CMPT 473
Software Testing, Reliability and Security

Security

Nick Sumner

Security in General

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  - Maintaining desired properties in the the presence of adversaries

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So what are the desired properties?

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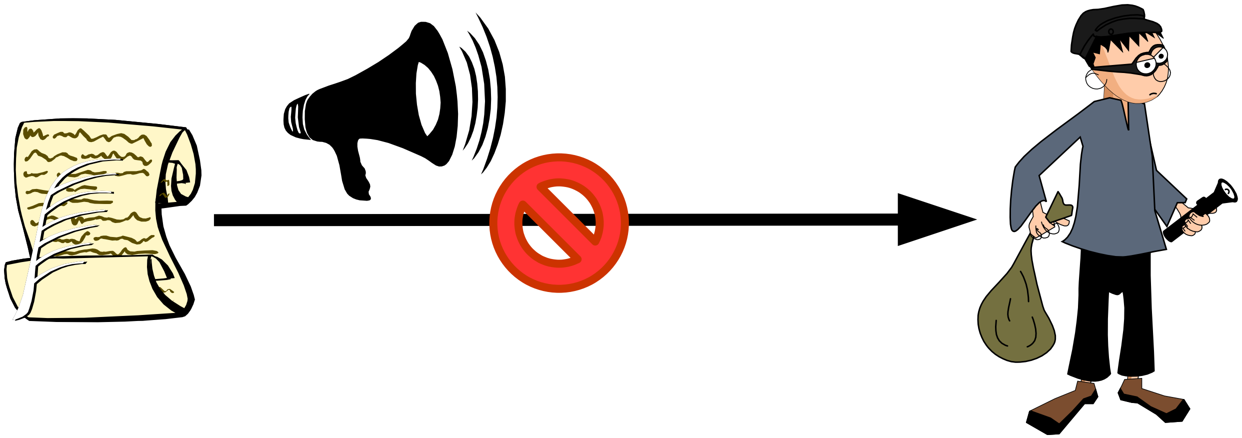
  - **Confidentiality**
    - Information is only disclosed to those authorized to know it



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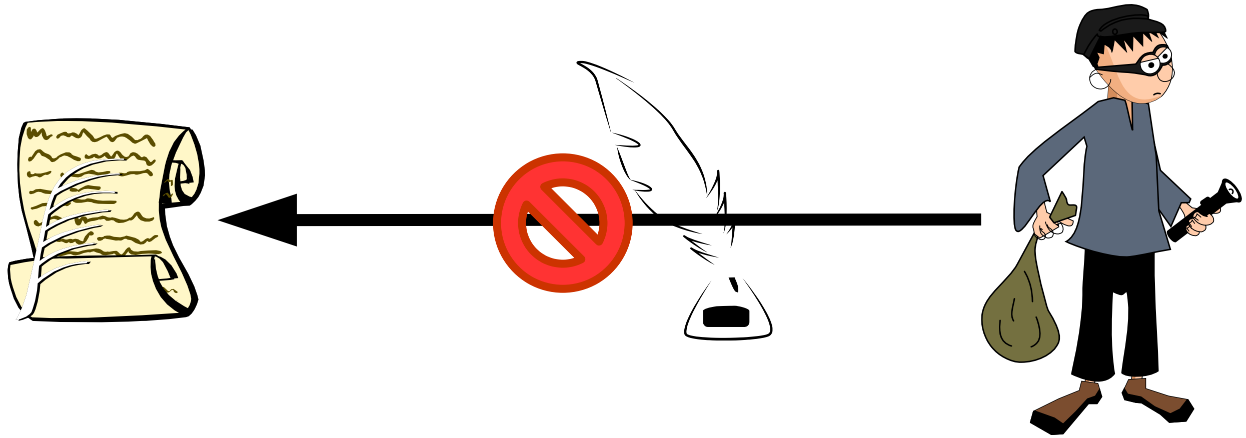

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  - Confidentiality
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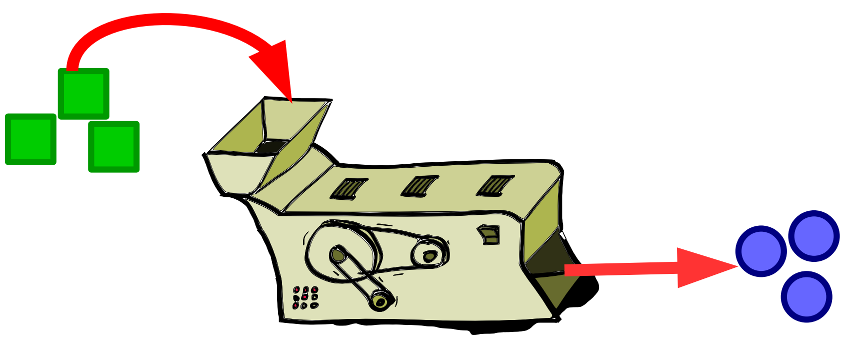
    - Only modify information in allowed ways by authorized parties
    - Do what is expected



Security in General

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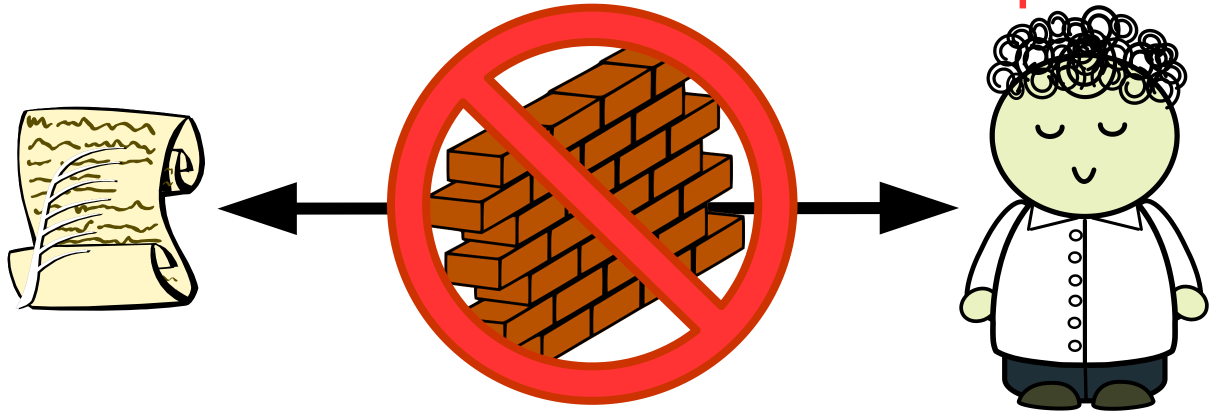
  - Confidentiality
  - Integrity
  - **Availability**
    - Those authorized for access are not prevented from it



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  - Information leaks (**C**)
  - Data Corruption (**I**)
  - Denial of service (**A**)
  - Remote execution – (**CIA**) arbitrarily bad!

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- *Bugs* in software can lead to policy violations
- *Bugs* make software vulnerable to attack
  - XSS
  - SQL Injection
  - Buffer overflow
  - Path replacement
  - Integer overflow
  - Race conditions (TOCTOU – Time of Check to Time of Use)
  - Unsanitized format strings
  - …

All create attack vectors for a malicious adversary

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- While our testing techniques so far find some security issues, many slip through! *Why?*
  - We cannot test everything
  - Concessions form part of an *attack surface*
    - Networks, Software, People
- Need additional policies & testing methods that specifically address security

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  - Risky Resource Management
    - Bad creation, use, transfer, & destruction of resources
  - Porous Defenses
    - Standard security practices that are missing or incorrect

[http://cwe.mitre.org/top25/#Categories]

Memory Safety

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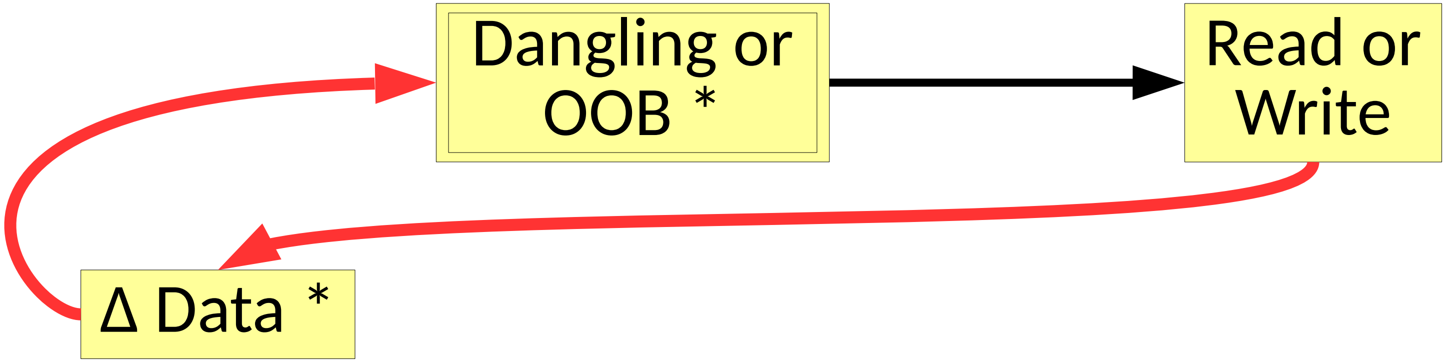

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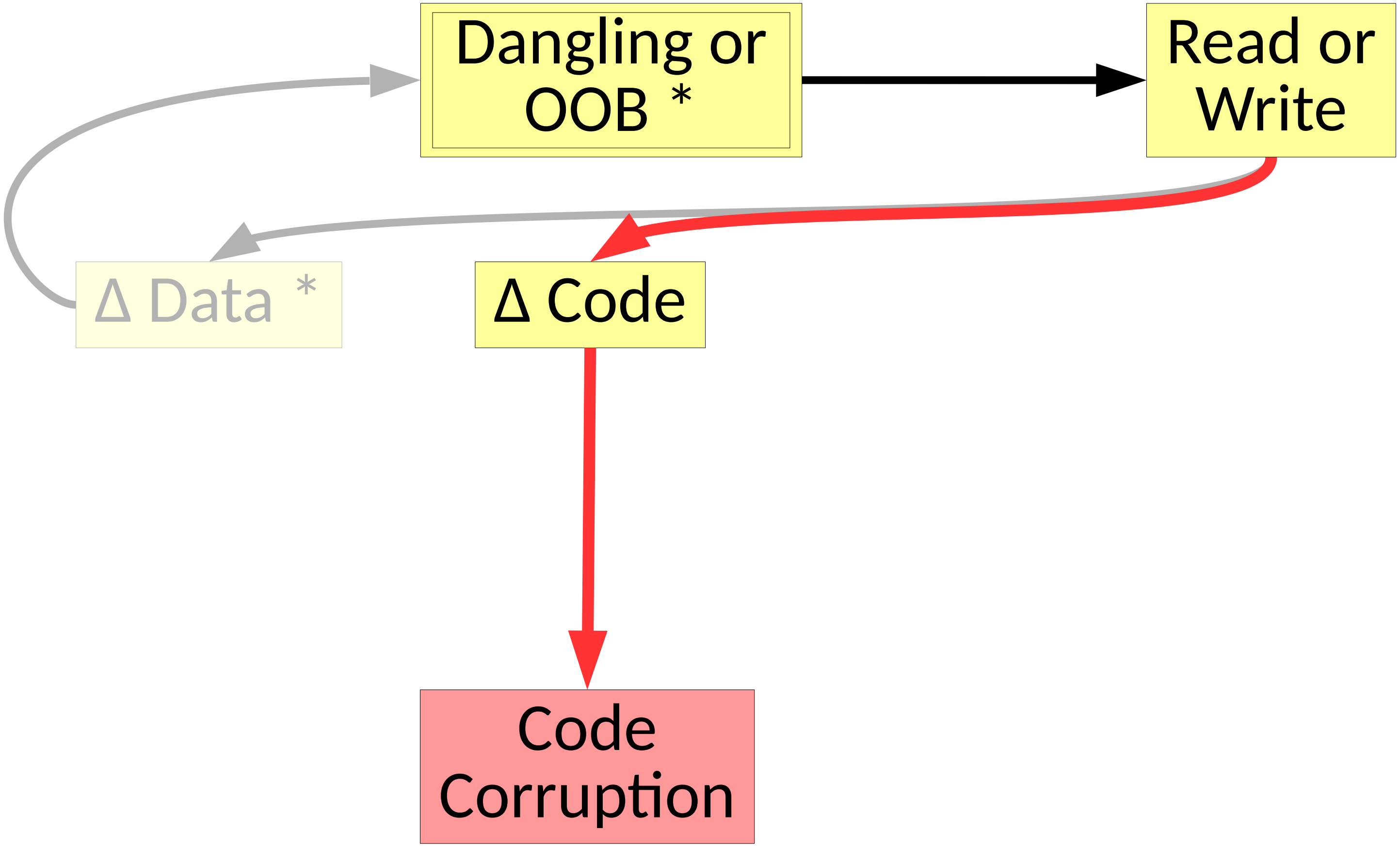

