Protection

Thierry Sans

Protecting Programs

How to lower the risk of a program security flaw resulting from a bug?

1. Build better programs
2. Build better operating systems

Build Better Programs

Why are we still vulnerable to buffer overflows?

Why code written in assembly code or C are subject to buffer overflow attacks?

- ➡ Because C has primitives to manipulate the memory directly (pointers ect ...)

Choosing a better programming language

Some languages are type-safe (i.e memory safe)

➡ Pure Lisp, pure Java, ADA, ML …

Some languages isolate potentially unsafe code

➡ Modula-3, Java with native methods, C# …

Some languages are hopeless

➡ Assembly languages, C …

Type-Safe Programs

- ➡ Cannot access arbitrary memory addresses
- ➡ Cannot corrupt their own memory
- ✓ Do not crash

So why are we still using unsafe programming languages?

If other programming languages are "memory safe", why are we not using them instead?

➡ Because C and assembly code are used when a program requires high performances (audio, vide, calculus …) or when dealing with hardware directly (OS, drivers ….)

Can we write better programs with unsafe programming languages?

Defensive Programming Approach

1. Adopting good programming practices
2. Being security aware programmer

Proactive Approach

3. Using security libraries
4. Performing penetration testing

Formal Approach

5. Using formal methods to <u>verify</u> a program
6. Using formal methods to <u>generate</u> a program

Defensive Programming Approach

2. Adopting good programming practices

Modularity

- ➡ Have separate modules for separate functionalities
- ✓ Easier to find security flaws when components are independent

Encapsulation

- ➡ Limit the interaction between the components
- ✓ Avoid wrong usage of the components

Information hiding

- ➡ Hide the implementation
- ◉ Black box model does not improve security

2. Being security aware programmer

- ✓ Check the inputs, even between components that belongs to the same application (mutual suspicion)
- ✓ Be “fault tolerant” by having a consistent policy to handle failure (managing exceptions)
- ✓ Reuse known and widely used code by using design patterns and existing libraries

Proactive Approach

3. Using security libraries - stack smashing protection

Check that the stack has not been altered when a function returns

➡ If it has been altered, the program exits with a segmentation fault

✓ Verification embedded into the program by the compiler

3. Using security libraries - examples

- ✓ Libsafe
- ✓ StackGuard
- ✓ ProPolice (gcc patches)
- ✓ Microsoft's Data Execution Prevention

4. Testing and Penetration Testing

Testing the functionalities

✓ Unit test, Integration test, Performance test and so on …

Testing the security

✓ Penetration tests

➡ Try to make the software fail by pushing the limits of a “normal” usage i.e test what the program is not supposed to do

Formal Approach

5. Using formal methods to verify a program

Static analysis - analyzing the code to detect security flaws

- Control flow - analyzing the sequence of instructions
- Data flow - analyzing how the date are accessed
- Data structure - analyzing how data are organized

➡ Abstract interpretation [Cousot]

✓ Verification of critical embedded software in Airbus aircrafts

6. Using formal methods to generate a program

Mathematical description of the problem

Refinement steps

Proof of correctness

Executable code
or hardware design

6. Using formal methods to generate a program

Hardware design (VHDL, Verilog)

- ✓ Used by semi-conductor companies such as Intel

Critical embedded software (B/Z, Lustre/Esterel)

- ✓ Urban Transportation
  (METEOR Metro Line 14 in Paris by Alstom)
- ✓ Rail transportation (Eurostar)
- ✓ Aeronautic (Airbus, Eurocopter, Dassault)
- ✓ Nuclear plants (Schneider Electric)

Pros and cons of using formal methods

- ✓ Nothing better than a mathematical proof
- ➡ A code "proven safe" is safe

- ◉ Development is time and effort (and so money) consuming
- ➡ Should be motivated by the risk analysis

