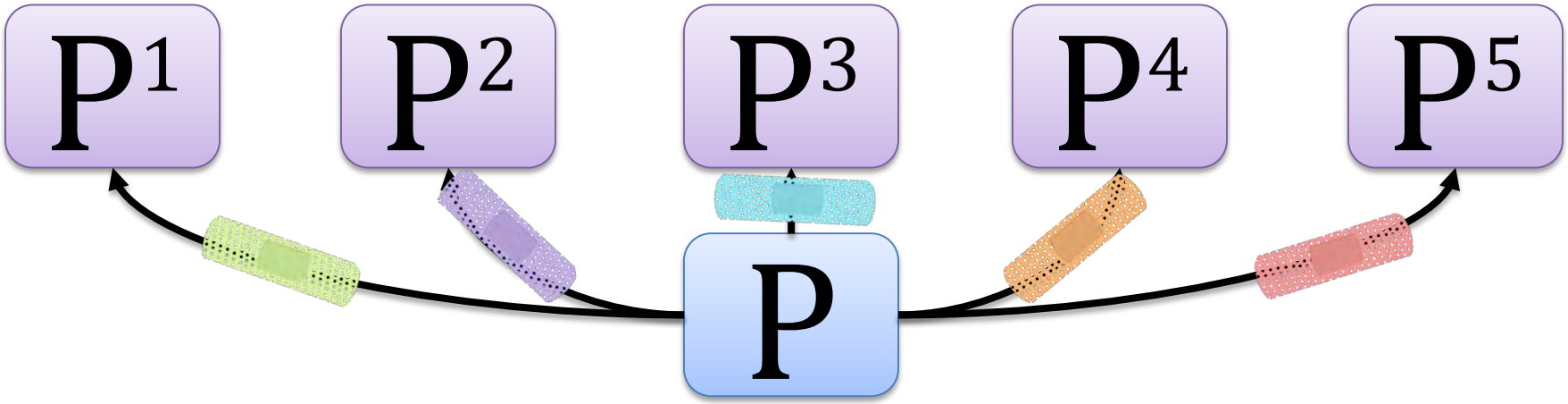
The Patch Tree:
Ability to Test Patches Independently



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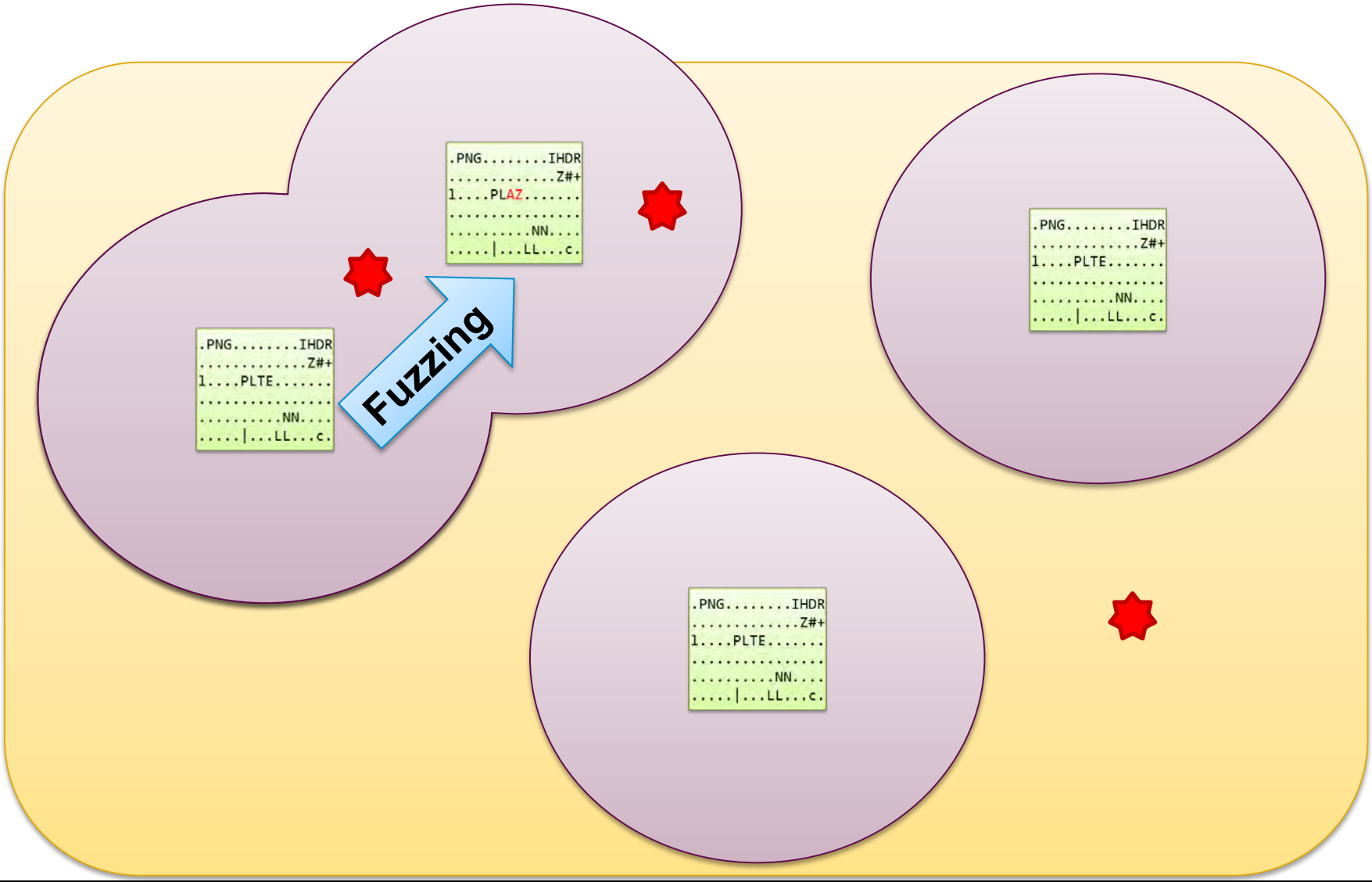