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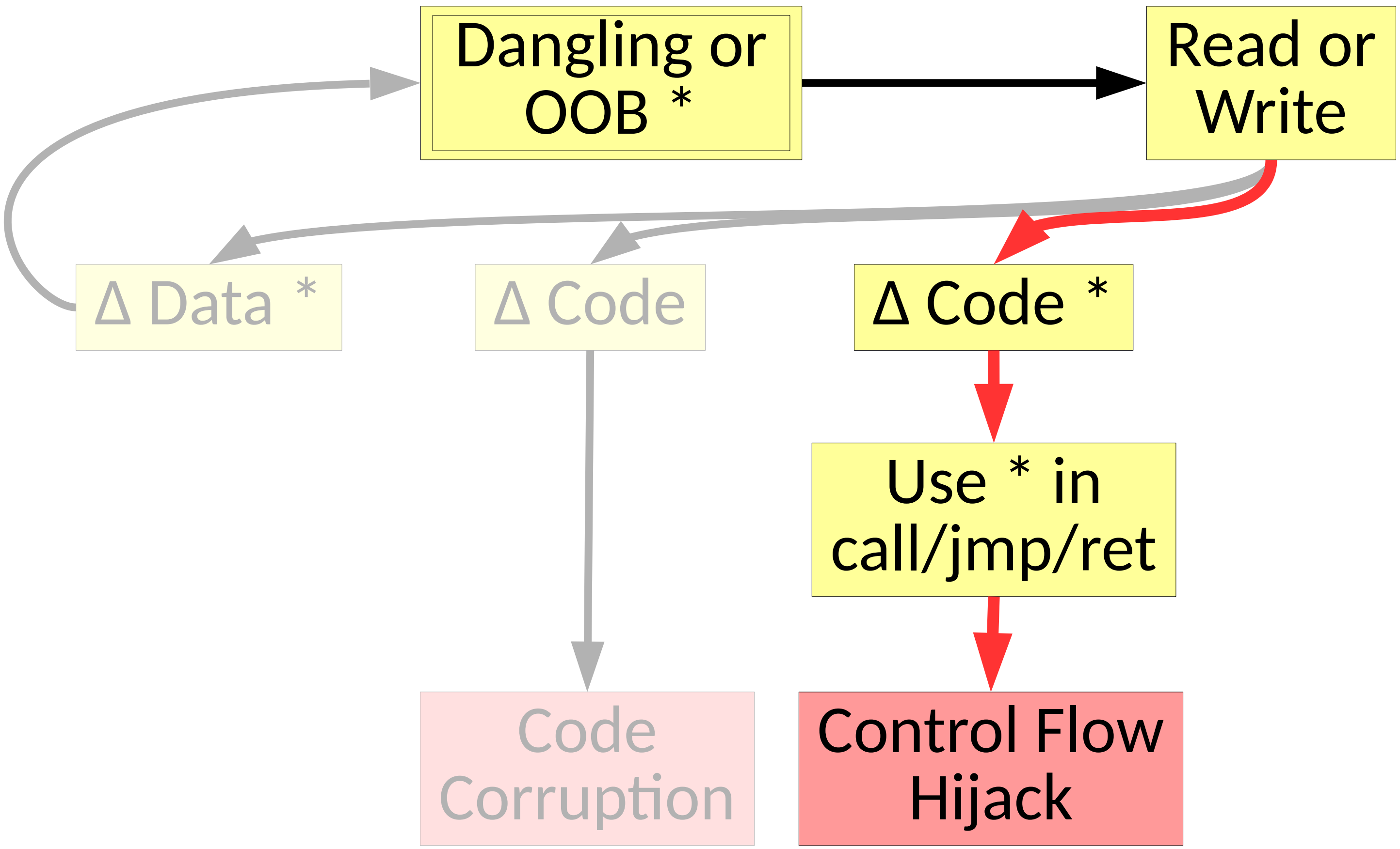

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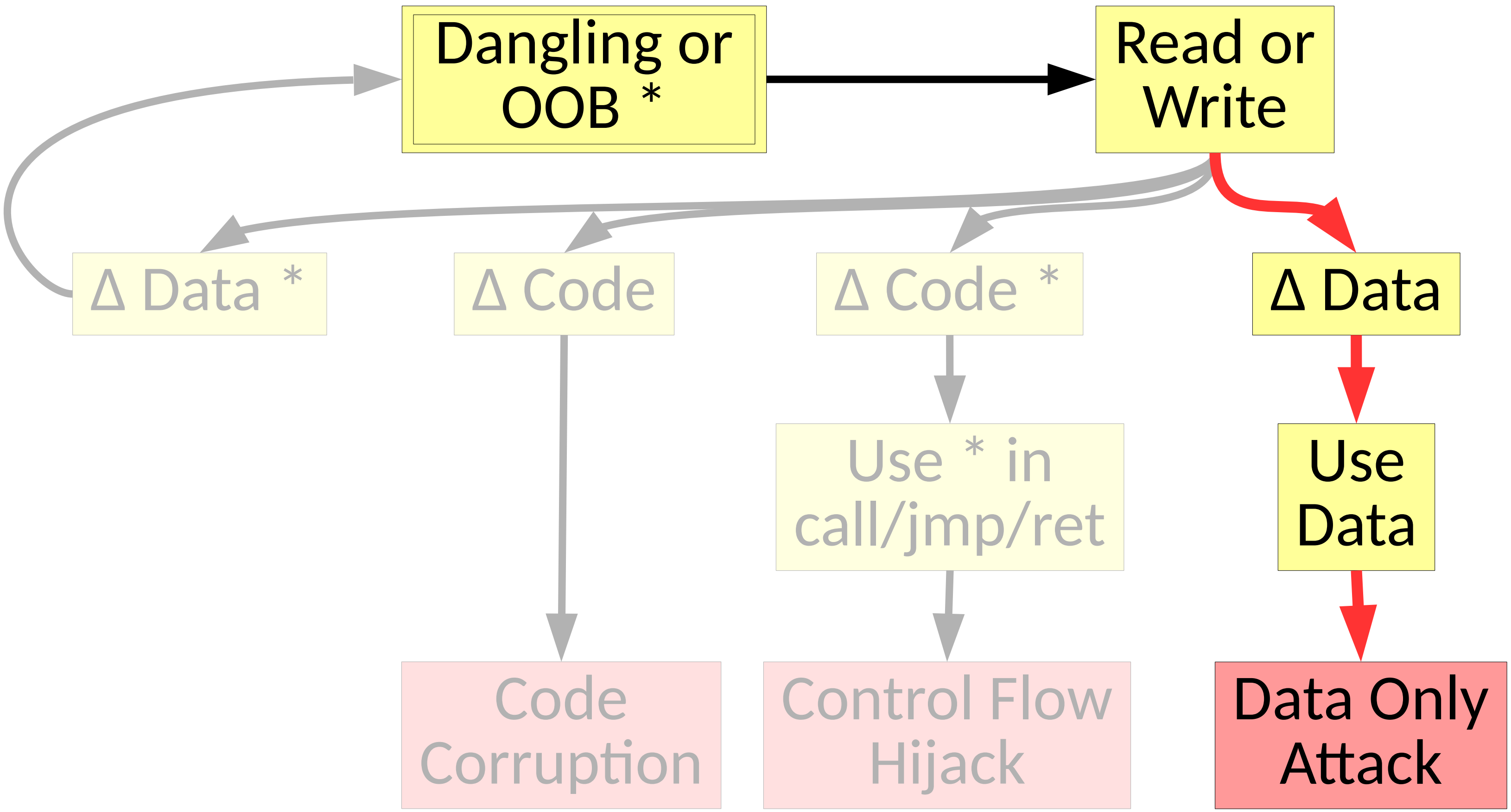

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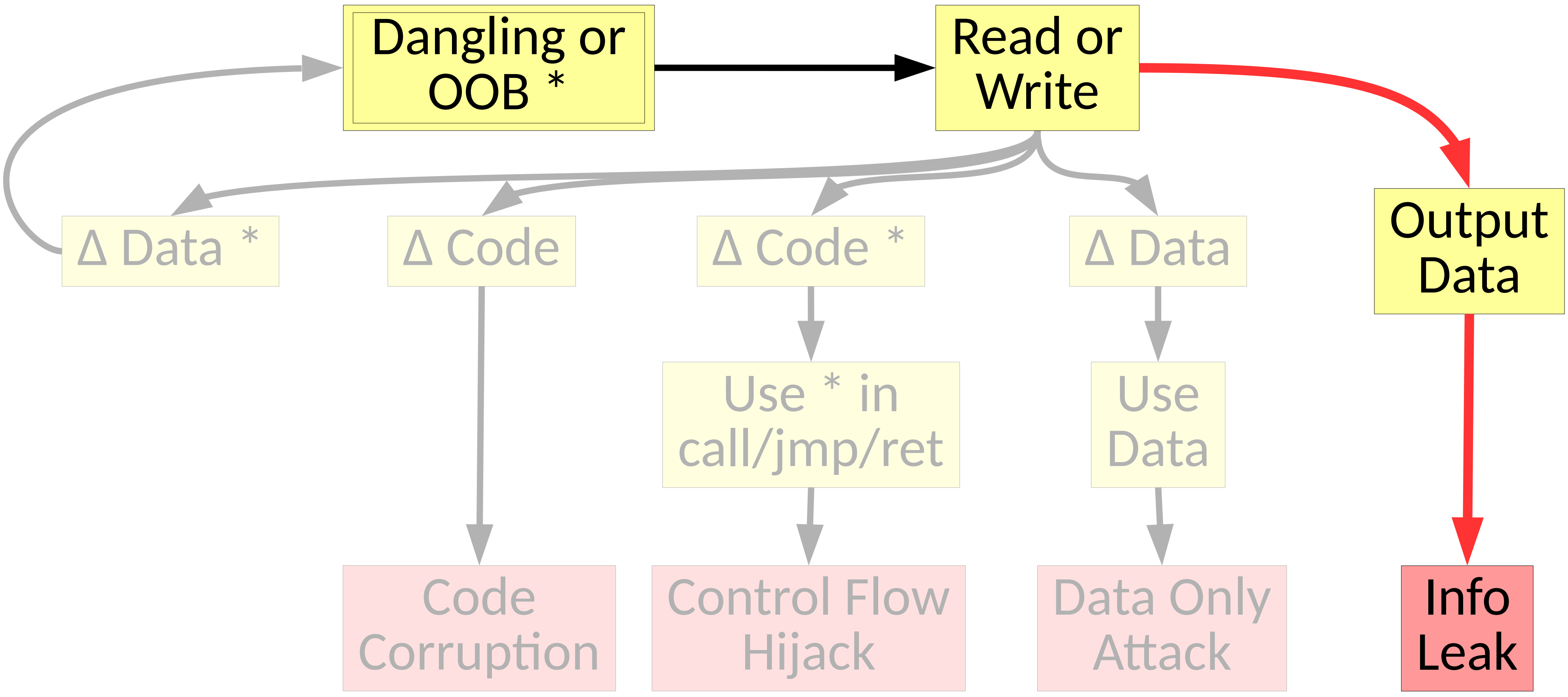


Code Corruption

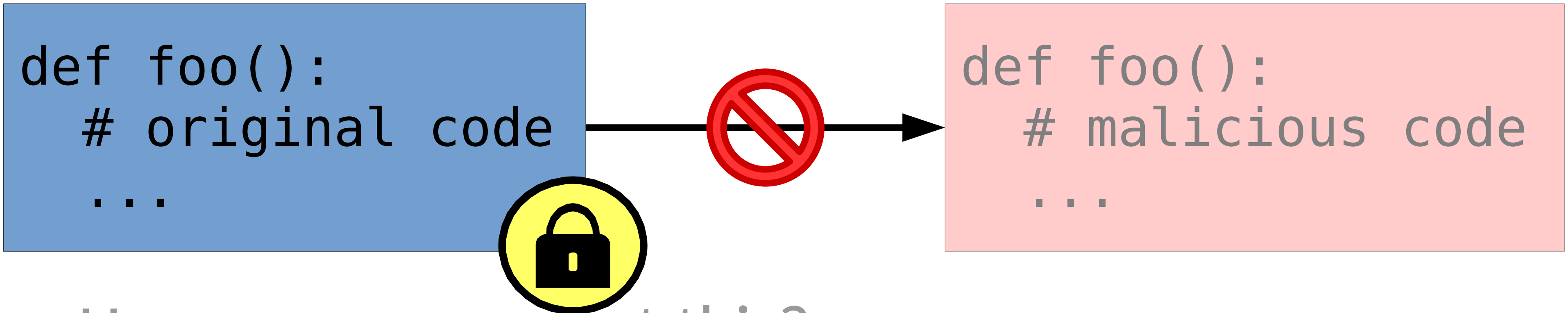
```
def foo():
  # original code
  ...
```

→

```
def foo():
  # malicious code
  ...
```

- How can we prevent this?

Code Corruption



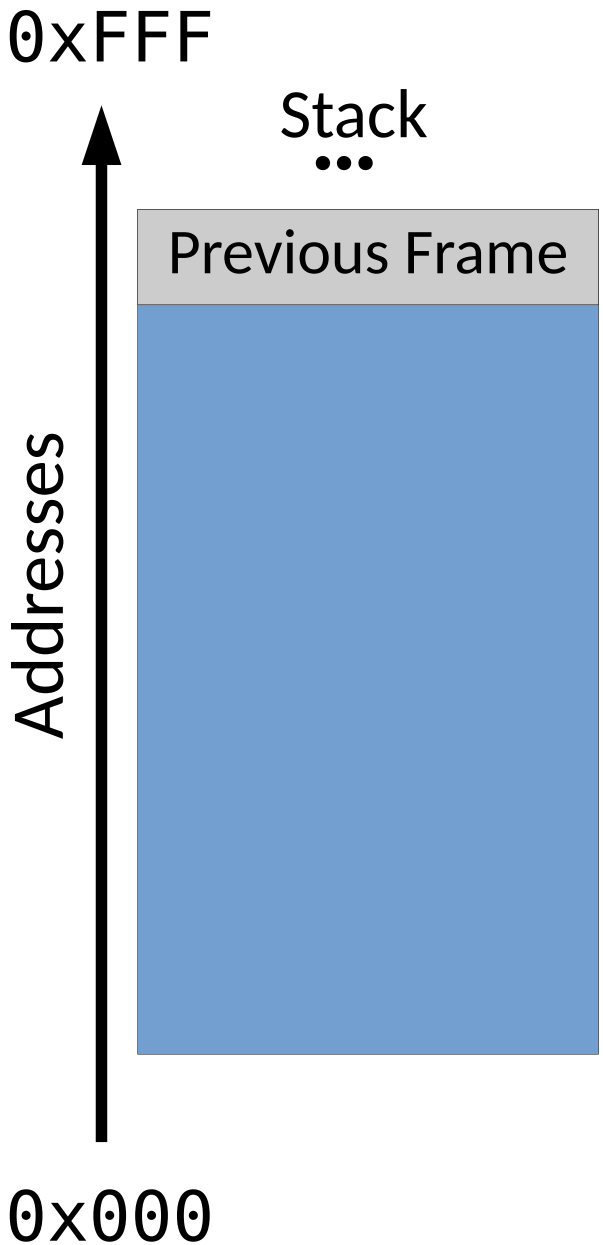
- How can we prevent this?
- What problems does this solution create?

