Lecture 4: Principles of Security

CS 181S

Spring 2024

Assurance

- **Security** = does what it should + nothing more
- This should be accompanied by an **assurance argument**, which is some compelling basis to believe the system is secure.

Axiomatic Trust

Analytic Trust

Synthetic Trust

- The set of system components that you have to trust in order for your security goals to be satisfied is called the **Trusted Computing Base (TCB)**

Principle: Economy of Mechanism

Prefer mechanisms that are simpler and smaller

- Easier to construct, understand, analyze
- Hence less likely to have unknown vulnerabilities

- TCB should be small

Assumptions

- Attacker cannot replace/modify mechanism
- Attacker cannot circumvent mechanism

Enforcement Mechanisms

- An enforcement mechanism must either
  1) prevent the execution of those instructions or
  2) eliminate or mitigate the effects of those instructions

- Possible approaches to enforcement:
  1) Isolation
  2) Monitoring

Isolation

- Key idea: prevent or restrict the ability of one principal to influence execution by another

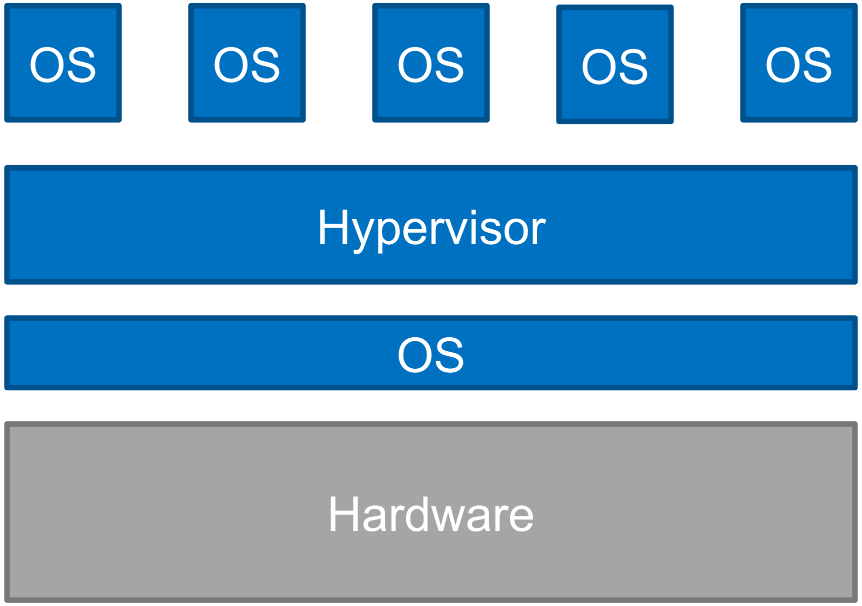
Isolation: Physical Isolation

- A Faraday cage is an enclosure made of conductive material or mesh
- The external electrical field causes electric charges to be distributed in a way that cancels out the field's effect on the interior
- This effectively blocks any sort of electromagnetic radiation
- US gov/military use rooms inside Faraday cages, called SCIFs, to hold classified meetings

