CSCI 1800 Cybersecurity and International Relations

Engineering for Security

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Outline

- Security modeling including access control
- Federal security regulations and standards
- Software vulnerability assessments
- Microsoft's Security Development Lifecycle
- Introduction to Threat Analysis
- Security can be violated even if code is perfect

Policy, Models and Trust

- To have secure systems, engineers need
  - Clear security goals
  - Effective implementation strategy

- A security policy puts constraints on actions that can taken by actors on objects in the system in order to achieve security goals.

Components of a Security Policy

- Actors
  - Individual or group agents interacting with a system.
- Objects
  - Informational/computational resources affected by policy.
- Actions
  - Possible modifications to objects, e.g. read, edit, copy, remove
- Permissions
  - Rules constraining actions that actors may take on objects.
- Protections
  - Policy features, e.g confidentiality, integrity, availability (CIA)

What is a Security Model?

- A security model is an abstraction providing conceptual language to specify security policies.
  - E.g. Unclassified (U), Confidential (C), Secret (S), Top Secret (TS)
  - Compartments for sensitive compartmentalized information (SCI), such as human intelligence (HUMINT), satellite observations (GEOINT), signals intelligence (SIGINT)
  - Why are these compartments sensitive?

Two Models of Access Control

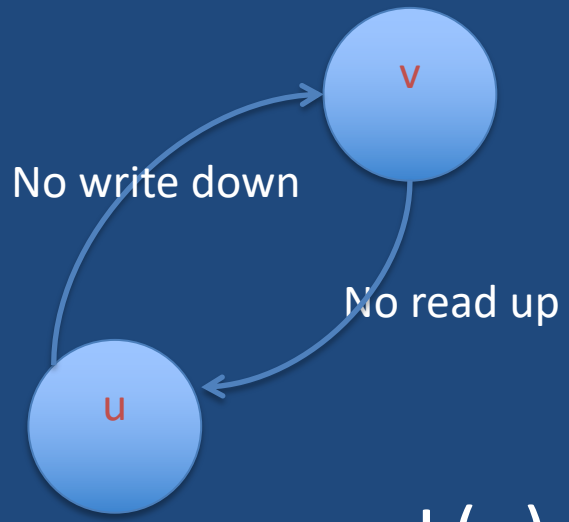
- Discretionary access control
  - Owner may specify permissions on files
  - A more relaxed form of control
- Mandatory access control
  - Administrator fixes permissions in advance.
  - More strict control
- Rules have subjects (parties requesting access) and objects (those things being accessed).

Bell-LaPadula (BLP) Access Control Model

- Next slide describes this slide graphically
- Applies to confidentiality – dates from the 1970s
- Object x and user u have security levels L(x) & L(u)
  - Some security levels: Unclass, Class, Secret, TopSecret
- For users u and v, v has higher clearance than u if L(u) ≤ L(v). u can pass info to v but not vice versa.

- No "read up" (user can't see more secure data)
  - User u can read x only if L(x) ≤ L(u)
- No "write down" (user can't use more secure data)
  - User u can write to object x only if L(u) ≤ L(x).

BLP Access Control Model



$L(u) \leq L(v)$

BLP model weakness: only handles confidentiality

Ken Biba ('77) Access Control Model

- Goal of Biba's model is to maintain data integrity:
  - i.e. data accuracy & consistency of data over its life-cycle.
- Let $\mathrm{I}(x)$ and $\mathrm{I}(u)$ be the integrity of user u & object x
  - The larger is $\mathrm{I}(u)$ or $\mathrm{I}(x)$ the more trustworthy is the user u or accurate the object x.
- Don't read from lower integrity level
  - User u can read object x only if $\mathrm{I}(u) \leq \mathrm{I}(x)$.
- Don't write to higher integrity level.
  - User u can write to object x only if $\mathrm{I}(x) \leq \mathrm{I}(u)$.