Control Flow Hijacking

```
void foo(char *input) {
  unsigned secureData;
  char buffer[16];
  strcpy(buffer, input);
}
```

How many of you recall what a stack frame looks like?

Data Only Attacks

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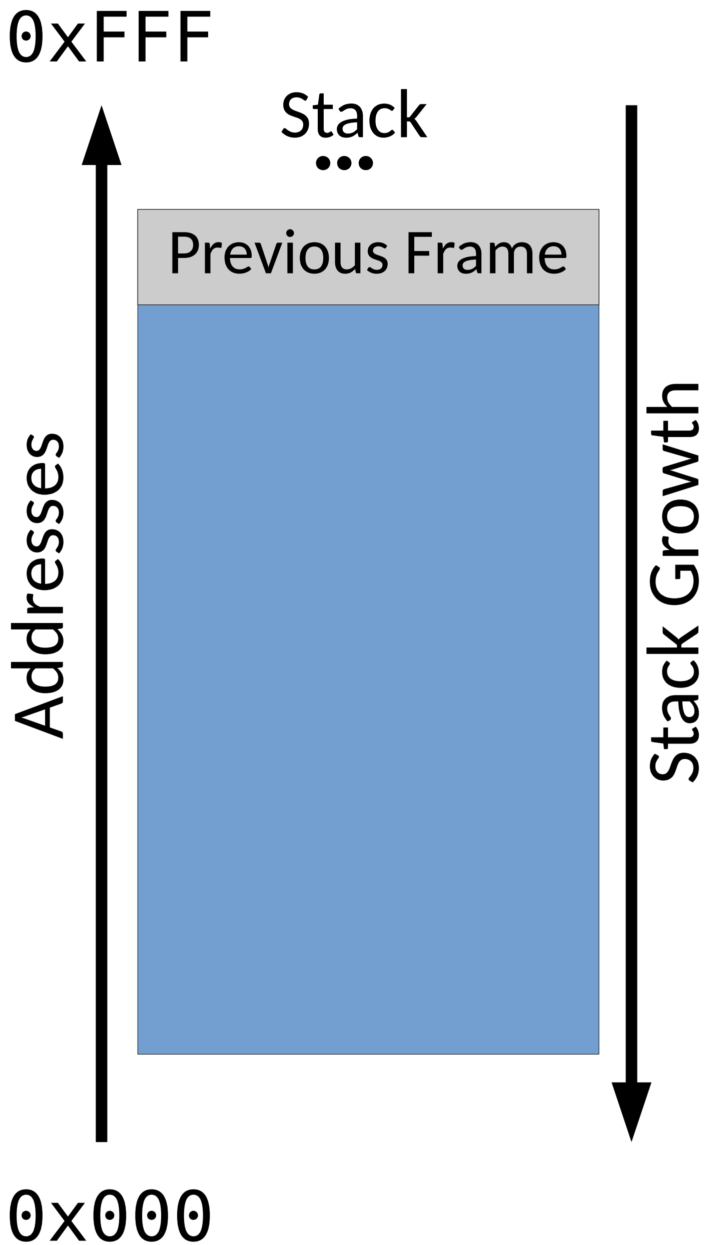


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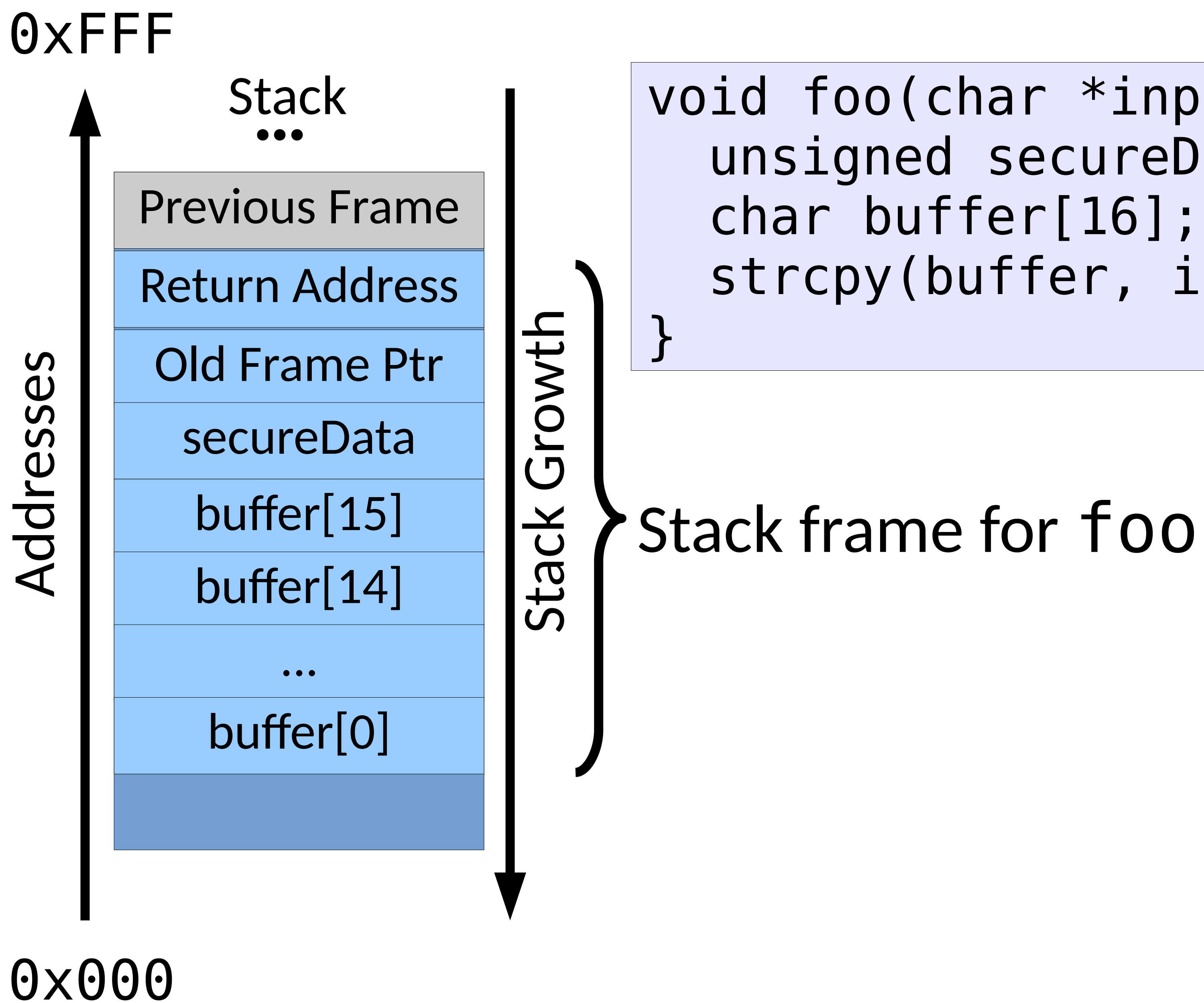


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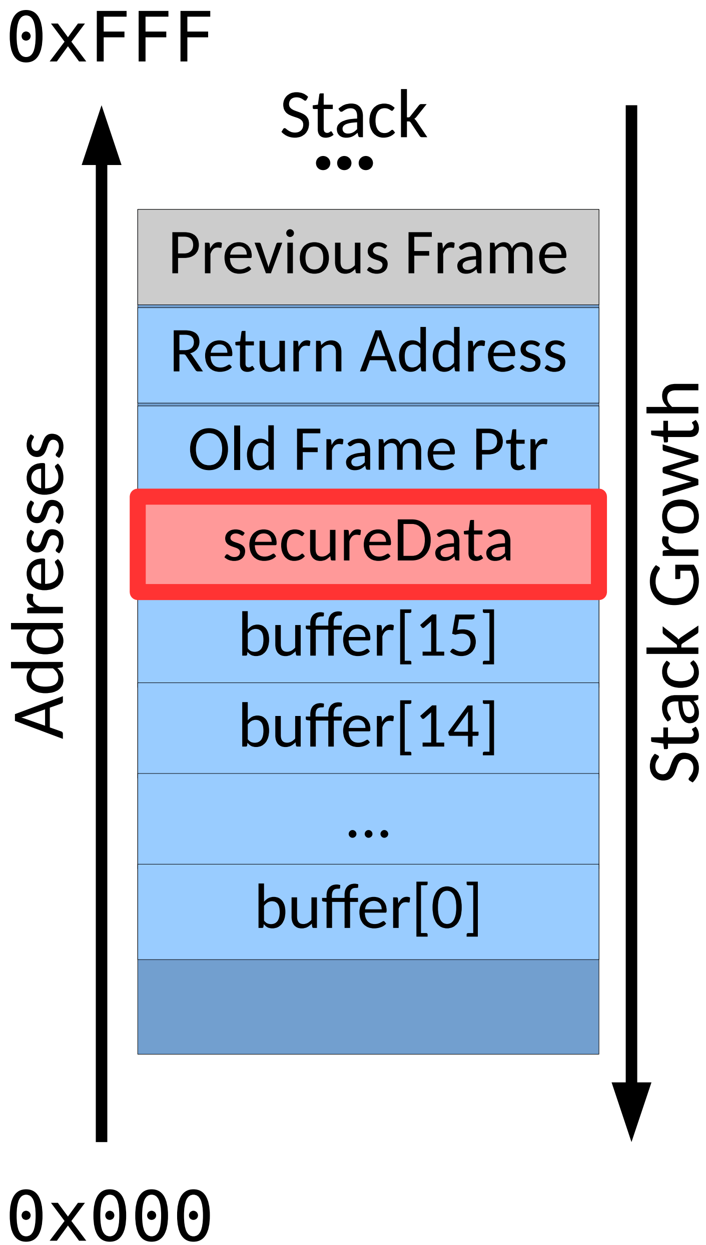


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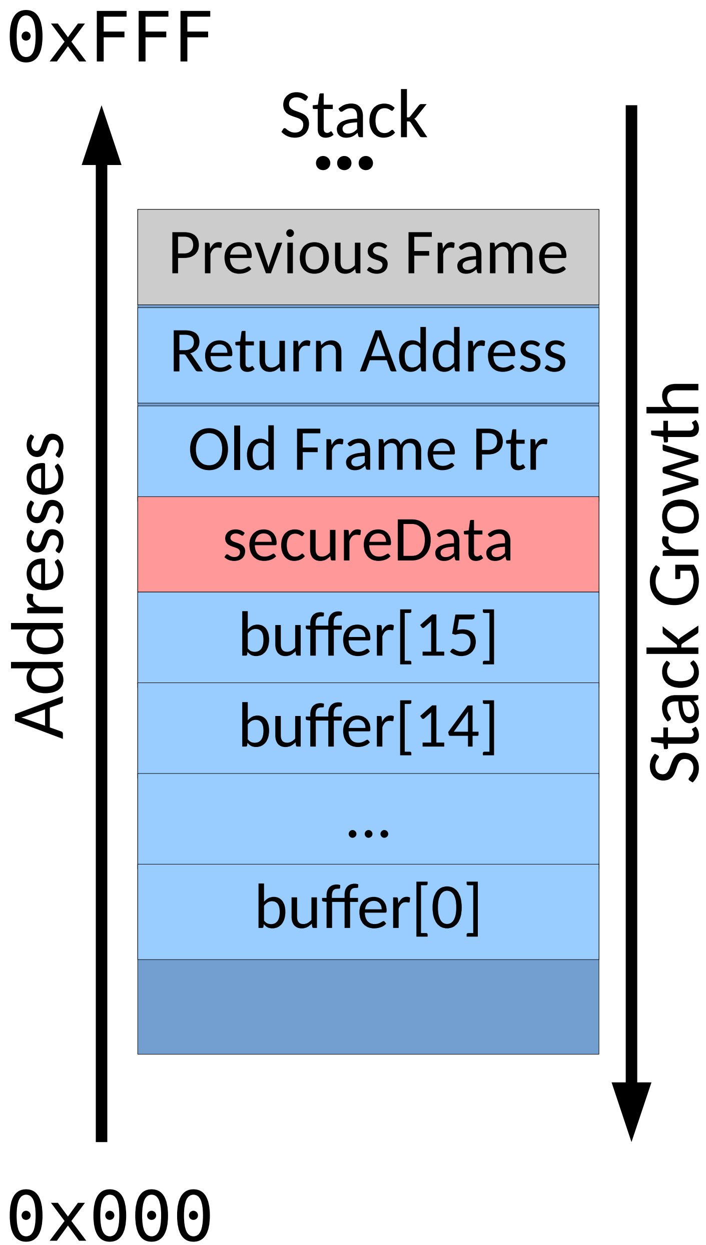


