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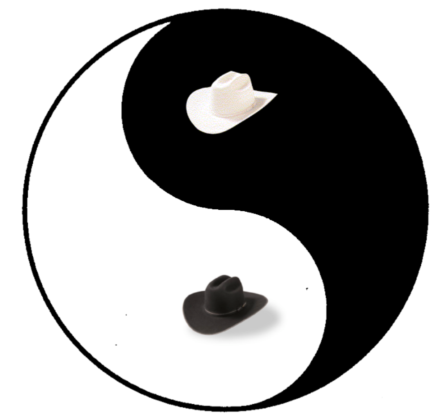
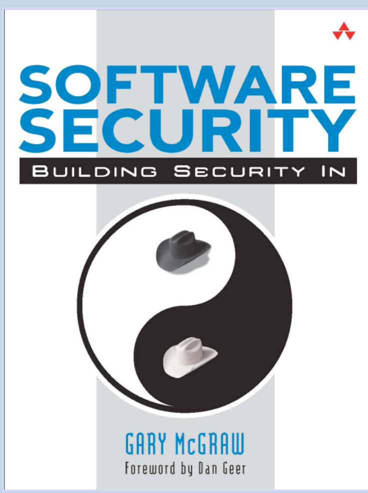
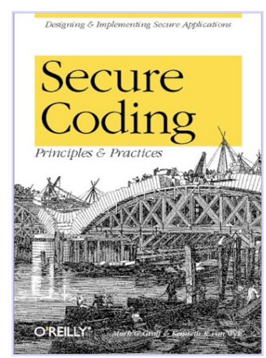
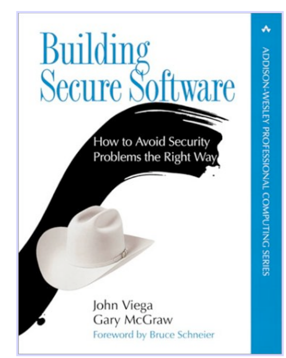
Software security

Setting the stage









Agenda

9:00-10:00	Software [in]security
10:15-12:00	Exploiting Software and exercise
1:00-2:30	Software security touchpoints
2:45-4:30	Seven pernicious kingdoms
4:30-5:00	Code review and next steps

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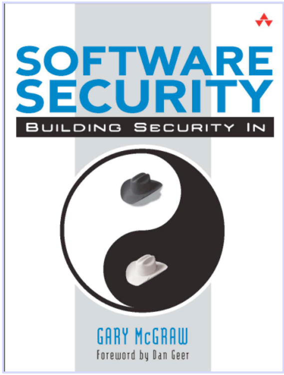
Pop quiz

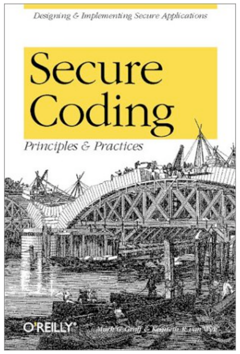
- What do wireless devices, cell phones, PDAs, browsers, operating systems, servers, personal computers, routers, public key infrastructure systems, and firewalls have in common?

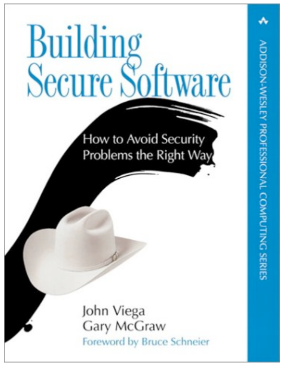
Questions for you

- Who is from dev? How about testing? Anyone here from product management?
- What languages do you use? C? C++? Java?
- How do you describe and capture software architecture and design?
- Do you follow a particular software process in your group?

Software [in]security

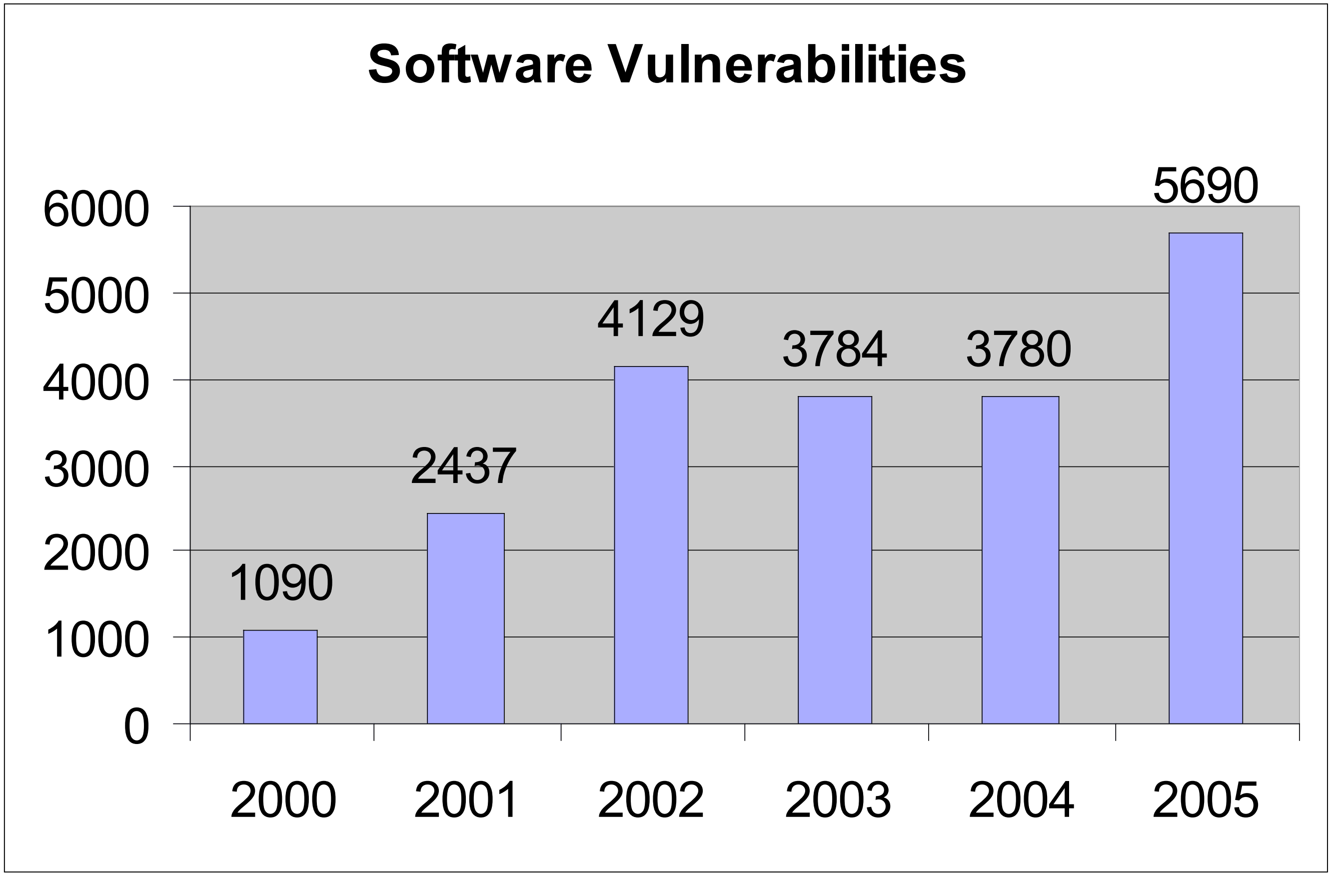






The Problem

Software vulnerability growth



The Trinity Of Trouble: Connectivity

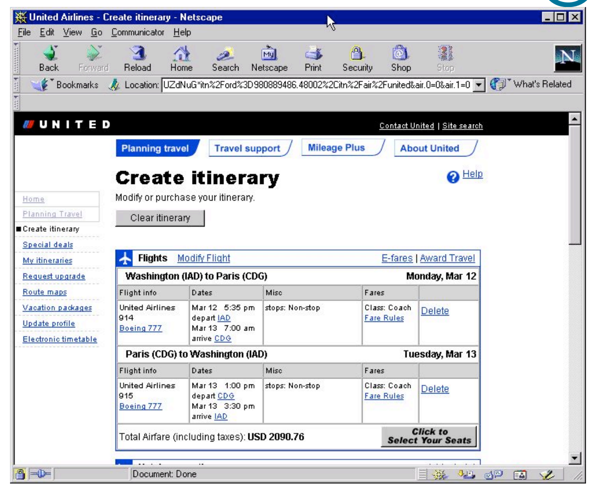
- The Internet is everywhere and most of our software is on it
- When was the last time that you did business with a major vendor who had no Internet connectivity?
- Tried VoIP on your mobile phone in a coffee shop WiFi hotspot yet?

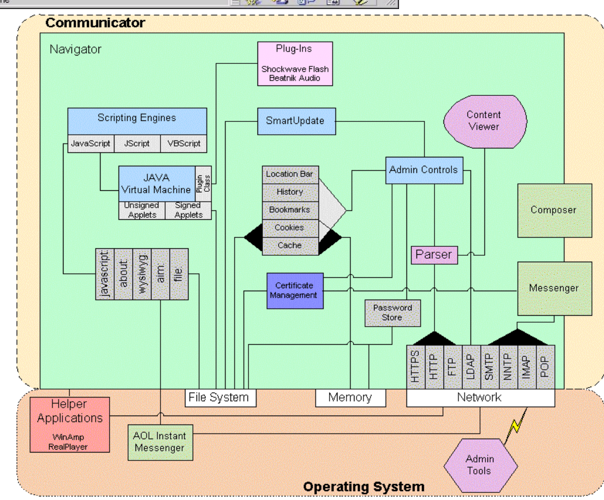
The network is the computer.

Sun microsystems

The Trinity Of Trouble: Complexity

- A simple user interface can be enormously complex "under the hood"
- Consider what happens behind the scenes in one of today's AJAX web applications
- But it sure does make for a compelling "user experience"





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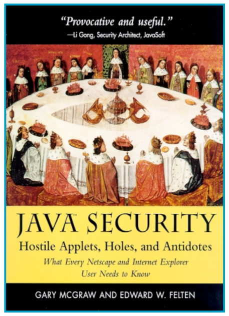
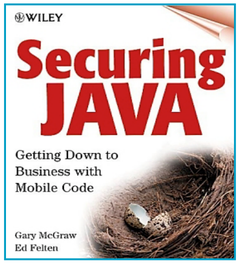
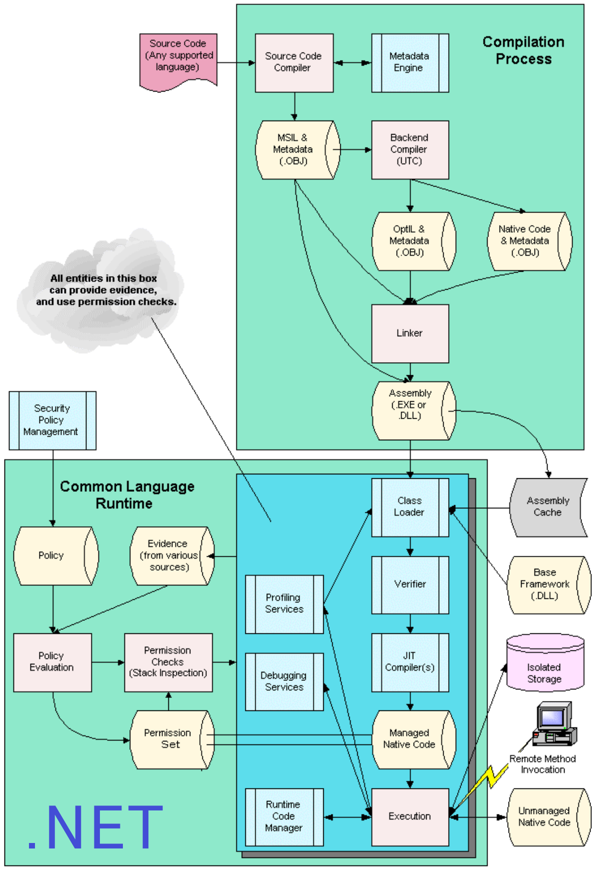
The Trinity Of Trouble: Extensibility

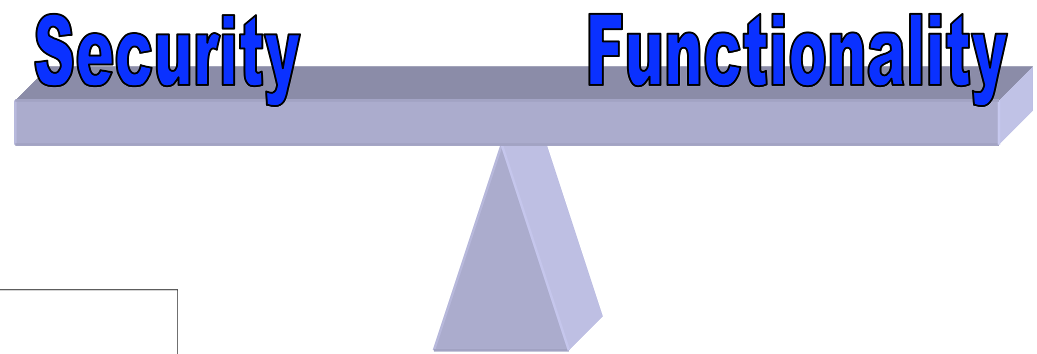
- Systems evolve in unexpected ways and are changed on the fly
- After all, who would want a computing device that can't be functionally extended?
- From J2ME to desktop PC users (running with administrative privileges)

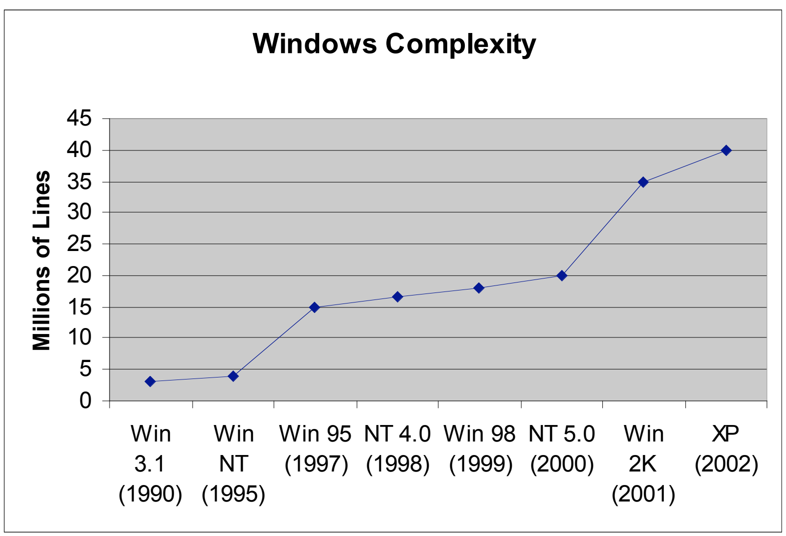






The classic security tradeoff





So what's the problem?

- Well, for starters
  - Consumers don't demand more
  - Software developers tend to lack knowledge of vulnerabilities, attacks, and threats
  - IT security tends to not understand software development
- But that's not all!

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Additional problems - 1

- We don’t pay enough attention to our failures
- Consider other engineering disciplines

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Additional problems - 2

- We fail to consider business risks first and foremost
- Business must drive technology
- Consider Wi-Fi, Word macros, USB drives, etc.

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Additional problems - 3

- Old school information security solutions don't adequately protect the software
- Consider IM, Skype, Wi-Fi, VPNs

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Additional problems - 4

- Software testing does not adequately address security
- Penetration testing is not sufficient

Additional problems - 5

- Too much attention is paid to functional spec
- Consider what can go wrong as well

Additional problems - 6

- IT security is viewed as an impediment to business
- Don’t just be the person that says no

Security problems are complicated

IMPLEMENTATION BUGS

- Buffer overflow
  - String format
  - One-stage attacks
- Race conditions
  - TOCTOU (time of check to time of use)
- Unsafe environment variables
- Unsafe system calls
  - System()
- Untrusted input problems

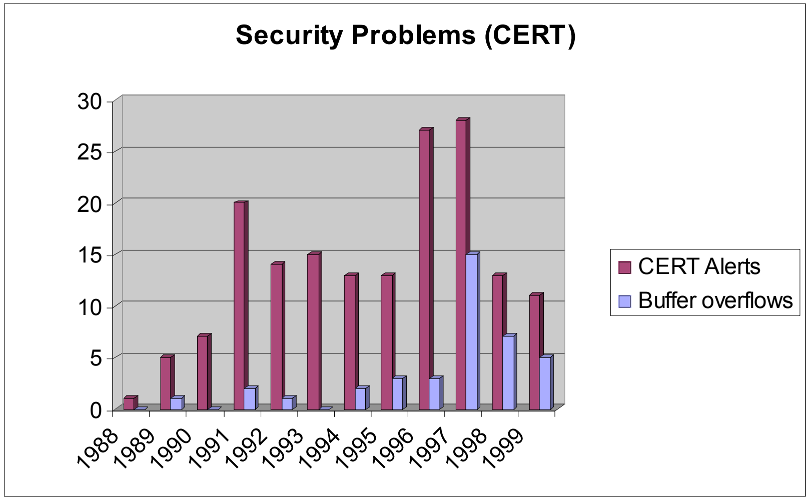
ARCHITECTURAL FLAWS

- Misuse of cryptography
- Compartmentalization problems in design
- Privileged block protection failure (DoPrivilege())
- Catastrophic security failure (fragility)
- Type safety confusion error
- Insecure auditing
- Broken or illogical access control (RBAC over tiers)
- Method over-riding problems (subclass issues)
- Signing too much code

BUG: The dreaded buffer overflow

- Overwriting the bounds of data objects
- Allocate some bytes, but the language doesn't care if you try to use more
  - `char x[12];`
    `x[12] = '\0';`
- Why was this done? Efficiency!
- Two main flavors of buffers
  - Heap allocated buffers
  - Stack allocated buffers
  - Smashing the stack is the most common attack

- The most pervasive security problem today in terms of reported bugs



Pervasive C problems lead to BUGS

```
void main() {
   char buf[1024];
   gets(buf);
}
```

- How not to get input
  - Attacker can send an infinite string!
  - Chapter 7 of K&R (page 164)

- Calls to watch out for

Instead of:	Use:
gets(buf)	fgets(buf, size, stdin)
strcpy(dst, src)	strncpy(dst, src, n)
strcat(dst, src)	strncat(dst, src, n)
sprintf(buf, fmt, a1,…)	snprintf(buf, fmt, a1, n1,…) (where available)
*scanf(…)	Your own parsing

- Hundreds of such calls
- Use static analysis to find these problems
  - ITS4, Fortify
- Careful code review is necessary

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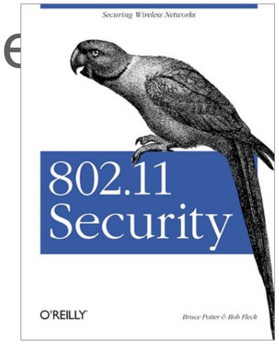
FLAW: 802.11b WEP crypto

- Well-documented flaws in the design of the WEP protocol
- Even if implemented 100% perfectly, the design is flawed and the encryption easily circumvented
- 802.11b is widely deployed and wildly popular
- It was designed by experts
- Would you entrust a mission-critical enterprise to run over it?



