Foundations of Software Assurance

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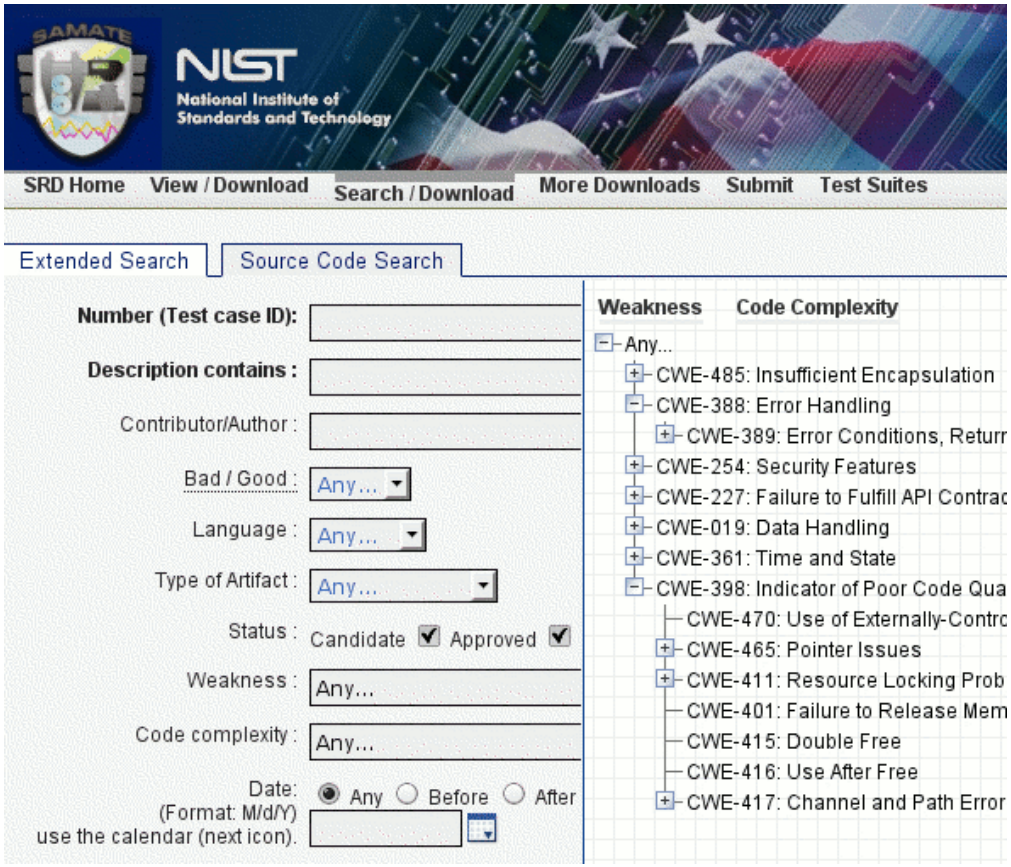
Outline

- **Software Assurance Reference Dataset (SARD)**
- **Bugs Framework (BF)**

Software Assurance Reference Dataset (SARD)

http://samate.nist.gov/SARD/

Software Assurance Reference Dataset (SARD)



- **Public repository for software assurance test cases with known vulnerabilities**
- **Over 140 000 cases in C, C++, Java, PHP, C#, and Python**
- **Contributions from NSA/CAS, IARPA, Fortify, TELECOM Nancy, Defence R&D Canada, Klocwork, MIT Lincoln Laboratory, Praxis, Toyota, Secure Software, etc.**

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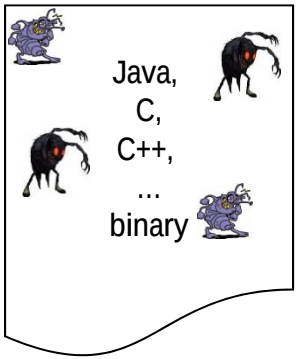
What is Static Analysis?