- ◉ Do not prevent from specification bugs
- ➡ Example of network protocols

Build Better
Operating Systems

Canaries

- The compiler modifies every function's prologue and epilogue regions to place and check a value (a.k.a a canary) on the stack
- When a buffer overflows, the canary is overwritten. The programs detects it before the function returns and an exception is raised
- Different types:
  - random canaries
  - xor canaries
- Disabling Canary protection on Linux
  ```
  $ gcc ... -fno-stack-protector
  ```
- Bypassing canary protection : *Structured Exception Handling (SEH)* exploit overwrite the existing exception handler structure in the stack to point to your own code

DEP/NX

- The program marks important structures in memory as non-executable
- The program generates an hardware-level exception if you try to execute those memory regions
- This makes normal stack buffer overflows where you set `eip` to `esp+offset` and immediately run your shellcode impossible
- Disabling NX protection on Linux
  ```
  $ gcc ...-z execstack
  ```
- Bypassing NX protection : *Return-to-lib-c* exploit
  return to a subroutine of the lib C that is already present in the process' executable memory

ASLR

- The OS randomize the location (random offset) where the standard libraries and other elements are stored in memory
- Harder for the attacker to guess the address of a lib-c subroutine
- Disabling ASLR protection on Linux
```
$ sysctl kernel.randomize_va_space=0
```
- Bypassing ASLR protection : Brute-force attack to guess the ASLR offset
- Bypassing ASLR protection : *Return-Oriented-Programming (ROP)* exploit use instruction pieces of the existing program (called "gadgets") and chain them together to weave the exploit

Confined execution environment - Sandbox

A sandbox is tightly-controlled set of resources for untrusted programs to run in

- ➡ Sandboxing servers - virtual machines
- ➡ Sandboxing programs
  - Chroot and AppArmor in Linux
  - Sandbox in MacOS Lion
  - Metro App Sandboxing in Windows 8
- ➡ Sandboxing applets - Java and Flash in web browsers

Intrusion Detection/Prevention Systems

- Host-based Intrusion Detection Systems (IDS)
- Host-based Intrusion Prevention systems (IPS)

✓ Based on signatures (well known programs)

✓ Based on behaviors (unknown programs)

➡ Example : Syslog and Systrace on Linux

◉ Vulnerable to malicious programs residing in the kernel called "rootkits"

Os security features

- **Ubuntu Linux** https://wiki.ubuntu.com/Security/Features
- **Windows 7** http://resources.infosecinstitute.com/windows-7-security-features/
- **OS X** https://www.apple.com/osx/what-is/security.html

Security Assurance

Thierry Sans

Why this lecture about "assurance"?

In my experience, Security Assurance is a boring part …

... but you may get a job just because you know what it is!

What is security assurance?

I ask your company to create a piece of software for me …

… as a non-security expert, what kind of assurance can you give me about the security of your product?

Why and how to evaluate security?

Why do we care about security assurance?

- ➡ If you think we should not care about security you have been sitting in the wrong class for half a semester

How to evaluate the security of a product/system?

- ➡ evaluate the person making the product
- ➡ or evaluate the product itself

Standards and certifications

How do we agree on evaluation criteria?

➡ Certifications based on Standards

Who should run the evaluation?
Who delivers the certification?

➡ A certification authority (trusted third-party) called a registrar

Outline

Evaluate and certify an organization

- ISO/IEC 27000 series

Evaluate and certify a product or a system

- TCSEC (“The Orange Book”) (1983-1999)
  was the American standard
- ITSEC (1991-2001)
  was the European standard
- ISO/IEC 15408 (“The Common Criteria”) (since 1998)
  is the actual international standard

Certification of an organization
ISO 27000-series

ISO/IEC 27k - Security Assurance

Objective - provide the best practice recommendations on information security management, risks and controls

➡ equivalent to the ISO/IEC-9000series (quality assurance)

ISO/IEC 27k in action

How to get certified?