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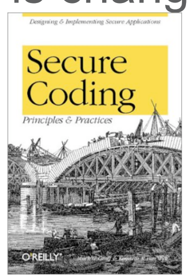
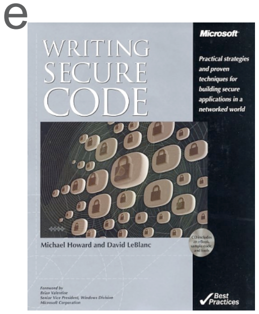
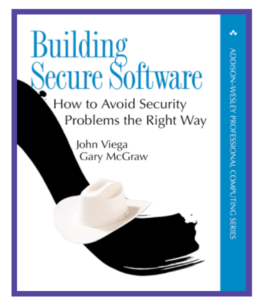
Software security: state of the practice

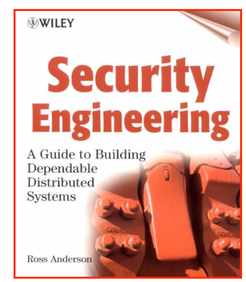
- Programming is hard
- Popular languages are really awful (C/C++)
- Many subtleties to learn
- Lots to know
- The only constant is change

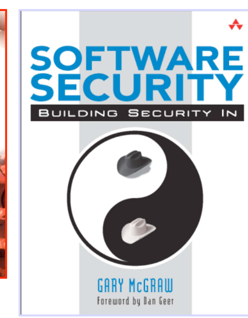
- Some good resources on software security
- Tools are getting better, but only cover BUGS





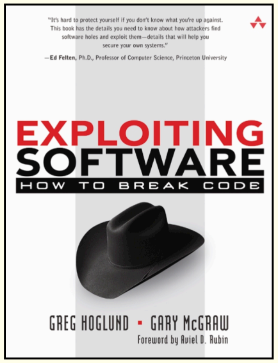






Software security is not security software!
Software security is about building things properly.

Exploiting software



Who is the bad guy?

- Hackers
  - "Full disclosure" zealots
- "Script kiddies"
- Criminals
  - Lone guns or organized
- Malicious insiders
  - Compiler wielders
- Business competition
- Police, press, terrorists, intelligence agencies

Above: Deputy Attorney General Christopher Bubb, center, N.J. Gov. Christie Whitman (left) and Attorney General Peter Verniero conferencing on alleged virus writer David L. Smith (right).

AP, ZDTV

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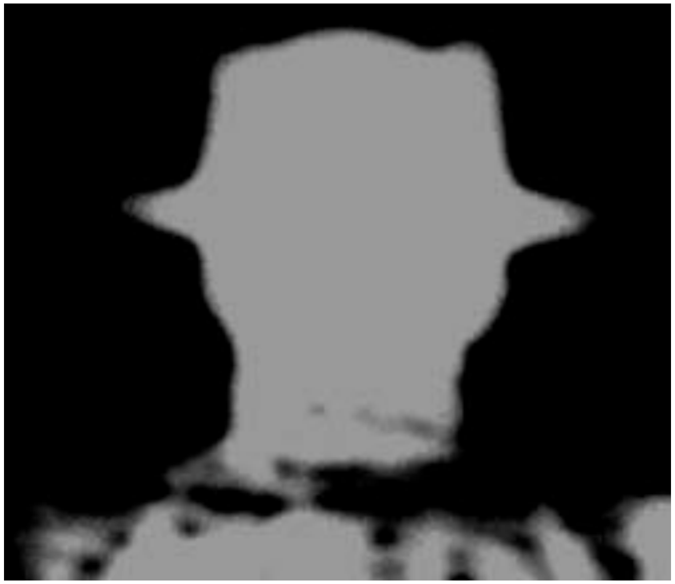
Attackers do not distinguish bugs and flaws

- Both bugs and flaws lead to vulnerabilities that can be exploited
- Attackers are pragmatic in their approach
- Attackers write code to break your software's design and/or implementation



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How attacks unfold

- Attacking a system is a process of discovery and exploration
  - Qualify target (focus on input points)
  - Determine what transactions the input points allow
  - Apply relevant attack patterns
  - Cycle through observation loop
  - Find vulnerability
  - Build an exploit

<u>The standard process</u>

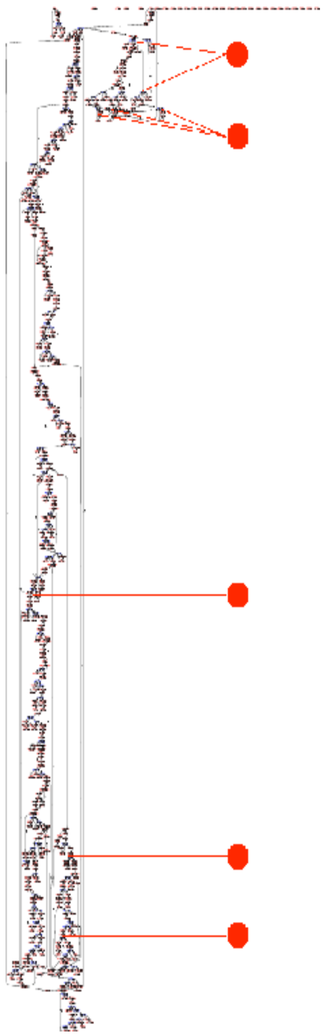
- Scan network
- Build a network map
- Pick target system
- Identify OS stack
- Port scan
- Determine target components
- Choose attack patterns
- Leverage environment faults
- Use indirection
- Plant backdoor

Attacker's toolkit: disassemblers and decompilers

- Source code is not a necessity for software exploit
- Binary is just as easy to understand as source code
- Disassemblers and decompilers are essential tools
- Reverse engineering is common and must be understood (not outlawed)
- IDA allows plugins to be created
- Use bulk auditing

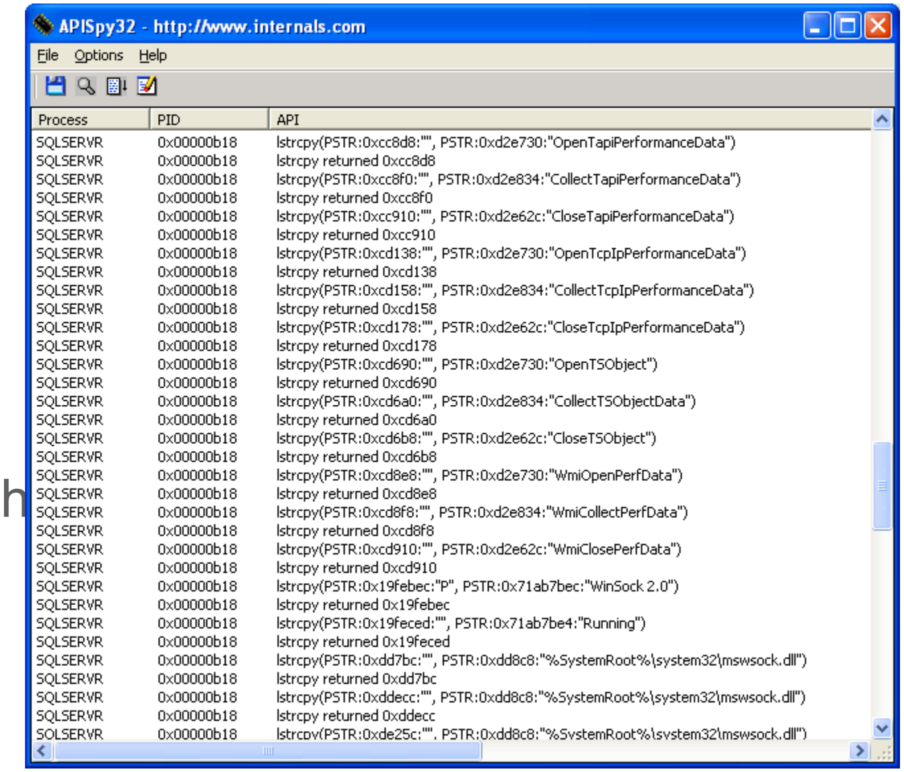
Attacker’s toolkit: control flow and coverage

- Tracing input as it flows through software is an excellent method
- Exploiting differences between versions is also common
- Code coverage tools help you know where you have gotten in a program
  - dyninstAPI (Maryland)
  - Figure out how to get to particular system calls
  - Look for data in shared buffers



Attacker's toolkit: APISPY32

- Look for broken system calls (at all levels in code)
- lstrcpy() makes a great example
- On win32 systems, use APISPY to determine which APIs are being used by a target program



Process	PID	API
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcc8d8:"", PSTR:0xd2e730:"OpenTapiPerformanceData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcc8d8
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcc8f0:"", PSTR:0xd2e834:"CollectTapiPerformanceData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcc8f0
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcc910:"", PSTR:0xd2e62c:"CloseTapiPerformanceData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcc910
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd138:"", PSTR:0xd2e730:"OpenTcpIpPerformanceData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd138
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd158:"", PSTR:0xd2e834:"CollectTcpIpPerformanceData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd158
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd178:"", PSTR:0xd2e62c:"CloseTcpIpPerformanceData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd178
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd690:"", PSTR:0xd2e730:"OpenTSObject")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd690
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd6a0:"", PSTR:0xd2e834:"CollectTSObjectData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd6a0
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd6b8:"", PSTR:0xd2e62c:"CloseTSObject")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd6b8
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd8e8:"", PSTR:0xd2e730:"WmiOpenPerfData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd8e8
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd8f8:"", PSTR:0xd2e834:"WmiCollectPerfData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd8f8
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xcd910:"", PSTR:0xd2e62c:"WmiClosePerfData")
SQLSERVR	0x00000b18	lstrcpy returned 0xcd910
SQLSERVR	0x00000b18	lstrcpy(PSTR:0x19febec:"P", PSTR:0x71ab7bec:"WinSock 2.0")
SQLSERVR	0x00000b18	lstrcpy returned 0x19febec
SQLSERVR	0x00000b18	lstrcpy(PSTR:0x19feced:"", PSTR:0x71ab7be4:"Running")
SQLSERVR	0x00000b18	lstrcpy returned 0x19feced
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xdd7bc:"", PSTR:0xdd8c8:"%SystemRoot%\system32\mswsock.dll")
SQLSERVR	0x00000b18	lstrcpy returned 0xdd7bc
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xddecc:"", PSTR:0xdd8c8:"%SystemRoot%\system32\mswsock.dll")
SQLSERVR	0x00000b18	lstrcpy returned 0xddecc
SQLSERVR	0x00000b18	lstrcpy(PSTR:0xde25c:"", PSTR:0xdd8c8:"%SystemRoot%\system32\mswsock.dll")

- Interposition attacks are a great thing to think about at this level

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Attacker's toolkit: breakpoints

- Breakpoints are central to debuggers
  - Use interrupt 3 on x86 architectures
- Mark entire blocks for access
- Single step at breakpoint (also as in debugging)

- Check out "The PIT" http://www.hbgary.com

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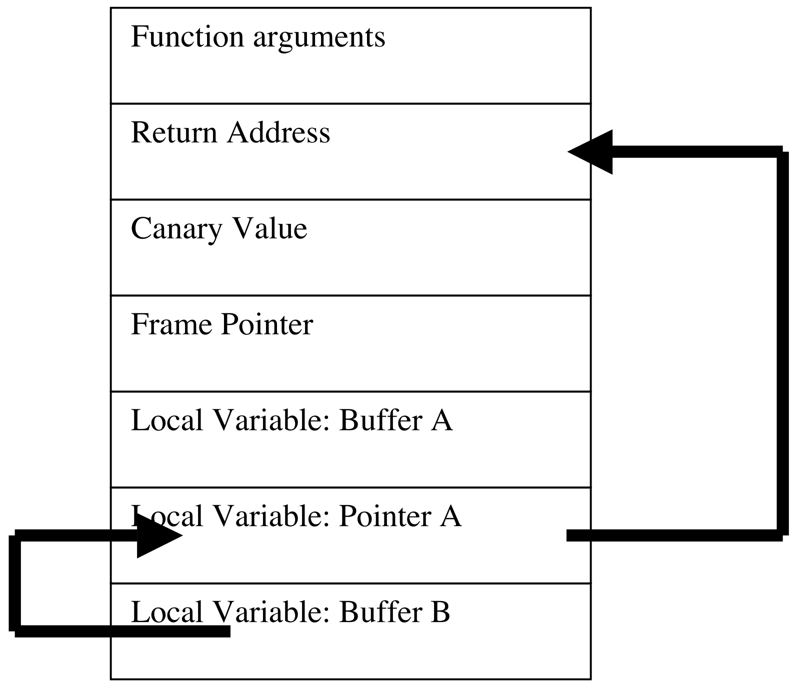
Attacker's toolkit: the buffer overflow

- Find targets with static analysis
- Change program control flow
  - Heap attacks
  - Stack smashing
  - Trampolining
- Particular examples
  - Overflow binary resource files (used against Netscape)
  - Overflow variables and tags (Yamaha MidiPlug)
  - MIME conversion fun (Sendmail)
  - HTTP cookies (apache)

- Trampolining past a canary



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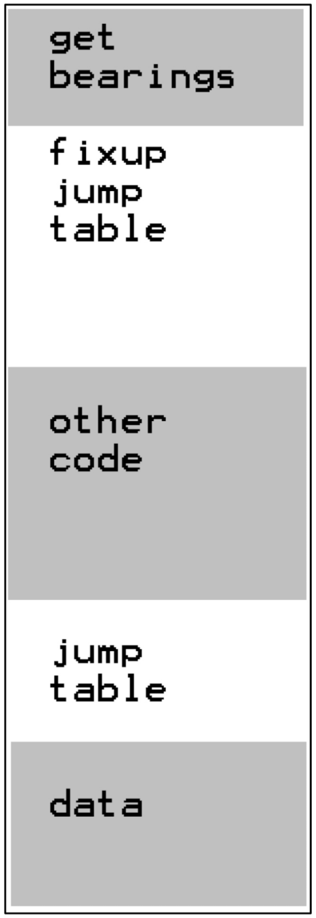
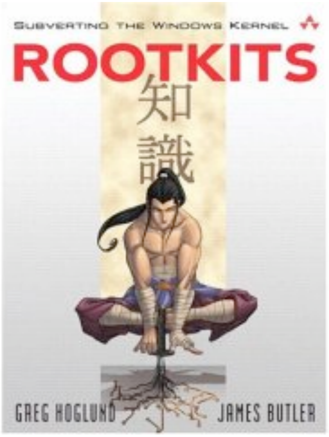
Attacker's toolkit: shell code and other payloads

- Common payloads in buffer overflow attacks
- Size matters (small is critical)
- Avoid zeros
- XOR protection (also simple crypto)

- Payloads for
  - X86 (win32)
  - RISC (MIPS and sparc)
  - Multiplatform payloads



Attacker's toolkit: rootkits



- The apex of software exploit…complete the machine
- Live in the kernel
  - XP kernel rootkit in the book
  - See http://www.rootkit.com
- Get into the microchips (hardware viruses)
- Hide files and directories by controlling access to process tables
- Provide control and access over the network

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Attacker’s toolkit: other miscellaneous tools

- Debuggers (user-mode)
- Kernel debuggers
  - SoftIce
- Fault injection tools
  - Failure simulation tool
  - Hailstorm
  - Holodeck
- Boron tagging
- The “depends” tool
- Grammar rewriters

Attack Patterns

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Knowledge: 48 Attack Patterns

- Make the Client Invisible
- Target Programs That Write to Privileged OS Resources
- Use a User-Supplied Configuration File to Run Commands That Elevate Privilege
- Make Use of Configuration File Search Paths
- Direct Access to Executable Files
- Embedding Scripts within Scripts
- Leverage Executable Code in Nonexecutable Files
- Argument Injection
- Command Delimiters
- Multiple Parsers and Double Escapes
- User-Supplied Variable Passed to File System Calls
- Postfix NULL Terminator
- Postfix, Null Terminate, and Backslash
- Relative Path Traversal
- Client-Controlled Environment Variables
- User-Supplied Global Variables (DEBUG=1, PHP Globals, and So Forth)
- Session ID, Resource ID, and Blind Trust
- Analog In-Band Switching Signals (aka “Blue Boxing”)
- Attack Pattern Fragment: Manipulating Terminal Devices
- Simple Script Injection
- Embedding Script in Nonscript Elements
- XSS in HTTP Headers
- HTTP Query Strings
- User-Controlled Filename
- Passing Local Filenames to Functions That Expect a URL
- Meta-characters in E-mail Header
- File System Function Injection, Content Based
- Client-side Injection, Buffer Overflow
- Cause Web Server Misclassification
- Alternate Encoding the Leading Ghost Characters
- Using Slashes in Alternate Encoding
- Using Escaped Slashes in Alternate Encoding
- Unicode Encoding
- UTF-8 Encoding
- URL Encoding
- Alternative IP Addresses
- Slashes and URL Encoding Combined
- Web Logs
- Overflow Binary Resource File
- Overflow Variables and Tags
- Overflow Symbolic Links
- MIME Conversion
- HTTP Cookies
- Filter Failure through Buffer Overflow
- Buffer Overflow with Environment Variables
- Buffer Overflow in an API Call
- Buffer Overflow in Local Command-Line Utilities
- Parameter Expansion
- String Format Overflow in syslog()