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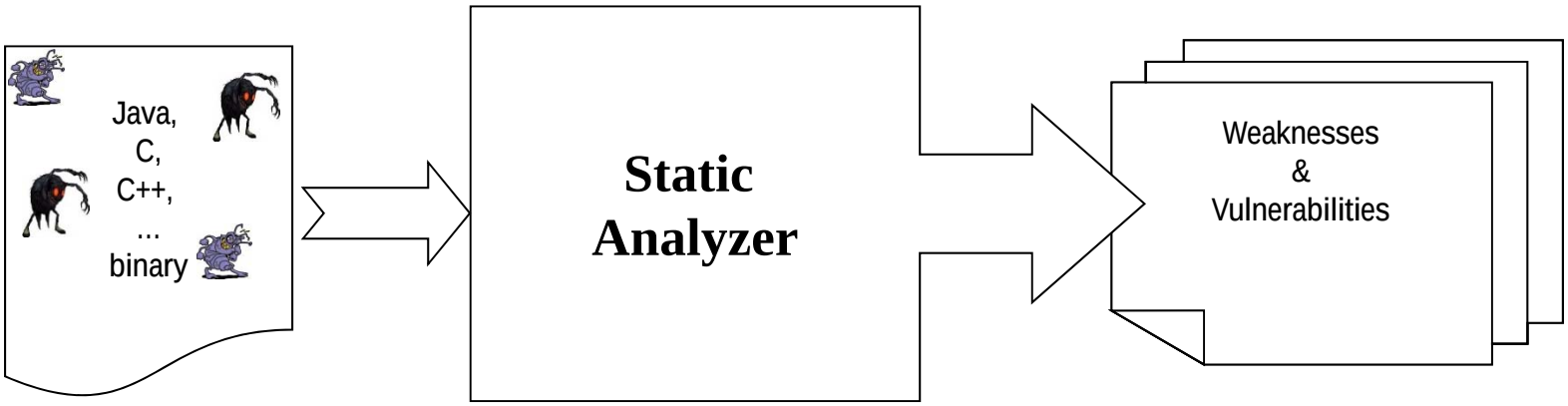
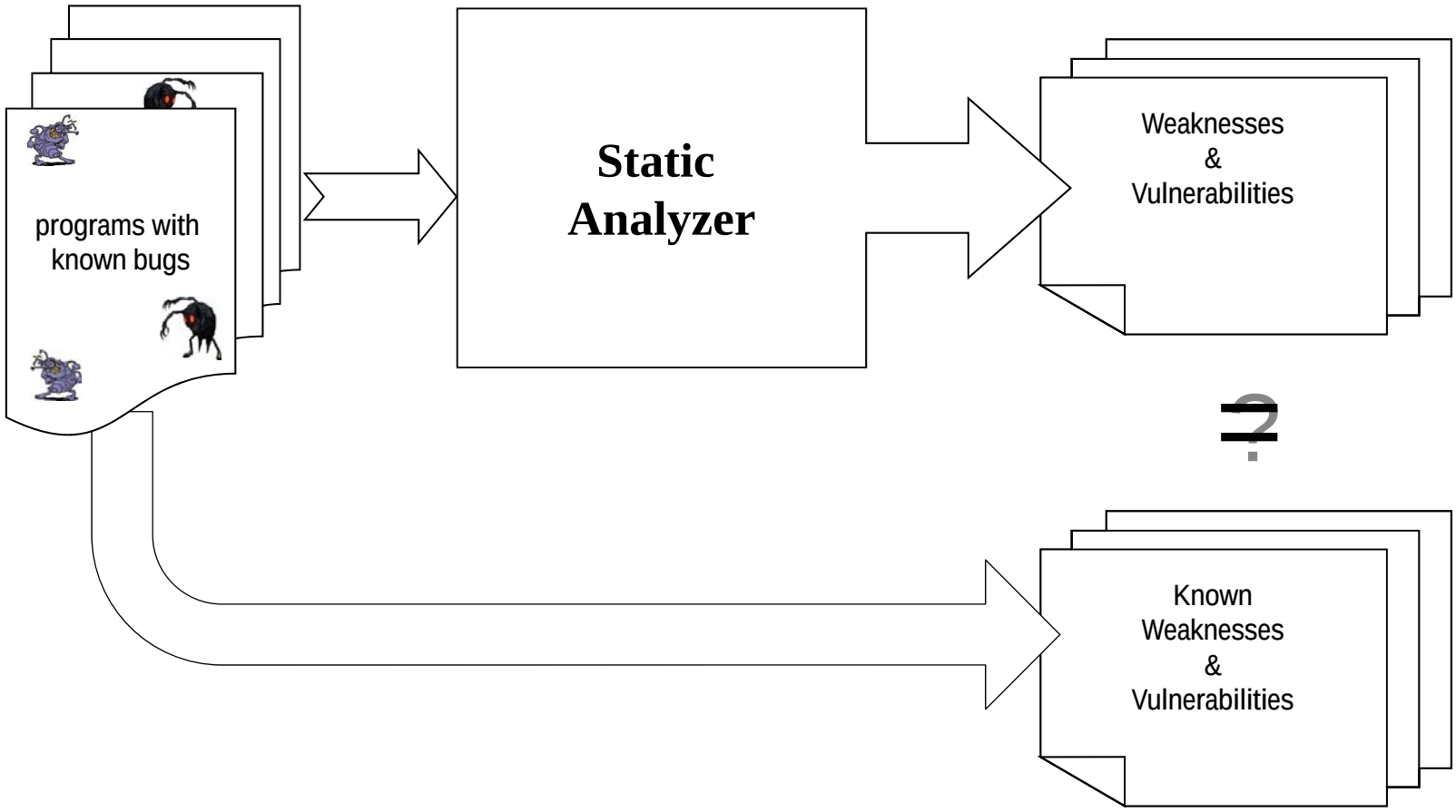
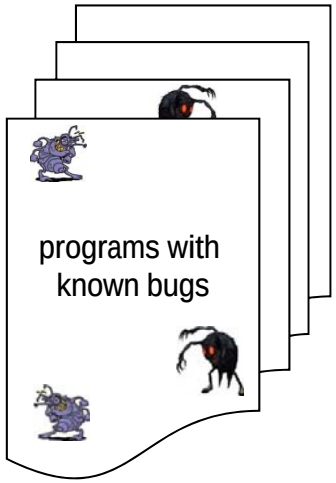


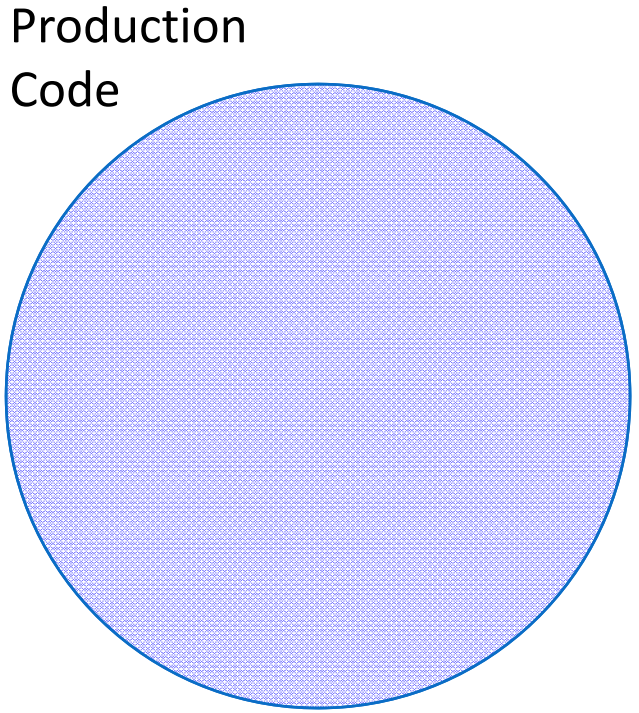
- **Examine source code or binary for weaknesses, adherence to guidelines, etc.**

How to Test Static Analyzers?