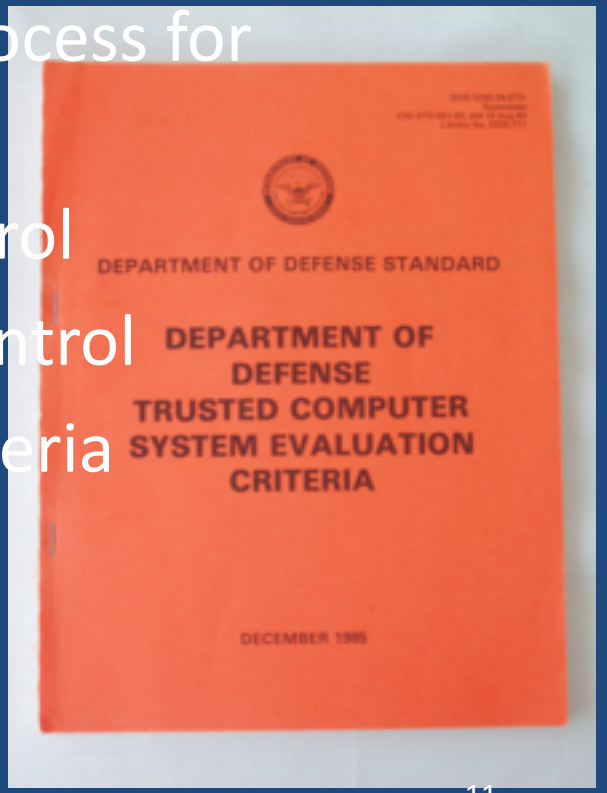
What is Role-Based Access Control?

- Components: users, roles, permissions, sessions
  - A role is a collection of users.
  - A session is an interaction for a period of time.
- Role hierarchy is defined, as in a corporation.
  - President IsA manager IsA employee
  - Higher role user inherits permissions of lower one
  - When is this not a good idea?

    Should the CEO be allowed to fix to an IT problem?
- Role constraints may be imposed
  - Example: avoid conflicts of interest.

Early USG Security Standards

- Trusted Computer System Evaluation Criteria, aka Orange Book – issued by DoD in 1983, 1985
  - Division A: system has a formal process for verification of security
  - Division B: mandatory access control
  - Division C: discretionary access control
  - Division D: minimal protection criteria



Newer USG Security Standards

- Common Criteria for Information Technology Security Evaluation – an ISO standard
  - It subsumes the Orange Book
  - Defines key concepts related to security evaluations
  - Framework for documenting security goals
  - Not a certification vouching for product security.

USG Regulations

- HIPAA (1996)
  - Sets privacy standards on patient records for healthcare providers and employers.
- Family Educational Rights and Privacy Act (FERPA) (‘74)
  - Requires protection of privacy of educational records in US
- Federal Information Security Management Act (FISMA)
  - Revised in 2014 – regulates government information security.
  - It requires federal agencies to implement processes and controls designed to ensure the confidentiality, integrity, and availability of system-related information.
  - Must follow FISMA and NIST standards, and legislative requirements , such as the Privacy Act of 1974.

Software Vulnerability Assessment

- The problem: software can be enormous
  - Mac OS X 10.4 has > 86 million lines of code!
  - Code can have both performance & security bugs

- "A vulnerability is a security exposure that results from a product weakness … the product developer did not intend to introduce and should fix once it is discovered." – Microsoft definition

How Many Errors are Tolerable?

- How many errors per 1,000 lines of code (KLOC)?
  - Estimates vary from 15-50 defects per KLOC
  - MSFT gets bug density of ½ bug/KLOC in production*

* https://labs.sogeti.com/how-many-defects-are-too-many/

Types of Vulnerability Assessment

- Black-box analysis
  - Penetration test (pentest) done without knowledge of innards.
  - Pentests look for security vulnerabilities
- White-box analysis
  - Same but with full knowledge of hardware/software, network environment, etc.