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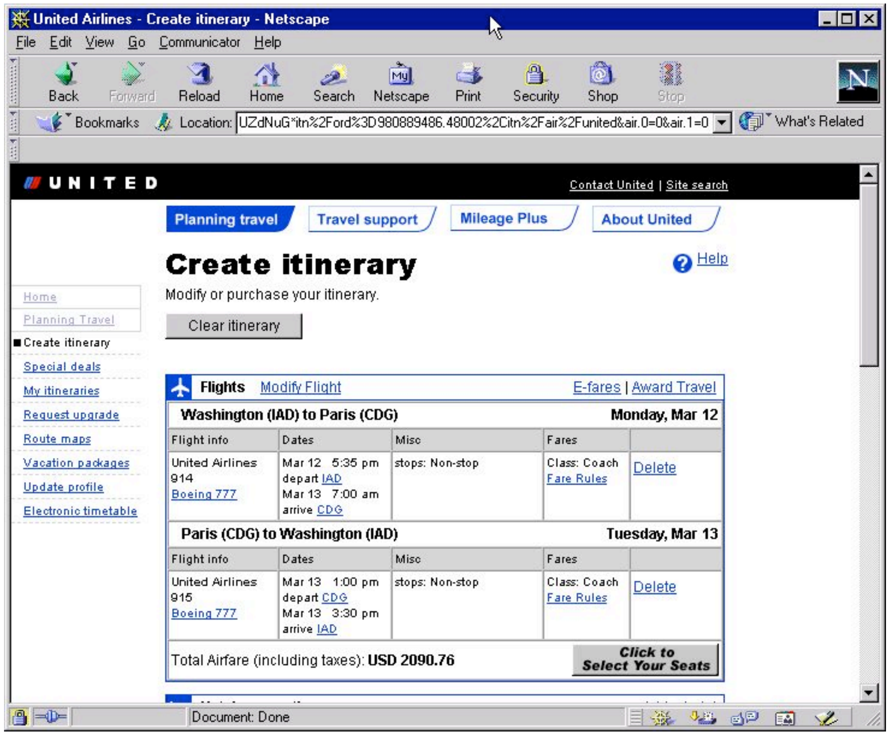
Attack pattern 1: Make the client invisible

- Remove the client from the communications loop and talk directly to the server
- Leverage incorrect trust model (never trust the client)
- Example: hacking browsers that lie



Attack pattern 2: Command delimiters

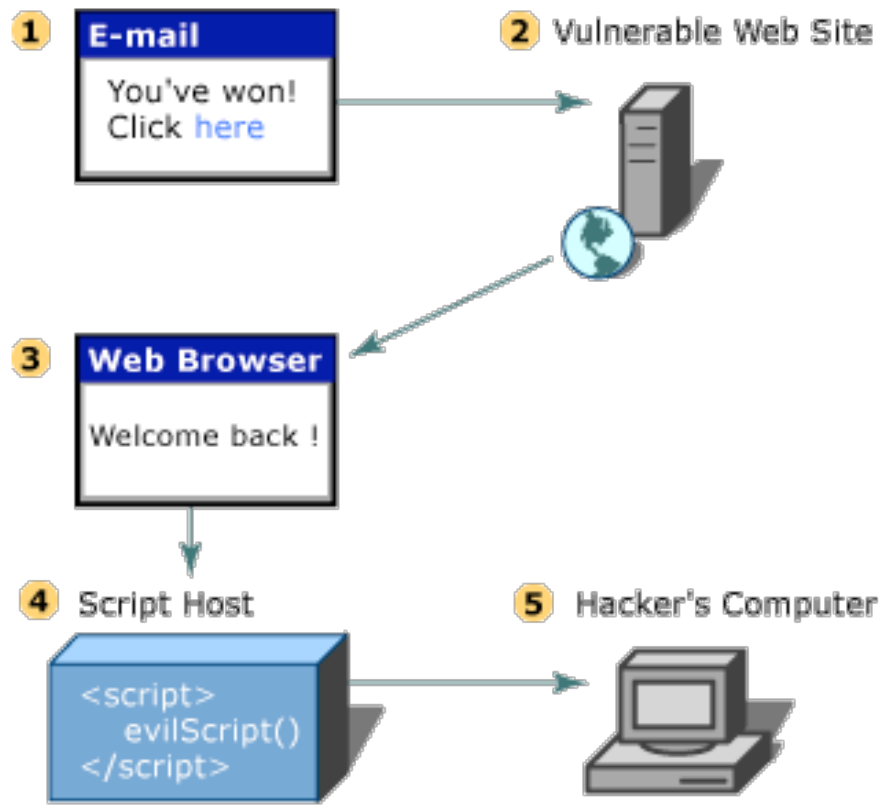
- Use off-nominal characters to string together multiple commands
- Example: shell command injection with delimiters

<input type=hidden name=filebase value="bleh; [command]”>

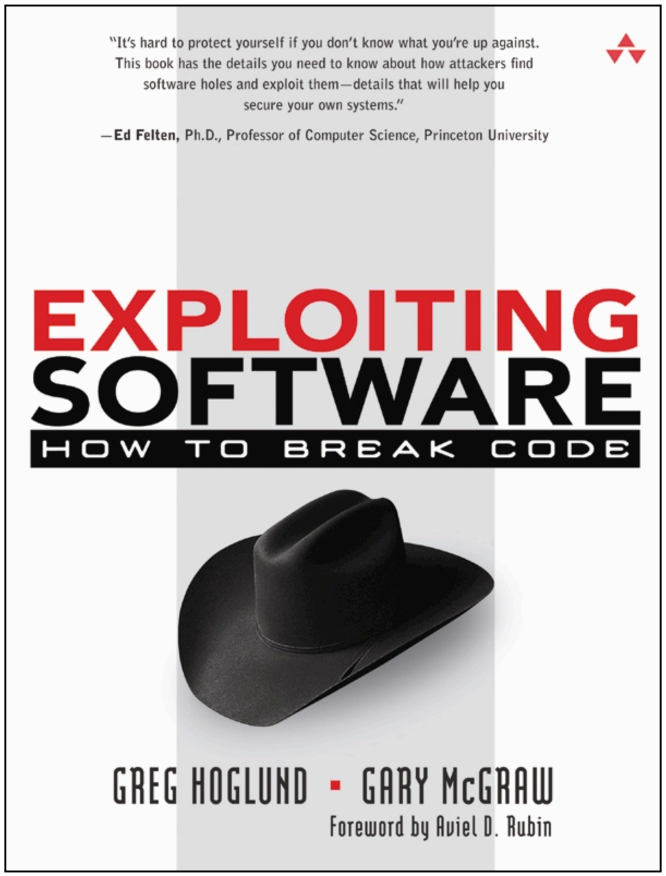
cat data_log_; rm -rf /; cat temp.dat

Attack pattern 3: Cross site scripting

- XSS
  - Attacker sends active content to a victim
  - Content invokes a script on the vulnerable website
  - Later invoked by a web browser hitting the website
  - The script runs
  - Attacker allowed access
- Examples
  - Javascript injection
  - Inject in non-script elements
  - HTTP headers
  - Query strings

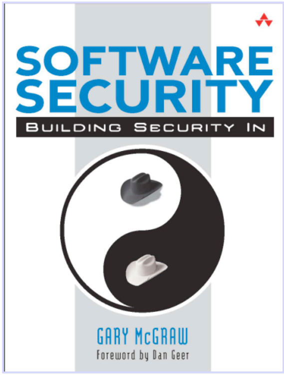


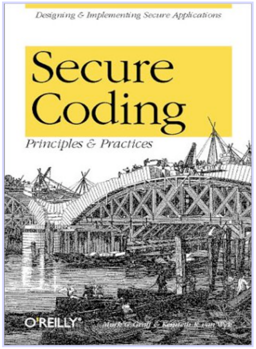
Breaking stuff is important

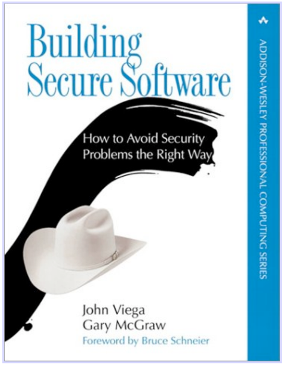


- Learning how to think like an attacker is essential
- Do not shy away from carrying out attacks on your own stuff
  - Engineers learn from stories of failure
- Attacking is fun! Fun is good!

Software security touchpoints







Software security touchpoints

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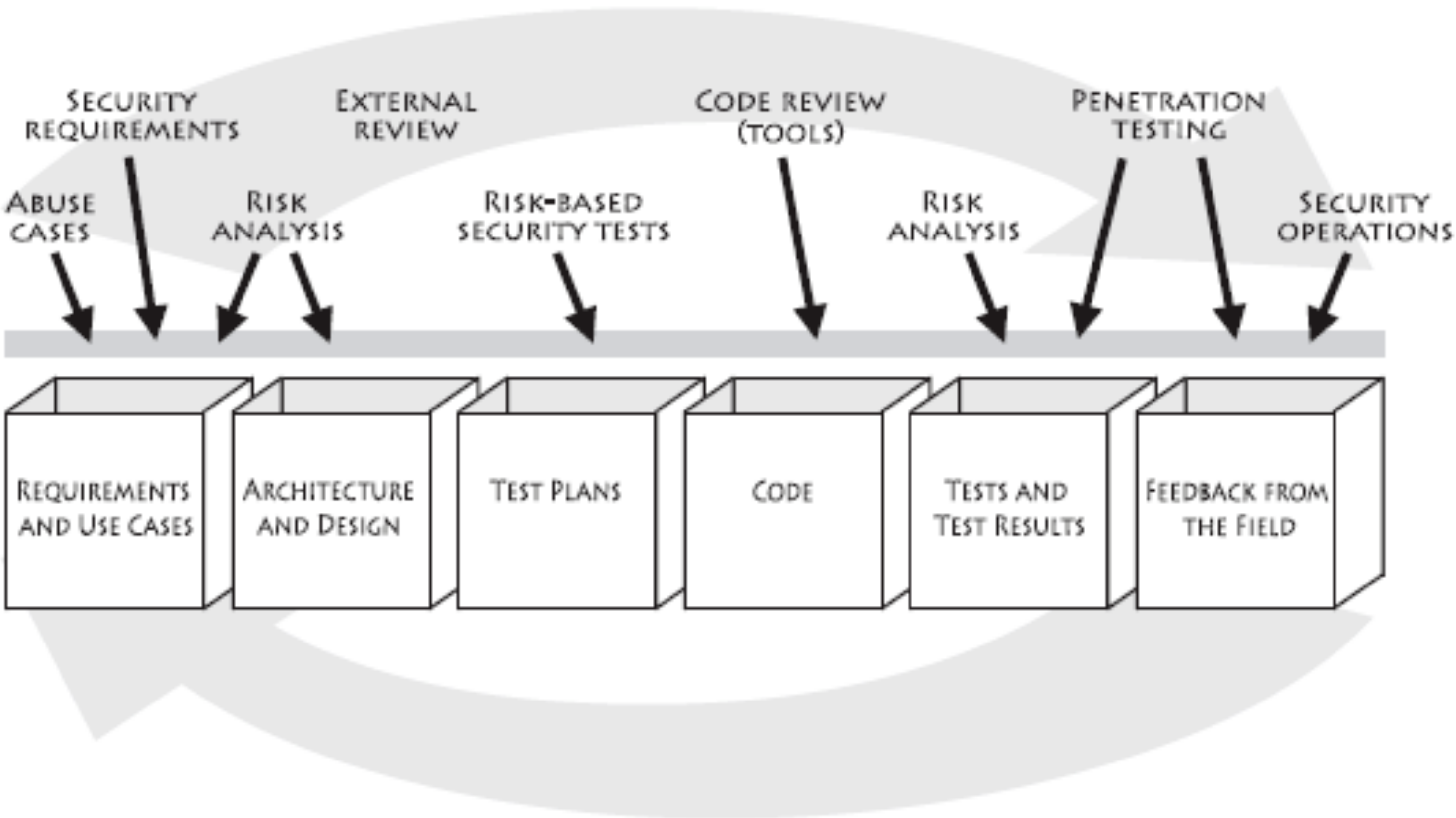
Software security touchpoints



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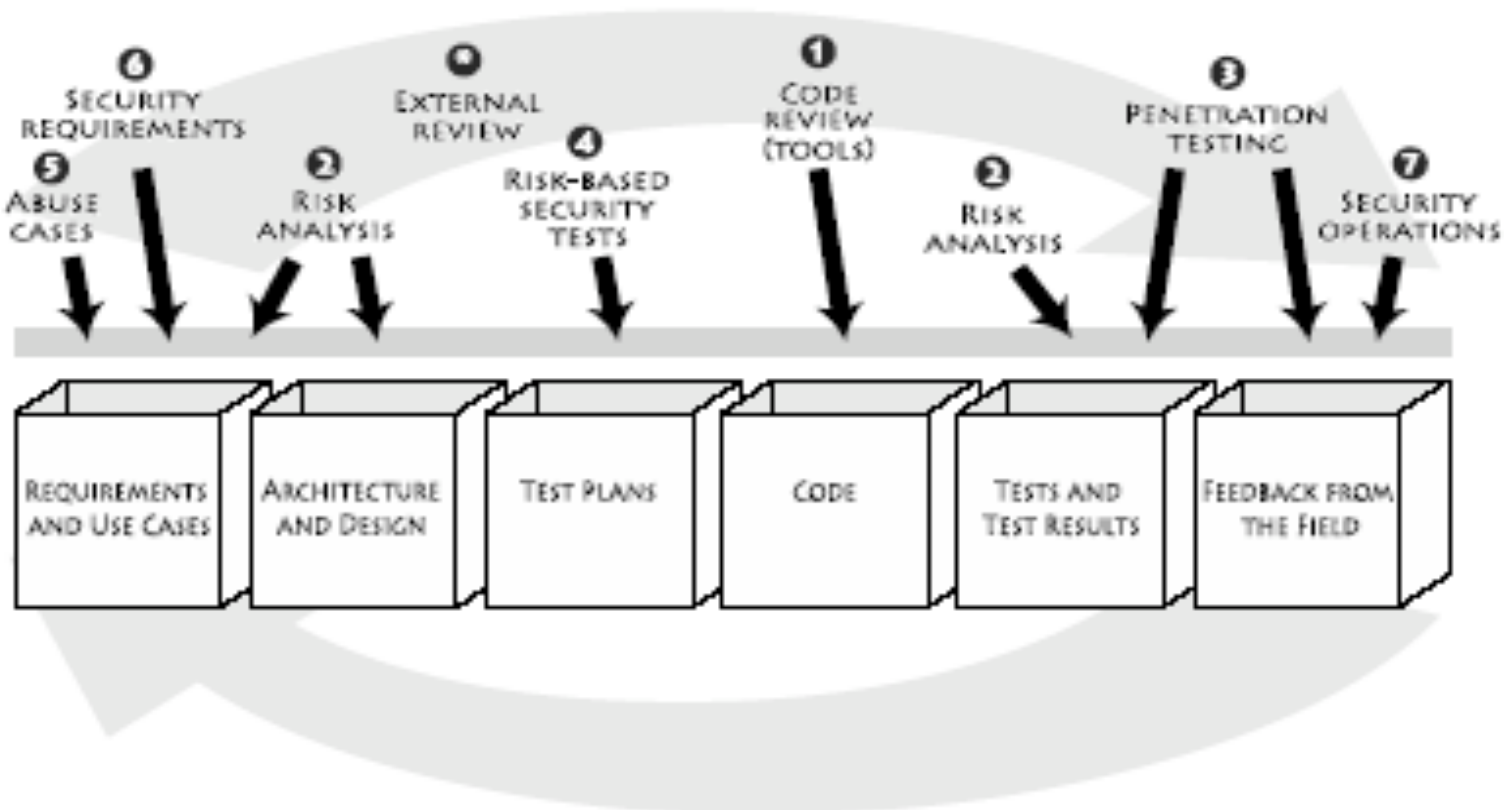
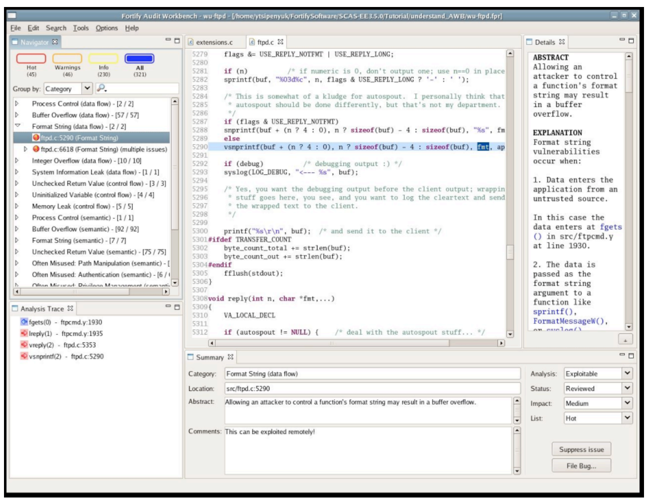
Adopting the touchpoints



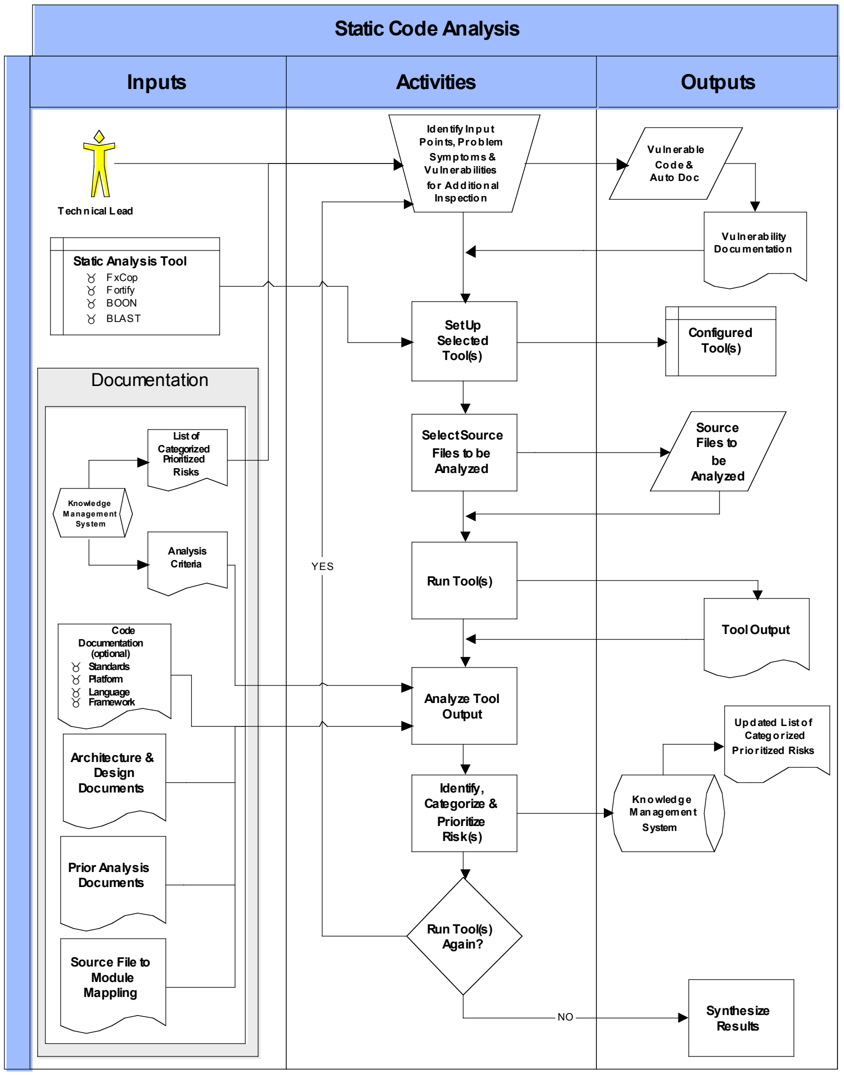
Touchpoint 1: code review (with a tool)

