Desenvolvimento de Software Seguro - As Is Can't Be

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Motivation

- "We wouldn't have to spend so much time, money, and effort on *network security* if we didn't have such bad *software security*"
  - Viega & McGraw, Building Secure Software, Addison Wesley 2002
- "the current state of security in commercial software is rather distasteful, marked by embarrassing public reports of vulnerabilities and actual attacks (…) and continual exhortations to customers to perform rudimentary checks and maintenance."
  - Jim Routh, Beautiful Security, O'Reilly, 2010
- "Software buyers are literally crash test dummies for an industry that is remarkably insulated against liability"
  - David Rice, Geekonomics: The Real Cost of Insecure Software, Addison-Wesley, 2007

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2010 in numbers

- Symantec Internet Security Threat Report, Vol 16, April 2011

286M+
Threats

Polymorphism and new delivery mechanisms such as Web-attack toolkits continued to drive up the number of malware variants in common circulation. In 2010, Symantec encountered more than 286 million unique variants of malware.

93%
Increase in Web Attacks

A growing proliferation of Web-attack toolkits drove a 93% increase in the volume of Web-based attacks in 2010 over the volume observed in 2009. Shortened URLs appear to be playing a role here too. During a three-month observation period in 2010, 65% of the malicious URLs observed on social networks were shortened URLs.

260,000
Identities Exposed per Breach

This was the average number of identities exposed in each of the data breaches caused by hacking throughout the year.

42%
More Mobile Vulnerabilities

In a sign that the mobile space is starting to garner more attention from both security researchers and cybercriminals, there was a sharp rise in the number of reported new mobile operating system vulnerabilities—up to 163 from 115 in 2009.

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2010 in numbers

6,253
New Vulnerabilities

Symantec recorded more vulnerabilities in 2010 than in any previous year since starting this report. Furthermore, the new vendors affected by a vulnerability rose to 1,914, a 161% increase over the prior year.

14
New Zero-Day Vulnerabilities

The 14 zero-day vulnerabilities in 2010 were found in widely used applications such as Internet Explorer, Adobe Reader, and Adobe Flash Player. Industrial Control System software was also exploited. In a sign of its sophistication, Stuxnet alone used four different zero-days.

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The problem is Software: Stuxnet

- Invaded Iranian nuclear enrichment facility; damaged many centrifuges
  - Modified programmable logic controllers (PLCs) –software too!
- Some features:
  - Self-replicates through USB drives exploiting a vulnerability allowing auto-execution
  - Spreads in a LAN through a vulnerability in the Win.Print Spooler
  - Spreads through SMB by exploiting a Windows RPC vulnerability
  - Exploits another 2 unpatched privilege escalation vulnerabilities
  - Contains a Windows and a PLC rootkit

The next Stuxnet?

- CNN, Sept. 2007 – "Researchers who launched an experimental cyber attack caused a generator to self-destruct"
  - Financed by the Dep. Homeland Security
- video

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The 7 Coolest Hacks Of 2011

- 1. Remotely starting a car via text message.
- 2. Powering down the power plant – literally.
- 4. Insulin pumps go rogue.
- 5. 'Warflying': Hacking in midair.
- 6. When laptop batteries turn against you.

Only industry's fault?

- "We at Oracle have (...) determined that most developers we hire have not been adequately trained in basic secure coding principles (...)
- In the future, Oracle plans to give hiring preference to students who have received such training and can demonstrate competence in software security principles."
    - Mary Ann Davidson, Oracle's Chief Security Officer

Problem is in the software

The characteristics of current software:

- Complexity
  - Attacks exploit *bugs* called vulnerabilities
  - Estimated 5-50 bugs per Klines of code
  - Windows Vista 50M
- Extensibility
  - What software is in your laptop? OS + production sw + patches + 3rd party DLLs + device drivers + plug-ins + …
- Connectivity
  - Internet (2.2 billion users) + control systems + PDAs + mobile phones + …