Code Analysis for Privacy/Security

- Goal: Find and remove privacy/security hazards.
- Good analysis requires training and investment
  - Software engineers generally need education on this.
  - Microsoft's Security Development Lifecycle (SDL) represents a big step forward.
- Benefits: Improved security, privacy and reliability.

Two Approaches to Code Analysis

- Static code analysis studies source code, that is, the text of programs.
  - This is an example of white-box testing.

- Dynamic analysis examines running programs.

Components of Static Code Analysis*

- Data Flow Analysis
  - Does analysis of basic blocks (next), sections of code in which control stays within a block during execution
- Control flow graph (CFG)
  - Shows all possible control paths, i.e. paths through code
- Taint analysis
  - A variables touched by a user is “tainted.”
  - How do tainted variables affect the CFG and actions?

* https://www.owasp.org/index.php/Static_Code_Analysis

Example of a Basic Block

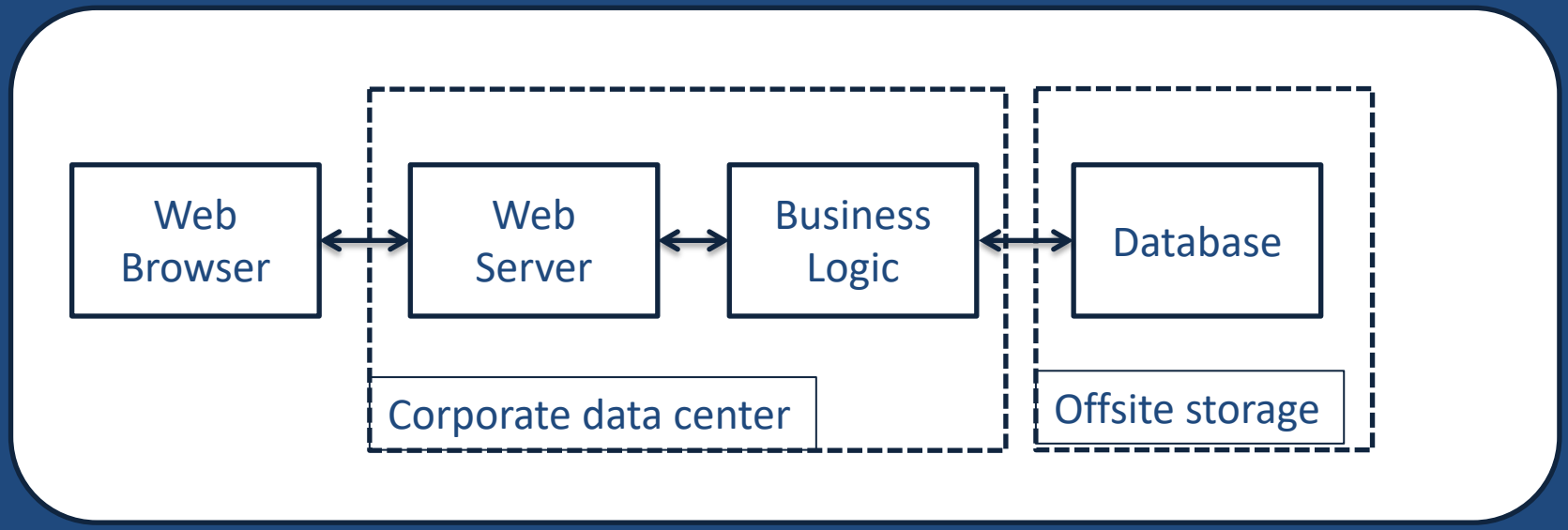
```
$a = 0;
$b = 1;

if ($a == $b)
{ # start of block
   echo “a and b are the same”;
} # end of block
else
{ # start of block
  echo “a and b are different”;
} # end of block
```