- Code review is a necessary evil
- Better coding practices make the job easier
- Automated tools help catch silly errors
    - Fortify/SCA (Cigital rules)



- Implementation errors do matter
    - Buffer overflows can be uncovered with static analysis
    - Static analysis
        - C/C++
        - Java
        - .NET
        - PSQL
- Tracing back from vulnerable location to input is critical

TP1: Code review



- There are many ways to apply code review technology
- Use a tool
- Integrate into the build

Touchpoint 2: Architectural risk analysis

- To assess and understand the risks, ask questions:
  - What is the likelihood of an attack?
  - What does the software do to support your organization’s mission?
  - Is there a disaster recovery plan?
  - What would the impact be if the software were unavailable?
  - What is a tolerable down time?
- Whom should you ask?
  - Software owner
  - IT manager
  - Key users

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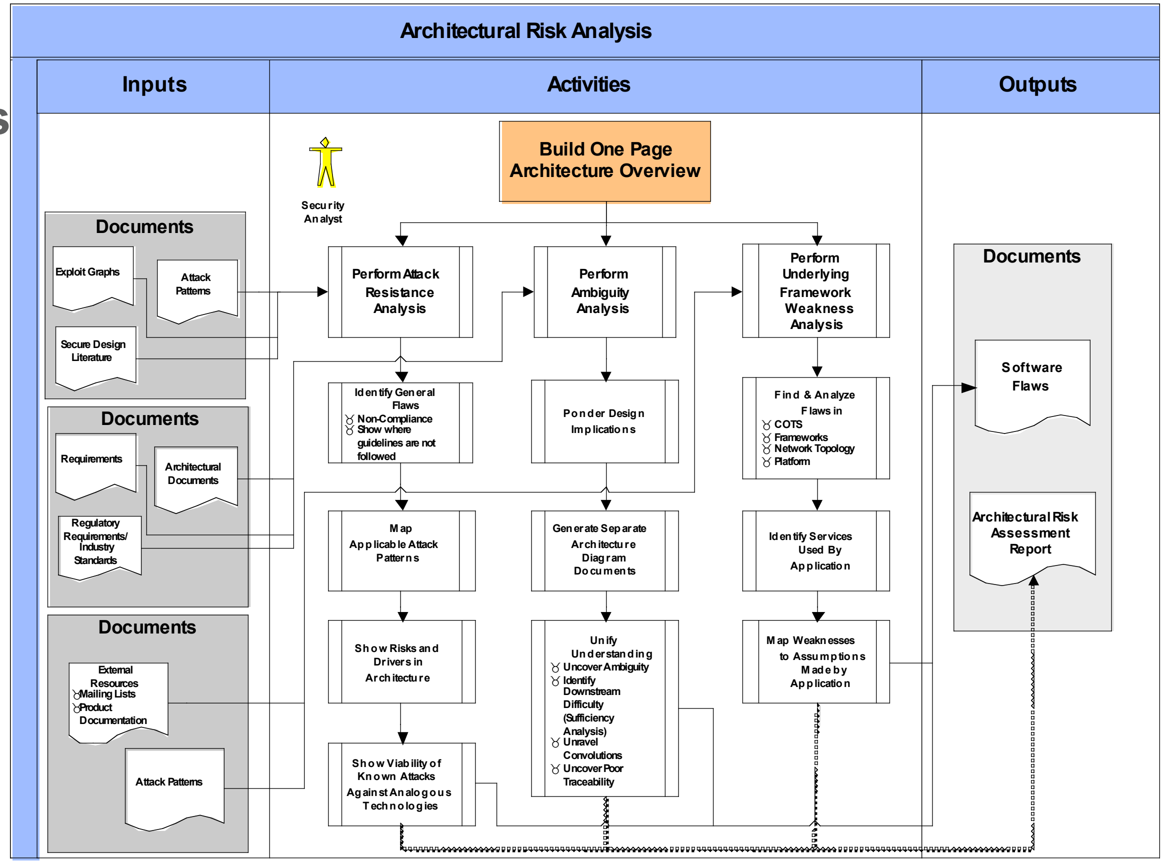
TP2: Architectural risk analysis

- **Follow a process**
- Build an overview (one page)
- Three steps
  - Attack resistance analysis
  - Ambiguity analysis
  - Weakness analysis
- Rank risks
- Build mitigations



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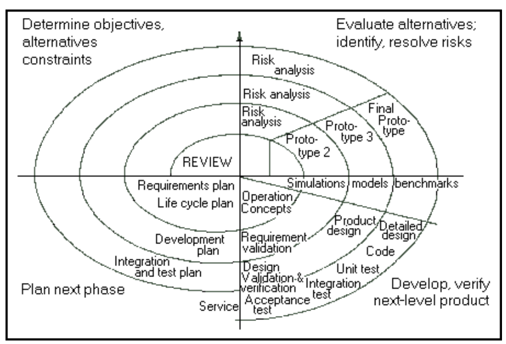
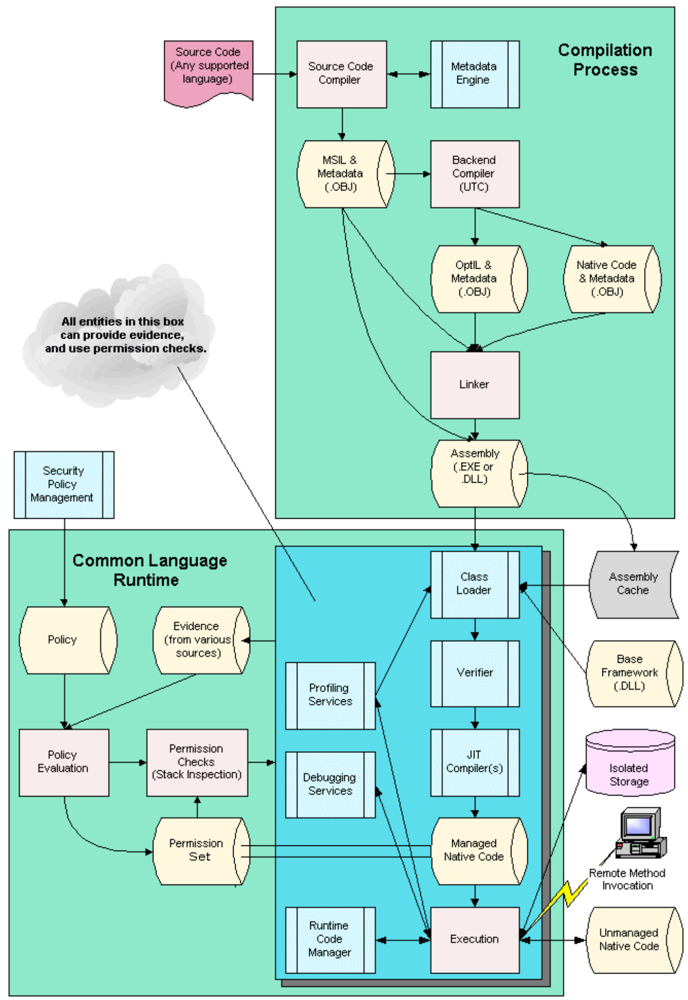
TP2: Architectural risk analysis

- Designers should not do this
- Build a one page white board design model (like that →)
- Use hypothesis testing to categorize risks
  - Threat modeling/Attack patterns
- Rank risks
- Tie to business context
- Suggest fixes
- Repeat





TP2 step: Attack resistance

- Identify general flaws
  - Non-compliance
  - Where guidelines are not followed
- Map applicable attack patterns
- Identify risks in architecture
- Consider known attacks against similar technologies

- Attack Patterns
  - Pattern language
  - Database of patterns
  - Actual flaws from clients
- Exploit Graphs
  - Ease mitigation
  - Demonstrate attack paths
- Secure design

Example flaws from experience…

- Transparent authentication token generation/management
- Misuse of cryptographic primitives
- Easily subverted guard components, broken encapsulation
- Cross-language trust/privilege issues

TP2 step: Ambiguity analysis

- Consider implications of design
- Generate separate arch. diagrams
- Unify understanding
  - Uncover ambiguity
  - Identify downstream difficulty (traceability)
  - Unravel convolution
- Apprenticeship model
- Use system, technology experts
  - Win32 knowledge
  - JVM/managed code
  - Language/compiler knowledge
- Previous experience

Example flaws from experience…

- Protocol, authentication problems
- Javacard applet firewall, inner class issues, instantiation in C#
- Type safety and type confusion
- Password retrieval, fitness and strength

TP2 step: Weakness analysis

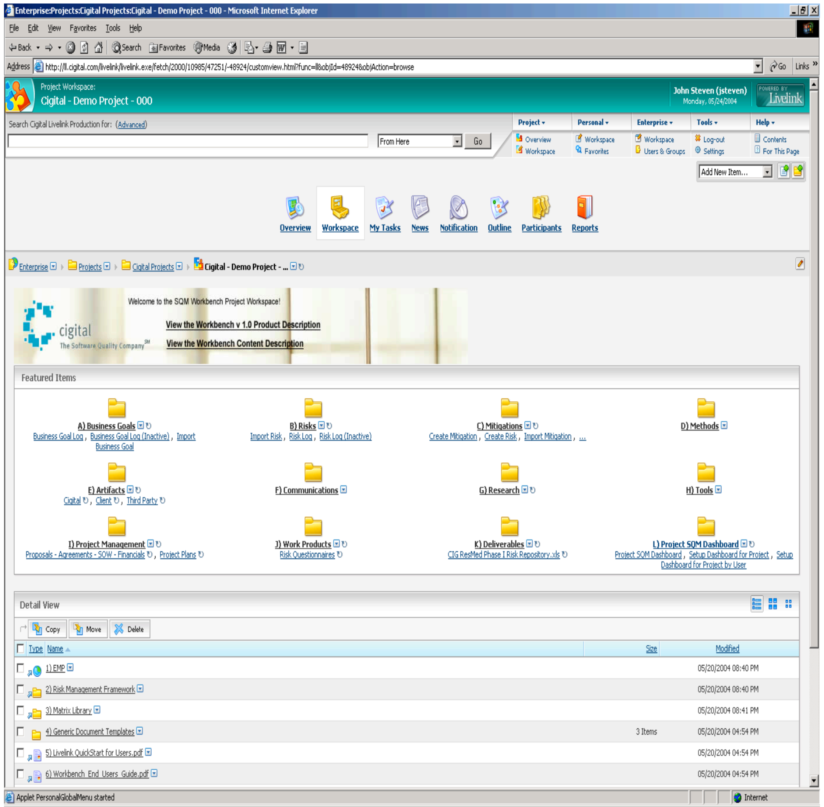
- Consider systemic flaws
  - COTS
  - Frameworks
  - Network topology
  - Platform
- Identify services
- Map weaknesses to assumptions
- Experience base
  - Assessments of COTS and platforms
- Attack patterns
- Other resources
  - Mailing lists
  - Product documentation

Example flaws from experience…

- Browser and other VM sandboxing failures
- Insecure service provision: RMI, COM, etc.
- Debug (or other operational) interfaces
- Unused (but privileged) product "features"
- Interposition attacks: DLLs, library paths, client spoofing

TP2: Keep track of risks

- The key to making a process like the one we described work is to KEEP TRACK of what you've found
- Use excel if you have nothing better
- Cigital uses the Cigital workbench
- Remember the RMF? Use it!



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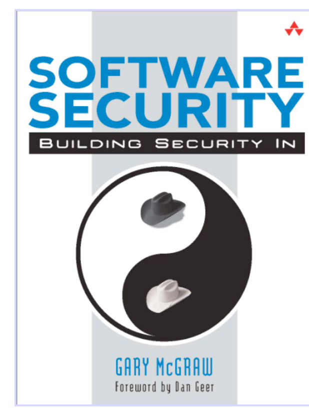
Touchpoint 3: Penetration testing

- A very good idea since software is bound in an environment
- How does the complete system work in practice?
  - Interaction with network security mechanisms
  - Firewalls
  - Applied cryptography
- Penetration testing should be driven by risks uncovered throughout the lifecycle
- Not a silver bullet!



Touchpoint 4: Security testing

- Test security functionality
  - Cover non-functional requirements
  - Security software probing
- Risk-based testing
  - Use architectural risk analysis results to drive scenario-based testing
  - Concentrate on what “you can’t do”
  - Think like an attacker
  - Informed red teaming

TP4: Risk-based testing

- Identify areas of potential risk in the system
  - Requirements
  - Design
  - Architecture
- Use abuse cases to drive testing according to risk
- Build attack and exploit scenarios based on identified risks
- Test risk conditions explicitly

- Example: Overly complex object-sharing system in Java Card

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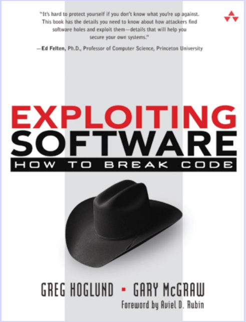
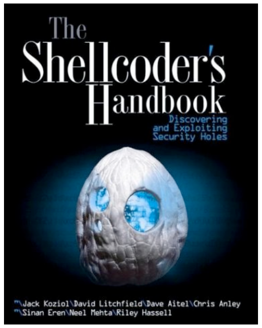
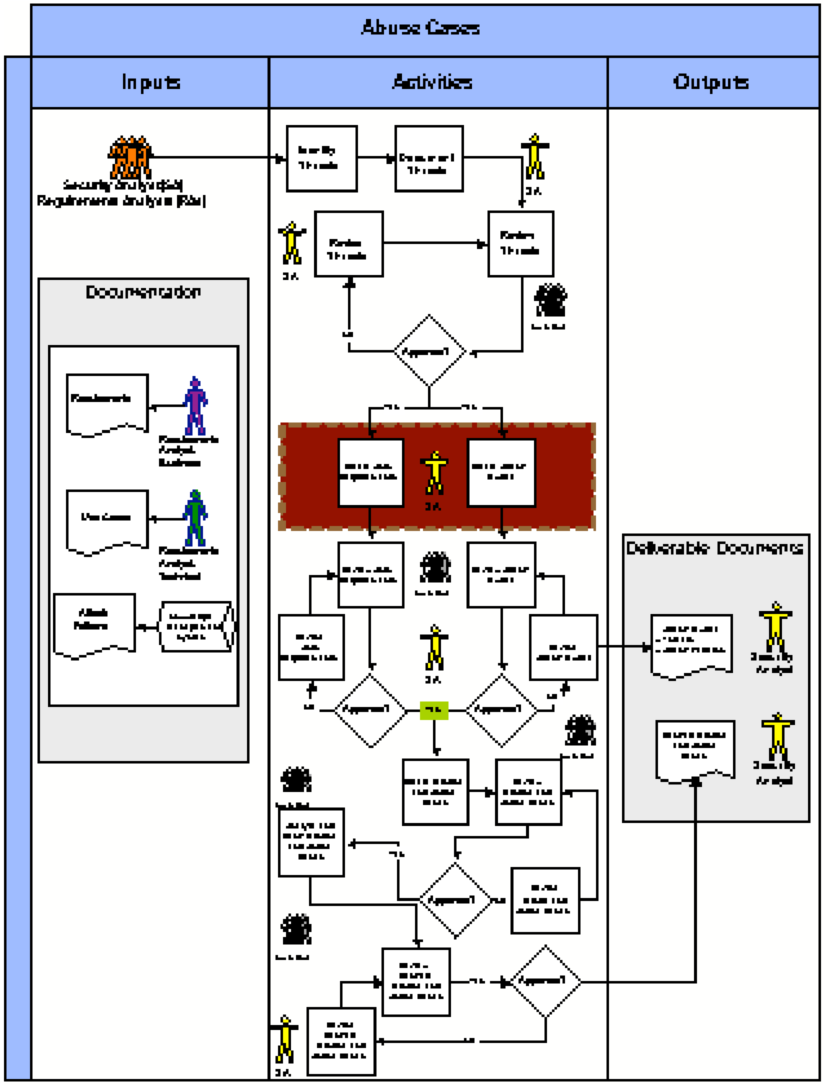
Touchpoint 5: Abuse cases

- Use cases formalize normative behavior (and assume correct usage)
- Describing non-normative behavior is a good idea
  - Prepare for abnormal behavior (attack)
  - Misuse or abuse cases do this
  - Uncover exceptional cases
- Leverage the fact that designers know more about their system than potential attackers do
- Document explicitly what the software will do in the face of illegitimate use
- Think like an attacker!