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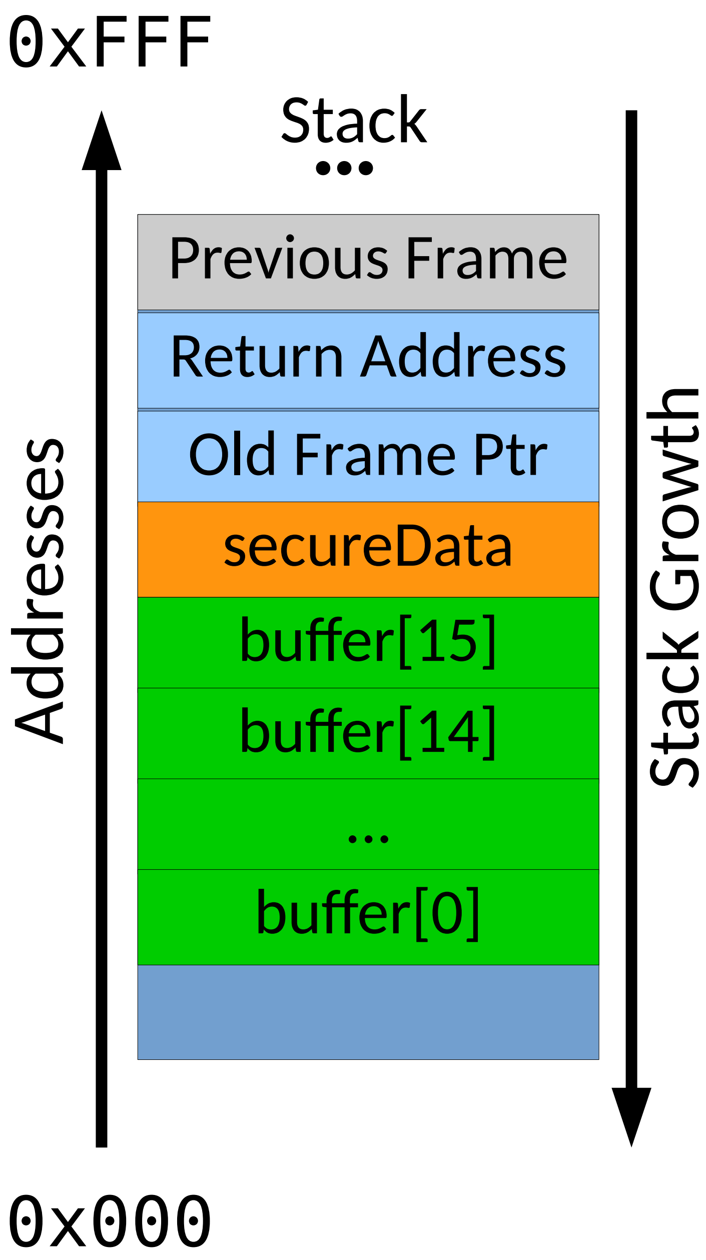
What can go wrong?

Data Only Attacks

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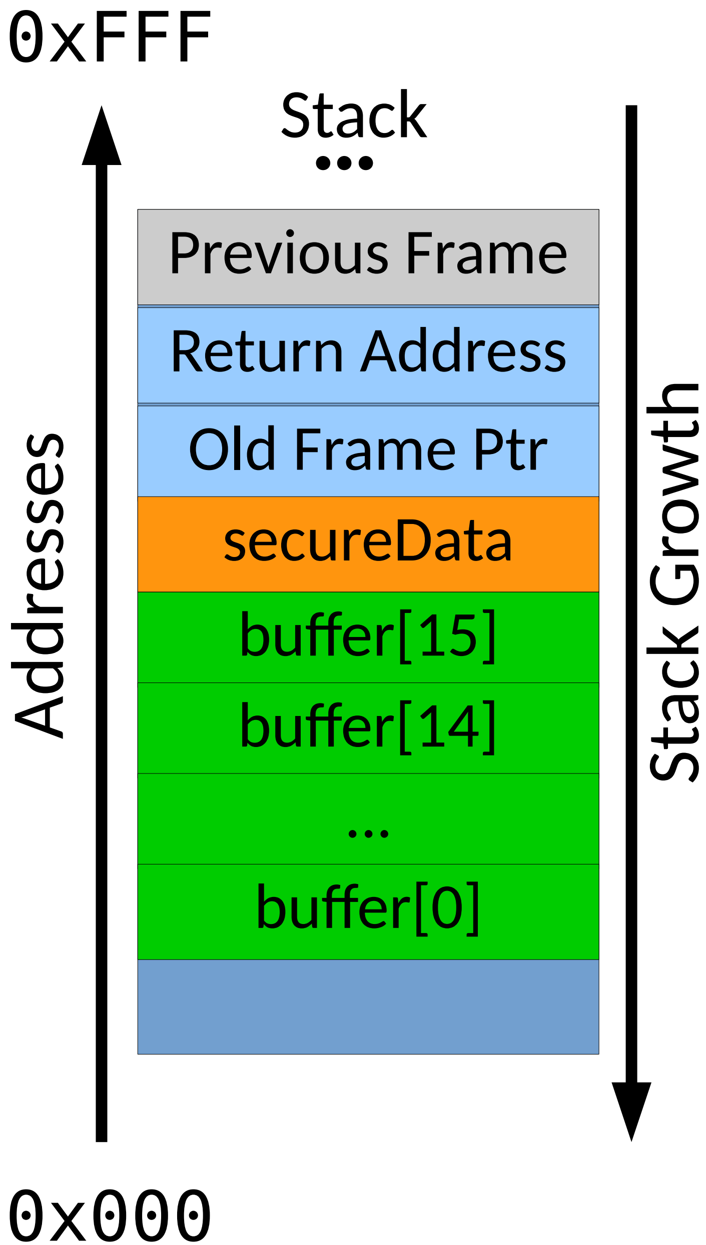
input = “normal input”
+ “insecureData”

Data Only Attacks

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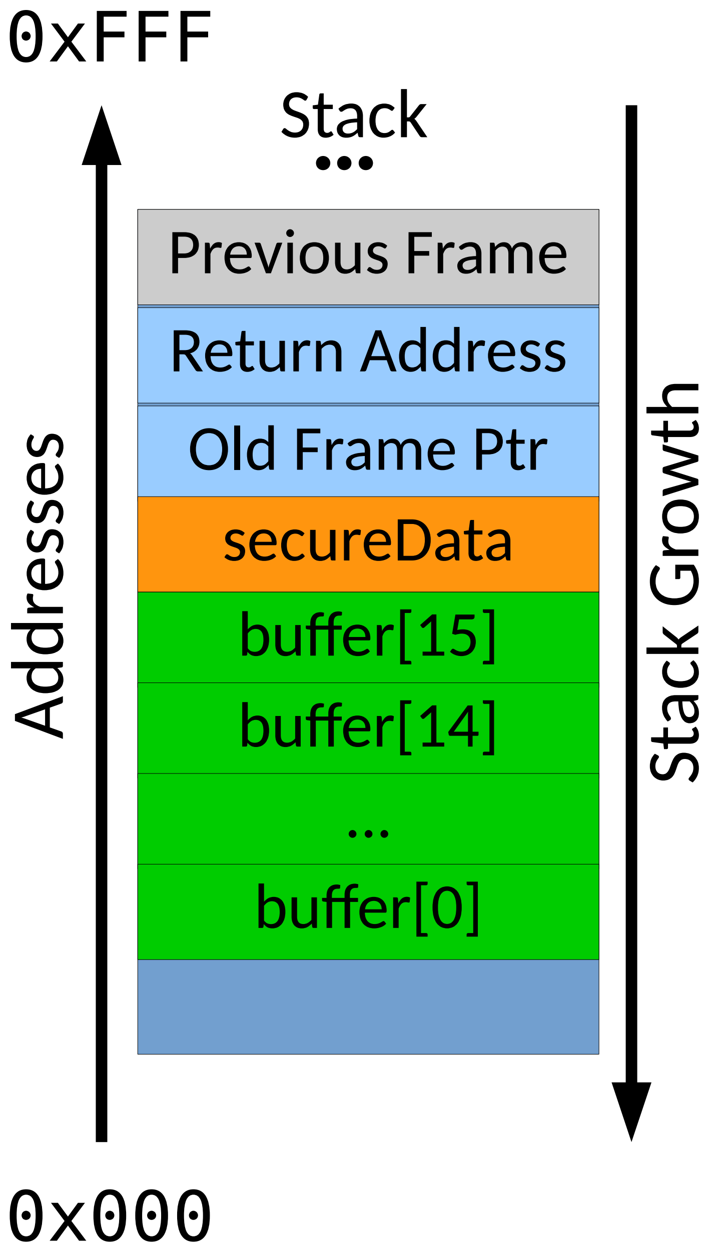
buffer overflow attack

Data Only Attacks

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The integrity of the secure data is corrupted.

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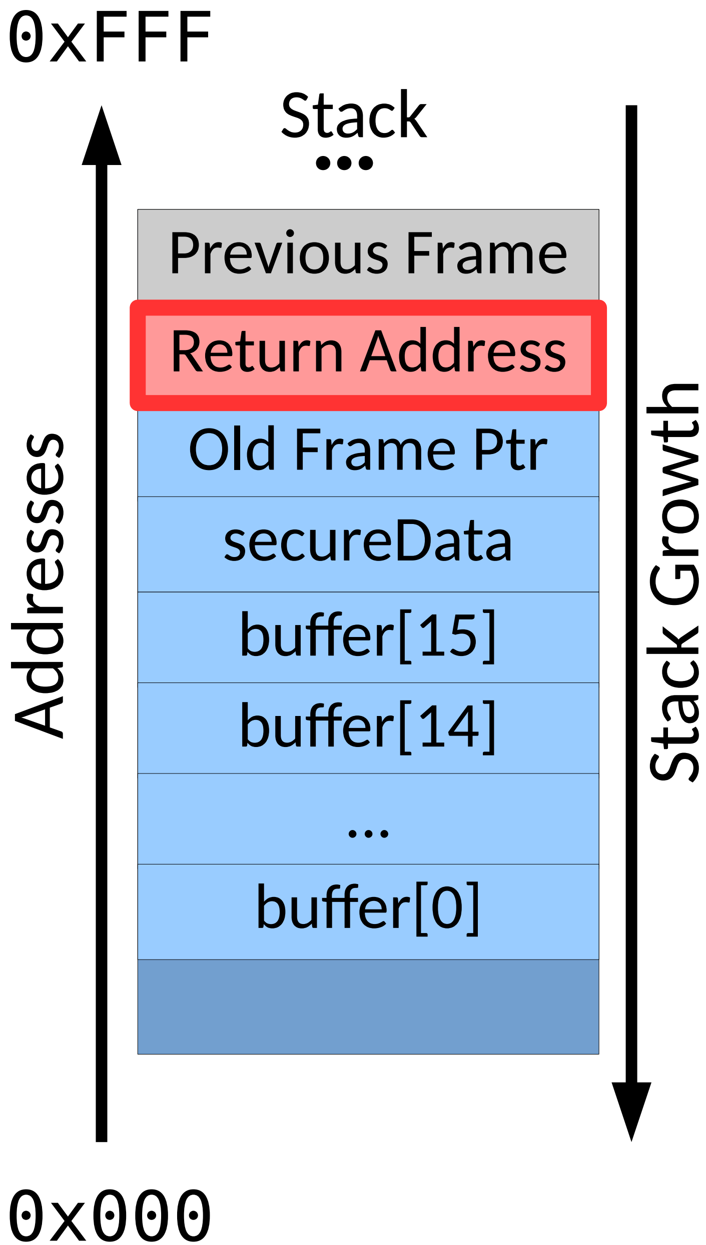


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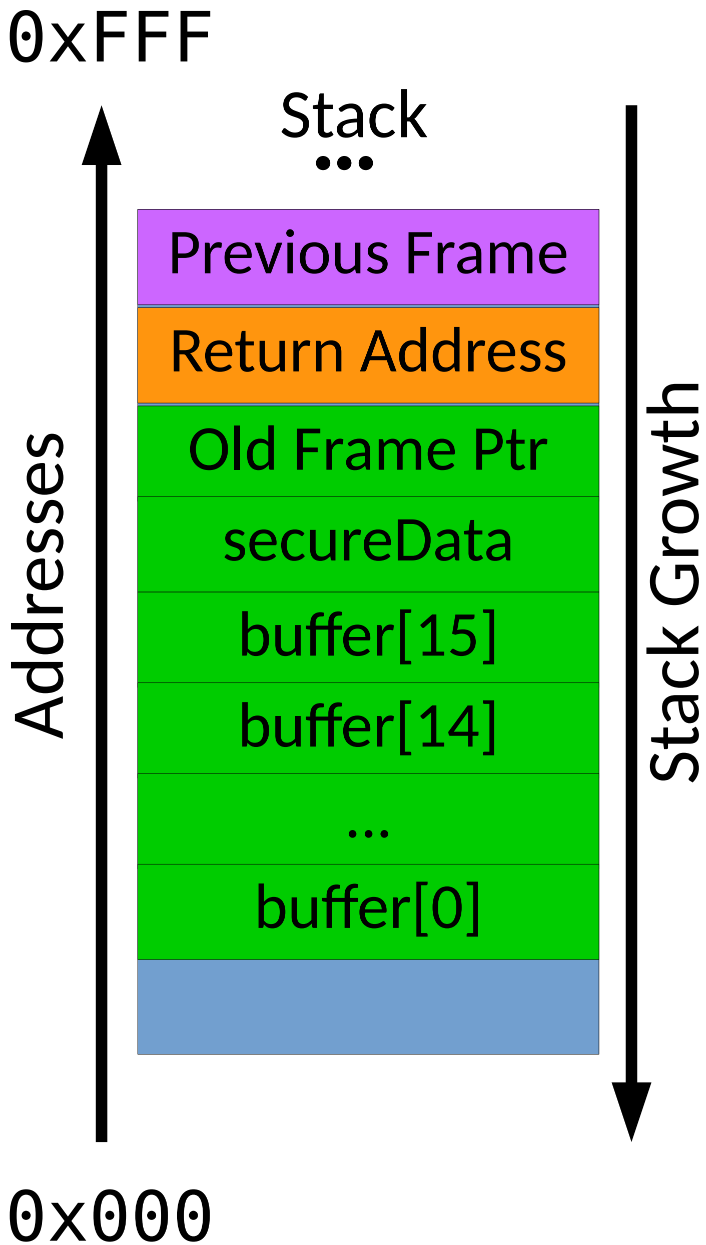