Isolation: Virtual Machines

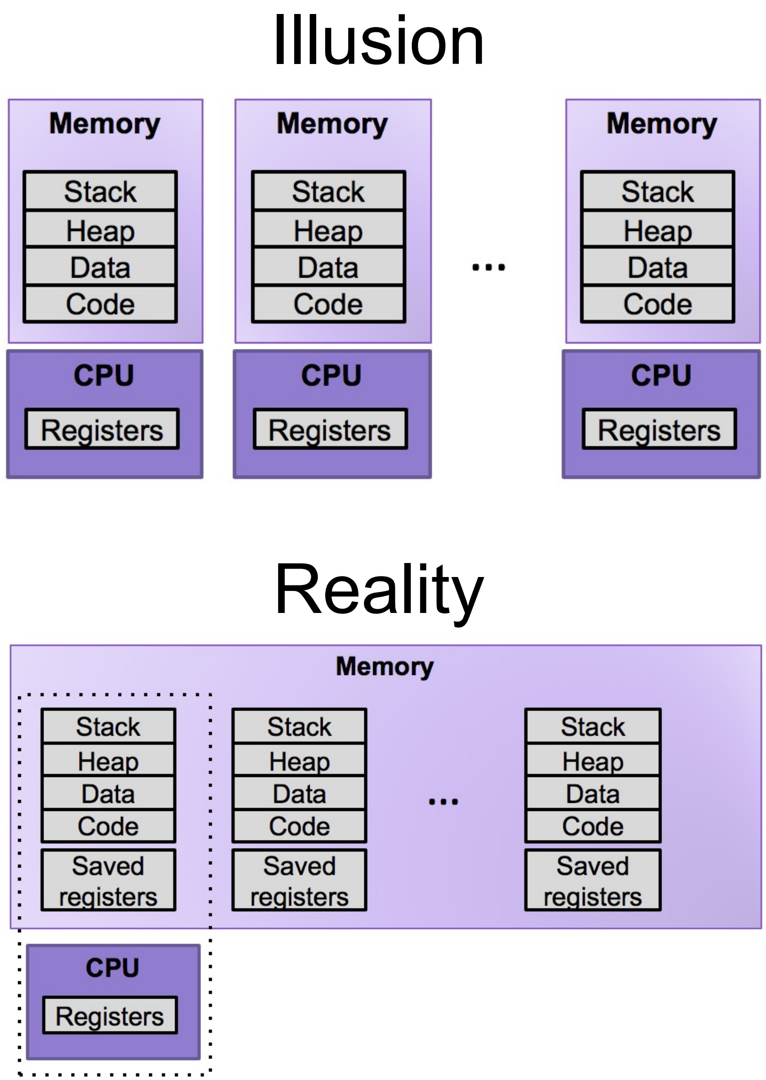
- A virtual machine behaves as if it were an isolated computer despite other execution on the underlying hardware

- A hypervisor implements virtual machines that have the same instruction set as the underlying hardware



Isolation: Processes

- The OS kernel multiplexes the actual processor and creates a set of processes
- Each process executes in its own isolated address space
- Kernel-supported instructions provide access to system services and shared resources



Isolation: Sandboxes

- A sandbox runs an application in a restricted environment
- Example: in Chrome, the entire HTML rendering and JavaScript execution is sandboxed (cannot access files or windows outside the current job, cannot read/write to clipboard)

Partial Isolation: Firewalls

- Idea: just enough isolation to block communications used for attacks
- A firewall interrupts the connection from some group of computers to some network
- It is configured to pass only certain messages (e.g., those to specific ports or from particular sources)

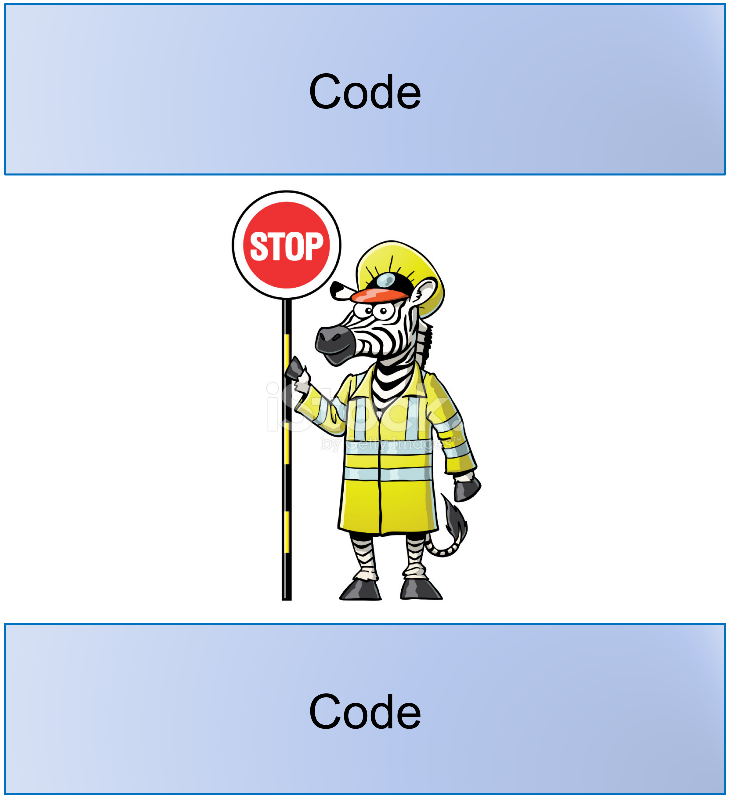
Partial Isolation: Code Signing

- Only code that is digitally signed by a trusted principal is allowed to execute
- Example: Microsoft Authenticode protects against web pages containing malicious executable content by only allowing downloaded content to be executed if it was produced by Microsoft or a Microsoft-approved software provider