TP5: Abuse cases



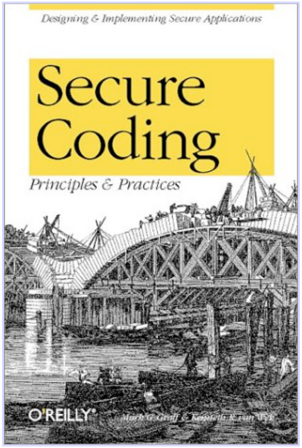
- Starting with attack patterns, requirements and use cases
- Identify anti-requirements
- Build an attack model
- Determine misuse and abuse cases

Touchpoint 6: Security requirements

- Some security functionality maps naturally to clear requirements
  - Medical data should be cryptographically protected
  - Strongly authenticate users
  - Meet GLBA regulatory guidelines
- But do not forget that security is an emergent property of a complete system
  - An attacker needs to find only one hole
  - "Do not allow buffer overflows" is not much of a requirement!
  - "Make it secure" is vague

Touchpoint 7: Security operations

- Use your resources!
- Network security people know an awful lot about real attacks
- Involve knowledgeable security people in as many touchpoint activities as possible
- Fine tune the deployed environment to the specific needs of your application
  - "Standard OS build" process is not enough



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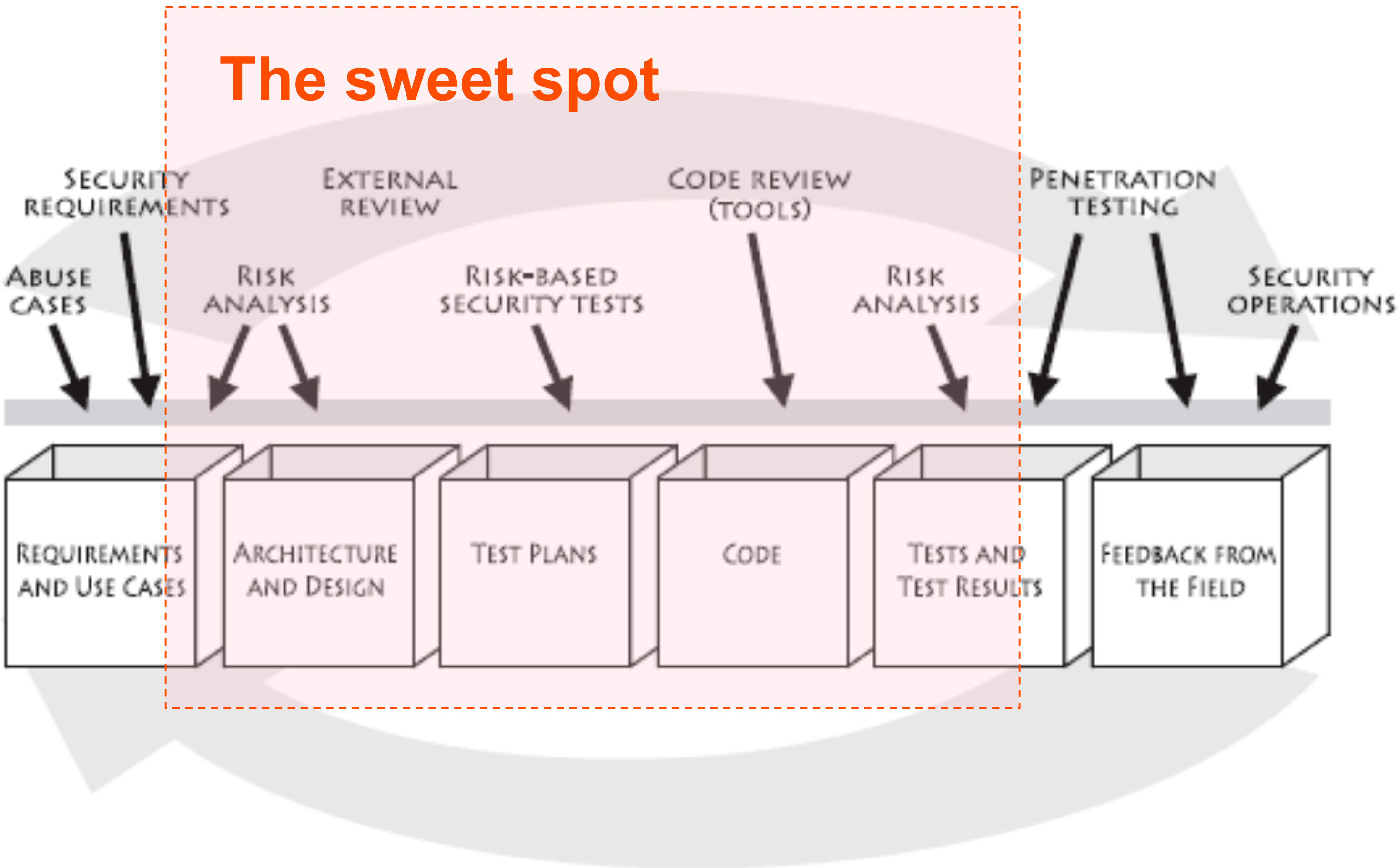
Always: External review

- Having outside eyes look at your system is essential
  - Designers and developers naturally get blinders on
  - External just means outside of the project
  - This is knowledge intensive
- Outside eyes make it easier to "assume nothing"
  - Find assumptions, make them go away
- Red teaming is a weak form of external review
  - Penetration testing is too often driven by outside→in perspective
  - External review must include architecture analysis
- Security expertise and experience really helps

Software security touchpoints



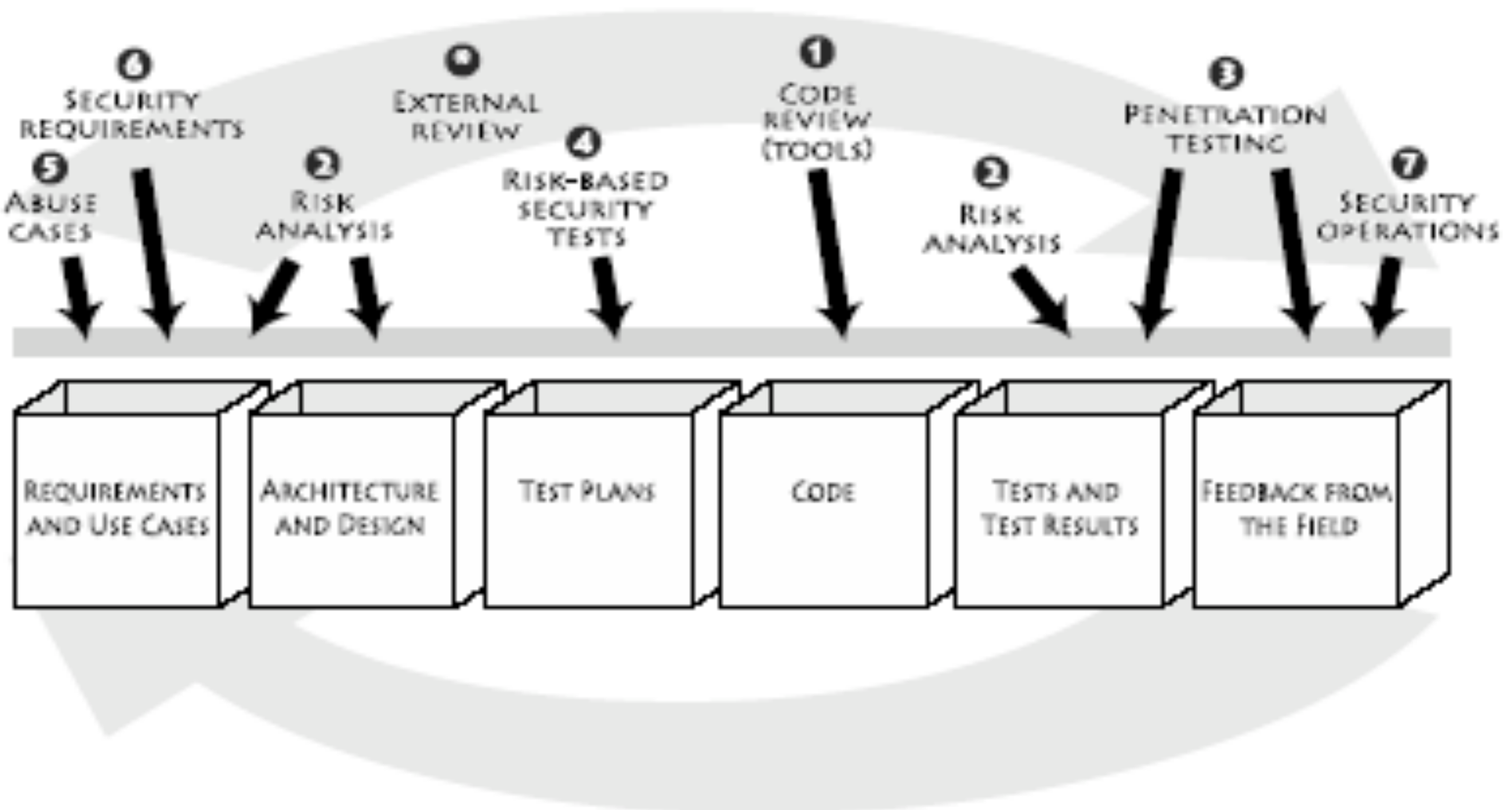
Reprise

Best practices reprise

- These best practices should be applied throughout the lifecycle
- Tendency is to "start right" (penetration testing) and declare victory
  - Not cost effective
  - Hard to fix problems
- Start as far to the left as possible

- Abuse cases
- Security requirements analysis
- Architectural risk analysis
- Risk analysis at design
- External review
- Test planning based on risks
- Security testing (malicious tests)
- Code review with static analysis tools

Adopting the touchpoints



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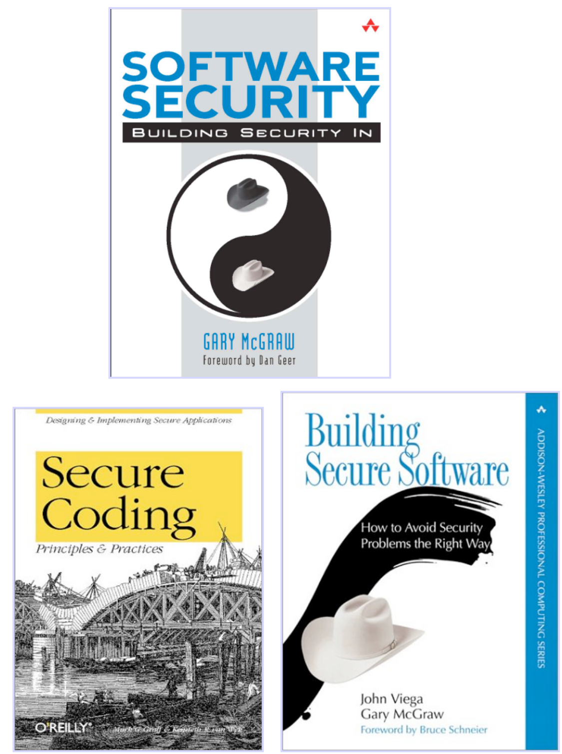
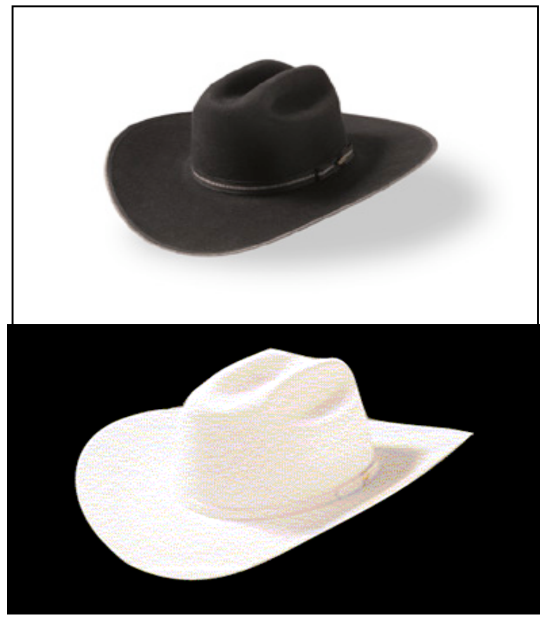
Seven pernicious kingdoms



Outline

- Classic Pitfalls
- Seven Kingdoms
- Static Analysis and Code Review



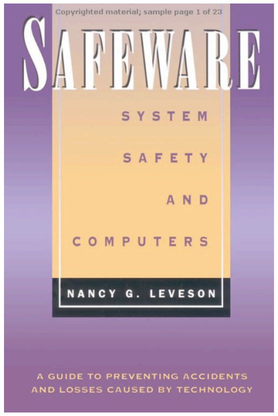
Classic Pitfalls

Learn from history

Those who cannot remember the past are condemned to repeat it.
-- Santayana

- Other engineering disciplines overcome failures by collecting failure data and analyzing failures for commonalty that could lead to avoidance of that kind of failure in the future

- Failure data in software is generally considered proprietary
  - Most failure data from product development is not available for open research



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Same old mistakes

- By understanding software security risks, developers can avoid them when writing their own code
- Learn by considering examples
  - Configuring applications
  - Scripts
  - Errors
  - Design flaws
- Many of the same problems crop up year after year
- Basic science to classify and categorize these problems has yet to be done
  - Bugs: implementation
  - Flaws: higher-level

Seven Kingdoms

Seven pernicious kingdoms

- Input validation and representation
- API abuse
- Security features
- Time and state
- Error handling
- Code quality
- Encapsulation
- Environment

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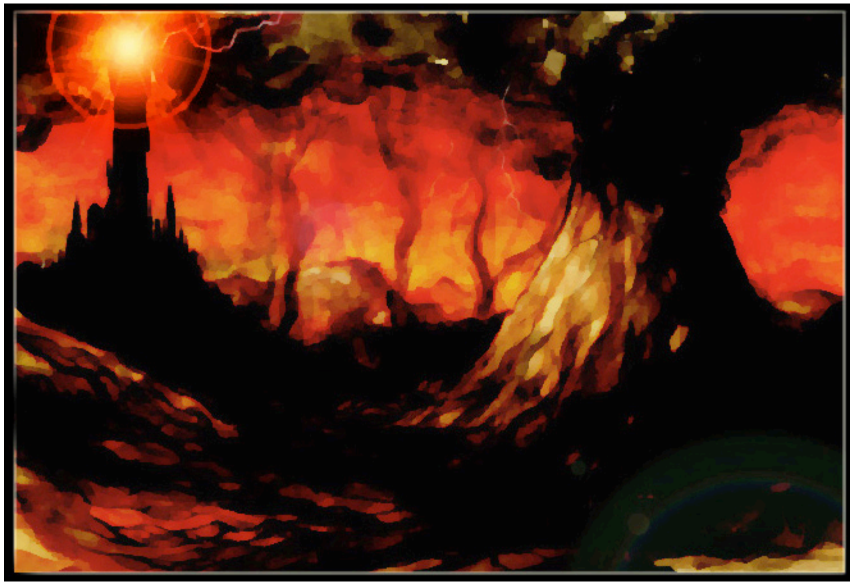
1. Input Validation and Representation



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Pernicious kingdom one

- **Input Validation and Representation**
  - Problems due to metacharacters, alternate encodings, numeric representations, and trusting input
  - Example: **Buffer Overflow** phylum

```
int main(char ** argv, int argc) {
        char buf[10];
        strcpy(buf, argv[1]);
}
```

The number one coding snafu

- “Scrubbing” user input pitfalls to avoid
  - SQL Insertion
  - Cross-Site Scripting (XSS)
  - Format string vulnerabilities
  - Integer overflows
  - Buffer overflows
    - Not a security problem per se in Java due to strict variable range enforcement
- Not a trivial issue, as complexity and subtlety abounds

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Buffer overflows

- Pervasive problem, primarily in C and other non-type-safe (sometimes called “unmanaged”) code
- Responsible for huge percentage of reported vulnerabilities today
- Exploited by some of the most damaging worms
  - 1988: Morris worm
  - 2001: Code Red
  - Others: Slammer, Blaster, Sasser, Zotob

Buffer overflow causes

- String manipulation libraries
  - Flawed libc functions: strcpy, strcat, …
  - Multibyte characters
  - Null termination errors
- Off by one errors
- Array manipulation
- Pointer arithmetic
- Others
  - Format strings
  - Integer overflow
- These all relate to reliability as well as security

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Historic example: the Morris worm of 1988

- Cornell grad student Robert Tappan Morris's "Internet worm" exploited a bug in the (then) popular BSD fingerd daemon
- The vulnerable fingerd contained the following code:

```
char line[512];
line[0] = "\0";
gets(line);
```

- 512 characters should be enough, shouldn't it?

Same issue in C++

- Although the gets() function was known to be horribly flawed for years, the same mistake was made in C++

```
char buf[BUFSIZE];
cin >> (buf);
```

- Those cows come home yet?

Problematic function: *strcpy()*

- Although not quite as bad as *gets(),* it's darn close

```
int main(char ** argv, int argc) {
  char buf[10];
  strcpy(buf, argv[1]);
}
```

Problematic function: *sprintf()*

- As with the likes of *strcpy(),* you can use *sprintf()* safely, but it isn't easy
- Is the following good or bad? (we already know it's ugly)

```
char buf[42];
sprintf(buf, “Val1=%.8s Val2=%.8s Val3=%.8s”,
val1, val2, val3);
```

What's the deal with the *n* functions?

- Although the bounded versions of string functions, like strncpy(), are better, there's still room for silly mistakes
- Truncation can cause odd behavior
- Example: One simple mistake is to bound the data to the src buffer, as in this example from MSDN

```
int main(int argc, char *argv[]) {
…
char DirSpec[MAX_PATH + 1];
printf("Target dir is %s.\n", argv[1]);
strncpy(DirSpec, argv[1], strlen(argv[1])+1);
```

Problematic function: *strncat()*

- Example: The *strncat()* function is misleading because it doesn't accept a bound on the total size of the destination buffer, but rather the remaining space available in the destination buffer

```
char* buf[512];
strcpy(buf, “The argument is”);
strncat(buf, argv[1], 512);
```

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Format string vulnerabilities

- Format string vulnerabilities occur when an attacker can control a format string
- Although not technically buffer overflows, they almost invariably lead to read/writes outside a buffer's bounds
  - Including execution of arbitrary code placed on stack by the attacker
- First seen around 1999, but in its first full year resulted in many root exploits
  - Wu-ftpd 2.*
  - Linux rpc.statd
  - Qualcomm qpopper 2.53
  - Apache + PHP3
  - BSD chpass
  - OpenBSD fstat

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Format strings: root cause

- Misuse of formatting functions
  - A programmer wants to print a string
  - Which is correct?

```
printf("%s", string);
printf(str);
```

- If an attacker can control the format string, then %n can be used to write arbitrary values anywhere in memory
- Exploits then work the same way as traditional buffer overflows
  - Overwrite return address
  - Function pointer
  - Other important values

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Example: *wuftpd 2.6.0*

- Widely publicized format string vulnerability occurs in the *vreply()* function, which looks much like this

```
while (fgets(buf, sizeof buf, f)){
  lreply(200, buf);
  …
}

void lreply(int n, char *fmt, …) {
  char buf[BUFSIZ];
  …
  vsnprintf(buf, sizeof buf, fmt, ap);
  …
}
```

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SQL insertion

- Problem can exist when Java or middle-tier code interacts with back-end SQL-based database
- User inputs must be pedantically screened for SQL code
  - White space, quotes, etc., are indicators
- Regular Expression (regex) filtering is key

Problem: SQL insertion

- Can enable attacker to execute arbitrary SQL commands on back-end database
- PHP/SQL Example:
  - PHP code inputs USERNAME and PASSWORD and passes to SQL back-end
  - USERNAME is entered as bob
  - PASSWORD is entered as ’ or USERNAME=‘bob
  - Back-end executes Select ID from USERS where USERNAME=‘bob’ and PASSWORD=‘’ or USERNAME=‘bob’
  - Instead of Select ID from USERS where USERNAME=‘bob’ and PASSWORD=‘password’

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SQL insertion - example

```
Pattern pattern;
Matcher matcher;
String regex = "\\W";

boolean userOkay = true;
boolean passOkay = true;

// check username field

pattern = Pattern.compile(regex);
matcher = pattern.matcher(userField.getText());

if (matcher.find()) {
   userOkay = false;
}
```

[1]

[2]

[1] Begin by defining the regular expression itself

[2] Compile the regex and apply it to the string in question

(Even better: use PreparedStatement)

Complications in parsing input

- Lots of things can make parsing through input fields complex
- Whitelisting and blacklisting approaches
  - Assume input is dangerous until it is proven to be safe
- Internationalization
  - Unicode can be used to obfuscate SQL insertion, XSS, etc.
  - /etc/passwd—seems easy enough to parse, right?