1. The organization submit an evaluation plan to the registrar
2. The registrar runs the first audit and grant the certification
3. The registrar keeps on auditing the organization to guarantee the certification

What is inside the ISO/IEC 27k

The code of practice (ISO/IEC 27002)

- ➡ List of 133 candidate control objectives and controls
- ➡ Each control must be addressed one by one in the evaluation plan (extras can be added)

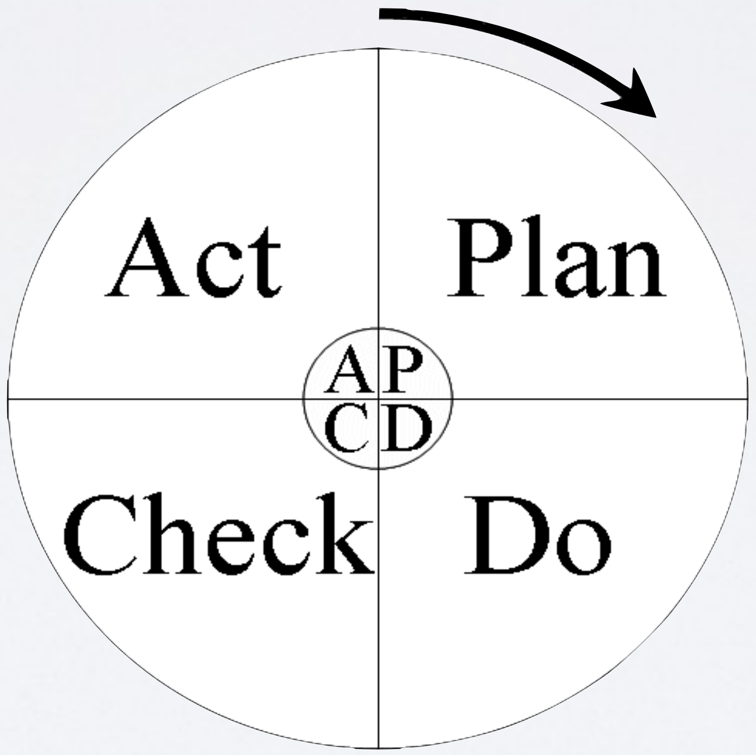
Governing principles

Based on an iterative problem-solving process

➡ Deming's Wheel (PDCA)

improve
the security assurance

run a risk analysis
and define the security policy



measure
the security solutions

design and build
security solutions
(called controls)

These controls about ...

- Risk assessment (how to drive the risk analysis)
- Security policy
- Organization of information security (governance)
- Asset management (inventory and classification of information assets)
- Human resources protection (security aspects for employees joining, moving and leaving an organization)
- Physical and environmental security (protection of computer facilities)

… and more

- Communications and operations management (infrastructure supporting the activity)
- Access Control (restrictions of access rights)
- Information systems acquisition, development and maintenance (result of the activity)
- Information security incident management (CERT)
- Compliance (ensuring conformance with security policies, standards, laws and regulations)

Certification of a product/system
Common Criteria

Objective and methods

Objective - provide an evaluation methodology

- Defining the set of security functionalities
- Defining a set of assurance requirements
- Determining whether the product or system meet the assurance requirements
- Determining a measure of the evaluation results Evaluation Assurance Level (EAL)

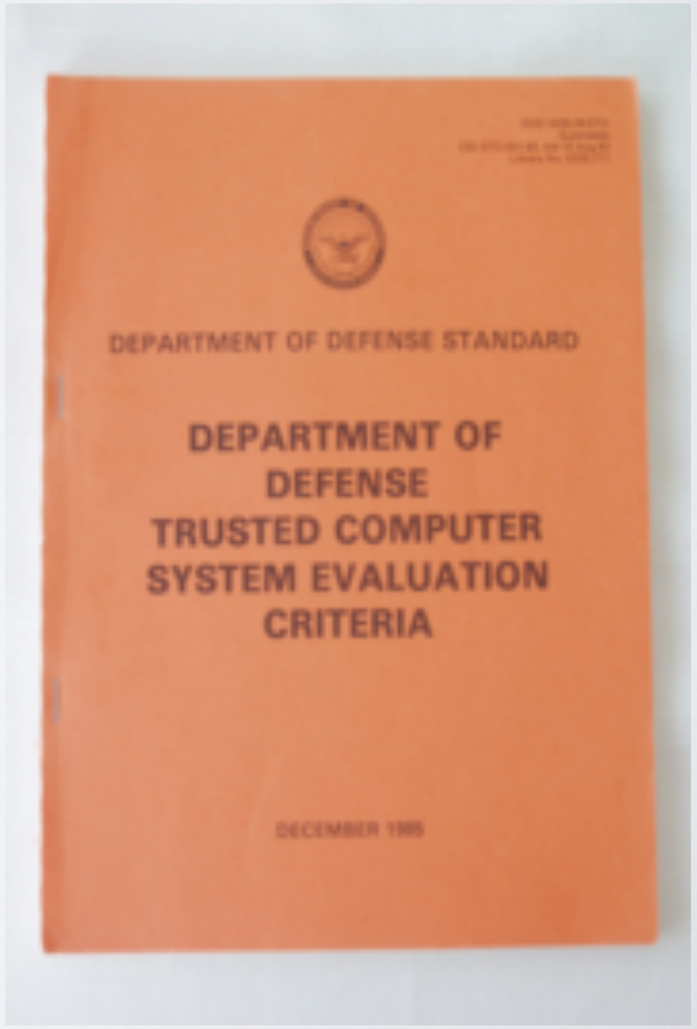
➡ Technical Evaluation based on security assurance methods