Characteristics of Test Cases





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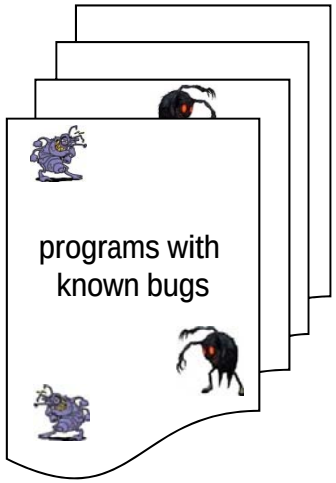

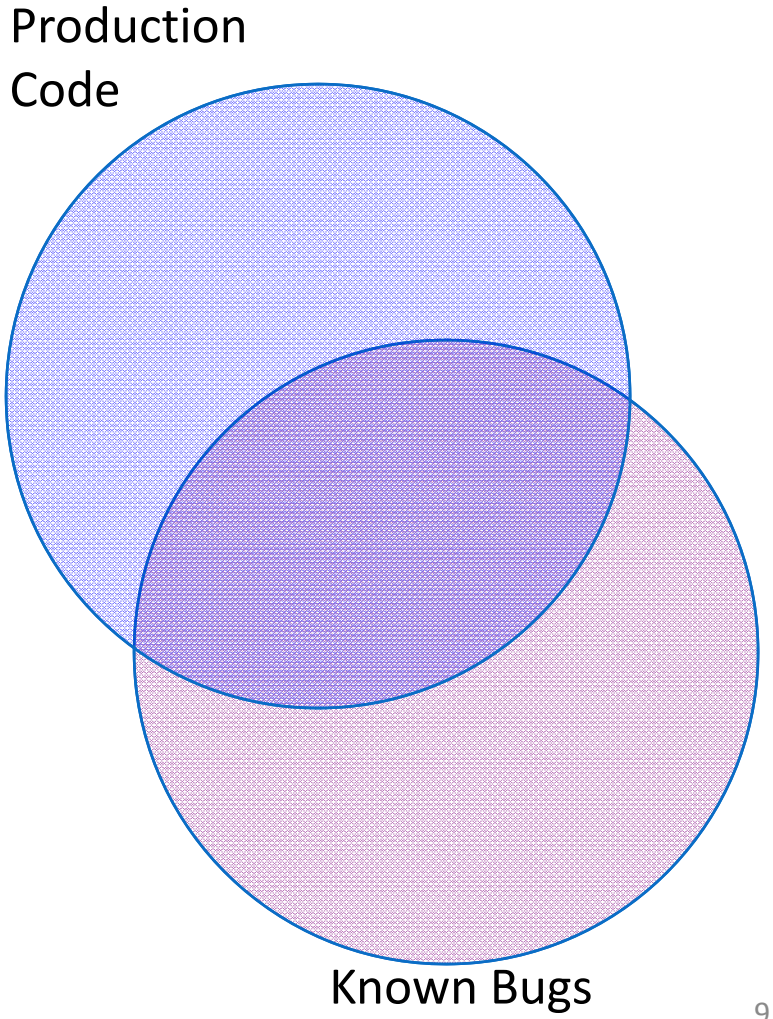

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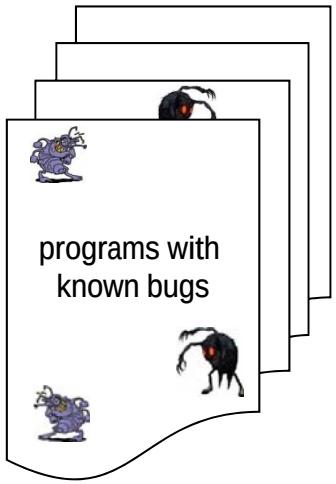
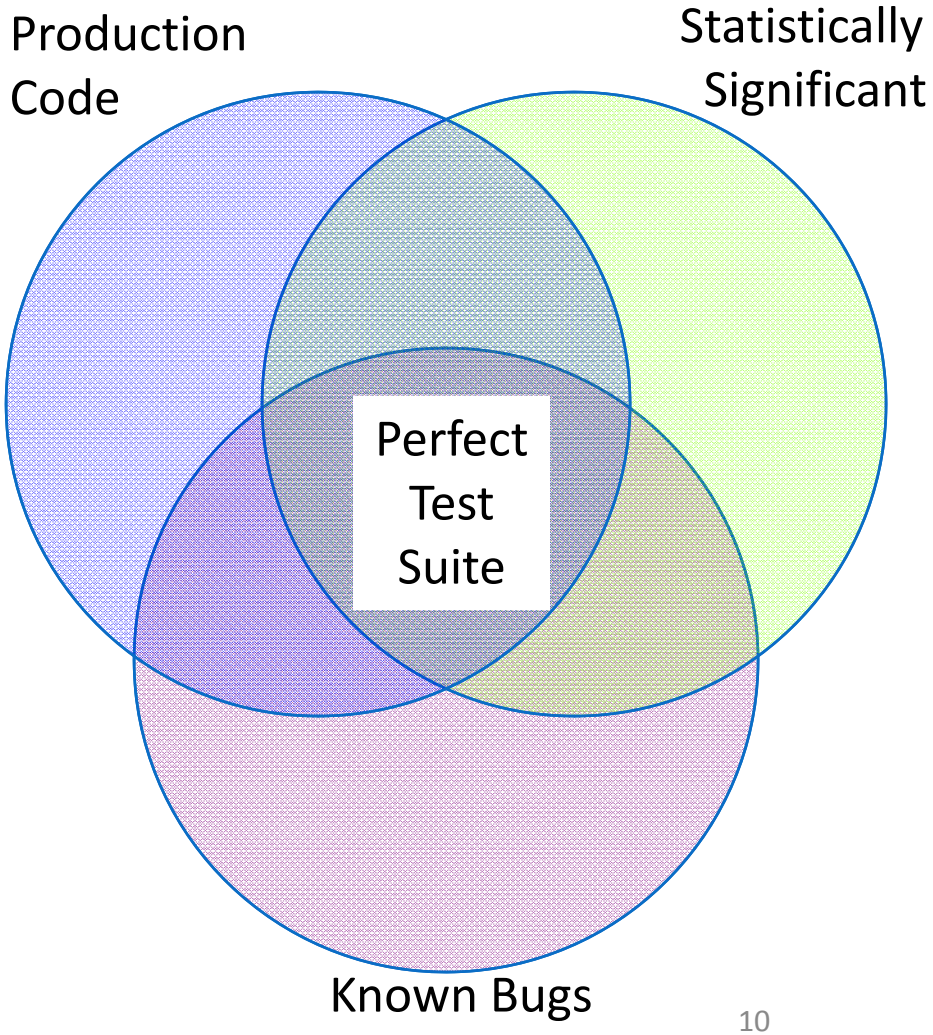
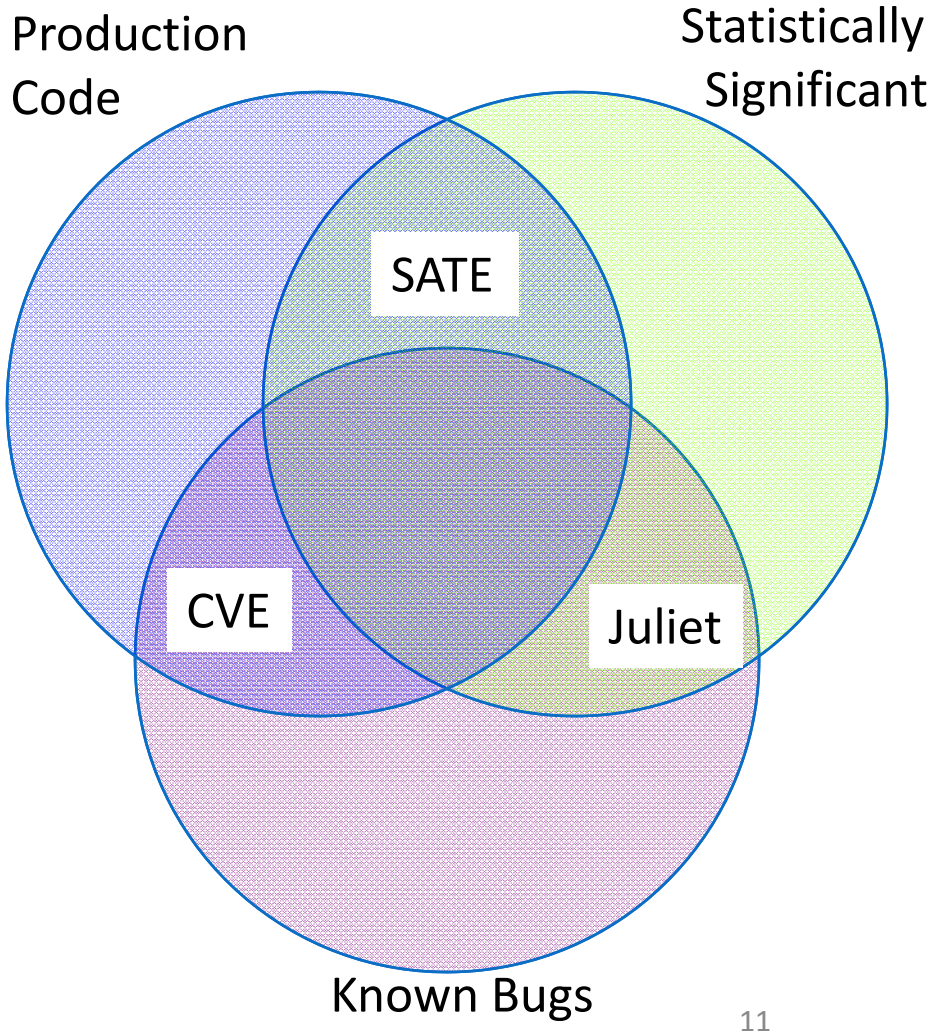