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Unicode - example

```
Pattern pattern;
Matcher matcher;
String regex = "[^(a-zA-Z0-9_\\-\\.)]";
String unicodeRegex = "[[u002f]u002F]";
String file = fileField.getText();

// check filename field

pattern = Pattern.compile(unicodeRegex);
matcher = pattern.matcher(file);

if (matcher.find()) {
   unicodeFound = true;
}

pattern = Pattern.compile(regex);
matcher = pattern.matcher(file);

if (matcher.find()) {
   filenameOkay = false;
}
```

[1]

[2]

[1] Define a regex to search for unicode characters (u002f = "\")

[2] Check for specified unicode characters in the file name

Good practice: take care with config files

- Check configuration files
  - Can be ripe target for attackers
  - Verify read/write controls are safe
  - Verify data content before acting
- User inputs
  - Command line parameters and desktop icons
  - URLs
  - Assume it to be harmful until proven otherwise
- Consider also where other user inputs can come from
  - Signals, registry keys, mouse actions, and so on…

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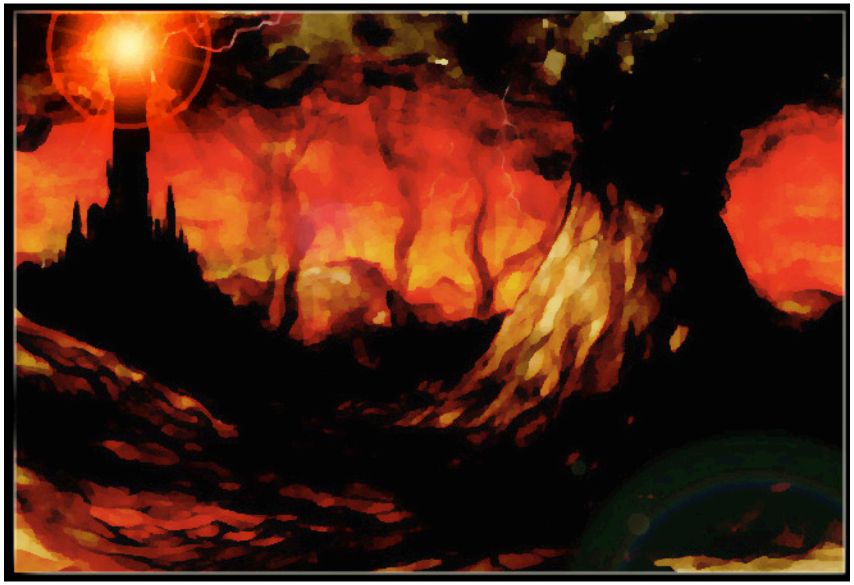
Phyla: Input validation and representation

- Buffer Overflow
- Command Injection
- Cross-Site Scripting
- Format String
- HTTP Response Splitting
- Illegal Pointer Value
- Integer Overflow
- Log Forging
- Path Traversal
- Process Control
- Resource Injection
- Setting Manipulation
- SQL Injection
- String Termination Error
- Struts: Duplicate Validation Forms
- Struts: Erroneous validate() Method
- Struts: Form Bean Does Not Extend Validation Class
- Struts: Form Field without Validator
- Struts: Plug-in Framework Not in Use
- Struts: Unused Validation Form
- Struts: Unvalidated Action Form
- Struts: Validator Turned Off
- Struts: Validator without Form Field
- Unsafe JNI
- Unsafe Reflection
- XML Validation

2. API Abuse



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Pernicious kingdom two

- **API Abuse**
  - A caller fails to honor the contract between the caller and the callee
  - Dangerous function, Unchecked Return Value, and others
  - Example: **Often Misused: Authentication** phylum

```
String ip = request.getRemoteAddr();
InetAddress addr = InetAddress.getByName(ip);
if (addr.getCanonicalHostName().endsWith(
            "trustme.com")) {
            trusted = true;
            // Relying on DNS lookup for recognizing trusted hosts
}
```

Comparing Java classes

- Never make a decision based on the name of a class
  - A program may treat two classes the same when they actually differ
  - Class names are trivial to forge or substitute
  - At the very least, verify that the name being checked is within the current classloader

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Example: *readlink()*

- Abuse of *readlink(),* which although it fills a string buffer does not null terminate the buffer

```
readlink(path, buf, MAXPATH);
int length = strlen(buf);
```

- The value returned from *strlen()* is likely to be incorrect – perhaps wildly so – and may even result in a buffer overflow or other runtime erratic behavior

Example: SYN flood

- Attacker initiates, but does not complete TCP session opening protocol
- Victim's TCP stack is left in a wait state
- Attacker repeats until victim's resource pool is saturated
- Victim is now effectively off the net – DoS
- Why would someone want to do this?

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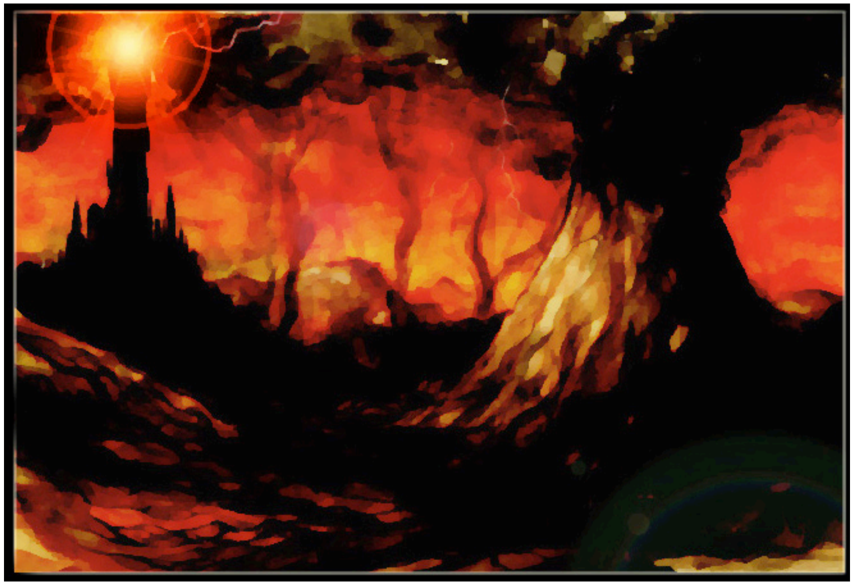
Phyla: API abuse

- Dangerous Function
- Directory Restriction
- Heap Inspection
- J2EE Bad Practices: getConnection()
- J2EE Bad Practices: Sockets
- Often Misused: Authentication
- Often Misused: Exception Handling
- Often Misused: Path Manipulation
- Often Misused: Privilege Management
- Often Misused: String Manipulation
- Unchecked Return Value

3. Security Features



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Pernicious kingdom three

- **Security Features**
  - Poorly handled authentication, access control, confidentiality, cryptography, and privilege management
  - Insecure Randomness, Password Management, Privacy Violation, and others
  - Example: **Privacy Violation** phylum

```
id = getId();
pass = getPassword();
type = getType();
tstamp = getTimestamp();
...                                   // Private info leaking into a log file
dbmsLog.log(id+“:”+pass+“:”+type+“:”+tstamp);
```

Signing JAR files

- Signing JAR files can be dangerous
- A signed JAR might be trusted more than is warranted
  - But, signed JARs also can be useful
  - Authentication and integrity checking
- If you must sign, put your signed classes into one JAR file, all by themselves

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Storing secrets

- "Hard coding" sensitive information in source code is dangerous
  - Class file can be viewed
  - Class de-compilers (e.g., jode) can expose

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Storing secrets - example

```
public class SecretInfo {

   public static void main(String[] args) {

      String username = ”bassethoundsruletheworld”;
      String password = ”t0ps3cr3t!”;

      /* do something with username and password */

   }
}
```

[1]

[1] Two strings are defined that contain sensitive information

Storing secrets – example (cont'd)

```
/* SecretInfo - Decompiled by JODE
 * Visit http://jode.sourceforge.net/
 */

public class SecretInfo
{
    public static void main(String[] strings) {
        String string = "bassethoundsruletheworld";
        String string_0_ = "t0ps3cr3t!";
    }
}
```

[2]

[2] Using a decompiler, the values of both strings can be retrieved from a compiled .class file

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Privilege handling

- Don’t forget the principle of least privilege
  - Avoid privileged code if at all possible
- Tips
  - Design things so that program does not need privileges
  - Develop code without privileges enabled
- Did you know?
  - 90% of Windows software can’t be installed without Administrator privileges
  - 70% can’t be run without Administrator privileges
  - 10,000 lemmings can’t be wrong!

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Why privileges are needed

- Interact directly with hardware
- Other shared resources
  - Network ports, config, registry
- Alter OS behavior
- Override file system protections
  - Install new files
  - Update protected files
  - Access files that belong to other users

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Case study: *lpr*

- Redhat lpr (Oct 1999)
- Setuid root in order to talk to printer device

```
int fd;
for (int i=1; i < argc; i++) {
   /* first make sure that the user can read the
   file, then open it */
   if (!access(argv[i], O_RDONLY)) {
        fd = open(argv[i], O_RDONLY);
   }
   print(fd);
}
```

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Case study: *lpr*

- File access race condition! Fix:

```
int fd;
for (int i=1; i < argc; i++) {
  int uid = getuid(); int gid = getgid();
  int original_euid = geteuid();
  int original_egid = getegid();
  seteuid(uid); setegid(gid);
  fd = open(argv[i], O_RDONLY);
  seteuid(original_euid);
  setegid(original_egid);
}
print(fd);
```

Case study: lpr

- Do you think that it's fixed now?
- No! *seteuid()* return value ignored
- No one expects *seteuid()* to fail since we're root

- POSIX capabilities vulnerability (June 2000)
- Attackers can cause *seteuid()* call to fail

- Not so simple, is it?

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When are random numbers needed?

- Some numbers need to be cryptographically secure
  - Crypto applications
  - Generated passwords
  - Port randomization
  - External unique identifiers such as session tokens
  - Discount codes
- Some do not
  - Monte Carlo simulation systems
  - Internal unique identifiers

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Example: Security depends on unpredictability

- The following code generates "unique" identifiers for online users who make a purchase. Because *lrand48()* is a statistical PRNG, it is easy for an attacker to predict

```
char* CreateReceiptURL() {
    int num; time_t t1;
    char *URL = (char*) malloc(MAX_URL);
    if (URL) {
            (void) time(&t1);
            srand48((long) t1)
            sprintf(URL, "%s%d%s, http://test.com,
                    lrand48(), ".html");
    }
    return URL; }
```

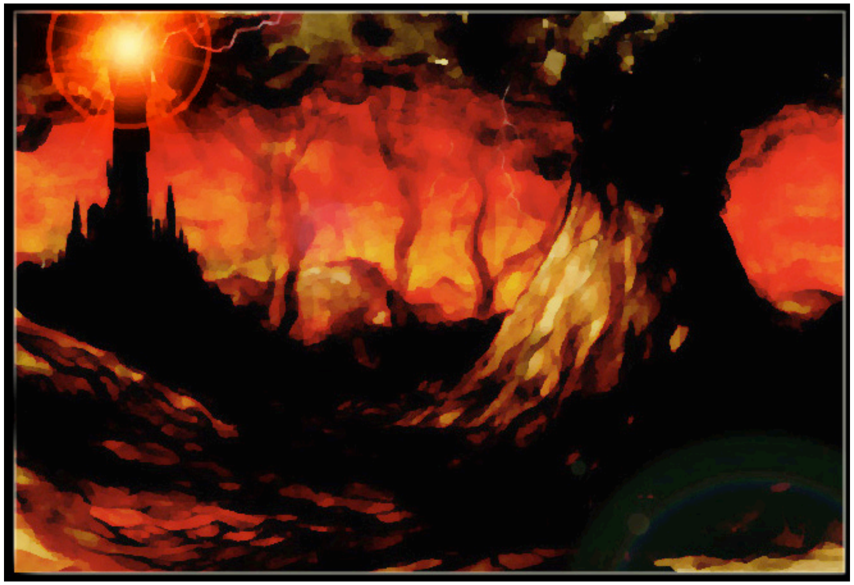
Choosing a PRNG

- Hardware can be good, if available
- OS may provide good random sources
  - /dev/urandom is almost always the right choice for user apps
  - /dev/random blocks and my be exhausted since shared
- Current state of the art
  - Fortuna (described in Schneier's Practical Cryptography)
  - Implementations
    - Win C++ (http://www.citadelsoftware.ca/fortuna/Fortuna.htm)
    - Linux /dev/urandom driver (http://jlcooke.ca/random)
- Freebie in Microsoft-friendly code
  - CryptoGenRandom()

Phyla: Security features

- Insecure Randomness
- Least Privilege Violation
- Missing Access Control
- Password Management
- Password Management: Empty Password in Configuration File
- Password Management: Hard-Coded Password
- Password Management: Password in Configuration File
- Password Management: Weak Cryptography
- Privacy Violation

4. Time and State



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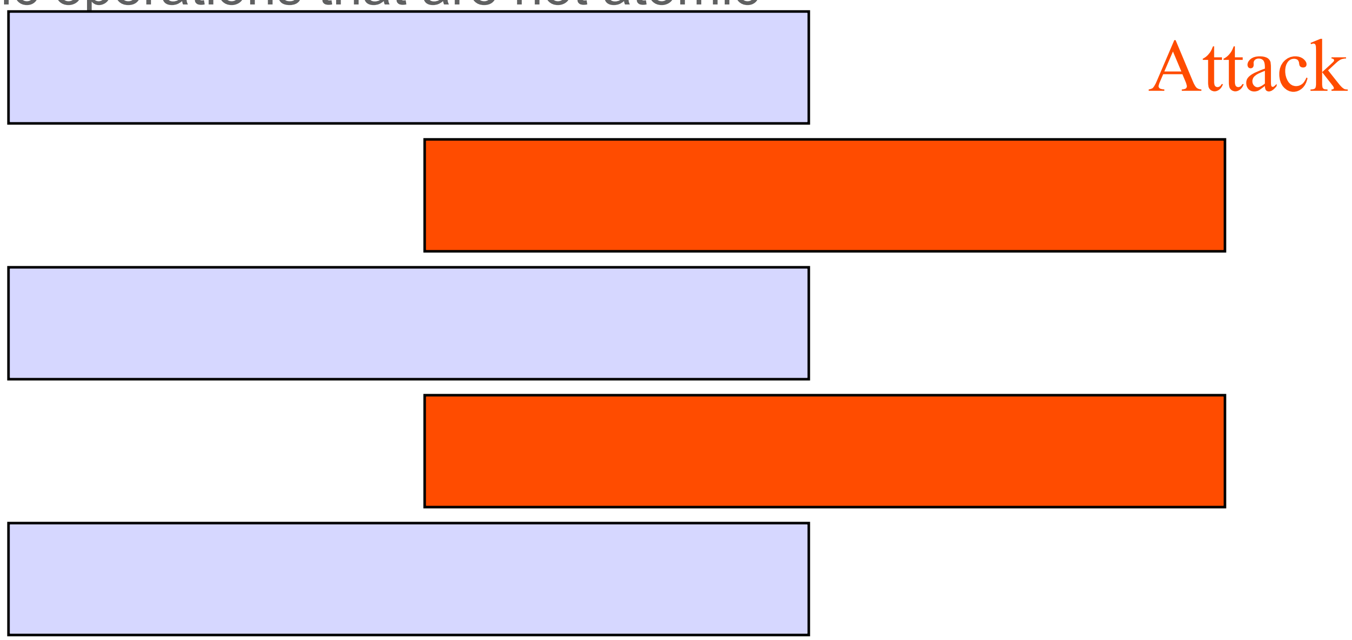
Pernicious kingdom four

- **Time and State**
  - Unexpected interactions between threads, processes, time, and information that happen through shared state: semaphores, variables, file system, etc.
  - File Access Race Condition TOCTOU, Deadlock, and others
  - Example: **Session Fixation** phylum

```
private void auth(LoginContext lc,
HttpSession session)
                    throws LoginException {
          …                          // No call to session.invalidate()
          lc.login();
          …
}
```

RISK: Race condition

- Time makes all the difference
- Atomic operations that are not atomic



A simple (broken) Java servlet

```
import java.io.*;
import java.servlet.*;
import java.servlet.http.*;
public class Counter extends HttpServlet{
  int count = 0;
  public void doGet(HttpServletRequest in, HttpServletResponse out)
                              throws ServletException, IOException {
     out.setContentType("text/plain");
     Printwriter p = out.getWriter();
     count++;
     p.println(count + " hits so far!");
  }
}
```

Race condition

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A simple (fixed) Java servlet

```
import java.io.*;
import java.servlet.*;
import java.servlet.http.*;
public class Counter extends HttpServlet{
  int count = 0;
  public synchronized void
      doGet(HttpServletRequest in, HttpServletResponse out)
                      throws ServletException, IOException {
    out.setContentType("text/plain");
    Printwriter p = out.getWriter();
    count++;
    p.println(count + " hits so far!");
  }
}
```

TOCTOU

- Race conditions on Unix files are famous
- Passwd example
  - Step 1: open file and read it in
  - Step 2: create and open “ptmp” in same directory
  - Step 3: open password file again, copying unchanged contents into ptmp while updating
  - Step 4: Close both password file and ptmp, then name ptmp the password file
- If an attacker makes use of unix’s linking facility, an attack is possible
- Change the system state in a subtle way in order to cause the system to do something dangerous

Threads (J2EE)

- Thread management in a web application is prohibited by the J2EE standard
- Difficult and likely to produce unpredictable results such as deadlocks, race conditions and other synchronization errors
- Rather than managing threads directly, use standards such as message driven beans and EJB timer service provided by the container