Outline

- The problem: Vulnerabilities
- Solution part 1 - Prevention
- Solution part 2 – Runtime protection
- A taste of research
- Conclusions

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EUROPEAN CYBER SECURITY MONTH

The problem: Vulnerabilities

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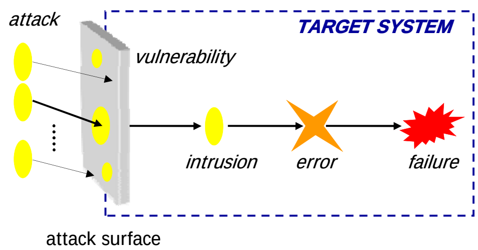
The problem

- Vulnerability + Attack → Intrusion → Security Failure
  - i.e., violation of confidentiality, integrity, availability



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The problem

- From the software point of view, the problem are its defects, i.e., its *vulnerabilities*
  - **Design vulnerability**: inserted during the software design (e.g., lack of access control)
  - **Coding vulnerability**: a bug (e.g., missing end of buffer verification)
  - **Operational vulnerability**: caused by the environment in which the software is executed or its configuration (e.g., weak password)

- "the team leaders conveniently assumed that security vulnerabilities were not defects and could be deferred for future enhancements or projects" - Jim Routh, op. cit.

Coding vulnerabilities

There are many classes; we are going to see the top 3:

- Buffer overflows – traditionally most important (OSs, binary apps)
- SQL injection
- Cross site scripting

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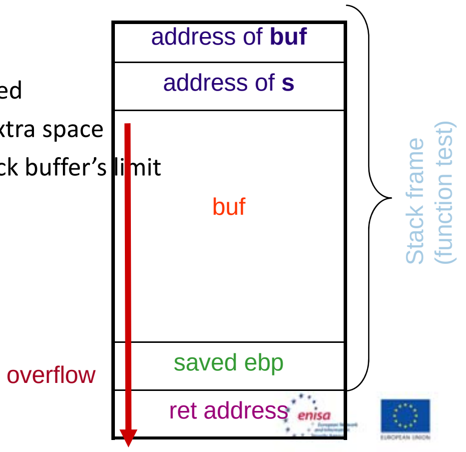
BO – Stack Smashing

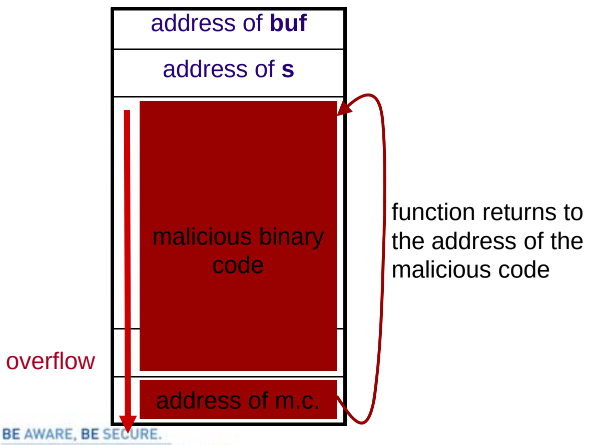
- Stack smashing is the “classical” *stack overflow* attack
- Vulnerable code (inserts untrusted data in buffer without checking the limits):

```
void test(char *s) { //s is untrusted
 char buf[10];      //gcc stores extra space
 strcpy(buf, s);    //doesn’t check buffer’s limit
}
```



