Defense Strategies

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Outline

- Problem – Strategies to prevent attacks
- Programs: Prevent overflows
- Systems: Confine process interactions (MAC)
- Still may be some attacks – where?
- Assurance

Our Goal

- In this course, we want to develop techniques to detect vulnerabilities and fix them automatically
- What's a vulnerability?
- How to fix them?

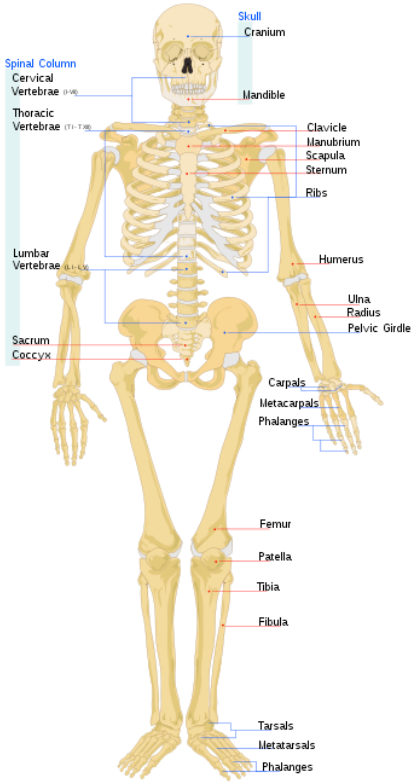
- *We will examine the second question today*

Vulnerability

- How do you define computer 'vulnerability'?
  - *Flaw*
  - *Accessible to adversary*
  - *Adversary has ability to exploit*

Anatomy of Control Flow Attacks

- Two steps
- First, the attacker changes the control flow of the program
  - In buffer overflow, overwrite the return address on the stack
  - What are the ways that this can be done?
- Second, the attacker uses this change to run code of their choice
  - In buffer overflow, inject code on stack
  - What are the ways that this can be done?



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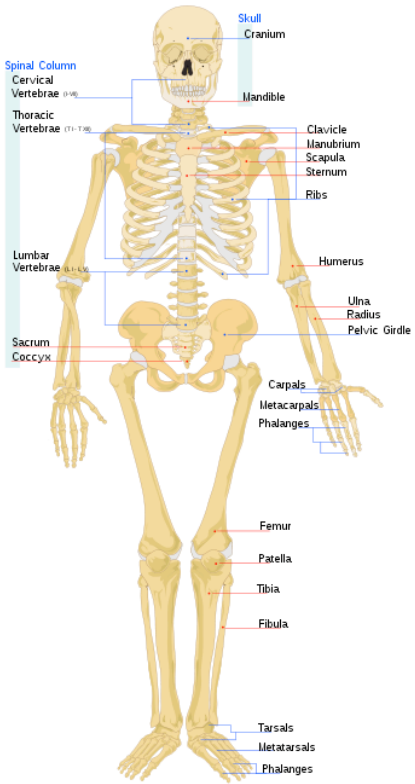
  - In buffer overflow, overwrite the return address on the stack
  - *How can we prevent this?*
- Second, the attacker uses this change to run code of their choice
  - In buffer overflow, inject code on stack
  - *How can we prevent this? ROP conclusions*