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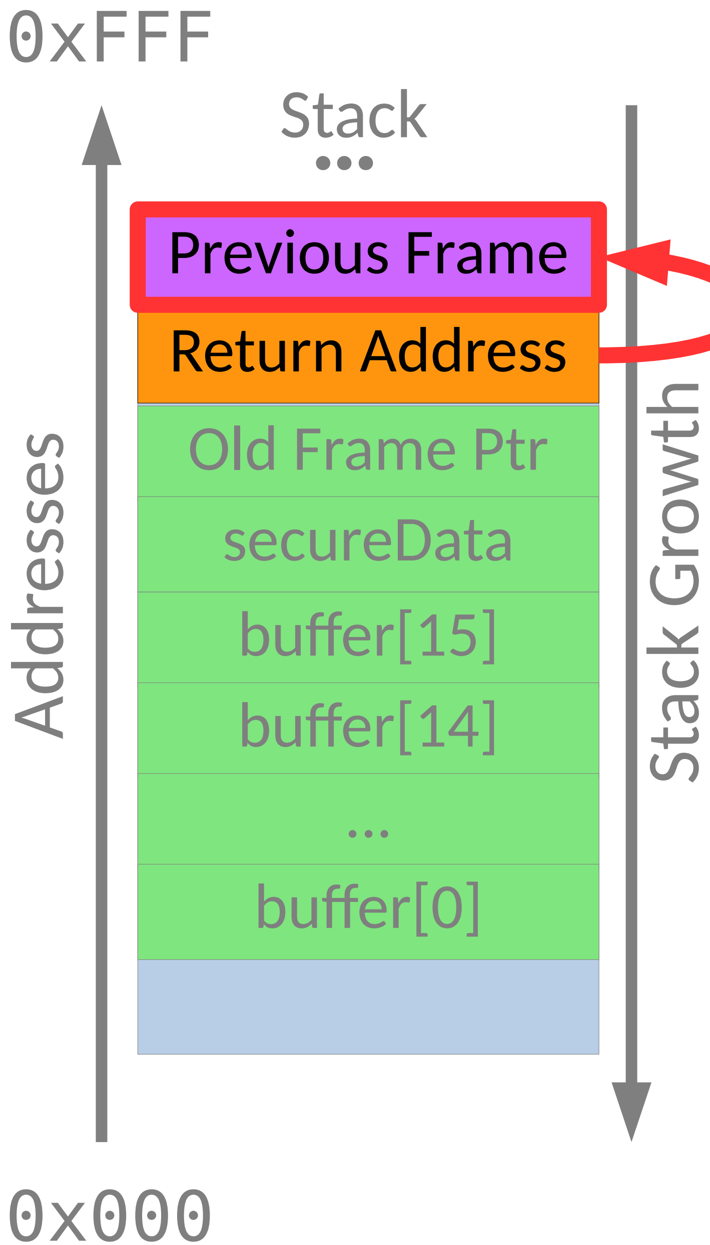


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On return, we'll execute the shell code

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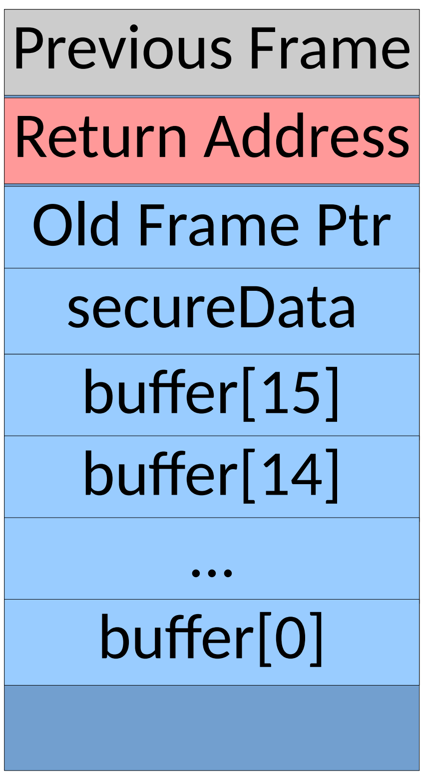

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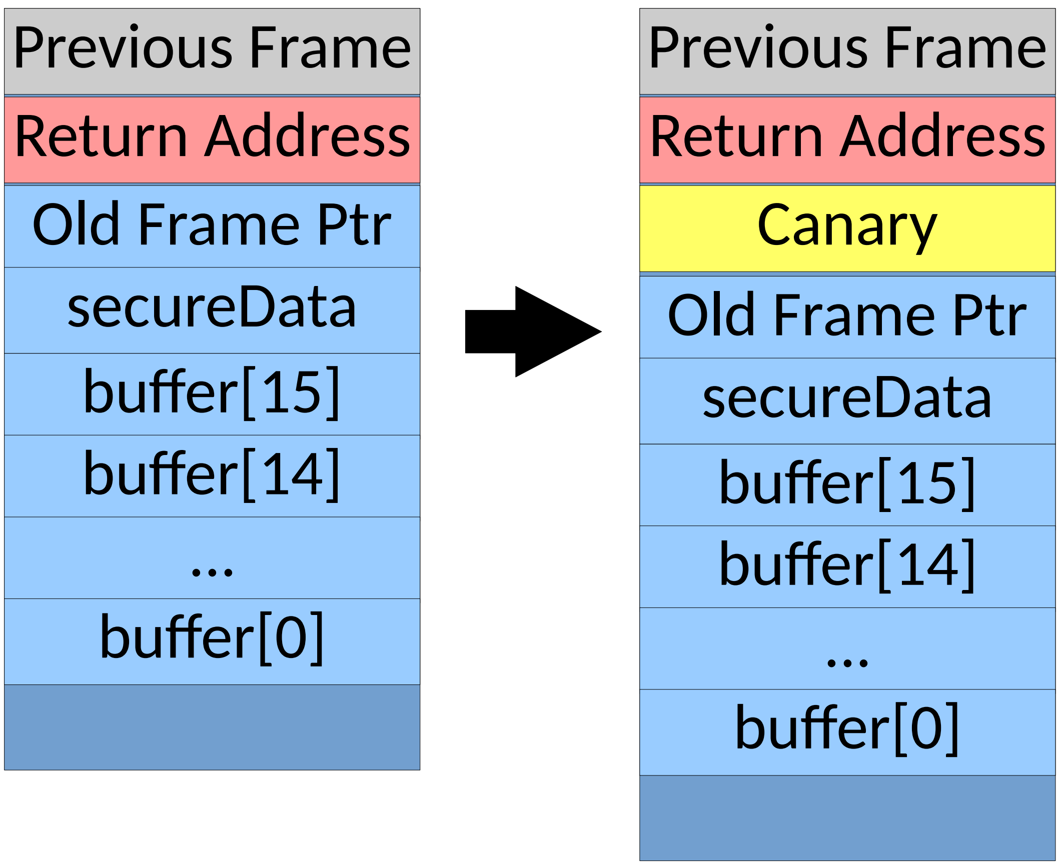

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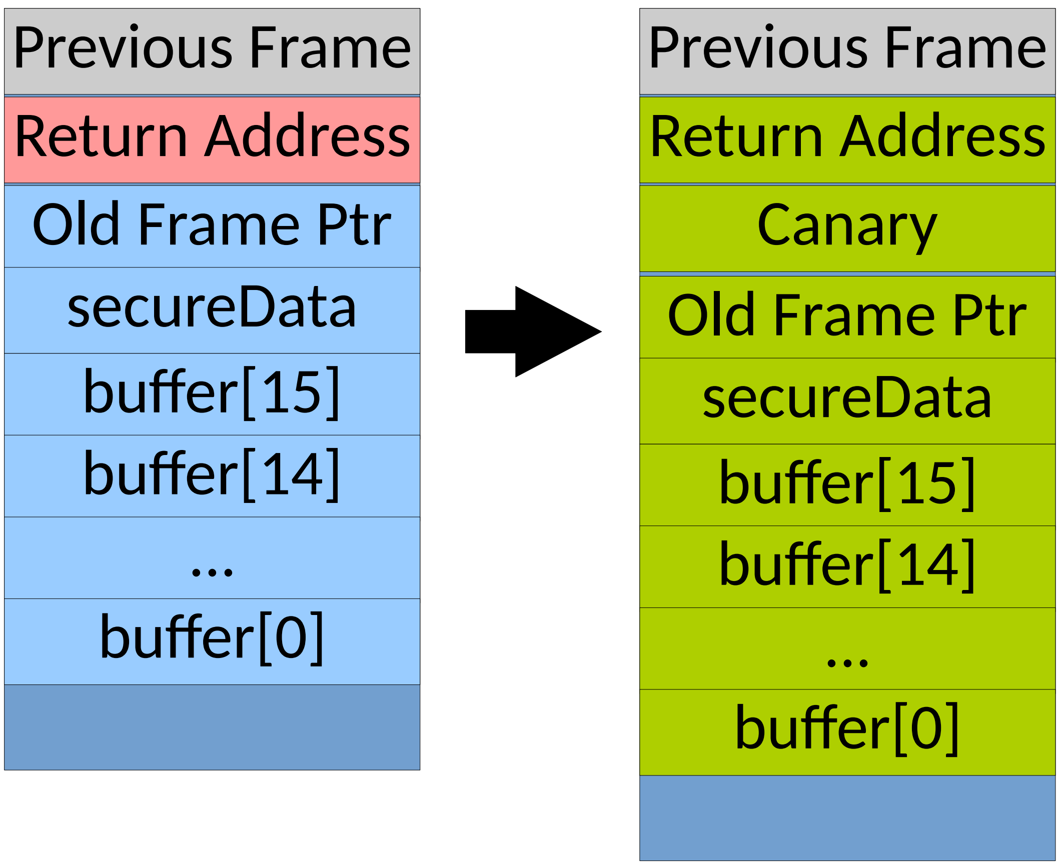

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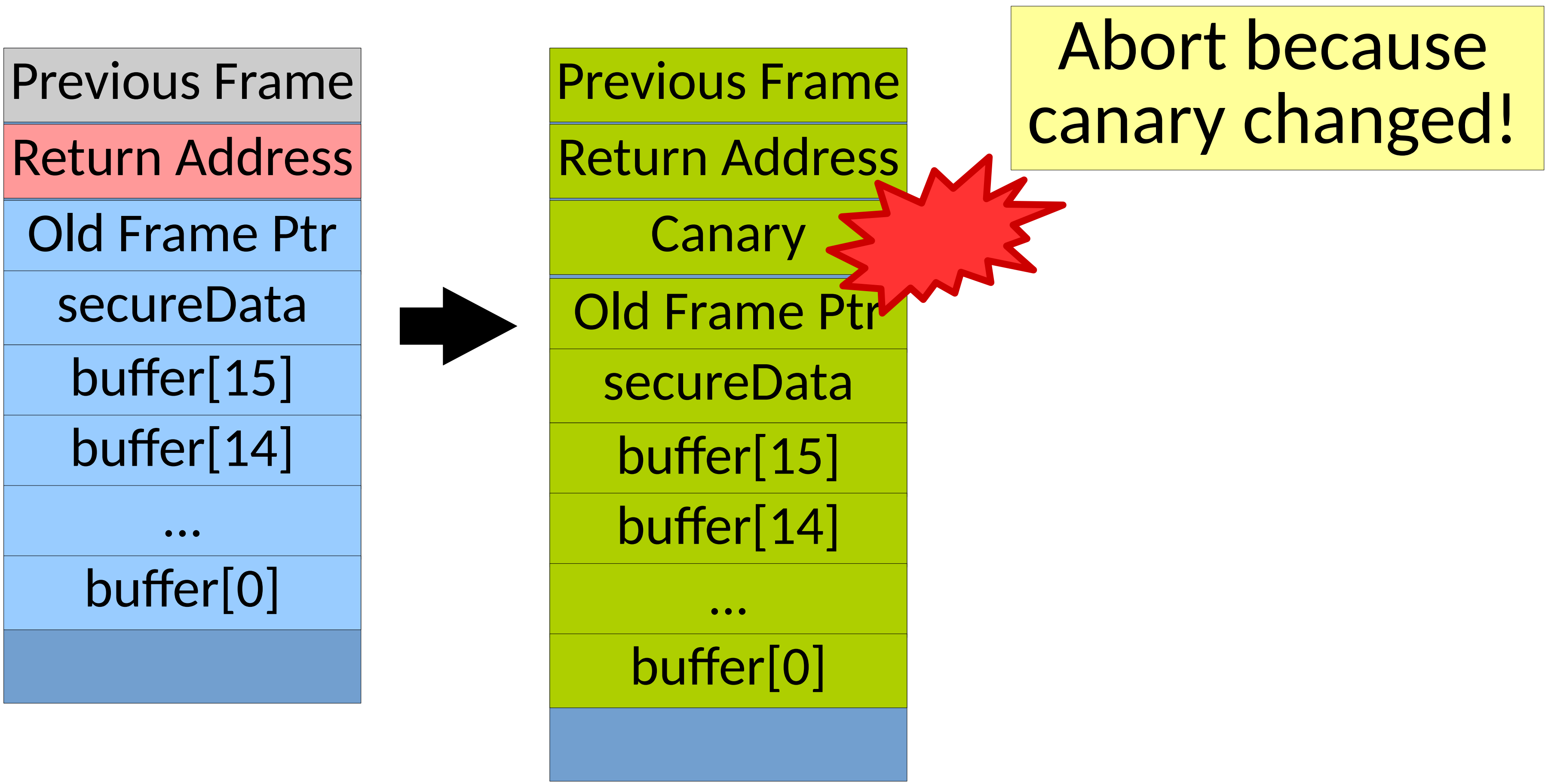