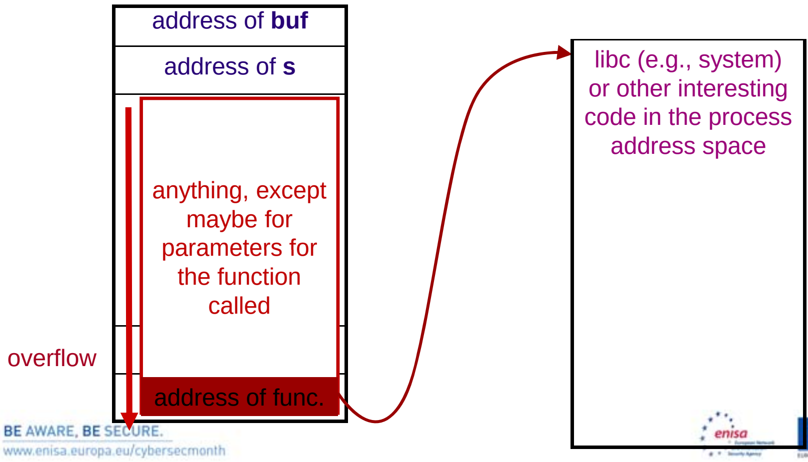
BO – Stack Smash. w/code injection

- Attacker executes arbitrary code in the victim’s machine:



BO – Arc injection / return-to-libc

- Attacker forces jump to code somewhere else:



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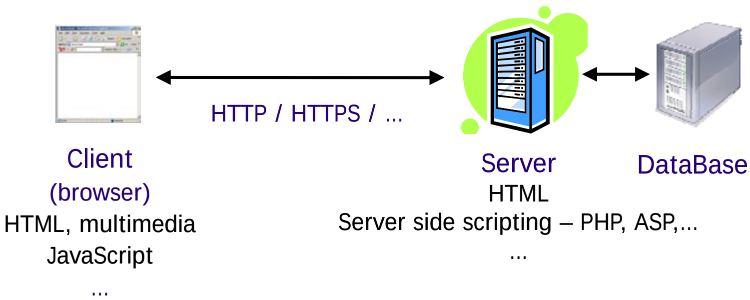
SQL Injection

- Totally different target: web applications



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SQL Injection – basic

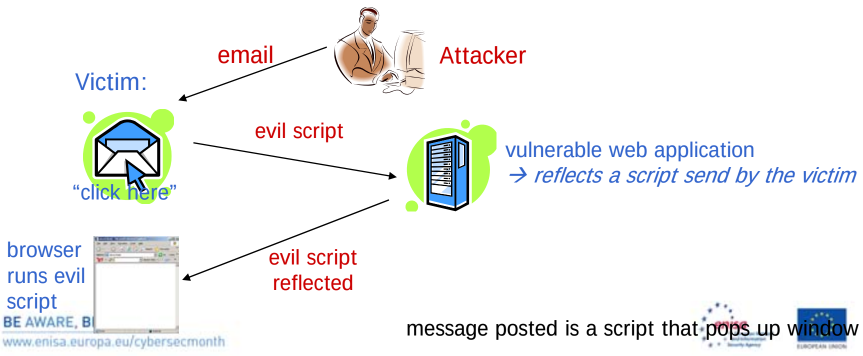
- The attack:
  - User provides inputs to the server
  - Inputs are inserted in queries to the DB
  - Client input with SQL metacharacters inserted in SQL queries
- Example – vulnerable PHP code in the server:

```
$order_id = $HTTP_POST_VARS ['order_id'];
$query = "SELECT * FROM orders WHERE id=" . $order_id;
$result = mysql_query($query);
```

- Good input: 123
  - SELECT * FROM orders WHERE id=**123**
- Attack input: 1 OR 1=1
  - SELECT * FROM orders WHERE id=**1 OR 1=1**

Cross Site Scripting (XSS)

- Also for webapps but the victim is the client/user
- Attack consists in running a malicious script in the browser of the victim (e.g. JavaScript)
- Example:
  - User does not trust email scripts but trusts the vulnerable site



Other vulnerabilities

- Race conditions
- Input validation – command injection, format string vulnerabilities
- Web – session management, direct reference to objects, cross site request forgery, …
- Configuration, authentication
- Malicious host – software piracy and tampering, fraud in online applications