Characteristics of Test Cases

- **Approximations**
  - **Collect millions of tool warnings for open source software from SATE.**
  - **Manually analyze hundreds of reported bugs (CVEs) to establish ground truth.**
  - **Publish Juliet test suite: hundreds of thousands of synthetic test cases with known bugs.**



SARD Content

- **Contributions also from Kratkiewicz, MIT Lincoln Laboratory, Praxis, etc.**
- **NSA Juliet 1.2 - over 86 000 small, synthetic test cases in C, C++, and Java, covering 150 bug classes**
- **IARPA STONESOUP Phase 3 - 15 000 cases based on 12 web apps with injected bugs from 25 classes**
- **1276 test cases from Toyota**
- **Test cases from Static Analysis Tool Exposition (SATE)**
- **2000 PHP cases developed at TELECOM Nancy**

Other SARD Content

- **Zitser, Lippmann, & Leek MIT cases**
  - **28 slices from BIND, Sendmail, WU-FTP, etc.**
- **Fortify benchmark 112 C and Java cases**
- **Klocwork benchmark 40 C cases**
- **25 cases from Defence R&D Canada**
- **Robert Seacord, “Secure Coding in C and C++” - 69 cases**
- **Comprehensive, Lightweight Application Security Process (CLASP) - 25 cases**
- **329 cases from our static analyzer suite**

Outline

- Software Assurance Reference Dataset (SARD)
- **Bugs Framework (BF)**

http://samate.nist.gov/BF/

The Bugs Framework (BF) is
a precise descriptive language for bugs.

Precise Medical Language

- **Medical professionals have terms to precisely name muscles, bones, organs, conditions, diseases, etc.**