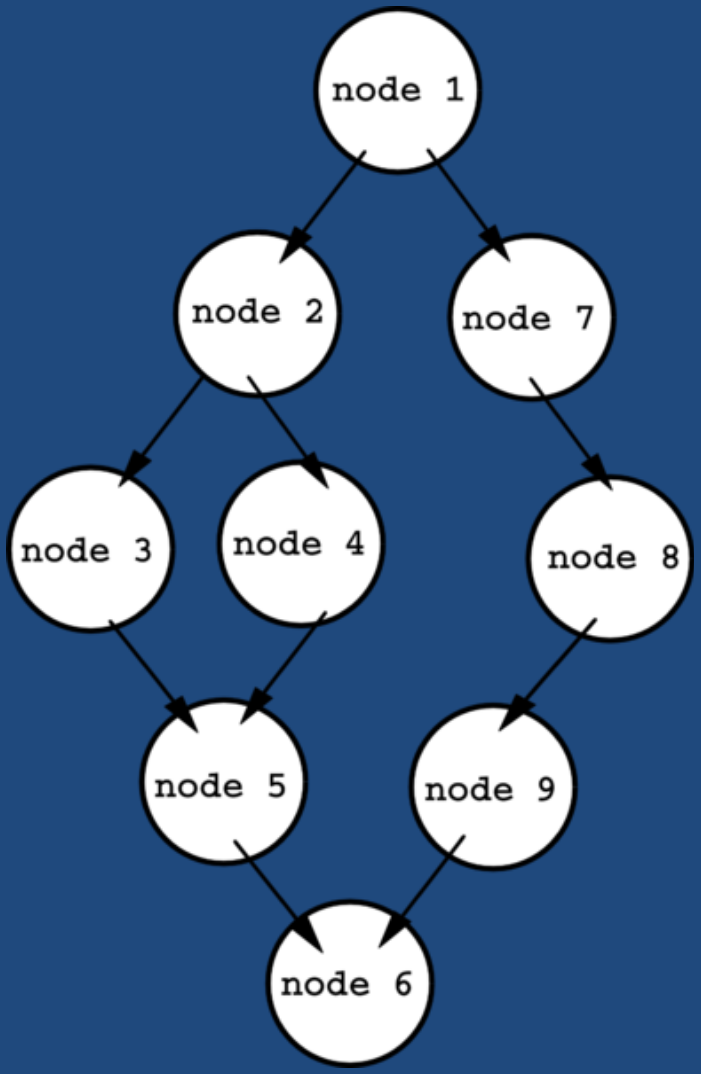
Note: # starts a comment

Modeling System Threats

- *Data flow analysis* is preferable to focusing on assets or studying motivations of attackers.
- Group components by trust boundaries, 3 below