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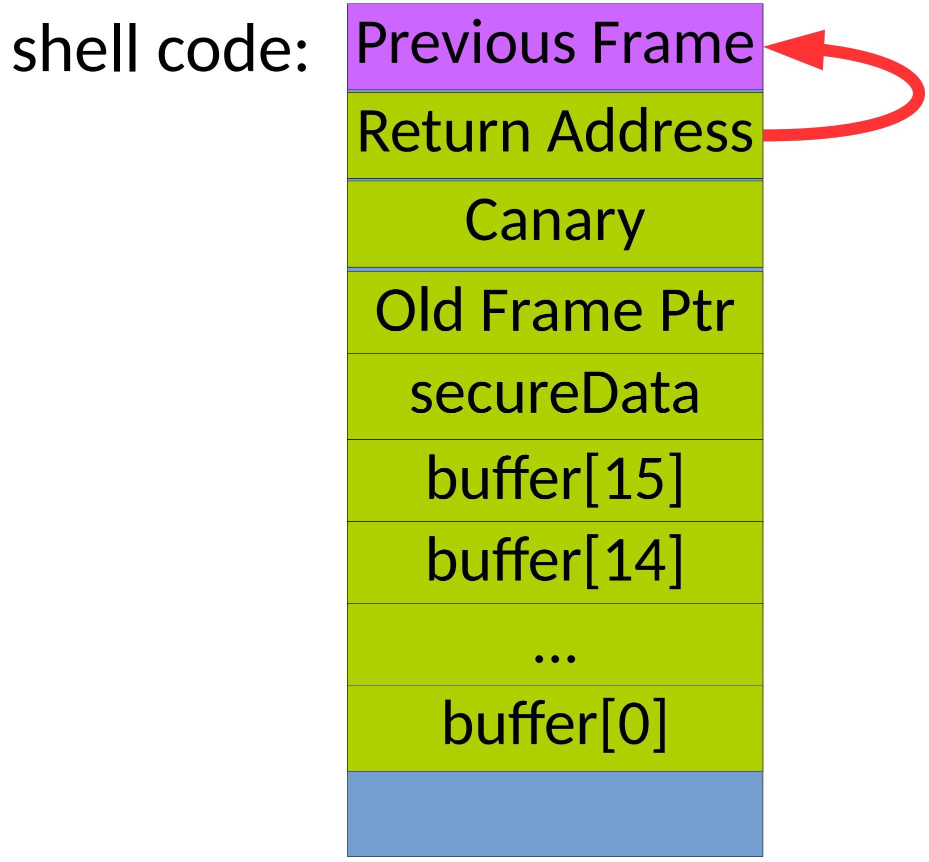

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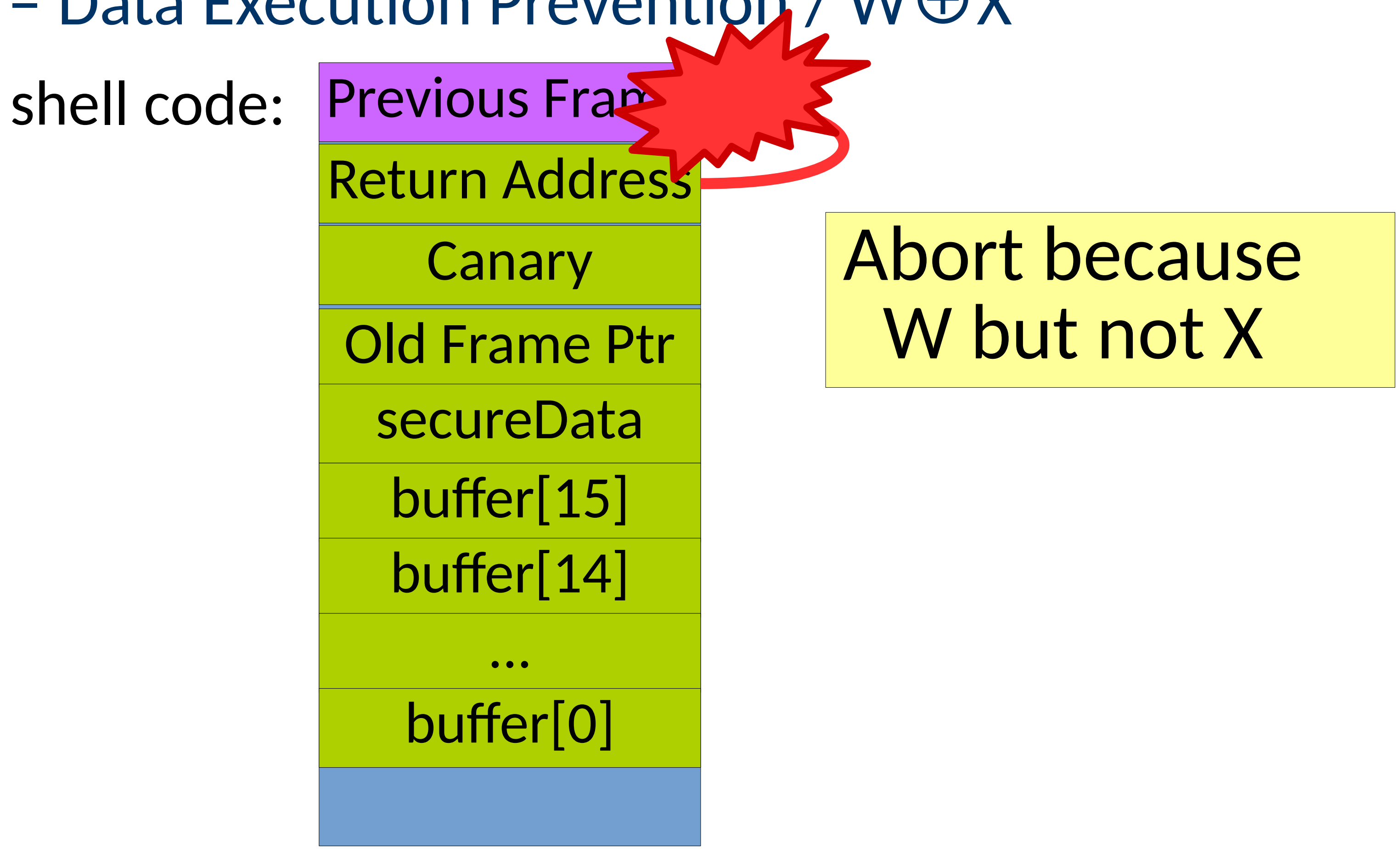

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But these are still easily bypassed!

Return to libc Attacks

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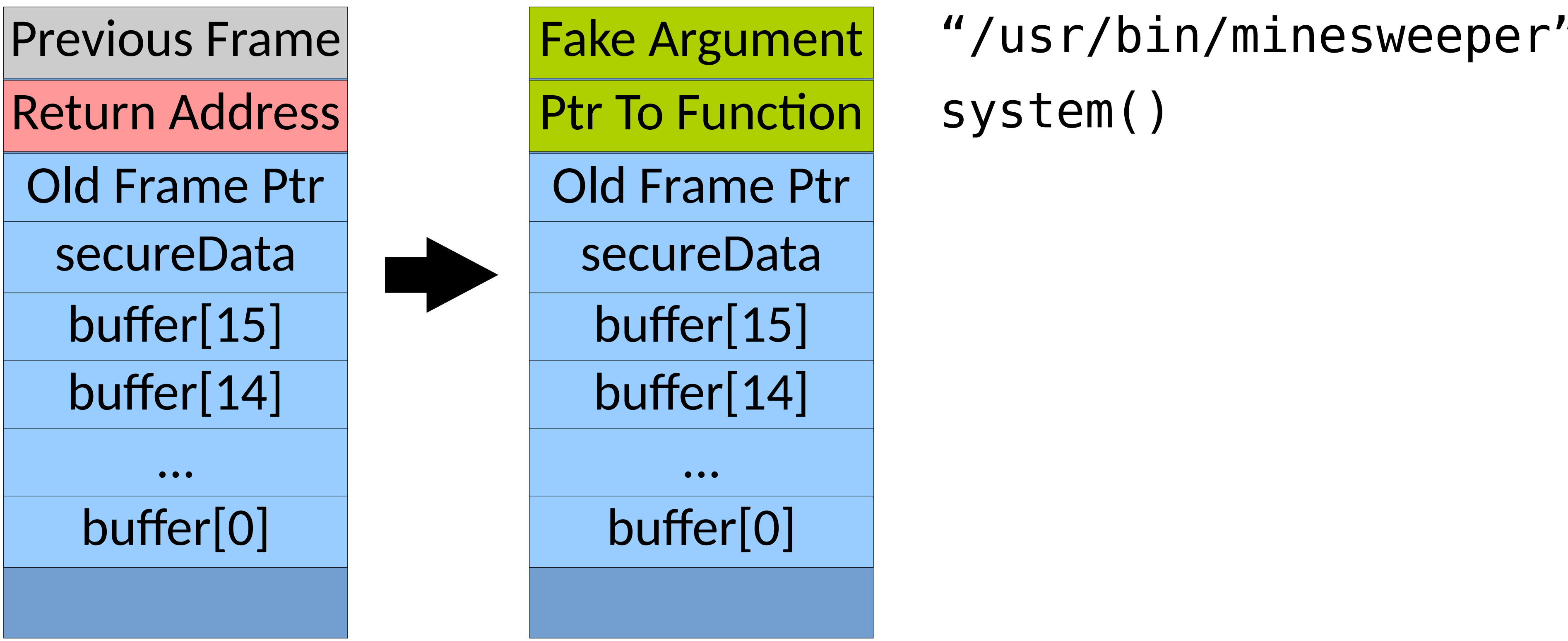

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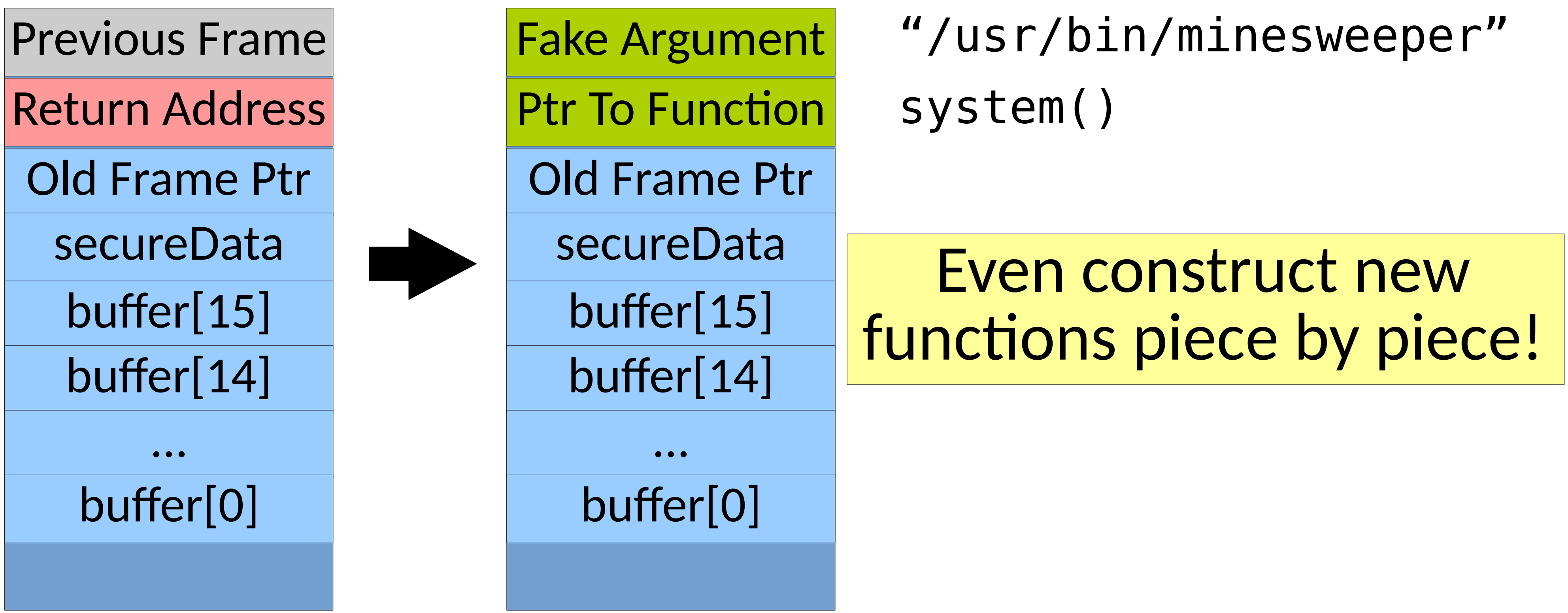