- Besides many variants of those we just saw…

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Solution part 1 - Prevention

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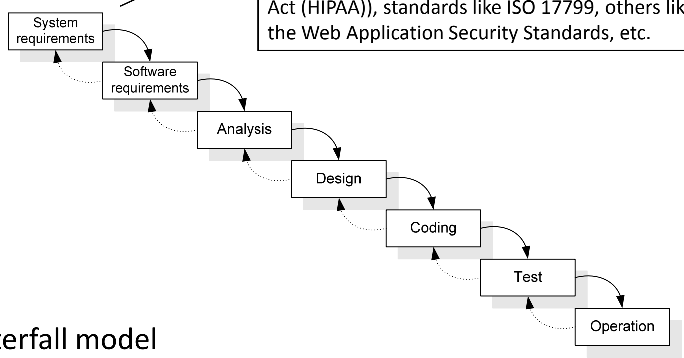
Solution 1 – Sec. development lifecycle

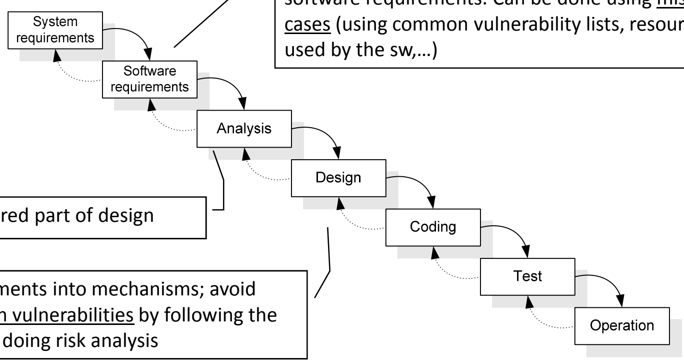
Consider current laws (Sarbanes-Oxley Act, Health Insurance Portability and Accountability Act (HIPAA)), standards like ISO 17799, others like the Web Application Security Standards, etc.



- Waterfall model

Solution 1 – Sec. development lifecycle

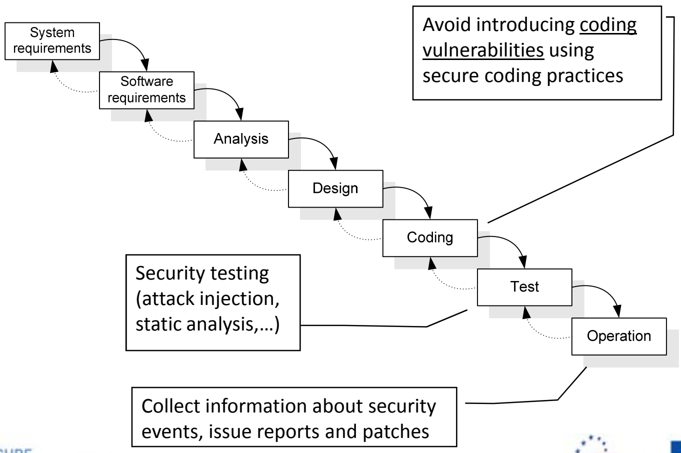
Translate generic requirements into specific software requirements. Can be done using misuse cases (using common vulnerability lists, resources used by the sw,…)



Now considered part of design

Translate requirements into mechanisms; avoid introducing design vulnerabilities by following the design principles, doing risk analysis

Solution 1 – Sec. development lifecycle



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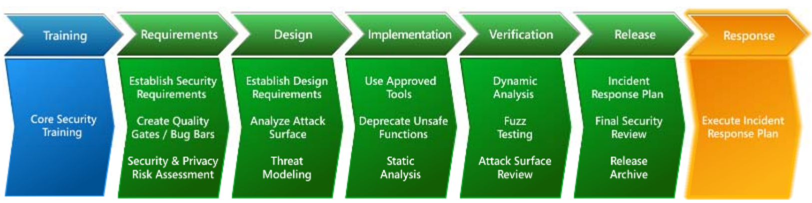
Solution 1 – Sec. development lifecycle