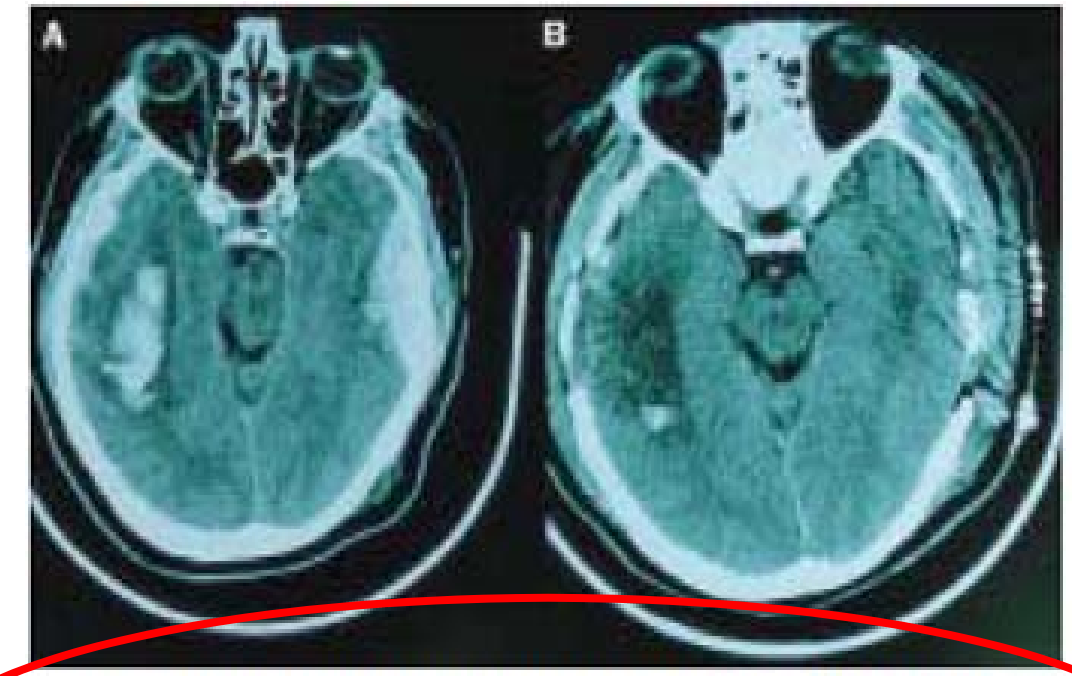


Figure 2: **Computed tomography of a comatose patient with a left temporal epidural haematoma, right parenchymal temporal lobe haematoma, and a right convexity subdural haematoma before and after craniotomy and evacuation of haematomas**

Current Bug Descriptions Have Problems

- **Common Weakness Enumeration (CWE)**
  - **Definitions are imprecise and inconsistent.**
  - **Coarse grained: bundling attributes, attacks, etc.**
  - **Uneven coverage: some combinations not given all.**
- **Software Fault Patterns (SFP)**
  - **Does not include upstream causes or consequences.**
  - **Based solely on CWEs.**
- **Semantic Templates**
  - **Does not distinguish many types of fault, weakness, location, or consequence.**
  - **Only cover two classes.**

What is the Bugs Framework?

- **It is a set of classes of bugs.**
- **Each bug class has**
  - **Causes**
  - **Attributes of a fault**
  - **Consequences**
- **Causes and consequences are directed graphs.**
- **BF uses precise terminology.**

Bugs Framework Classes

- **Injection (INJ), e.g.**
  - **SQL injection**
  - **OS injection**
- **Control of Interaction Frequency (CIF), e.g.**
  - **Limit number of login attempts**
  - **Only one vote per voter**
- **Information Exposure (IEX), e.g.**
  - **Password leak**
- **Buffer Overflow (BOF)**

Buffer Overflow: Attributes

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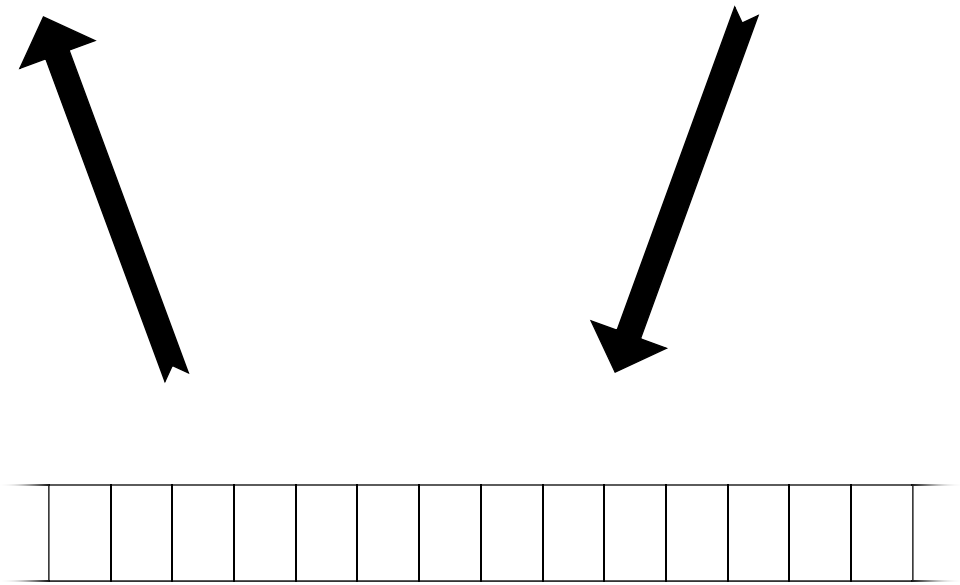
- **Access:**
  - **Read, Write.**



Buffer Overflow: Attributes

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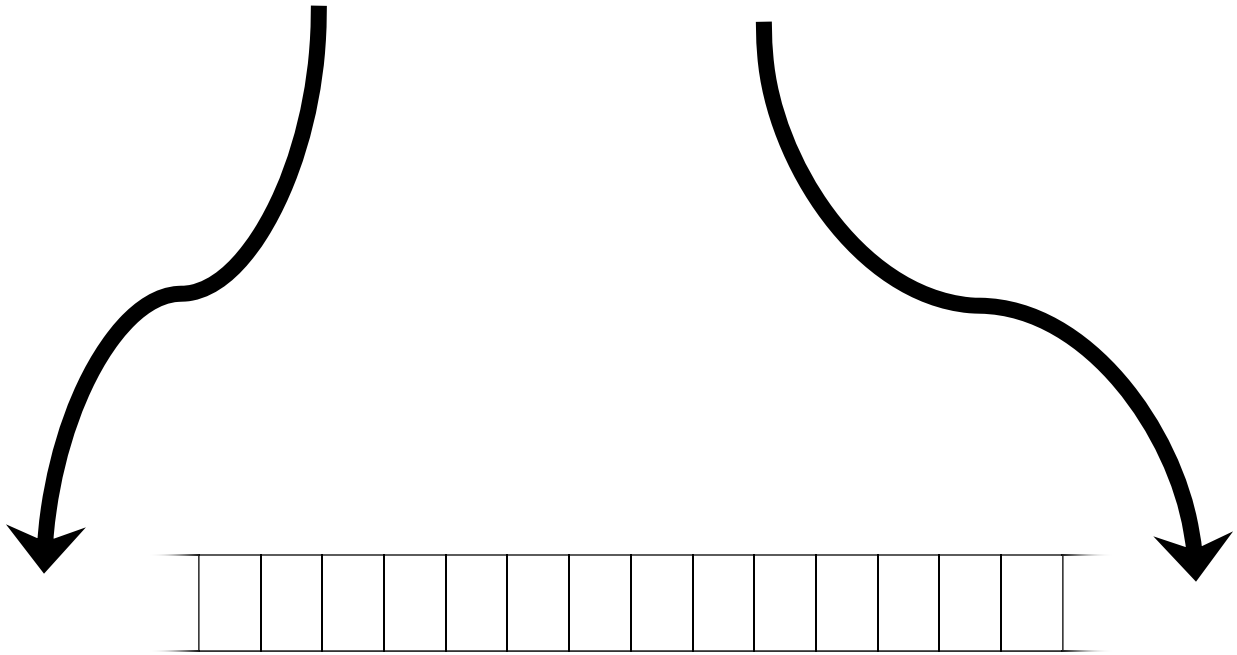