Monitoring

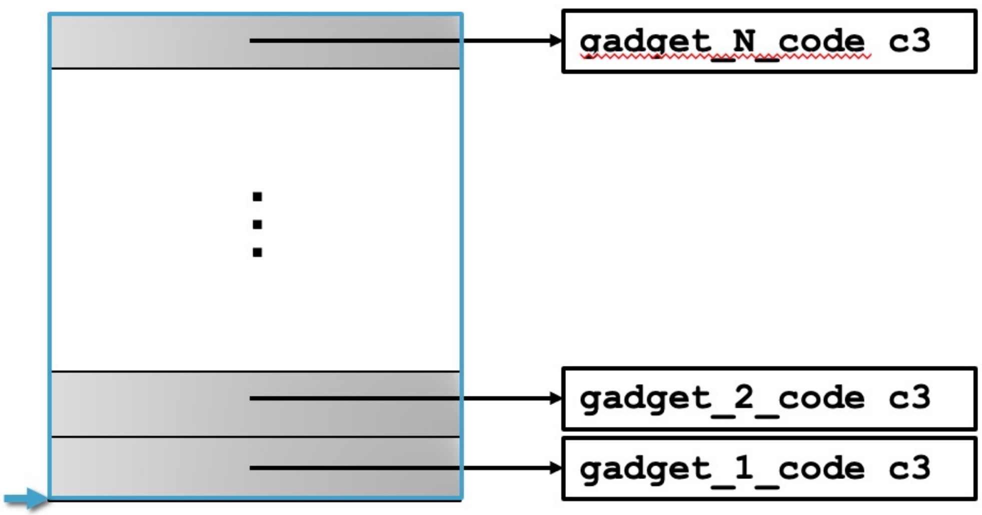
- Key idea: monitor a set of interfaces and halt malicious execution before any damage is done

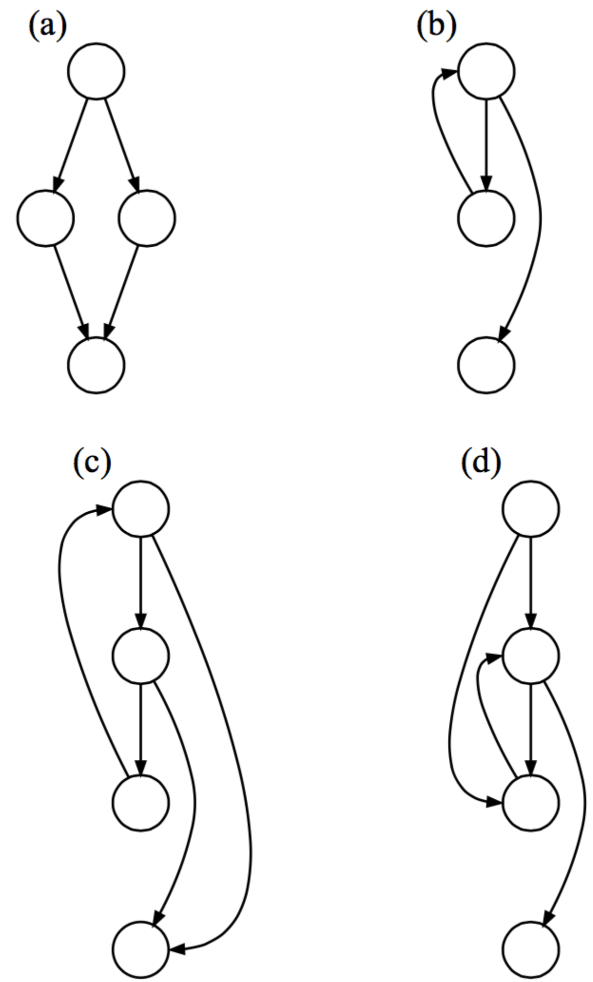
- a **security policy** that describes acceptable sequences of operations
- a **reference monitor** that receives control whenever operations are requested
- a means by which the reference monitor can **block** further execution that does not comply with the policy



Monitoring: Control Flow Integrity

```
<setval>:
4004d9: c7 07 d4 48 89 c7  movl $0xc78948d4,(%rdi)
4004df: c3                 ret
```