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Good practice: watch out for web content

- Web data
  - Watch out for data in hidden fields
  - Even though it is within page, user can still alter
- Web cookies
  - Can also be manipulated by user
  - Classic example: changing customer ID or shopping cart price totals
- State data must be protected
  - Encryption is commonly used
  - Verify that no data has been tampered with

Serialization

- Largely fixed in latest JDK versions
  - Previous default allowed serialization
  - New default requires class to implement Serializable interface
- When serialized, an object is written to disk directly, including internal memory
- If you must make something serializable, declare private data transient

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Serialization - example

```
public class SerializableClass implements Serializable {

   private transient String secret = "Cats are smarter than dogs.";
   private String notSecret = "Dogs drool everywhere.";

   public SerializableClass() { }
```

[1]

```
notSecrett^@^RLjava/lang/String;xpt^@^VDogs drool everywhere.x
```

[2]

[1] A serializable class that defines two private strings

[2] Output of the serialized class when read by a simple text editor (note that the transient string is not displayed)

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Phyla: Time and state

- Deadlock
- Failure to Begin a New Session upon Authentication
- File Access Race Condition: TOCTOU
- Insecure Temporary File
- J2EE Bad Practices: System.exit()
- J2EE Bad Practices: Threads
- Signal Handling Race Conditions

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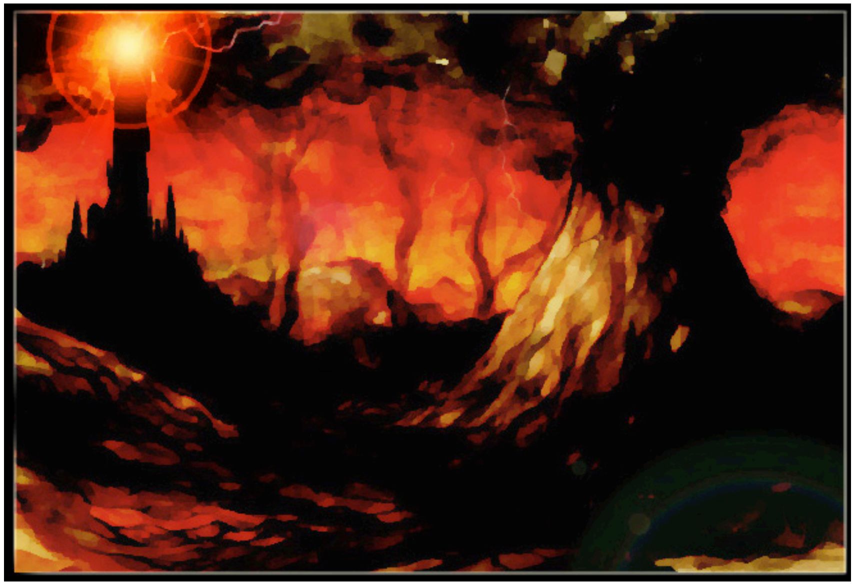
5. Error Handling



Pernicious kingdom five

- **Error handling**
  - Both poor error handling and generation of errors that either leak information or are difficult to handle
  - Empty Catch Block, Overly-Broad Catch Block, and others
  - Example: **Empty Catch Block** phylum

```
try {
        attempToDoSomethingImportant();
}
catch (ImportantException e) {
                        // How should this exception be handled?
}
```

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Error handling: the problem

- Ignoring exceptional conditions and their ramifications
  - A symptom: failure to think about what could go wrong
  - An outcome: leads to inconsistent and unexpected program state
- Unchecked return values
- Exception handling
- Signal handling

Legacy problems

- Many standards to choose from
  - *fork()* – 0 == success
  - *strtol()* – 0 == failure
  - *strcmp()* – 0 == true
  - *issetugid()* – 0 == false
  - *fork() -- >0* == success
- And this doesn’t even address multithreaded apps
- Always check those reference manuals before assuming!

Allocation problems

- Failure to check for memory allocation failure

```
buf = (char*) malloc(req_size);
strncpy(buf, xfer, req_size);
```

- What could go wrong?
- Bad for at least three reasons
  - No opportunity to recover
  - Impossible to exit gracefully
  - No opportunity of collecting diagnostic information

Missing error handling (J2EE)

- Un-handled exceptions can provide an attacker with potentially dangerous information, such as an SQL query string, the type of database being used, or application version numbers
- Web applications should always specify default error pages and handle standard HTTP error codes

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Missing error handling - example

Include the following entries in the *web.xml* file to specify default error pages...

```
<error-page>
    <exception-type>java.lang.Throwable</exception-type>
    <location>/error.jsp</location>
</error-page>
<error-page>
    <error-code>404</error-code>
    <location>/error.jsp</location>
</error-page>
<error-page>
    <error-code>500</error-code>
    <location>/error.jsp</location>
</error-page>
```

Phyla: Error handling

- Catch NullPointerException
- Empty Catch Block
- Overly Broad Catch Block
- Overly Broad Throws Declaration
- Unchecked Return Value

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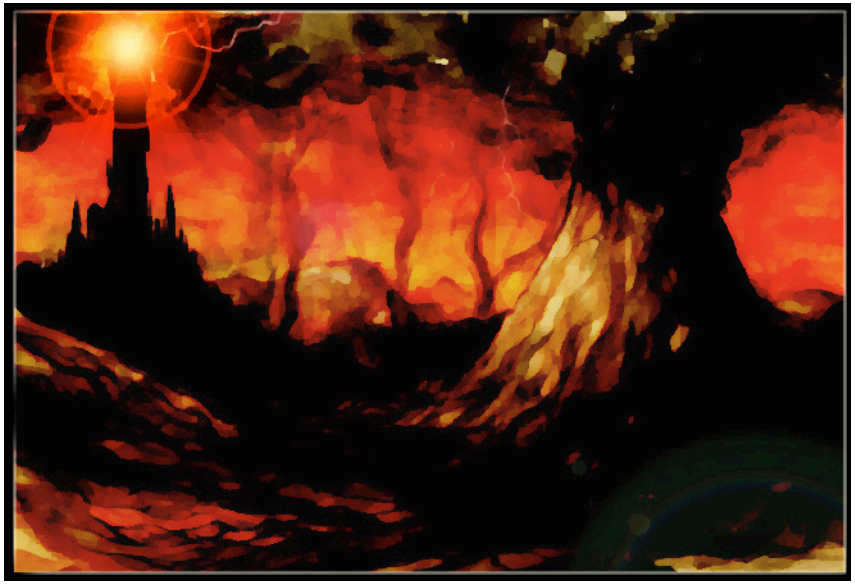
6. Code Quality



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Pernicious kingdom six

- **Code Quality**
  - Poor code quality indicates security problems likely
  - Memory Leak, Null Dereference, Uninitialized Variable, and others
  - Example: **Attribute Stored in HttpSession Might Not Be Serializable** phylum

```
public class MyAttribute {        // Not Serializable
    …
}

public void add (HttpSession s, MyAttribute a) {
    session.setAttribute("attribute", a);
}
```

Code quality issues

- All have the potential to allow denial of service attacks
- More often leads to unpredictable behavior
  - Exceedingly difficult to test for
  - Read “The Bug” by Ellen Ullman
- Unpredictable behavior is the friend of the attacker

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Example: memory leak

- Find easy cases with tools like Purify
- Hard cases can be dynamic flow driven and really tough to find
- Common causes: error conditions, confusion over responsibility

```
char* getBlock(int fd) {
    char* buf = (char*( malloc(BLOCK_SIZE);
    if (!buf) {
        return NULL;
    }
    if (read(fd, buf, BLOCK_SIZE) != BLOCK_SIZE) {
        return NULL;
    }
}
return buf;
```

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Example: use after free

```
char* ptr = (char*) malloc(SIZM);
…
if (err) {
   abrt = 1;
   free(ptr);
}
…
if (abrt) {
   logError("operation aborted before commit", ptr);
}
```

- And sometimes it works!
- Memory may be re-allocated by the time the error is logged

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Example: double free

- Most often causes a crash, but can result in buffer overflow under rare circumstances

```
char* ptr = (char*) malloc(SIZM);
…
if (abrt) [
  free(ptr);
}
…
free(ptr);
```

Portability problems

- Internal buffer overflows in some implementations of *getopt()*
  - Avoid with good input validation
- In many cases, you cannot avoid problems
- Examples
  - *vfork()* behavior varies by platform
  - *strcmpi()* is not defined on many UNIX systems
  - *memmem()* problematic due to changes between versions whereby order of the arguments is reversed

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Returning mutable objects

- Mutable objects are references to specific locations in memory
  - The most common example is an array
- Returning a mutable object to malicious code enables an attacker to modify the contents of memory pointed to by the object

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Returning mutable objects - example

```
public static void main(String[] args) {

   EmployeeInfo info = new EmployeeInfo("Steve", "Dallas", "Red");

   // modify the employee name (because we can)

   String[] localname = info.getName();         [1]

   // Here's where the danger is; the employee's name is being
   // stored into an array.  Since that is mutable, it can be changed
   // by an attacker, even if it is declared private.

   localname[0] = "L33t";
   localname[1] = "H4x0r";          [2]

   String[] name = info.getName();

   System.out.println("\nEmployee Name: " + name[0] + " " +
      name[1]);

   // will output "Employee Name: L33t H4x0r"
```

[1] Store a reference to a mutable array in a local context

[2] Modify the original array by changing the local array

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Storing mutable objects

- In a similar way as returning mutable objects, storing mutable objects passed to your code can lead to problems
  - Especially if you act on the returned object(s)
- See example—MutableStorage

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Public static final mutable objects

- Public static final mutable objects can still be modified, because only the reference to the object is constant

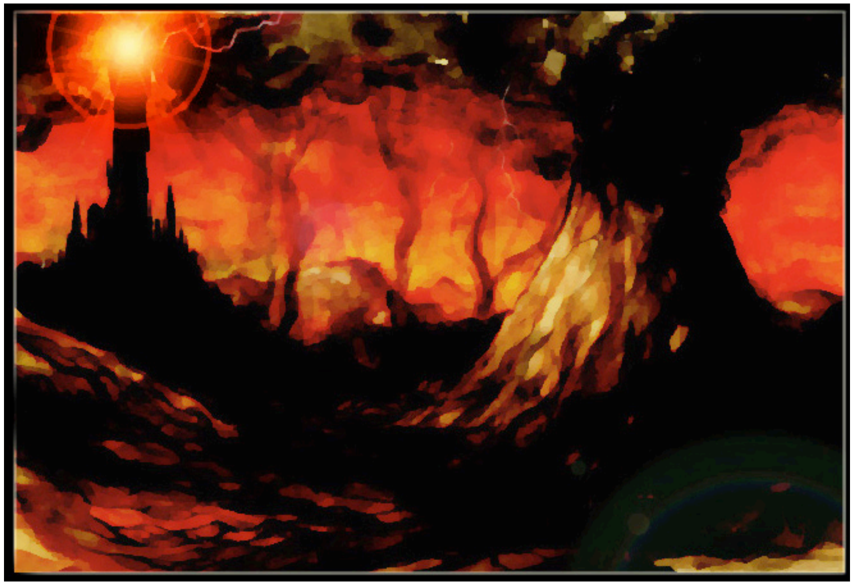
Java Initialization

- Java is supposed to initialize new variables cleanly, but it's still good practice to do so manually
  - Apart from anything else, this is just a good housekeeping

Phyla: Code quality

- Double Free
- Inconsistent Implementations
- Memory Leak
- Null Dereference
- Obsolete
- Undefined Behavior
- Uninitialized Variable
- Unreleased Resource
- Use After Free

7. Encapsulation



Pernicious kingdom seven

- Encapsulation
  - Violation of boundaries between software components with various trust level
  - System Information Leak, Trust Boundary Violation, Mobile Code: Non-Final Public Field, and others
  - Example: **Field Assignment in a Servlet** phylum

```
MyServlet extends HttpServlet {                          // Shared field
    private User user = new User();
    …
    void getInfo(HttpServletRequest req) {
        Session s = req.getSession();
        user.userId = s.getAttribute(“id”);
    }
}
```

Public fields

- Public fields can be accessed by all classes
- Declare private and provide get/set methods unless they must be public
- If you absolute have to use a public field, be sure to make it final

Public fields - example

Not a good idea...

```
public class BadUserInfo {

   public String username;
   public String favColor;

   public BadUserInfo(String username, String favColor) {
      this.username = username;
      this.favColor = favColor;
   }
}
```

A better idea...

```
public class GoodUserInfo {

   private String username;
   private String favColor;

   public GoodUserInfo(String username, String favColor) {
      this.username = username;
      this.favColor = favColor;
   }

   public String getUsername() {
      return username;
   }
```

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Public methods

- Similarly, make sure that your methods are explicitly made private
- Prevents interface from being maliciously accessed
  - E.g., providing tainted data
- If a method must be made public, be sure to document the reason
- See example – MethodAccess

Public methods - example

```
private String username;
private String favColor;

public BadUserInfo(String username, String favColor) {
   setUsername(username);

   this.favColor = favColor;
}

public void setUsername(String user) {
   username = user;
}
```

[1]

[1] Be sure that methods are made private unless they must be public, otherwise they can be invoked by any class

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Public static modifier

- Public static fields and methods can be accessed by other classes even if they don't instantiate

Public static modifier - example

```
public class Widget {

   public static int height = 2;
   public int width = 10;

   public Widget() {}
}
```

[1]

```
public class StaticModifier {

   public static void main(String[] args) {

      System.out.println("\nWidget height: " + Widget.height + "\n");
   }
}
```

[2]

[1] The *Widget.height* field is defined as public static

[2] Any class is now able to access/modify the *height* field without instantiating the *Widget* class

Package scope

- Any class within a package can access the public and protected variables within other classes in the same package
- Thus, if you don't want to provide access to something, make it private explicitly

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Package scope - example

```
package somepackage;

public class Widget {

   protected int height;
   int width;

   public Widget() {
      height = 2;
      width = 10;
   }
```

[1]

[1] The *height* field is accessible to any class that declares itself part of the *somepackage* package

Inner classes

- The manner in which JVMs compile inner classes opens up a loophole that enables an attacker to access private members of the outer class
- Entails making creative use of the Reflection API
- See example – InnerClasses

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Inner classes - example

```
public class InnerClassExample {
   private int outerValue = 2;     [1]     // note the "private" modifier

   // an inner class...

   private class Inner {
      private int innerValue;

      Inner() {

         // accessing a private field in the outer class

         innerValue = outerValue;     [2]
      }
   }
}
```

[1] A private integer field is defined in the outer class

[2] The inner class accesses the private field in the outer class (the Java compiler must create a loophole to allow this)

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Inner classes – example (cont'd)

```
// call the access$000 method using reflection

Method access = insecure.getDeclaredMethod("access$000", new Class[]
   {insecure});
Object value = access.invoke(null, new Object[] {example});
```

[3]

[3] The Java compiler creates a method called *access$000* that can be called using Reflection to obtain the value of the private field

Finalization

- If methods and classes aren't made final, they can be extended in unforeseen ways and may enable an attacker to access or alter otherwise protected objects and information

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Finalization - example

```
public final class Widget {     [1]

   private int height;
   private int width;

   public Widget(int height, int width) {
      this.height = height;
      this.width = width;
   }

   public final int getHeight() {
      return height;
   }
```

[1] Define classes to be final whenever possible to prevent them from being extended in unforseen ways

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Cloning

- If an object can be cloned, an attacker may be able to bypass its constructor, which could lead to disclosing uninitialized memory space
- If an object must implement the Cloneable interface, make sure to provide an explicit final clone() method as early in the inheritance hierarchy as possible

Cloning - example

```
class Widget {

   private int height = 2;
   private int width = 10;

   public Widget() { }

   public int getWidth() {
      return width;
   }

   public final Object clone() throws java.lang.CloneNotSupportedException {
      throw new java.lang.CloneNotSupportedException();
   }
}
```

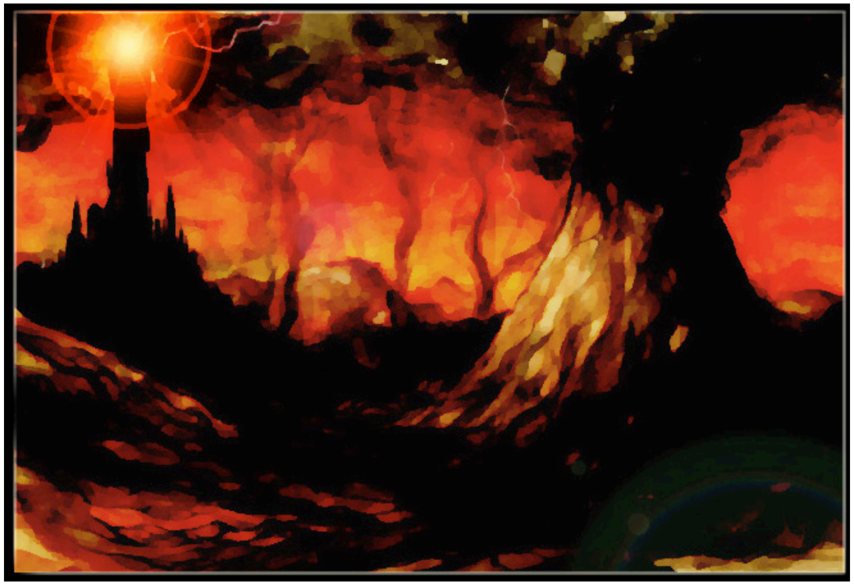
[1]

[1] To prevent cloning, override the *clone()* method and throw a *java.lang.CloneNotSupportedException*

Phyla: Encapsulation

- Comparing Classes by Name
- Data Leaking Between Users
- Leftover Debug Code
- Mobile Code: Object Hijack
- Mobile Code: Use of Inner Class
- Mobile Code: Non-Final Public Field
- Private Array-Typed Field Returned from a Public Method
- Public Data Assigned to Private Array-Typed Field
- System Information Leak
- Trust Boundary Violation

*. Environment



Bonus pernicious kingdom

- **Environment**
  - Everything that is outside of source code but is still critical to security
  - ASP .NET Misconfiguration: Password in Configuration File, Insecure Compiler Optimization, and others
  - Example: **ASP .NET Misconfiguration: Creating Debug Binary** phylum

```
<configuration>
        <compilation debug="true">          // Debug binary
                ...
        </compilation>
        ...
</configuration>
```

CLASSPATH

- Modifying the CLASSPATH environment variable is the equivalent of modifying a Windows/Unix PATH
  - An attacker can construct classes with “value added” features that perform malicious acts
  - Classic example is theft of username/password
  - Involves duping a user into running attacker's code