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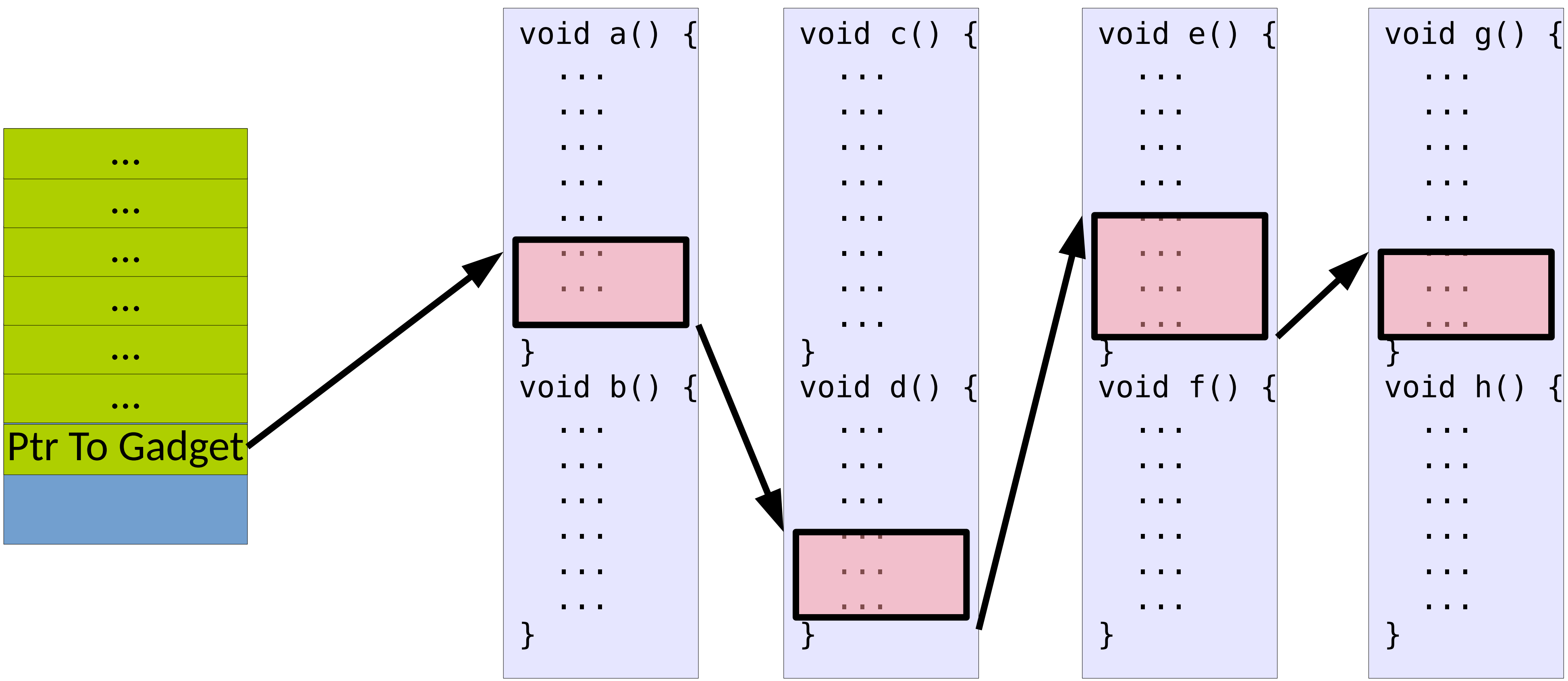

ASLR

- Address Space Layout Randomization
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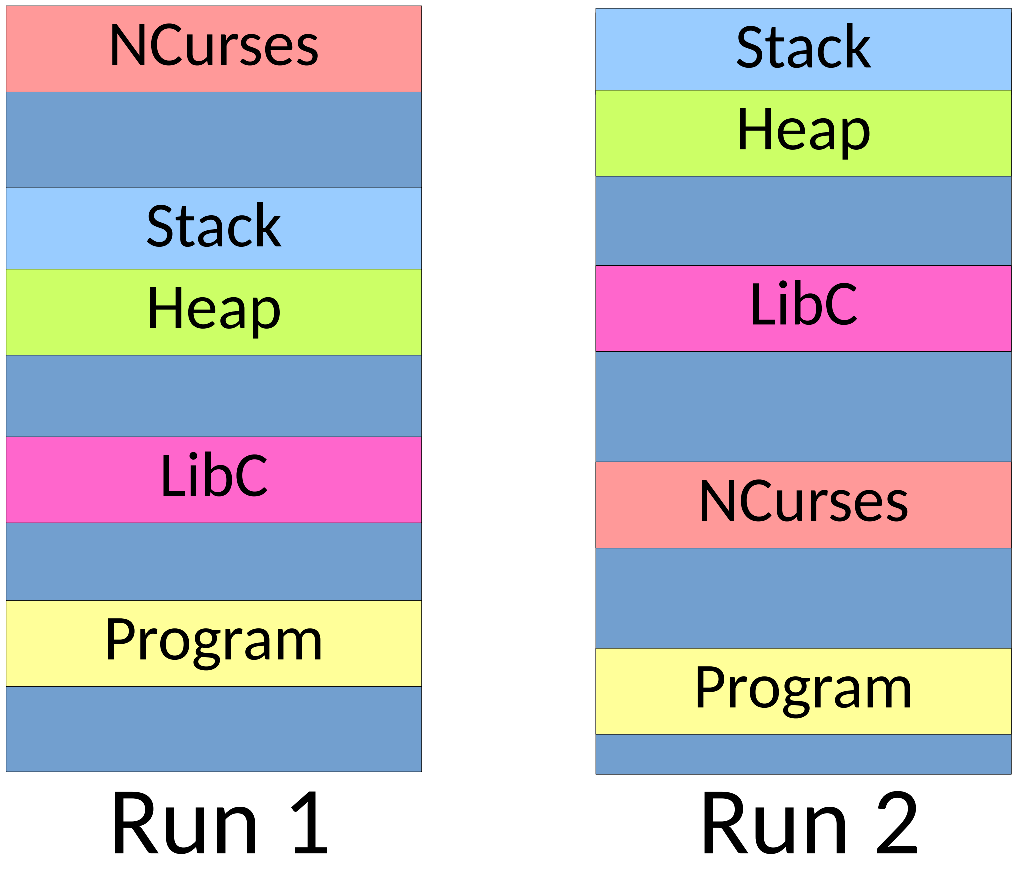

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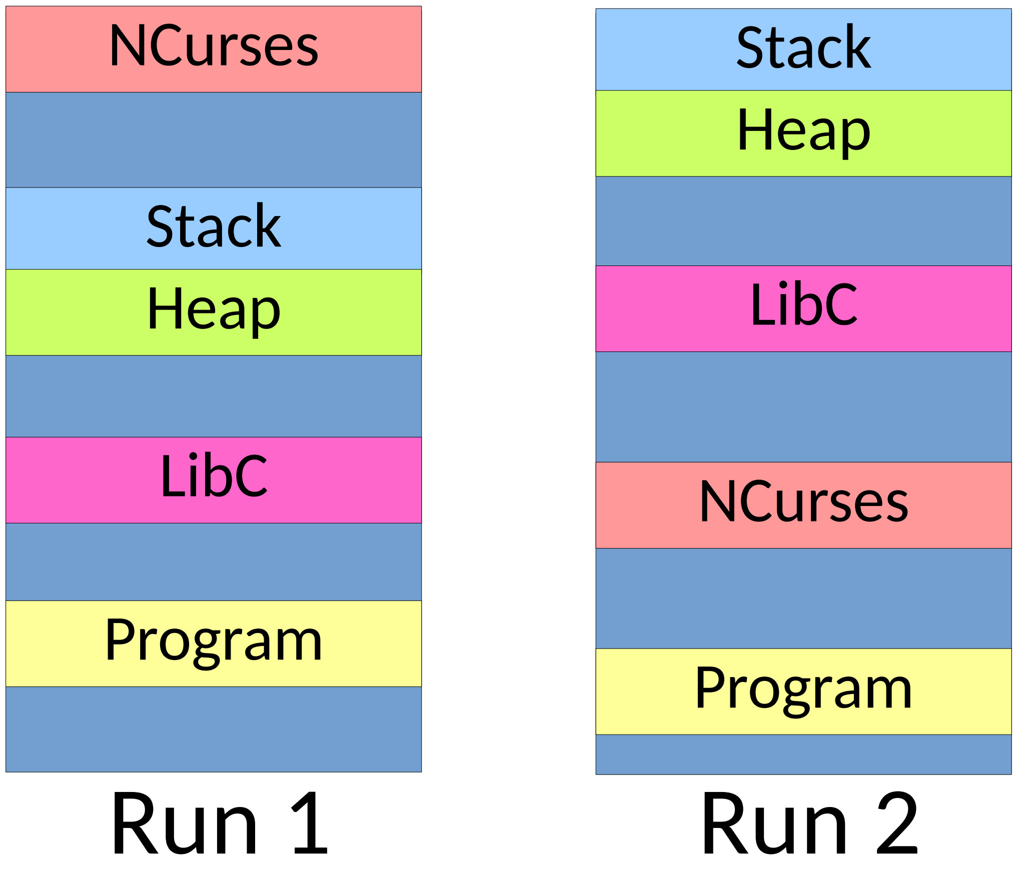

But even this is "easily" broken

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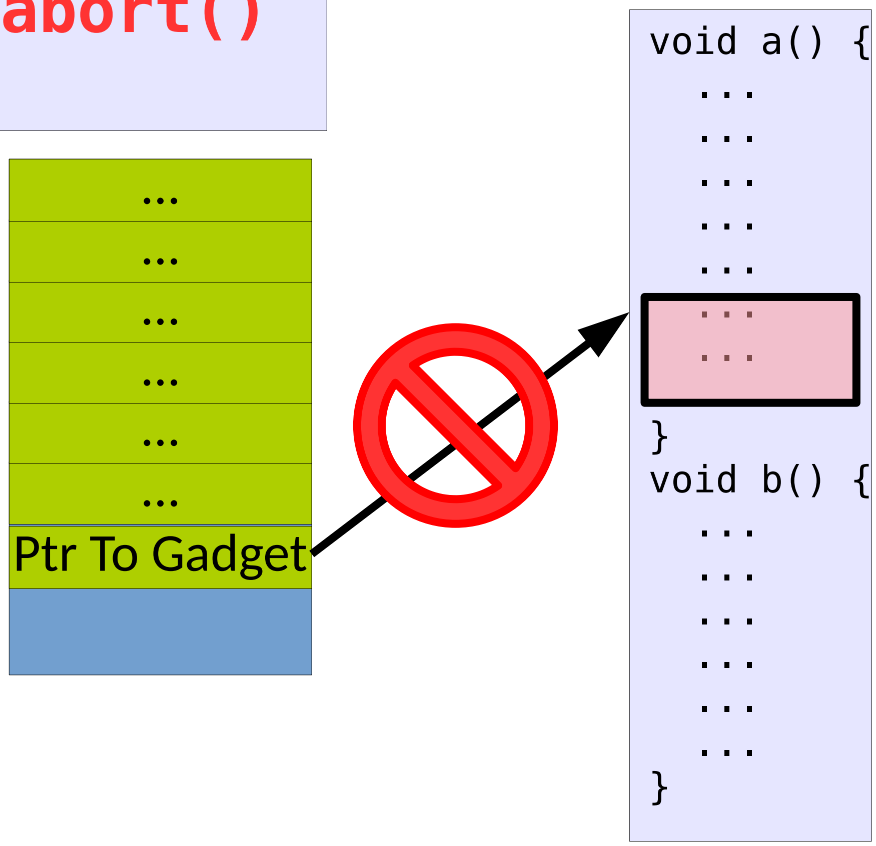

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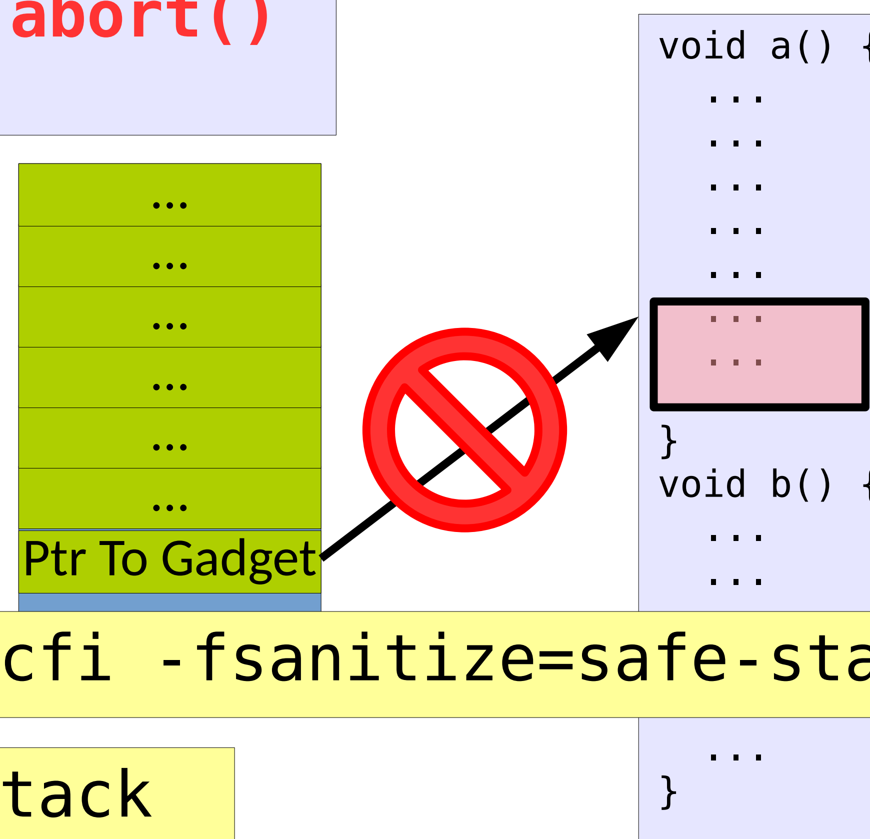


```
clang -flto -fsanitize=cfi -fsanitize=safe-stack
```