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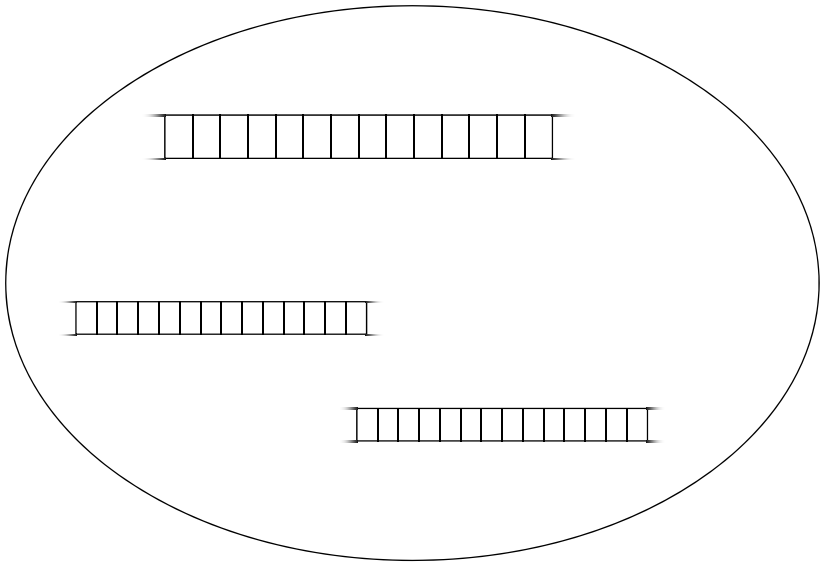

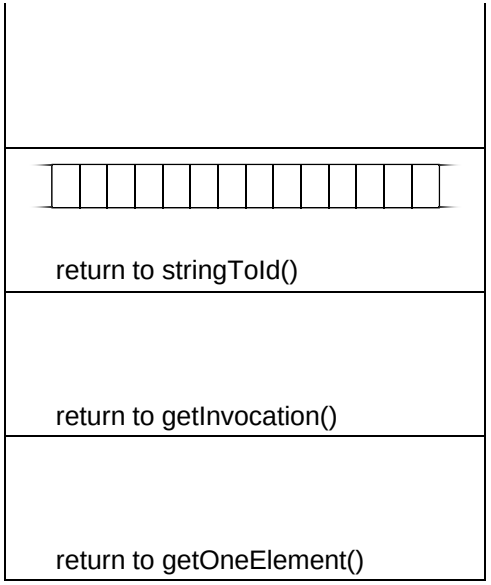

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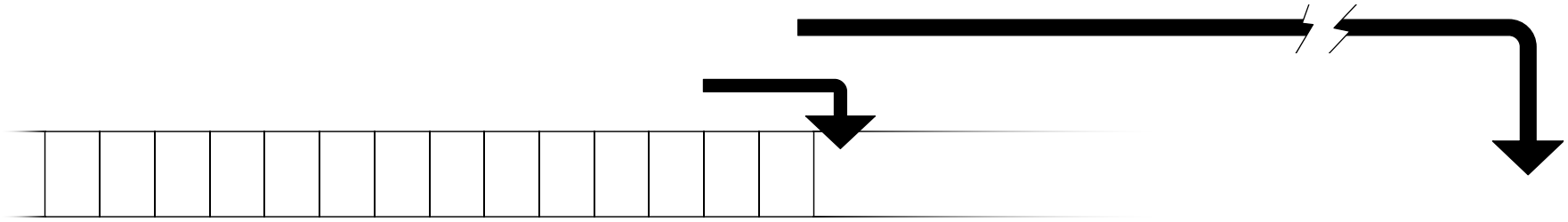
- **Magnitude (how far outside):**
  - **Small (just barely outside), Far (e.g. 4000).**



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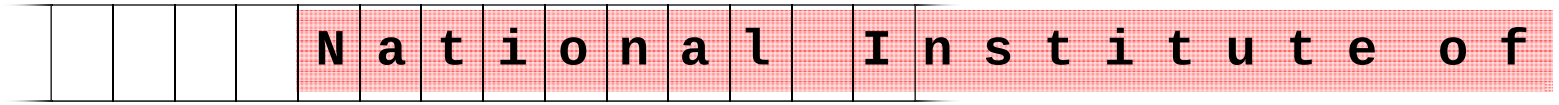