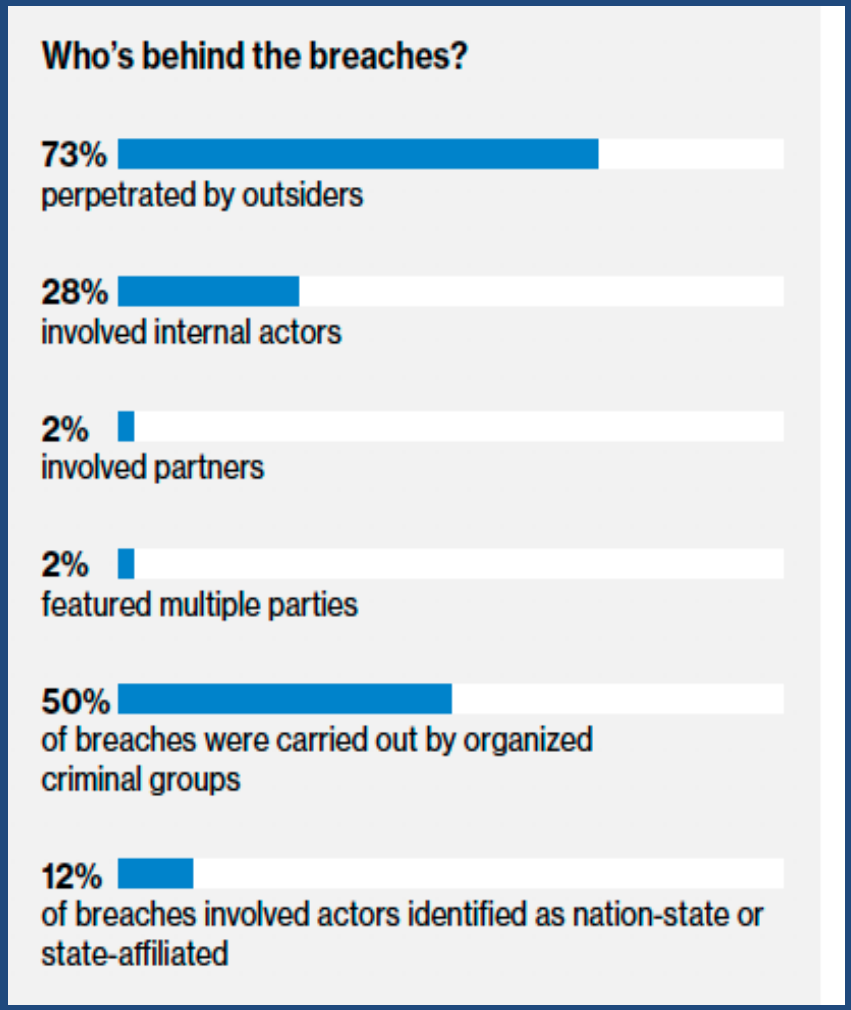
Control Flow Graph



Dynamic Code Analysis

- Good analysis explores all important paths
  - Good choice of test data will exercise more paths
  - Incomplete testing can result in catastrophic failure
- Fuzzing can reveal hidden errors. What is it?
  - Run code on virtual machine – no damage from crash
  - Try inputs of length 1, 2, 3, … until crash, maybe
  - Note: malware may detect it is being run in a virtual machine and not exhibit its malicious behavior

2018 Verizon Data Breach Report*



Source: 444 x 10^6 malware detections
Organizations: 130,000
22 = Median number malwares/org/year

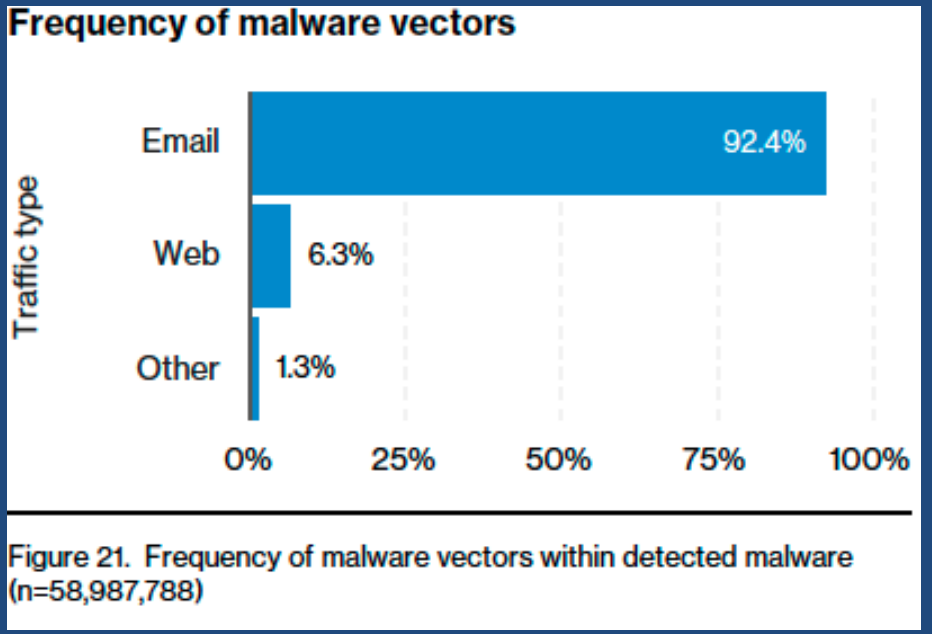


Figure 21. Frequency of malware vectors within detected malware (n=58,987,788)