Guided Fuzzing



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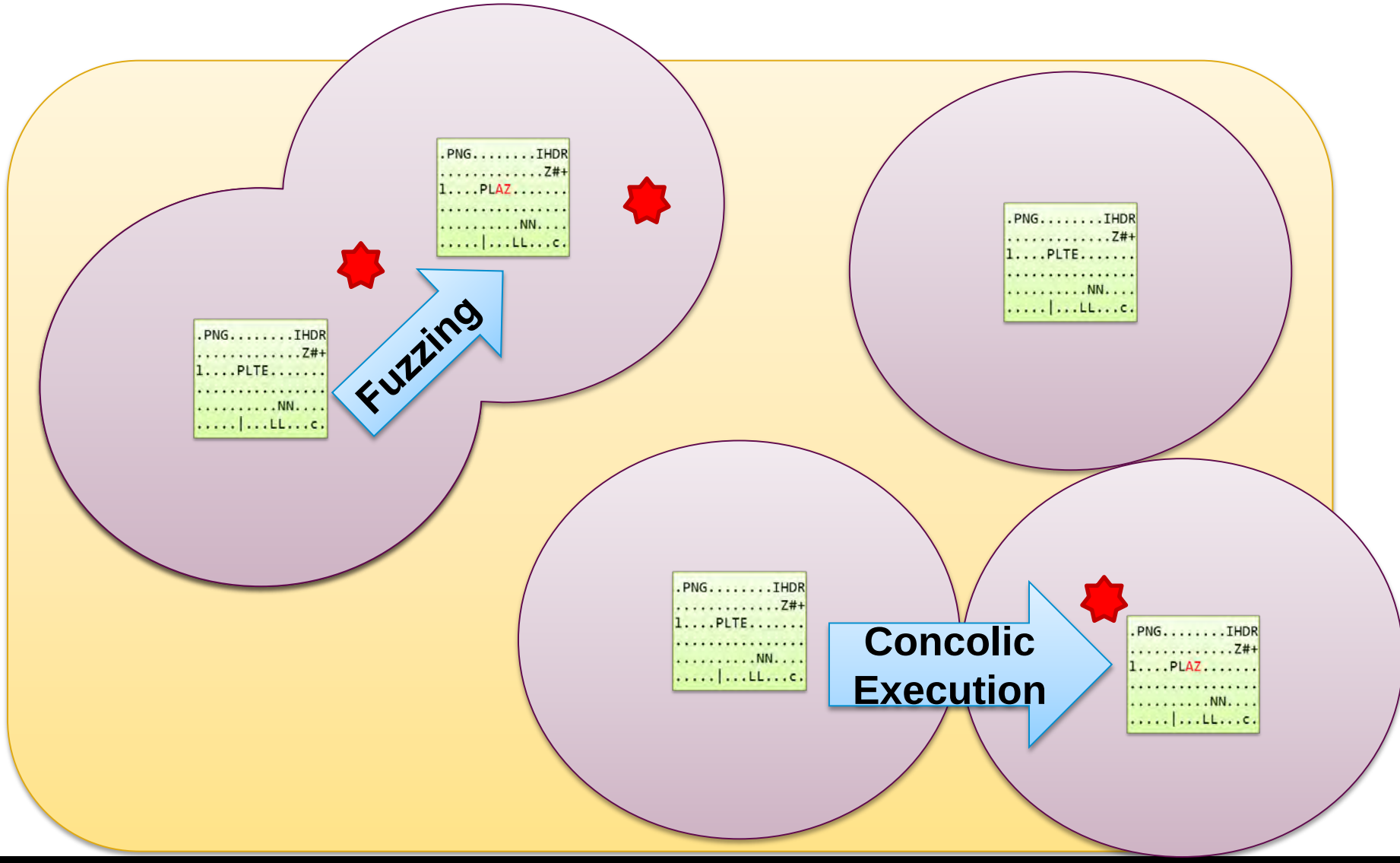
Fuzzing vs. Concolic Execution