- Microsoft has been doing an excellent job disseminating its Security Development Lifecycle
  - Documentation and tools
  - http://www.microsoft.com/security/sdl/



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Solution 2 – Risk analysis

- For software security, the idea is mainly to find and rank design vulnerabilities
- Several approaches, one is Threat Modeling; steps:
  - Information gathering: from developers, documentation, code profiling
  - Application decomposition, in attack targets (data flow diagrams, UML)
  - Identify vulnerabilities: by analyzing each component and interaction using a vulnerability taxonomy (e.g., STRIDE)
  - Rank vulnerabilities: to prioritize which to correct first (e.g., with DREAD)

STRIDE taxonomy
✓Spoofing identity
✓Tampering with data
✓Repudiation
✓Information disclosure
✓Denial of service
✓Elevation of privilege

DREAD
✓Damage potential
✓Reproducibility
✓Exploitability
✓Affected users
✓Discoverability

Solution 3 – Secure coding

- Buffer overflows
  - Simply check if there is enough space in the destination buffer
- SQL injection
  - Sanitize the inputs (it's easier to say than do)
- Cross Site Scripting
  - Sanitize the inputs, encode the outputs (but it's also easier…)
- but *errare humanum est,* code can be huge…

Solution 4 – Static code analysis

- Vulnerabilities are in the source code so a solution is… to look for them
  - But it's like finding a needle in the haystack
- Code analyzers do it automatically
  - "read" the (source) code and check if certain rules are satisfied (e.g., is memory free'd twice?)
- Commercial tools are available
  - HP-Fortify, Coverity, Ounce Labs, Veracode
  - Many open, free,…

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Solution 4 – Static code analysis

- Code analyzers work essentially in two phases
  - Generate an Abstract Syntax Tree – AST (like a compiler)
  - Search for vulnerabilities in the AST; several ways:
- Syntactic analysis – check if "dangerous" functions are called (e.g., *gets* almost always vulnerable)
- Taint checking – follow the data flow and check if input reaches dangerous functions (e.g., *strcpy*)
- Control-flow analysis – follow the control flow paths and do several checks (e.g., if there are double frees)

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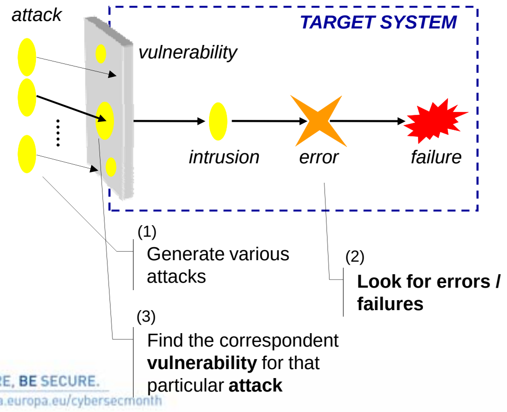
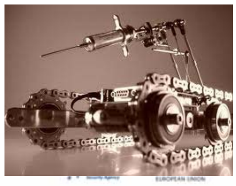
Solution 5 – Attack injection/fuzzing

- Look for vulnerabilities without delving into the complexity of the software, i.e., looking at it as a black box





Solution 5 – Attack injection/fuzzing

- Fuzzers
  - Late 80s/early 90s Miller/Fredrikse/So were studding the integrity of Unix command line utilities
  - During a thunderstorm one was attempting to use the utilities over a dial-up connection but the utilities were crashing
  - Data was being modified in the line due to noise
  - Thus they developed an utility called *fuzz* to generate random input and test the robustness of software
- Currently used to find vulnerabilities in software
  - Very successfully…