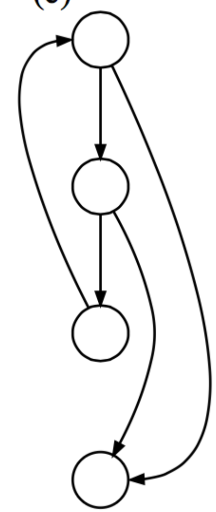




Monitoring: Control Flow Integrity

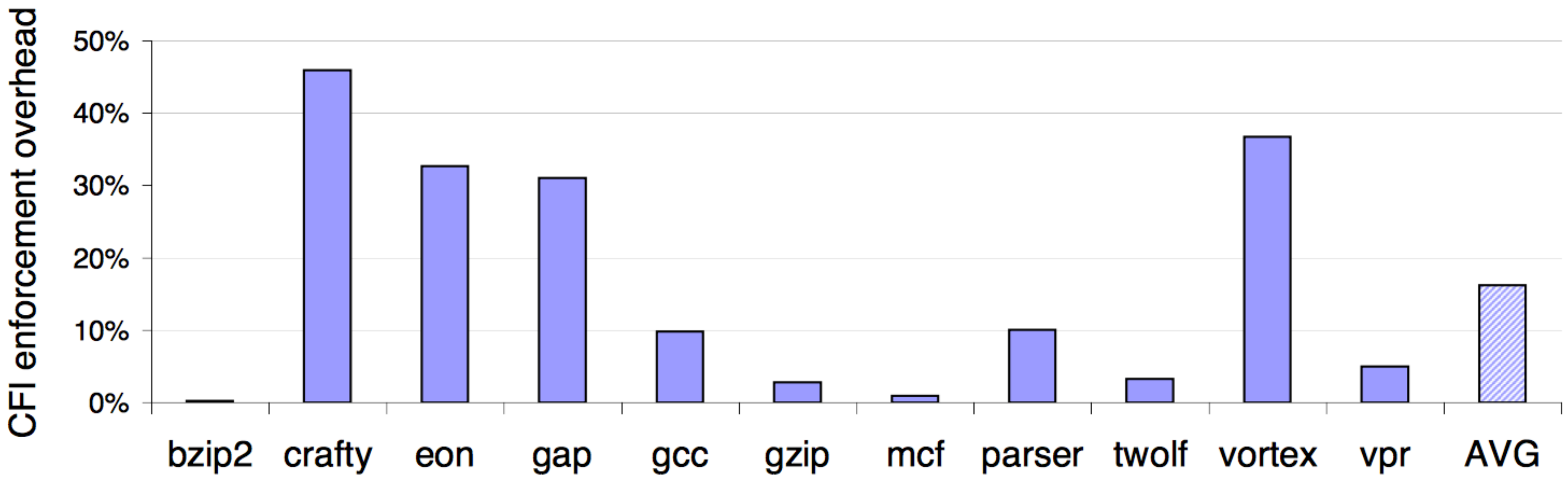
Code

(c)