StackGuard

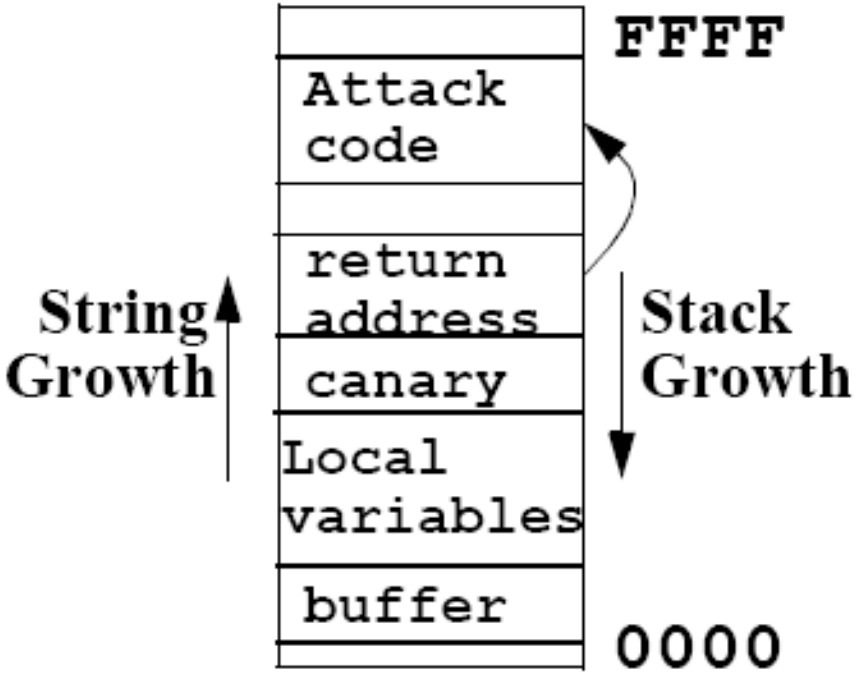


Figure 2: StackGuard Defense Against Stack Smashing Attack

StackGuard

PENNSTATE 1855

- How do you think that Stackguard is implemented?

More Smashing

- Pincus and Baker, Beyond Stack Smashing, IEEE S&P, 2004
- Pointer modification
  - Function pointers and exception handlers
  - Data pointer – modify arbitrary memory location
  - Virtual functions – overwrite pointers to these functions
- Provide payload from earlier operation
  - Environment variables
  - Arc injection – provide exploit code on command line

StackGuard

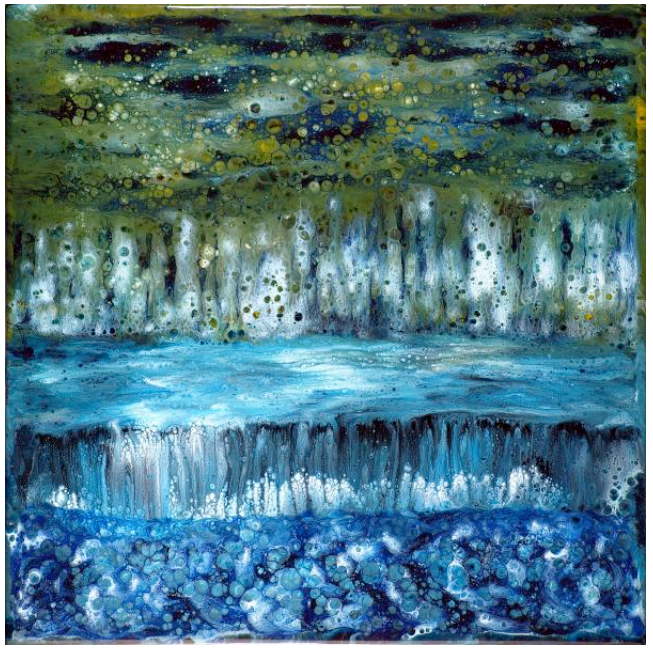
- Related defenses
  - Reorder local variables on stack
  - Protect return address when set
  - Canaries to protect pointers

Vulnerable Program	Result Without StackGuard	Result With Canary StackGuard	Result With MemGuard StackGuard
`dip 3.3.7n`	`root` shell	program halts	program halts
`elm 2.4 PL25`	`root` shell	program halts	program halts
`Perl 5.003`	`root` shell	program halts irregularly	`root` shell
`Samba`	`root` shell	program halts	program halts
`SuperProbe`	`root` shell	program halts irregularly	program halts
`umount 2.5k/libc 5.3.12`	`root` shell	program halts	program halts
`wwwcount v2.3`	`httpd` shell	program halts	program halts
`zgv 2.7`	`root` shell	program halts	program halts

Table 1: Protecting Vulnerable Programs with StackGuard

Other Overflows

- Heap overflows
  - Overwrite data or metadata
  - Defend in manner similar to buffer overflows
- Integer overflows
  - No systematic defense
- Input filtering
  - No systematic defense



Confining Processes

- Mandatory Access Control
  - SELinux

Attack Surfaces

- Attack Surfaces
- http://www.cs.cmu.edu/afs/cs/usr/wing/www/publications/Howard-Wing05.pdf

Assurance

- Problem: Prove to a third party that your system provides particular security protections
- Challenges
  - What security protections are provided?
  - How do we prove that such protections are designed/implemented correctly?
- Additionally
  - How do we even know what security protections would be valuable to have?