Solution 5 – Attack injection/fuzzing

- Recursive fuzzing
  - Iterating though all possible combinations of characters from an alphabet
  - Ex.: URL followed by 8 hexadecimal digits; try all possible combinations of the 8 digits
- Replacive fuzzing
  - Iterating though a set of predefined values, called fuzz vectors
  - Ex.: look for XSS vulnerabilities by providing the following inputs:
    - >"><script>alert("XSS")</script>&
    - '';!--"<XSS>=&{()}
- Attack injection (AJECT project)
  - Pick a state for the target and an input to inject; put the target in that state; inject; monitor; repeat

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Solution part 2 – Runtime protection

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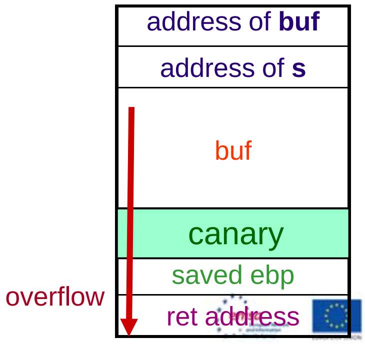
Solution 6 – Runtime protections

- Canaries / Stack cookies
  - Like canaries in coal mines
- Compiler introduces canaries and checks

```
void test(char *s) {
  push canary;
  char buf[10];
  strcpy(buf, s);
  …
  if (canary is changed) {log; exit;};
}
```



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Solution 6 – Runtime protections

- Address space layout randomization
- The idea is to randomize the addresses where code and data are mapped in runtime
  - The memory layout tends to be the same for every execution
  - Does not prevent exploitation but usually makes it unreliable – what address shall be written over the return address?

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Solution 7 – Language security

- Java's (later .NET) challenge: running mobile (not trusted) code in a machine
- Solution/part 1: run code in a sandbox
  - Sandbox imposes a security policy to the code: it can only access the resources permitted by the sandbox
  - Sandbox administrator defines the policy
  - Policy depends on the code's origin (URL) and/or signature
- Solution/part 2: secure the language conventions
  - Type safety – data always manipulated following its type
  - Memory safety – memory accesses restricted to object's memory space
  - Control flow safety – jumps made only to valid places
  - These invariants are enforced in 3 moments: compile time, load time, run time

Java

Solution 8 – Trusted computing

- Trusted Computing Group – an industry consortium defining open specifications for "trusted computing"
- Main achievement is the Trusted Platform Module (TPM) – a chip now found on the mainboard of many PCs
- Two basic functions:
  - Storage of cryptographic keys – for keeping them secure
  - Storage of integrity measurements – to help detect software modifications

TRUSTED COMPUTING GROUP

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Solution 8 – Trusted computing

- What's inside?

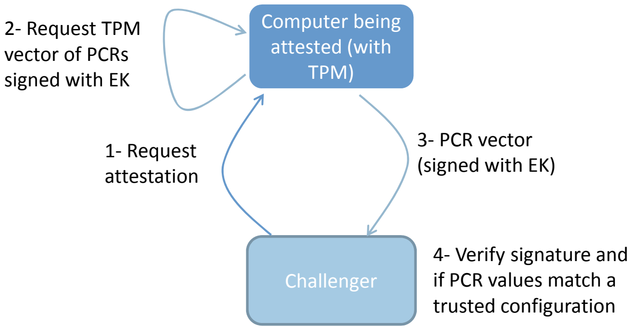
Component classes	Subcomponents
Functional units	Random number generator Hash unit HMAC calculator RSA key generator RSA encryption/decryption/signing
Non-volatile memory	Endorsement key Storage root key Owner authorization secret key
Volatile memory	RSA key pairs Platform configuration registers Key handles Authorization session handles