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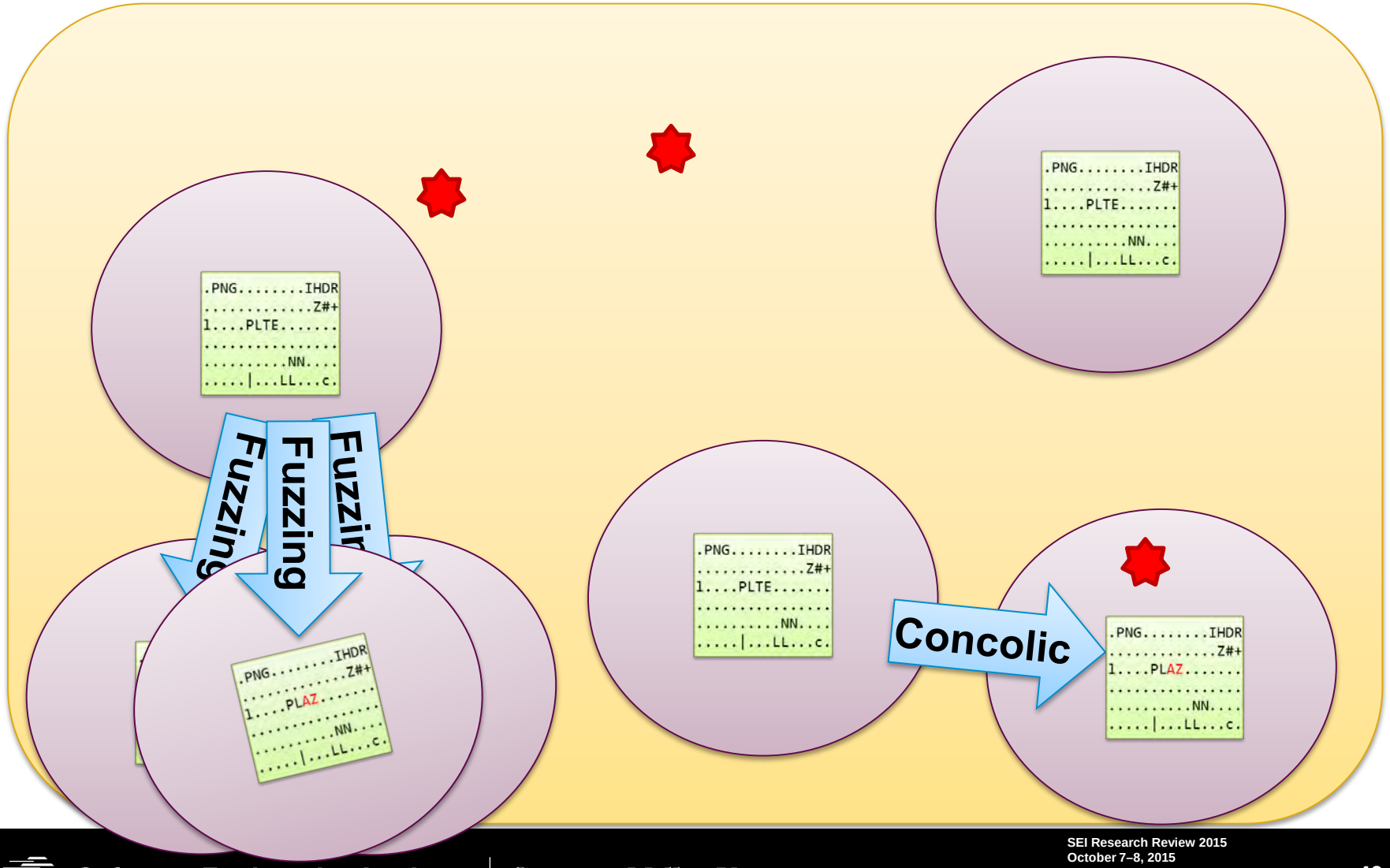
Combining Fuzzing and Concolic Execution



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