* Verizon Data Breach Digest, 2018, http:// verizonenterprise.com/DBIR2018

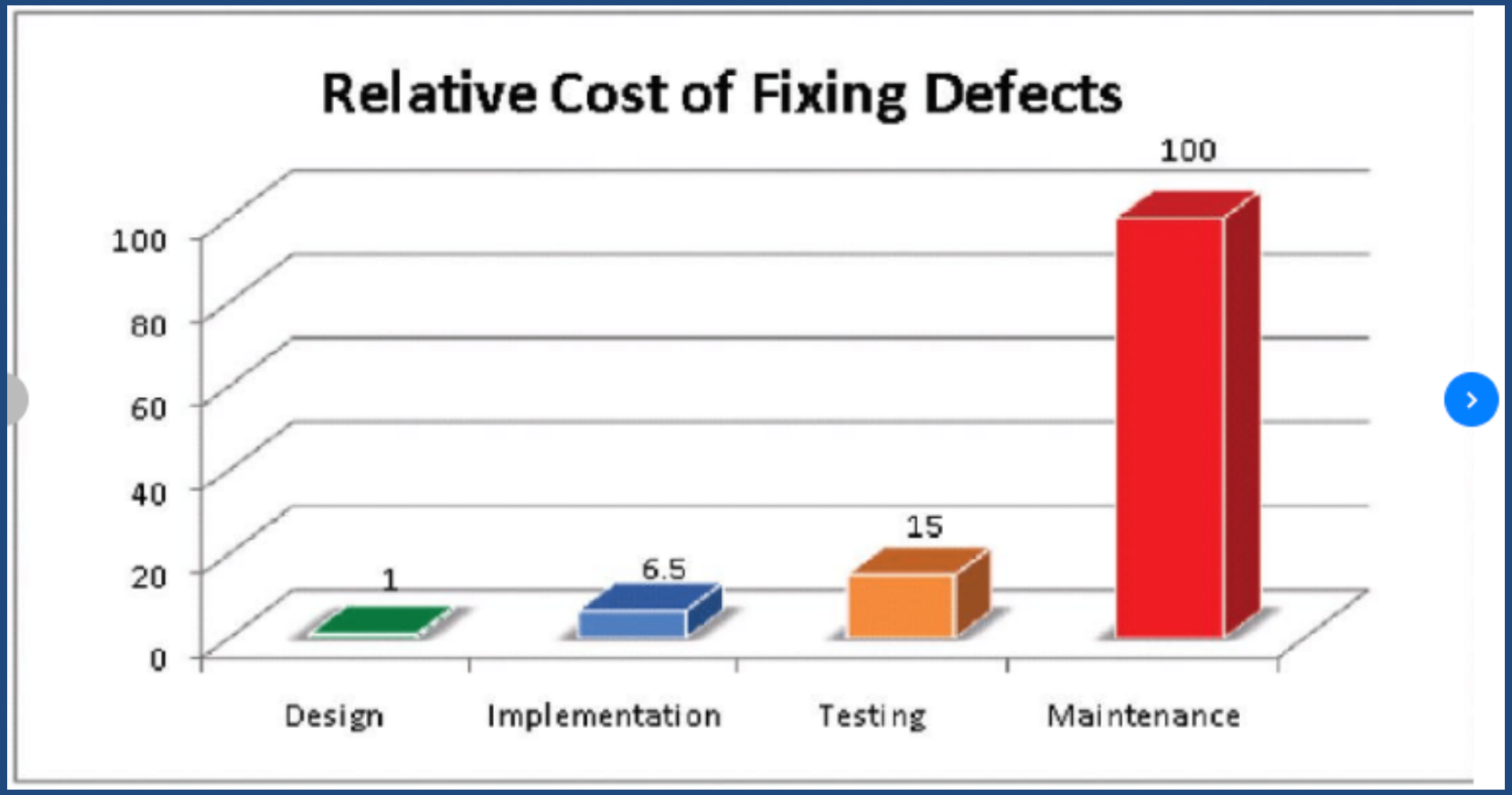
Information Security Attributes
The CIA Triad

- **Confidentiality**: Access to information is limited to those with proper authorization.
- **Integrity**: Maintaining the consistency, accuracy and trustworthiness of data during its life cycle.
- **Availability**: Reliable access is maintained to resources by authorized parties.