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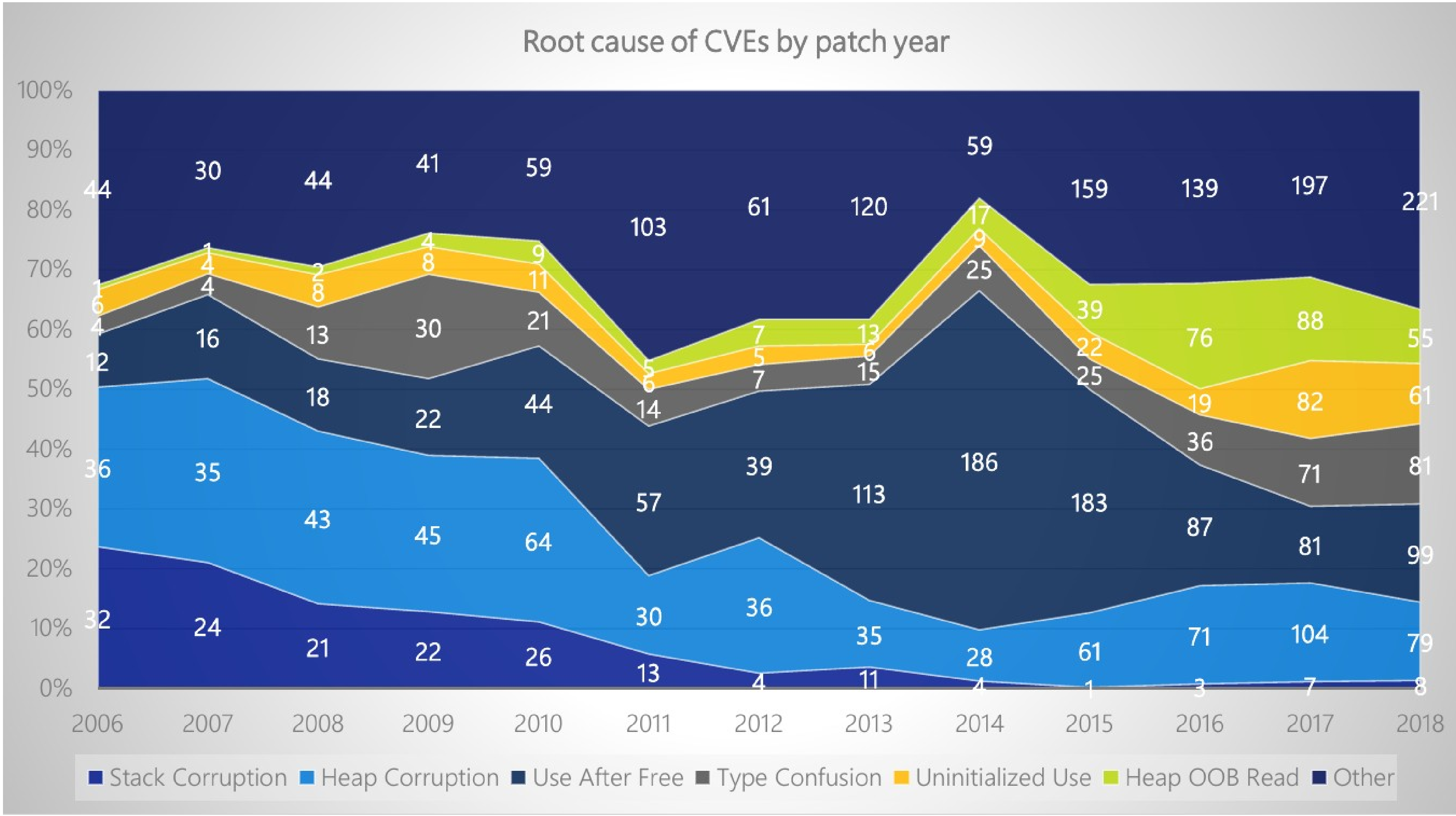
  - http://www.symantec.com/security_response/vulnerability.jsp?bid=70332
  - http://www.cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2016-0015
  - http://seclists.org/oss-sec/2016/q1/645
  - ...

Root Causes Over Time



[Matt Miller – BlueHat 2019]

Another Case: SQL Injection

SQL – a query language for databases

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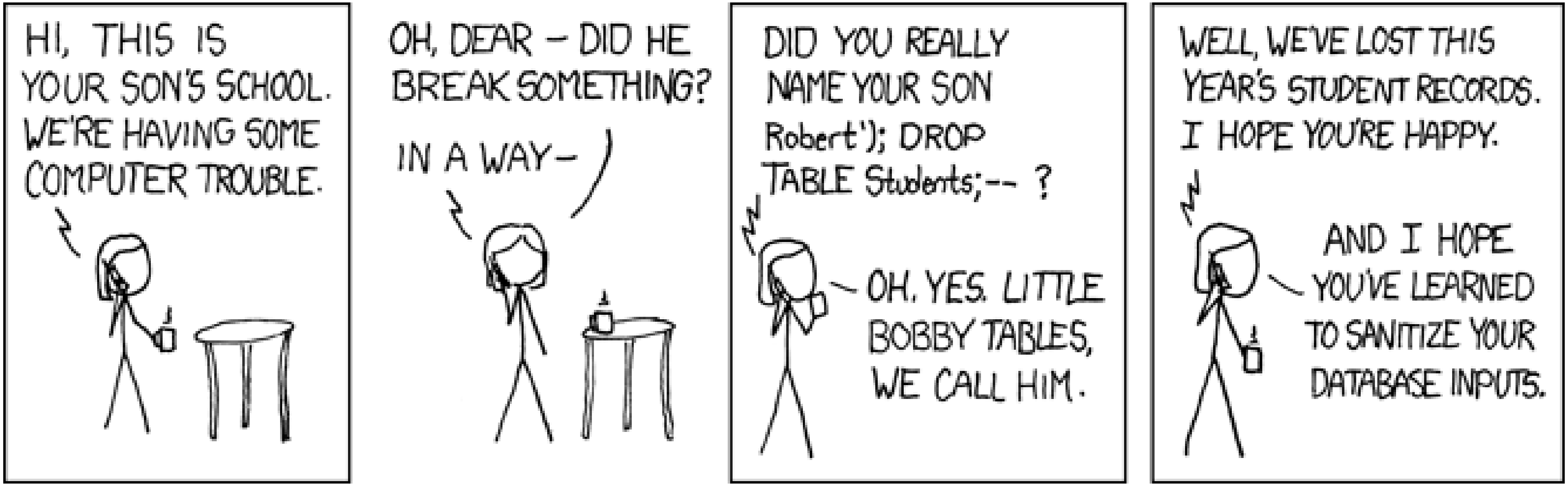
Why is this a problem?

Another Case: SQL Injection

```
username = “'bob'; DROP TABLE students”
```

- What happens?

SQL Injection



[http://xkcd.com/327/] [http://bobby-tables.com/]

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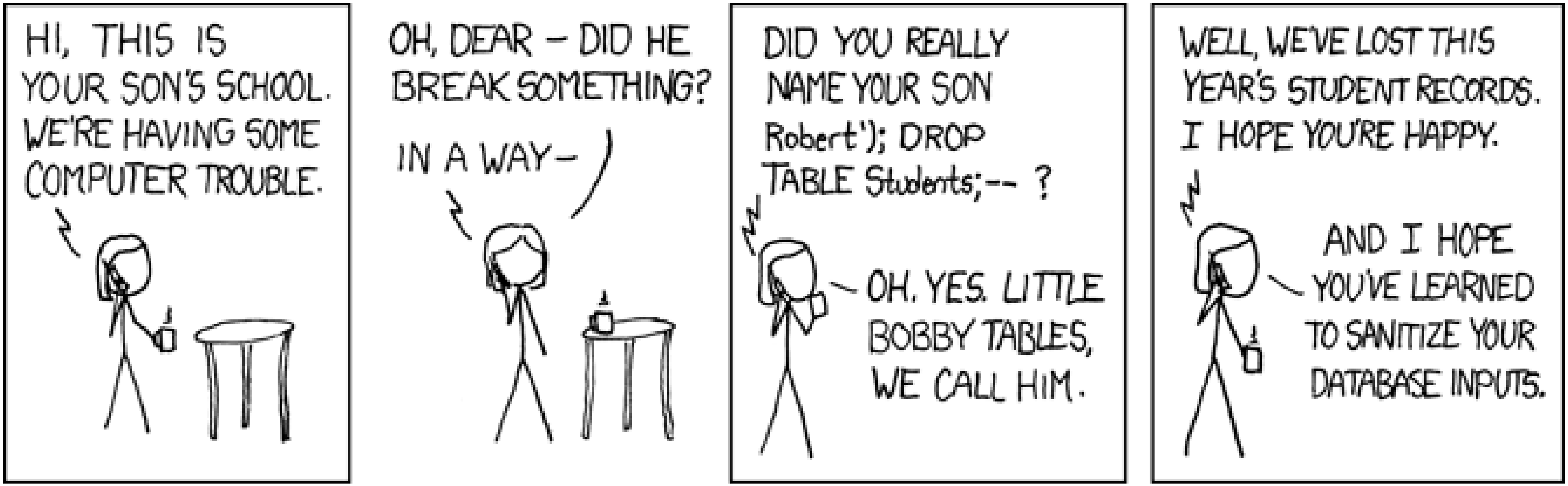
SQL Injection



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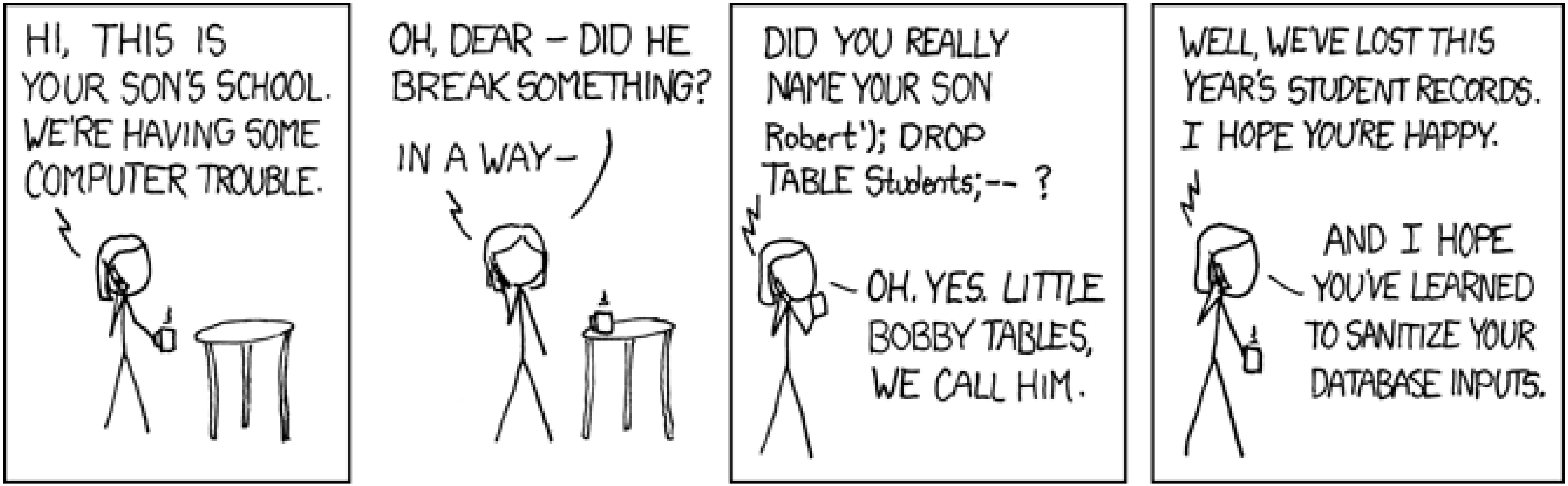

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How would you prevent this problem?

SQL Injection

- Do not write raw SQL. (examples from bobby-tables.com)

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```
List<Person>; people = //user input
Connection connection = DriverManager.getConnection(...);
connection.setAutoCommit(false);
try {
    PreparedStatement statement = connection.prepareStatement(
            "UPDATE people SET lastName = ?, age = ? WHERE id = ?");
    for (Person person : people){
        statement.setString(1, person.getLastName());
        statement.setInt(2, person.getAge());
        statement.setInt(3, person.getId());
        statement.execute();
    }
    connection.commit();
} catch (SQLException e) {
    connection.rollback();
}
```

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```
EntityManager em = getEntityManager();
Query query = em.createNativeQuery("SELECT E.* from EMP E, ADDRESS A
                                    WHERE E.EMP_ID = A.EMP_ID AND A.CITY = ?",
                                    Employee.class);
query.setParameter(1, "Ottawa");
List<Employee> employees = query.getResultList();
```

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```
String name = //user input
int age = //user input
Session session = //...
Query query = session.createQuery(
        "from People where lastName = :name and age > :age");
query.setString("name", name);
query.setInteger("age", age);
Iterator people = query.iterate();
```

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- Use abstractions that design error away if possible!
  - Applies whenever you generate code in another language (think web apps)

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  - *Side channel attacks* can infer secret information about a system based on implementation details
  - These leaks can be present even for algorithms that are mathematically correct
  - Leaks can come from:
    Output, Timing (compute, cache, MDS,…), Power, Sound, Light, …

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- Consider code that directly leaks a sensitive boolean

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    …
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  - The ***value*** of the sensitive information can be inferred by the ***existence*** of the nonsensitive information!

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This has been the downfall of crypto implementations!

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def subtly_bad(greeting, sensitive):
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    if sensitive:
        expensive_computation()
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```

```
def deviously_bad(greeting, sensitive):
    …
    if sensitive:
        a[not_in_cache] = …
    log_to_nonsensitive(greeting)
    …
```

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The sensitive data is speculatively read and used!

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2) train the branch to speculate true
3) extract the data through a 1-hot encoding in the time to access elements of array2 (or a buffer sharing the cache mapping of array2)

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# foo is a function pointer
foo()
```

Foo can be trained to speculate to an arbitrary gadget!

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Return targets can be trained to speculate to gadgets!

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Note: This means that ROP gadgets can once again be used!
Newer compiler options can mitigate but not remove the challenge

[Speculative Load Hardening in LLVM] clang -mretpoline -mspeculative-load-hardening ...

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  - MDS attacks leverage other CPU artifacts to achieve similar goals (line buffers, ports, etc.)
    - Contention on any resource affects timing

A Subtle Problem in General

- The problems may be much more subtle:

  User A can read files X,Y,Z and write to S,T
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Can you envision a scenario
that creates this problem?

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- Care may be required to enforce *access control policies*
  - Discretionary access control – owner determines access
  - *Mandatory* access control – clearance determines access

Assuring Security

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  - e.g. Google Checkout, PayPal, Amazon, etc.

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  - Apple secure coding policies
  - CERT Top 10 Practices
  - Mitre Mitigation Strategies

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- Formal certification
- Follow established security workflows (OWASP, BSIMM, ...)

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  - Prepared Statements, Safe Arrays, etc.
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  - Retrospective analysis & suggestions
- Penetration testing (Pen Testing)
  - Can someone skilled break it?

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  - e.g. Google standard 90 day window
    7 month window for Spectre due to severity
    …

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Not planning for security concerns from the beginning is a broken approach to development