Weak access permissions (J2EE)

- EJB method permissions should never grant access to the ANYONE role
- Indicates that access control for an application has not been carefully thought through
- Method permissions should always be restricted to the minimum set of roles that should be granted access

Weak access permissions - example

The following example illustrates the improper use of method access controls...

```
<ejb-jar>
    ...
    <assembly-descriptor>
        <method-permission>
            <role-name>ANYONE</role-name>
            <method>
                <ejb-name>SomeBean</ejb-name>
                <method-name>someMethod</method-name>
        </method-permission>
    </assembly-descriptor>
    ...
</ejb-jar>
```

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Phyla: Environment

- ASP .NET Misconfiguration: Creating Debug Binary
- ASP .NET Misconfiguration: Missing Custom Error Handling
- ASP .NET Misconfiguration: Password in Configuration File
- Insecure Compiler Optimization
- J2EE Misconfiguration: Insecure Transport
- J2EE Misconfiguration: Insufficient Session-ID Length
- J2EE Misconfiguration: Missing Error Handling
- J2EE Misconfiguration: Unsafe Bean Declaration
- J2EE Misconfiguration: Weak Access Permissions

Static Analysis and Code Review

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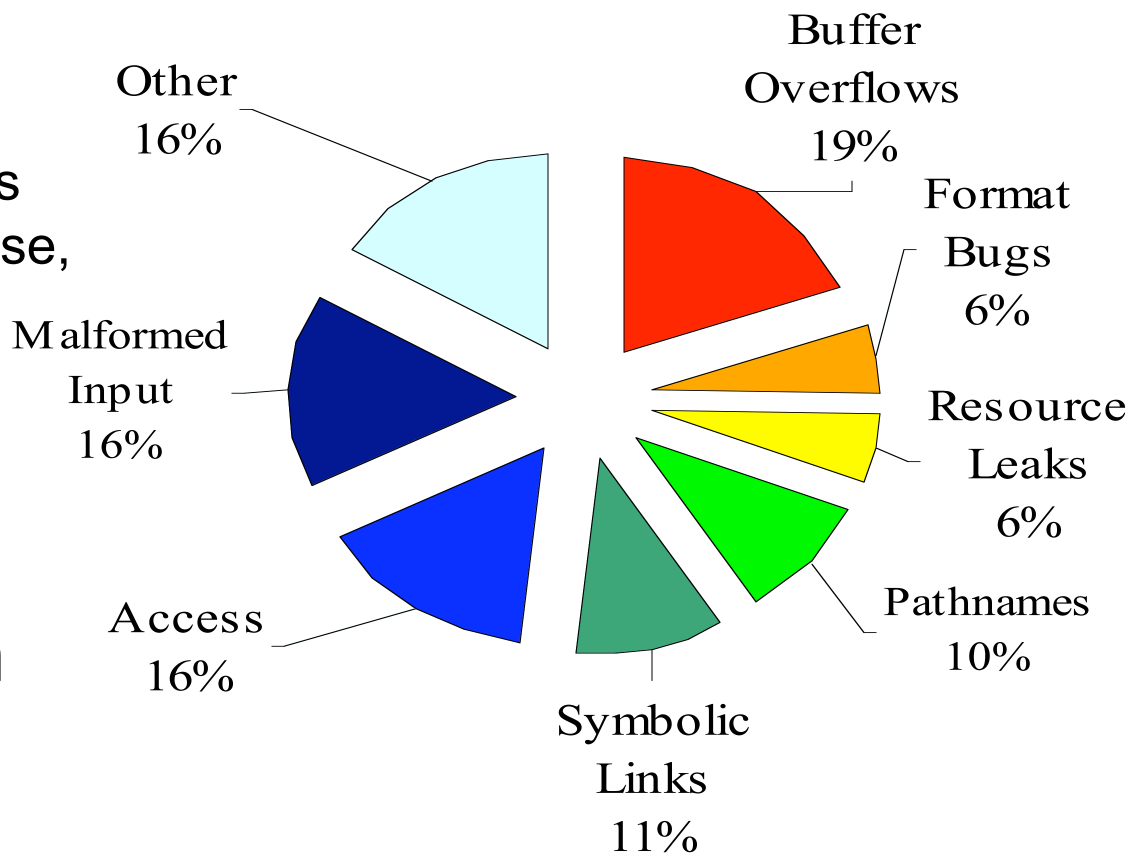
Reported flaws in Common Vulnerabilities and Exposures Database, Jan-Sep 2001.

56 % of CVE vulnerabilities could have been detected with straightforward static analyses!



[Evans & Larochelle, IEEE Software, Jan 2002]

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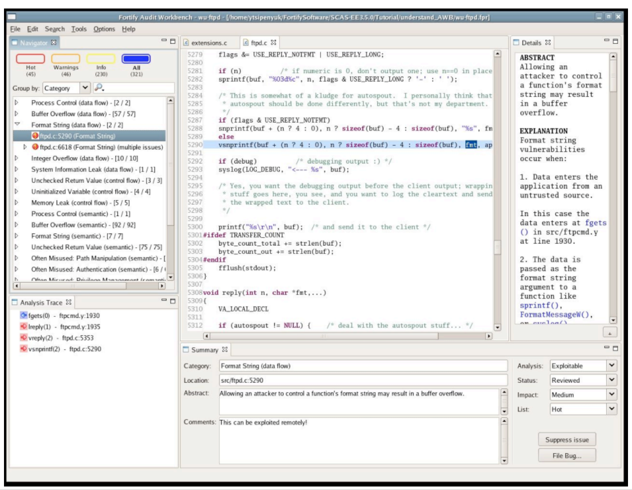
Touchpoint: code review (with a tool)

- Code review is a necessary evil
- Better coding practices make the job easier
- Automated tools help catch silly errors
  - Fortify/SCA (Cigital rules)



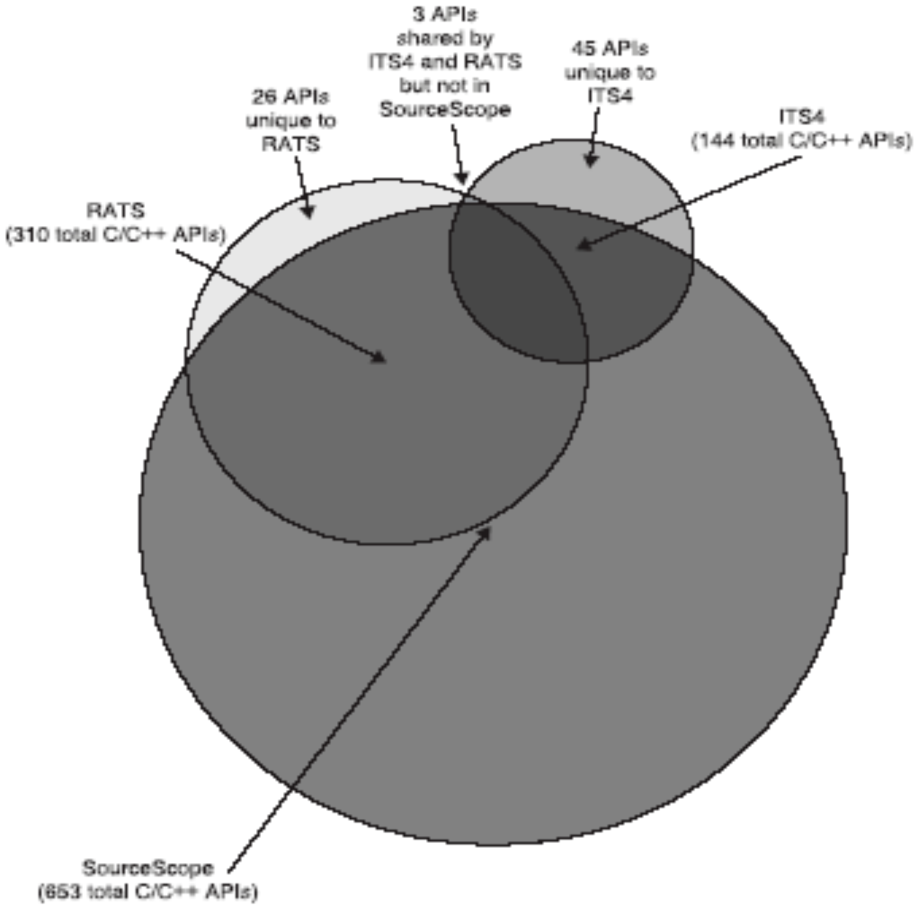
- Implementation errors do matter
  - Buffer overflows can be uncovered with static analysis
  - Static analysis
    - C/C++
    - Java
    - .NET
    - PSQL
- Tracing back from vulnerable location to input is critical

FORTIFY SOFTWARE

Code scanning tools

- Early static analysis tools (tokenizers)
  - ITS4
  - RATS
  - Flawfinder
- Modern tools (parsers)
  - Prefix
  - Fortify source code analysis suite
  - Ounce labs
  - Coverity
- The key is encapsulated know-how

Bug space coverage and early tools



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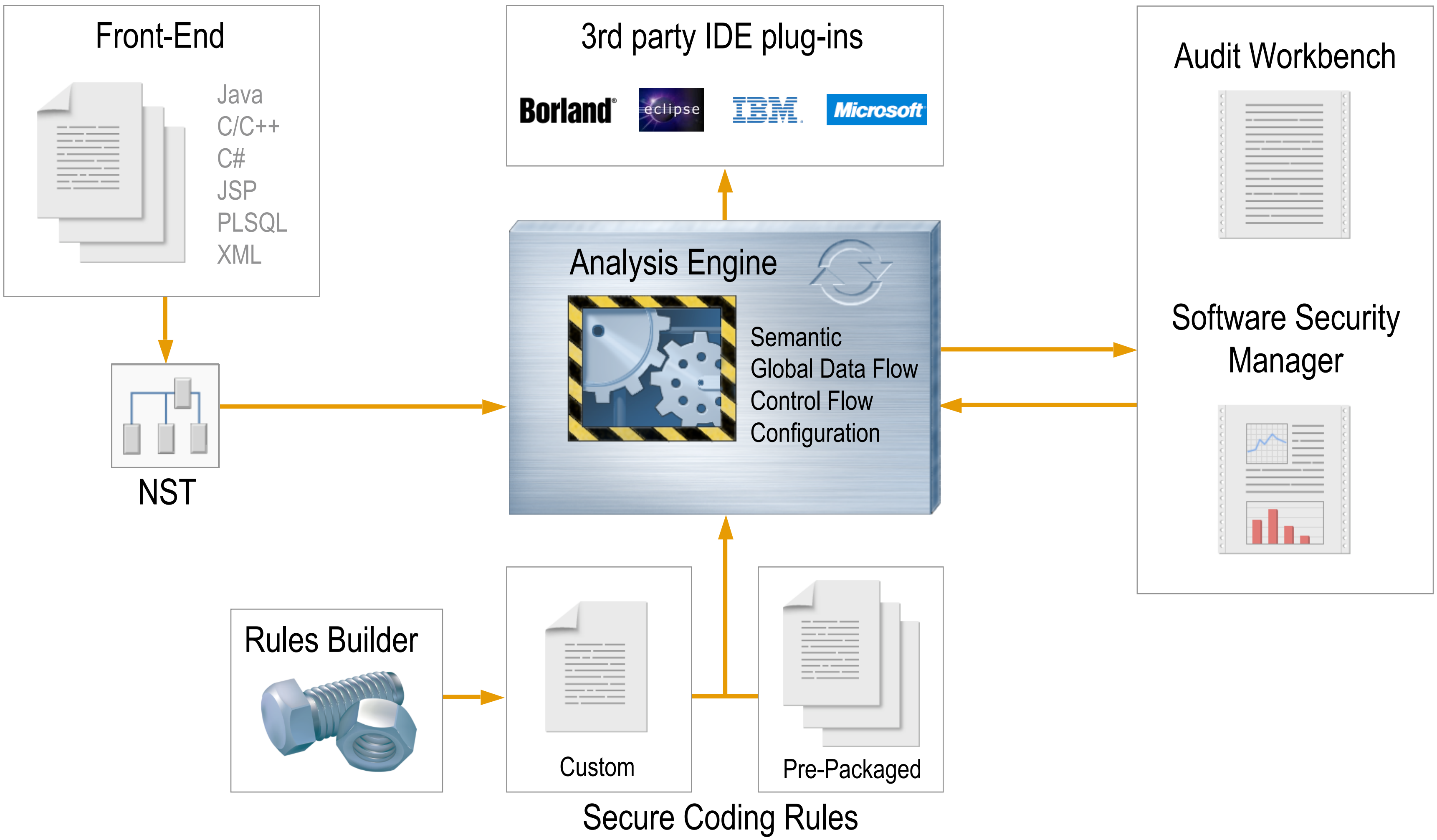
Fortify Source Code Analysis

- Integrated data flow analysis
- Broad platform support
- A comprehensive set of secure coding rules
  - Capability to add your own rules
- Proven large scale deployability

Commercially viable, accurate and effective analysis

Fortify architecture



Comprehensive secure coding rules

- Secure coding rulepacks based on the seven kingdoms
- Continuously updating and improving rulepacks
- Fortify Rules Builder allows you to further extend rulepacks to meet individualized needs
- Advanced context sensitive guidance inside in the IDE
- Intellectual property based on ten years of Cigital work

- see vulncat.fortifysoftware.com

The single largest compilation of secure coding techniques and guidance ever written

Next steps

Software security critical lessons

- Software security is more than a set of security functions
  - Not magic crypto fairy dust
  - Not silver-bullet security mechanisms
  - Not application of very simple tools
- Non-functional aspects of design are essential
- Security is an emergent property of the entire system (just like quality)
- Breaking stuff is important
- To end up with secure software, deep integration with the SDLC is necessary

Bottom up software security actions

- A few relatively simple things can make a tangible difference and can help you get started with software security
- Build checklists and use them
  - Sun's SAG checklist http://www.securecoding.org/companion/checklists/SAG/
- Begin to develop a resource set (e.g., portal)
- Start small with simple architectural risk analyses (think Smurfware)
- Don't forget to include business-case justifications
- Use code scanning tools

Top down software security actions

- Think of the problem as an evolutionary approach
- Chart out a strategic course of action to get where you want to be
  - Have a gap analysis performed
  - Make achievable, realistic milestones
  - Think about metrics for success
- Use outside help if you need it (Cigital)

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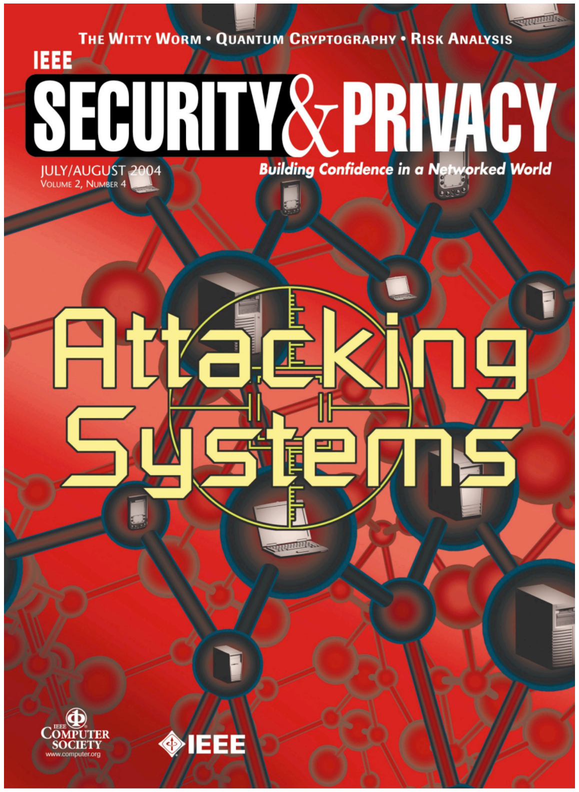
IEEE Security & Privacy Magazine

- Monthly Department on Software Security Best Practices called "Building Security In"

Table 1. Building Security In articles.

TITLE	KEY	AUTHOR	*IEEE SECURITY & PRIVACY* CITATION	URL: WWW.CIGITAL.COM PAPERS/DOWNLOAD/
Software Security	BSI1	Gary McGraw	2(2):80–83	bsi1-swsec.pdf
Misuse and Abuse Cases: Getting Past the Positive	BSI2	Paco Hope, Gary McGraw, Annie Anton	2(3):32–34	bsi2-misuse.pdf
Risk Analysis in Software Design	BSI3	Denis Verdon, Gary McGraw	2(4):79–84	bsi3-risk.pdf
Software Security Testing	BSI4	Bruce Potter, Gary McGraw	2(5):81–85	bsi4-testing.pdf
Static Analysis for Security	BSI5	Brian Chess, Gary McGraw	2(6):76–79	bsi5-static.pdf
Software Penetration Testing	BSI6	Brad Arkin, Scott Stender, Gary McGraw	3(1):84–87	bsi6-pentest.pdf
Knowledge for Software Security	BSI7	Sean Barnum, Gary McGraw	3(2):74–78	bsi7-knowledge.pdf
Adopting a Software Security Improvement Program	BSI8	Dan Taylor, Gary McGraw	3(3):88–91	bsi8-program.pdf
A Portal for Software Security	BSI9	Nancy R. Mead and Gary McGraw	3(4):75–79	bsi9-portal.pdf
Bridging the Gap between Software Development and Information Security	BSI10	Kenneth R. van Wyk and Gary McGraw	3(5):75–79	bsi10-bridge.pdf



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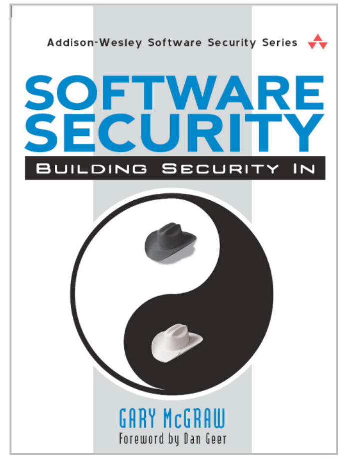

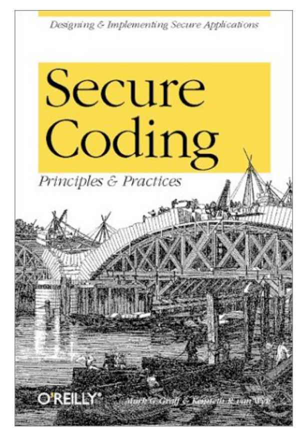

- See the Addison-Wesley Software Security series
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"So now, when we face a choice between adding features and resolving security issues, we need to choose security."

-Bill Gates