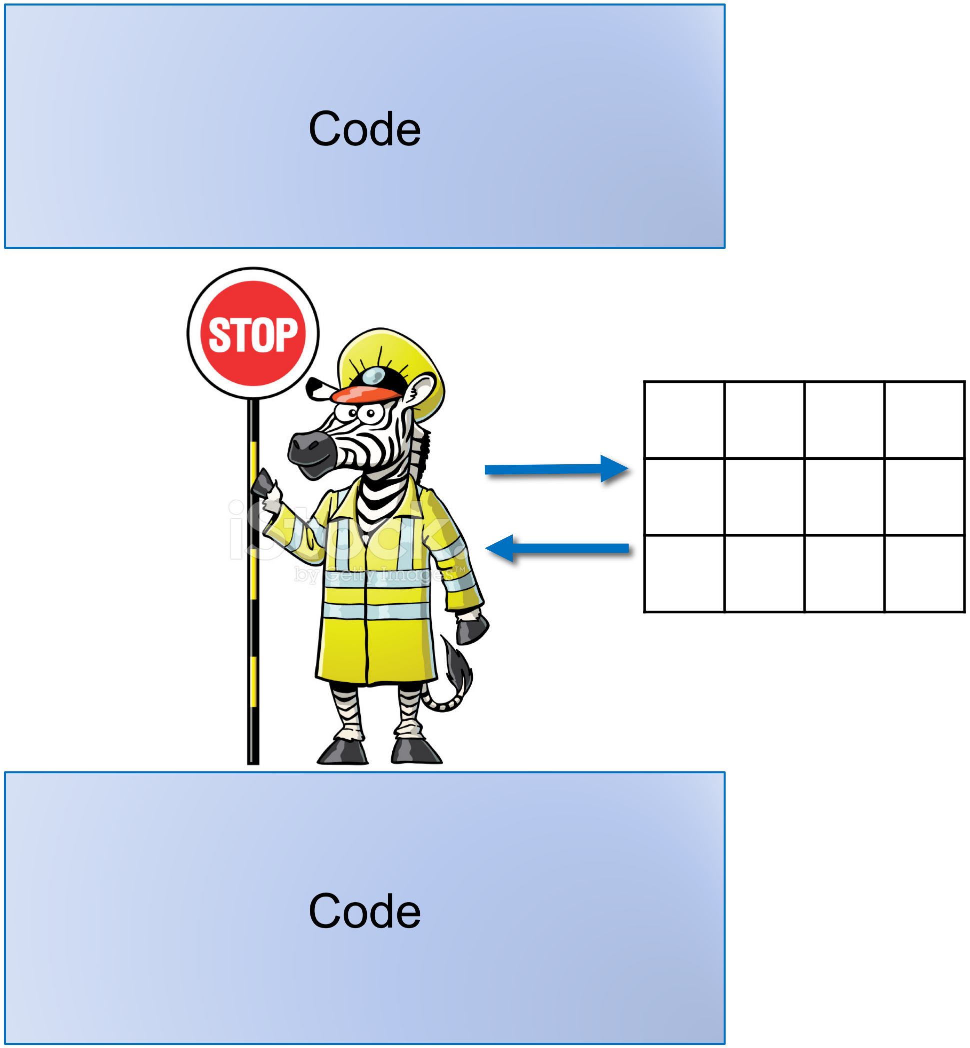
Code

Monitoring: CFI Overhead

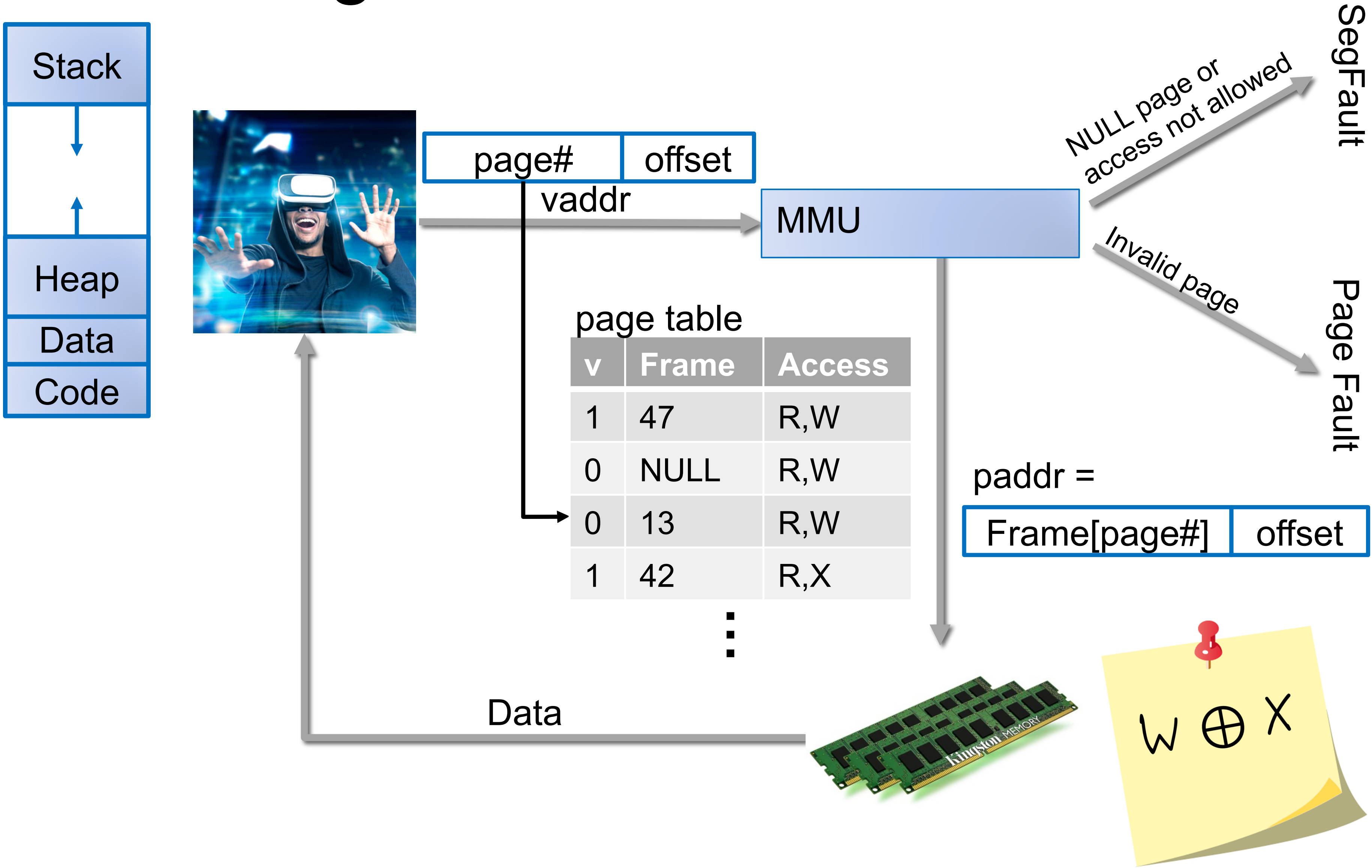


Monitoring: Control Flow Guard

- Approximate CFI implementation introduced in Windows 8.1
- Jump is valid if it beginning of function
  - Granularity: 8 bytes
- Check implemented as bitmap



Monitoring: Address Translation



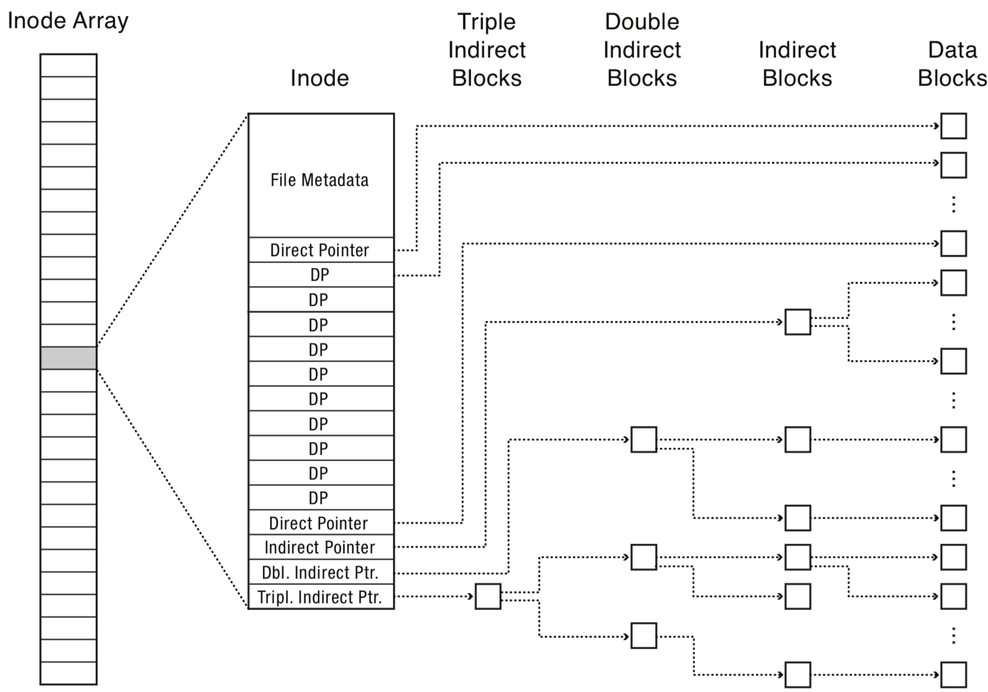
page table

v	Frame	Access
1	47	R,W
0	NULL	R,W
0	13	R,W
1	42	R,X

⋮

Monitoring: File Access Control

- inode for each file stores permission bits (r, w, x)
- Operating system enforces access control when file is is opened
- Error if principal is not authorized



Principle: Complete Mediation

Every operation requested by a principal must be intercepted and determined to be acceptable according to the security policy

- Component that does the interception and determination is the reference monitor
- Restricts caching of information, including previous decisions

Exercise 1: Complete Mediation

- Consider the security mechanisms deployed in your dorm.
  These systems are designed to prevent access by unauthorized people.

  - To what extent do those security features enforce Complete Mediation?