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- **Magnitude (how far outside):**
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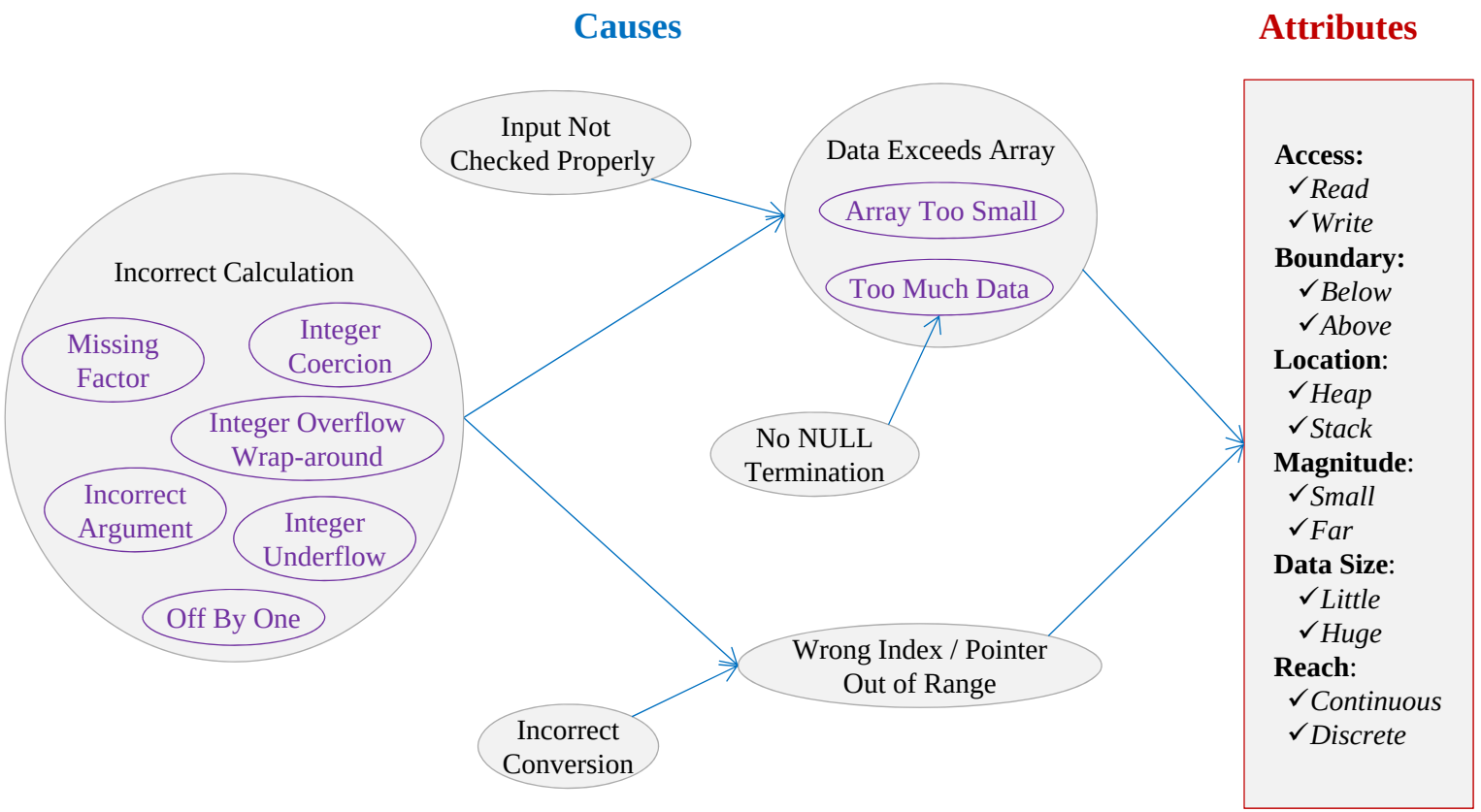
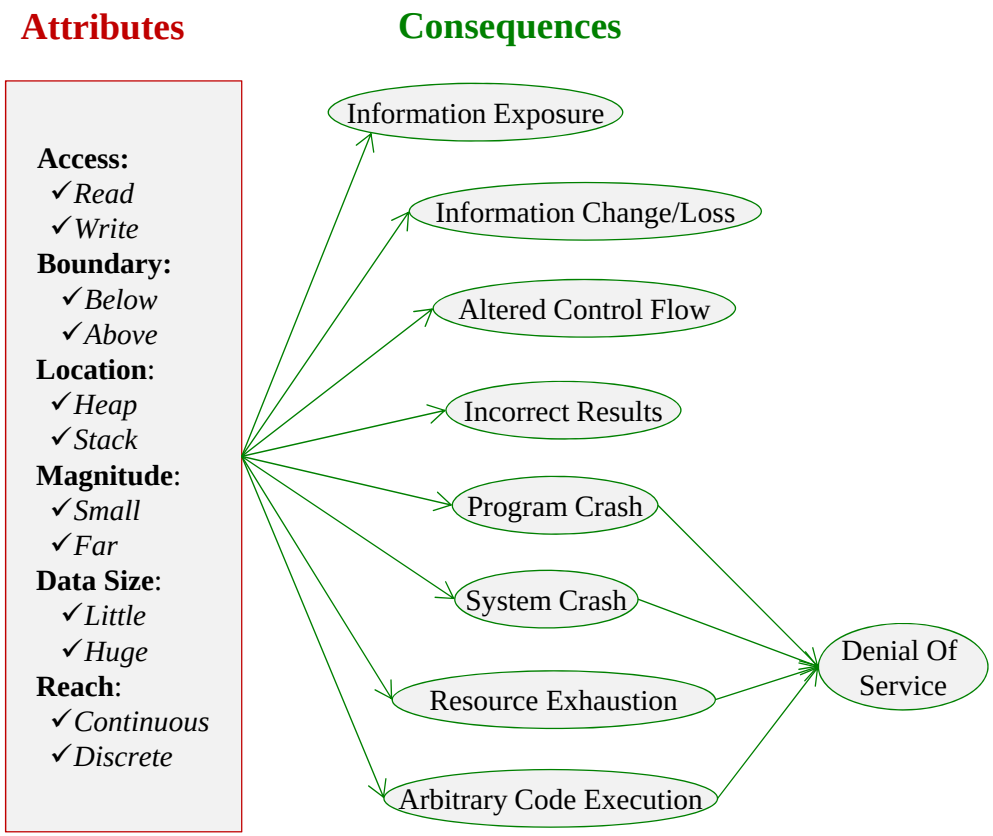
- **Reach (one-by-one or arbitrary):**
  - **Continuous, Discrete.**