Solution 8 – Trusted computing

- TPM has at least 16 Platform Configuration Registers (PCR)
- A PCR stores (typically) a measurement of a software block, i.e., its cryptographic hash
  - During system boot, the i^{th} module to run stores the hash of the $(i+1)^{th}$ module in PCR_{i-1}
  - Example: BIOS stores *hash(boot loader)* in PCR_0; boot loader stores *hash(hypervisor)* in PCR_1
  - A vector of PCR values gives a trusted measurement of the software configuration
- Can't the 1st module provide a false hash of the 2nd?
  - We assume we can trust the 1st module, thus called the Static Root of Trust for Measurement (SRTM)
- Can't a PCR be overwritten at any time?
  - No, there is no *write* operation, only extend
  - $PCR_i \leftarrow H(PCR_i \mid\mid h)$ (the 1st time, PCR_i=0)

Solution 8 – Trusted computing

- Remote attestation: computer gives to challenger a measurement of the software configuration, i.e., a vector of PCR values
  - Challenger has the Endorsement Key Certificate, signed by the TPM vendor (means it's a real TPM!)



Solution 8 – Trusted computing

- Other usages for the TPM:
- Store cryptographic keys
  - Inside the TPM or outside of it but encrypted by it
- Bind release of cryptographic key to a certain software configuration
  - Used in Microsoft's BitLocker Drive Encryption (but optional and typically disabled)
- Assign unique id to a blob of data
  - Using a TPM counter and its signature

A taste of research

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Static analysis with code correction

- Preliminary
- AWAP: static analysis of PHP code + automatic correction
  - When a vulnerability is found, a “patch” is inserted
  - Also, a detailed report is created for the programmer to learn with the mistake
- Example of vulnerable code:
  - $a = $_GET[’user’];
  - $b = $_GET[’pass’];
  - $query = “SELECT * FROM users WHERE u = ’$a’ AND p = ’$b’”;
  - $r = mysql_query($query);
- Corrected code:
  - $a = mysql_real_escape_string($_GET[’user’]);
  - $b = mysql_real_escape_string($_GET[’pass’]);
  - …

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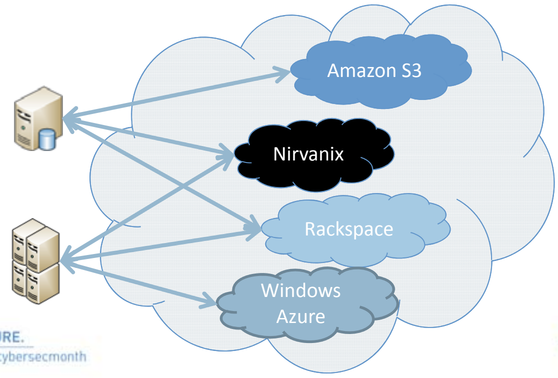
Intrusion tolerance with replication

- Basic idea
  - Accept the inevitability of vulnerabilities and successful attacks
  - Replicate in several and guarantee that it works as long as no more than *f* are suffer intrusions
- Example instantiation: a storage cloud-of-clouds



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Intrusion tolerance with replication

- Benefits:
  - Can tolerate data corruption, e.g., due to malicious insiders, successful attacks, accidental faults (e.g., due to bugs)
  - Can tolerate datacenter and cloud outages
  - No vendor lock-in
  - Confidentiality (data is encrypted)
- Costs
  - $ cost doubles
  - Reads become faster
  - Writes become slower
  - (experiments with 437000+ reads/writes between Sep. 10th and Oct. 7th 2010, clients scattered through the world, from Brazil to Japan)

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Conclusions

Conclusions

- Software security is important + interesting + difficult
  - New vulnerabilities every day
  - New types of vulnerabilities every year
  - New solutions every…
- Requires
  - Knowing current vulnerabilities
  - Know the new ones that appear (especially new types)
  - Know the solutions and use them
  - Run tools, run tools, run tools
- Much research going on
- *THIS SOFTWARE IS* PROVIDED "*AS IS*" is not acceptable

Thank you. Questions?

- To probe further:

- Miguel Pupo Correia
  http://homepages.gsd.inesc-id.pt/~mpc/
  http://www.seguranca-informatica.net/

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