Orange Book

- Part of Rainbow Series from NCSC
  - Covers many facets of computer security
- AKA *Trusted Computer System Evaluation Criteria*
  - To evaluate, classify, and select among computer systems
- Defines both
  - Criteria for different categories of secure systems
  - Evaluation requirements to satisfy those criteria

Orange Book

- Categories of Security Covered
- Access control
  - Mandatory and discretionary
- Accountability
  - Authentication and audit
- Assurance
  - Development and deployment
- Documentation
  - "Whoomp factor"

Orange Book

- Most important results were a set of security targets
- D – Minimal protection
- C – Discretionary protection
- B – Mandatory protection
- A – Verified Protection

Orange Book

- Most important result were a set of security targets
- B – Mandatory protection
  - B1 – Labeled Security: MAC covers some exported
  - B2 – Structured Security: Comprehensive MAC and covert channels
  - B3 – Security Domains: Satisfies Reference Monitor
- A – Verified Protection
  - A1 – Verified Design: B3 Function with formal assurance
  - Beyond A1

Protection Requirements

- B2 – Structured Security (3.2, Pg. 27)
- Security policy (protections)
  - Object reuse – clean before reuse
  - Labels – TCB labels all subjects and objects
    - Label Integrity – Labels match levels
    - Export – Single level and Multi-level
  - MAC – Enforce over all resources
  - Accountability: Trusted Path and Audit

Assurance Requirements

- B2 – Structured Security (3.2, Pg. 27)
- Assurance
  - Operational
    - TCB protected from tampering
    - Periodically validate integrity
    - Covert storage channels (detect and mitigate/eliminate)
  - Lifecycle
    - Testing – to find if works as claimed
    - Formal model – of security policy (i.e., function) design and configuration
  - Documentation

Common Criteria

- Problem with Orange Book was the binding of function (security policy) and assurance
- The Common Criteria separates these
  - Security Targets
  - Assurance Levels
- Although these are at least partially bound by *protection profiles*

Labeled Security Protection

- Essentially the B2 Security Policy
- Assurance
  - Expected to EAL3
- Covering
  - Configuration
  - Delivery
  - Development (High-level design)
  - Guidance (Administration)
  - Testing
  - Vulnerability Assessment

Current Approach to Assurance

- Document from initial design
  - Build system from formal models
  - E.g., seL4 and VAX VMM
- Document existing system
  - Collect design, config, admin, etc. from existing system
  - E.g., Windows, Linux, Solaris, etc.
- Assurance level of existing systems are limited to EAL4 in practice

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Limited Impact on Systems

- Old Claim: Full assurance for existing systems is impractical
- Old world
  - Assurance is a design-time task
    - All deployments are proven secure
  - Few components are trusted to make security decisions
    - But trusted completely
  - Development is either done in a unified way or few guarantees are possible
    - Composition of modules or independent tasks (config and design) is non-trivial

Goal: Defend Existing Systems

- New Claim: Given a set of components, determine whether they defend themselves proactively
- New world
  - Can assurance be done at design and deployment?
    - All deployments are consistent with defenses
  - Can we work with layers of TCBs?
    - Trust monotonically decreased in a logical way
  - Can we compose a system from independent components?
    - Analysis of what is built

Summary

- We envision that program compromises are prevented in several ways
  - Program integrity
  - Mandatory access control
  - Attack surfaces
- However, the results of these defensive efforts must be unified
  - Assurance
- But, current assurance techniques do not match the practical challenges in software development