Microsoft's Security Development Lifecycle (SDL)

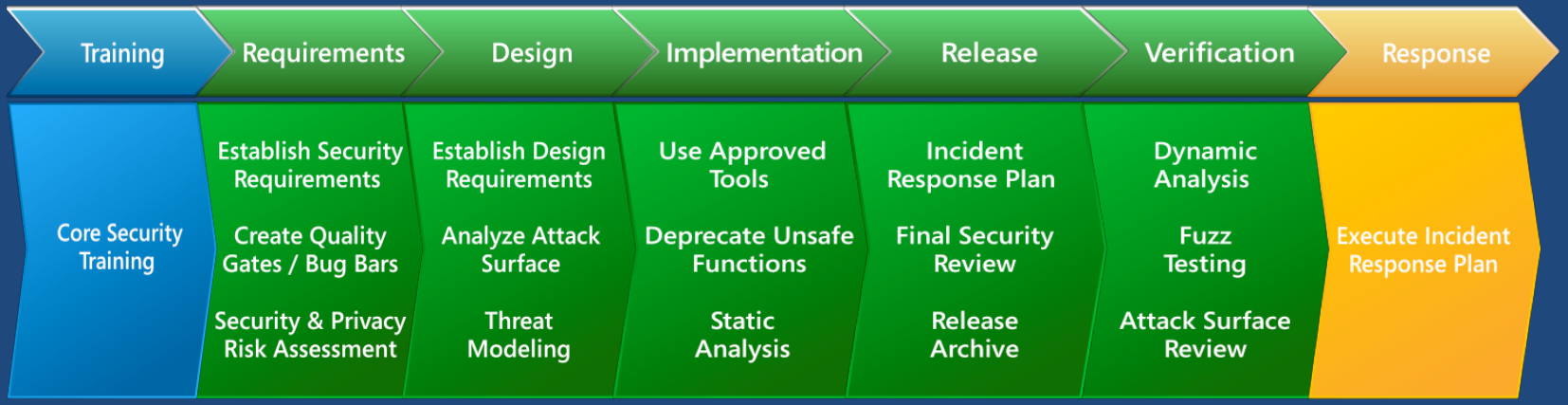
- Bill Gates inaugurated Microsoft's Trustworthy Computing Initiative in 2002.
  - Success with major new corporate initiatives often requires support from top management.
- Every product that impacts privacy or may be used by children needs security analysis.
  - This means almost all hardware/software products
- Microsoft code is now among the most secure!

Less Costly to Fix Defects Early*



* https://www.researchgate.net/figure/255965523_fig1_Figure-3-IBM-System-Science-Institute-Relative-Cost-of-Fixing-Defects

Microsoft's SDL



- Personnel must be trained.
- Security requirements, risk assessment needed
- Threat modeling (STRIDE) will reduce attack surface.
  - **S**poofing, **T**ampering, **R**epudiation, **I**nformation Disclosure, **D**enial of service, **E**levation of privilege.
- Implementation requires good tools to protect against attacks
- Plan to handle errors found after release of code.
- Verification needed via dynamic analysis including fuzzing.