Buffer Overflow: Causes



Buffer Overflow: Consequences



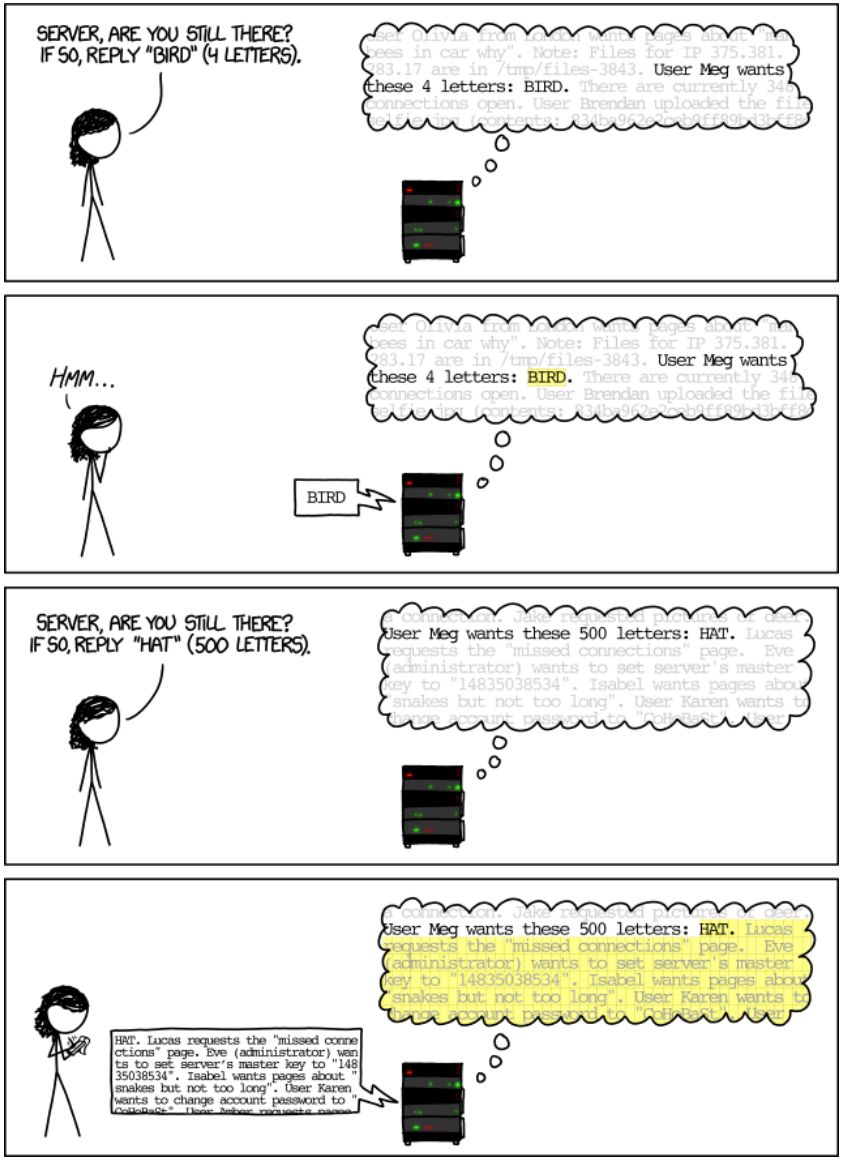
What is BF Good For?

- **Precisely explain why techniques work in some cases and not others.**
- **More clearly describe vulnerabilities (e.g. Heartbleed, Shellshock, and Ghost).**
- **Help programmers write better code, because they understand weaknesses more clearly.**
- **Accurately state the classes of bugs that software assurance tools cover (and do not cover).**

Example 1: BF Explains Techniques

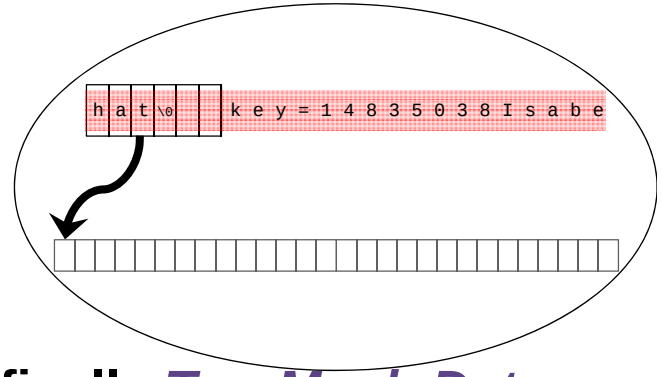
- **Canaries**
  - **A *canary* is extra memory above and below an array with unusual values, e.g., 0xDEADBEEF**
  - **Useful with attributes**
    - **Write *Access***
    - **Small *Magnitude***
- **Address Space Layout Randomization (ASLR)**
  - **Allocate arrays randomly about memory**
  - **Useful with attributes**
    - **Heap *Location***
    - **Stack *Location* - limited**

Example 2: Heartbleed



from http://xkcd.com/1354/

Example 2: Heartbleed

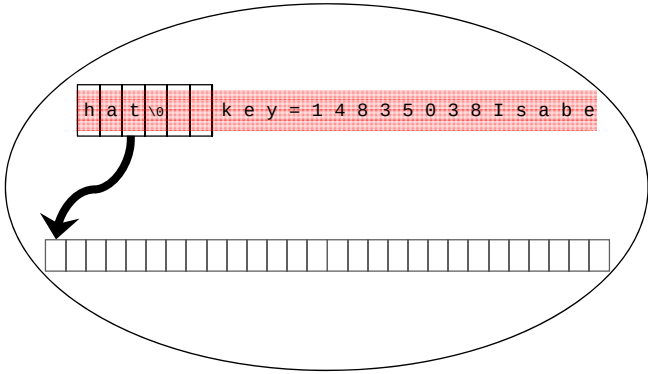


Heartbleed buffer overflow is:

- **caused by *Data Exceeds Array*, specifically *Too Much Data***
- **because of *Input not Checked Properly***
- **where there was a *Read* that was *After* the end, *Far* outside**
- **in a *Continuous* read of a *Huge* number of bytes**
- **from an array in the *Heap***
- **that may be exploited for *Information Exposure***
- **when enabled by *Sensitive Information Uncleared Before Release (CWE-226)*.**

“The (1) TLS and (2) DTLS implementations … do not properly handle Heartbeat Extension packets, which allows remote attackers to obtain sensitive information from process memory via crafted packets that trigger a buffer over-read, as demonstrated by reading private keys, …” (CVE-2014-0160)

Example 2: Heartbleed



Sensitive Info Uncleared Before Release

Information Exposure

Input Not Checked Properly

Data Exceeds Array

Too Much Data

Access:
✓*Read*
✓*Write*
Boundary:
✓*Below*
✓*Above*
Location:
✓*Heap*
✓*Stack*
Magnitude:
✓*Small*
✓*Far*
Data Size:
✓*Little*
✓*Huge*
Reach:
✓*Continuous*
✓*Discrete*

Incorrect Calculation
Missing Factor
Integer Coercion
Integer Overflow Wrap-around
Incorrect Argument
Integer Underflow
Off By One
Array Too Small
No NULL Termination
Wrong Index / Pointer Out of Range
Incorrect Conversion
Information Change/Loss
Altered Control Flow
Incorrect Results
Resource Exhaustion
System Crash
Program Crash
Denial Of Service
Arbitrary Code Execution