Principle: Least Privilege

Principals should be given the minimum privileges necessary to accomplish their task

- Limits the damage that can result from accident or malice
- Cf. "need to know"

Exercise 2: Least Privilege

- Consider the security mechanisms deployed on campus.
  These systems are designed to prevent access by unauthorized people.

  - To what extent do those security features enforce Least Privilege?

Principle: Separation of Privilege

- Different operations should require different privileges
- Disseminate privileges for an operation amongst multiple principals (Separation of Duty)

```
drwxr-xr-x   5 eleanor  staff     160 Mar 21 12:14 .
drwx------+ 54 eleanor  staff    1728 Mar 21 09:45 ..
-rw-r--r--@  1 eleanor  staff   98971 Mar 21 05:15 download.png
-rwxr-xr-x   1 root     wheel  103632 Mar 21 12:14 java
-r--------@  1 eleanor  staff    2085 Mar 21 12:07 rsa-demo.pem
```

Principle: Failsafe Defaults

Base decisions on the presence of privilege, not the absence of prohibition

- The default answer is "no"
- Say "yes" only when there is an explicit reason to do so
- Principals who discover they don't have access will complain
- Attackers who discover they do have access won't complain!

Principles of Prevention

[Saltzer and Schroeder, *The Protection of Information in Computer Systems*, 1975]

- Accountability
- Complete Mediation
- Least Privilege
- Failsafe Defaults
- Separation of Privilege
- Defense in Depth
- Economy of Mechanism
- Open Design

Principle: Defense in Depth

Prefer a set of complementary mechanisms over a single mechanism

Complementary:

- **Independent:** attack that compromises one mechanism is unlikely to compromise others
- **Overlapping:** attacks must compromise multiple mechanisms to succeed

Exercise 3: Defense in Depth

- Consider the security mechanisms deployed on campus.
  These systems are designed to prevent access by unauthorized people.
  - To what extent do those security features satisfy the overlapping requirement of Defense in Depth?
  - How could the security features be modified to add defense in depth if it does not already exist?

Principle: Open Design

Security shouldn't depend upon the secrecy of design or implementation

DVD™

```
/*     efdtt.c     Author:  Charles M. Hannum <root@ihack.net>            */
#define m(i)(x[i]^s[i+84])<<
unsigned char x[5],y,s[2048];main(n){for(read(0,x,5);read(0,s,n=2048);write(1,s
,n))if(s[y=s[13]%8+20]/16%4==1){int i=m(1)17^256+m(0)8,k=m(2)0,j=m(4)17^m(3)9^k
*2-k%8^8,a=0,c=26;for(s[y]-=16;--c;j*=2)a=a*2^i&1,i=i/2^j&1<<24;for(j=127;++j<n
;c=c>y)c+=y=i^i/8^i>>4^i>>12,i=i>>8^y<<17,a^=a>>14,y=a^a*8^a<<6,a=a>>8^y<<9,k=s
[j],k="7Wo~'G_\216"[k&7]+2^"cr3sfw6v;*k+>/n."[k>>4]*2^k*257/8,s[j]=k^(k&k*2&34)
*6^c+~y;}}
```

Principle: Open Design

Security shouldn't depend upon the secrecy of design or implementation

Arguments for open design:

- Secrets eventually come out: reverse engineering is possible, employees move around
- Making details public increases chance of identifying and repairing vulnerabilities

Principle: Open Design

Security shouldn't depend upon the secrecy of design or implementation

Arguments against open design:

- Secrecy supports Defense in Depth by making it harder to find vulnerabilities
- Lack of hard evidence that Linus' Law really holds ("given enough all eyeballs, all bugs are shallow")
- After identification, some vulnerabilities cannot quickly or easily be repaired

Exercise 4: Defense in Depth

Consider the security mechanisms deployed on campus.

To what extent do these defenses implement open design?

Exercise 4: Open Design

- Briefly (1-2 sentences) argue why you believe a system should or should not follow the principle of open design.

Countermeasures

A defense that protects against attacks by neutralizing either the threat or vulnerability involved

Strategy:

- Prevent: block attack or close vulnerability — Prevention
- Deter: make attack harder
- Deflect: make other targets more attractive
- Mitigate: make harm less severe
- Detect: as it happens or after the fact
- Recover: undo harm

Deter, Deflect, Mitigate — Risk Management

Detect, Recover — Deterrence through Accountability

Priniciples of Security

"Security is lax on this side."