- Testing and penetration testing
- Formal development and/or formal verification

TCSEC - "The Orange Book" (1983-1999)

Objective - evaluate and classify computer systems (i.e. OS) regarding the storage, retrieving and processing of sensitive data

- ➡ Initiated by the US DOD in the 70's



DEPARTMENT OF DEFENSE STANDARD

DEPARTMENT OF DEFENSE TRUSTED COMPUTER SYSTEM EVALUATION CRITERIA

DECEMBER 1985

photo from Wikipedia

Governing principles

Introduce the concept of **policy**

- It must be explicit and enforceable by a computer system
- Two kind of policies are considered DAC and MAC

Introduce the concept of **accountability**

- Users must be identified and authenticated
- Each access must be logged

TCSEC - security assurance classes (1991-2001)

Class D - minimal protection

➡ No security requirements

Class C - discretionary security protection

➡ Multi-user environment and data with different sensitivity levels

Class B - mandatory security protection

➡ Object labels, user clearance levels and multilevel security policy

Class A - verified protection

➡ Formal design and verification

The Common Criteria (since 1998)

Protection Profile - the functionalities and the security requirements of the product/system

- ➡ Written by the system consumer

Security Target - identifies the security properties

- ➡ Written by the software designer in response to the protection profile

Let's look at some protection profiles on http://www.commoncriteriaportal.org/pps/

Evaluation Assurance Levels (EAL)

EAL 1 - Functionally Tested

➡ Requires a documentation of the security functions vouching for a minimum confidence regarding their correction but threats are not considered as serious

EAL 2 - Structurally Tested

➡ Requires the delivery of test procedures and test results

EAL 3 - Methodically Tested and Checked

➡ Requires the developers to be aware of good software engineering practices

Evaluation Assurance Levels (EAL)

EAL 4 - Methodically Designed, Tested and Reviewed

➡ Requires good commercial developments methods to ensure good software engineering practices

EAL 5 - Semi-formally Designed and Tested

➡ Requires rigorous commercial development practices supported by a security expert

Evaluation Assurance Levels (EAL)

EAL 6 - Semi-formally Verified Design and Tested

➡ Requires a rigorous development environment

EAL 7 - Formally Verified and Tested

➡ Requires a rigorous security-oriented development environment

Let's see some certified products on http://www.commoncriteriaportal.org/products/

Drawbacks of product evaluation

1. Preparing the documentation for evaluation is a long time effort

➡ The product is obsolete once certified

2. Going through such an evaluation is a costly process

➡ The return on investment is not necessarily a more secure product

3. The evaluation is performed on the documentation and not on the product itself

➡ A good EAL does not prevent from security flaws

What are the related jobs

You can become

- an auditor evaluating an organization or a product and delivering the certification
- a consultant helping to write the documents needed to pass the certification

What do you need to know/do?

- CS and IT systems in general
- the standards
- get certified as an auditor or a consultant
  and get hired by a registrar