STRIDE Threats*

- S – **Spoofing**
- T – **Tampering**
- R – **Repudiation**
- I – **Information Disclosure**
- D – **Denial of Access or Service**
- E – **Elevation of Privilege**

* Microsoft's mnemonic for types of software threats

STRIDE Explained

- S – pretending to be another person or thing
- T – modifying something one should not
- R – falsely claiming not to have taken an action
- I – exposing information to those unauthorized
- D – denying users access to a service
- E – acquiring access at an elevated level

STRIDE Elaborated

Threats	Objectives
Spoofing	Authenticity
Tampering	Integrity
Repudiation	Non-Repudiation
Information Disclosure	Confidentiality
Denial of Service	Availability
Elevation of Privilege	Proper Authorization

Four Ways to Address Threats (META)

- Mitigate it
  - Increase the work to exploit it
- Eliminate it
  - Usually requires elimination of features
- Transfer it
  - Let some other system element cope with it
- Accept it
  - Risk acceptance may be less costly than other steps

Source Material

- *Threat Modeling: Designing for Security* by Adam Shostack, John Wiley & Sons, 2014.
- *Writing Secure Code: Second Edition*, Howard and LeBlanc, Microsoft Press, 2009

Is Open Source Software a Panacea?

- Software is available for modification under liberal copyright policy.
- Do many eyeballs on the code make it secure?
  - "… in reality that doesn't happen" Cowan 2002.
- Russia believes it – avoids US software.
  - Putin orders Russian government to move to Open Source Software by 2015. (12/28/2010)
- Problems: No incentive to find bugs. Coders not trained to find them. It is hard!
  - See Software Security for Open-Source Systems*, 2003

* See http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=7425509061C29FEDE840C8C4F9F69089?doi=10.1.1.12.8679&rep=rep1&type=pdf

Bug-Free Software Can Be Exploited!*

- Talk: Software Exploitation: Hardware is the New Black by Cristiano Giuggrida, MIT, 11/5/08
  - "Verified bug-free software can be exploited by a relatively low-effort attacker."
  - "[S]tate-of-the-art security defenses, which have proven useful to raise the bar against traditional software exploitation techniques, are completely ineffective against such attacks."
- Surprisingly, some operating systems vulnerable

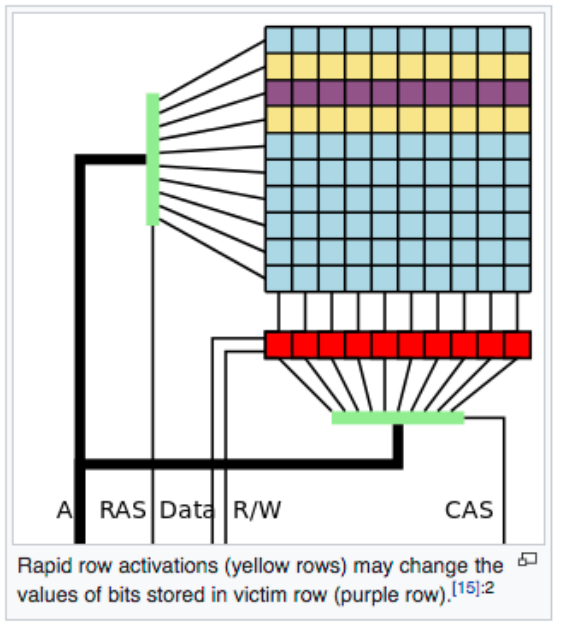
* https://www.csail.mit.edu/event/software-exploitation-hardware-new-black

Exploitation of Bug-Free Software

- "Dedup Est Machina: Memory Deduplication as an Advanced Exploitation Vector" by Cristiano Giuffrida †
  - Uses Rowhammer to changes bits in memory
    - See next slide
  - Exploits de-duplication to obtain side information
  - Allows user to obtain gain arbitrary read/write access to memory

† https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7546546

Row-Hammer Attack



Rapid row activations (yellow rows) may change the values of bits stored in victim row (purple row).[15]:2

- De-duplication
  - Space saved by holding only one copy of a file
  - If one copy changed, a new copy created, which takes time
  - This provides one bit of side information!
  - Which is enough to violate security (too hard to explain)

Review

- Security modeling including access control
- Federal security regulations and standards
- Software vulnerability assessments
- Microsoft's Security Development Lifecycle
- Introduction to Threat Analysis
- Security can be violated even if code is perfect