Protection and security of information systems

Security check

prof. Ph.D. Krešimir Fertalj

University of Zagreb

Faculty of Electrical Engineering and Computing

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Security check

Security Testing

Software correctness check (general)

- Program testing, program verification, program testing
  - detection of errors or defects within the program
  - the success of the test is proportional to the number of errors found
- According to the purpose of testing
  - Verification - verification of correctness (good implementation)
  - Validation - confirmation of validity (real, acceptable product)
- According to the check object
  - Structural (white-box testing) - source code
  - Functional (black-box) - compilation
- According to the verification method
  - static analysis - no startup, source code or .NET MSIL, Java Bytecode
  - dynamic analysis - by running, which does not exclude the source code

Key terms

- **["normal"] Test**-verifies that some aspect of the software is correct

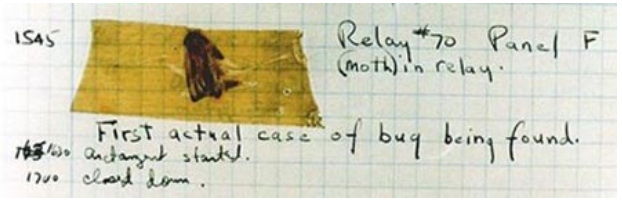
- **Security test**-tries to prove that some part is not working properly

-**Error**(error) - an omission by the programmer, eg due to misunderstanding
  - -leads to one or more failures
  - -we distinguish in relation to "error" which means an unwanted state, i.e. a malfunction

-**Failure**(fault), defect, informally bug - defective part of the code
  - -eg wrongly assuming that an array is indexed by 1 instead of 0 causes an array element access failure

-**A standstill**in operation (failure) - condition caused by one or more malfunctions
  - -eg system shutdown due to "buffer overrun" error

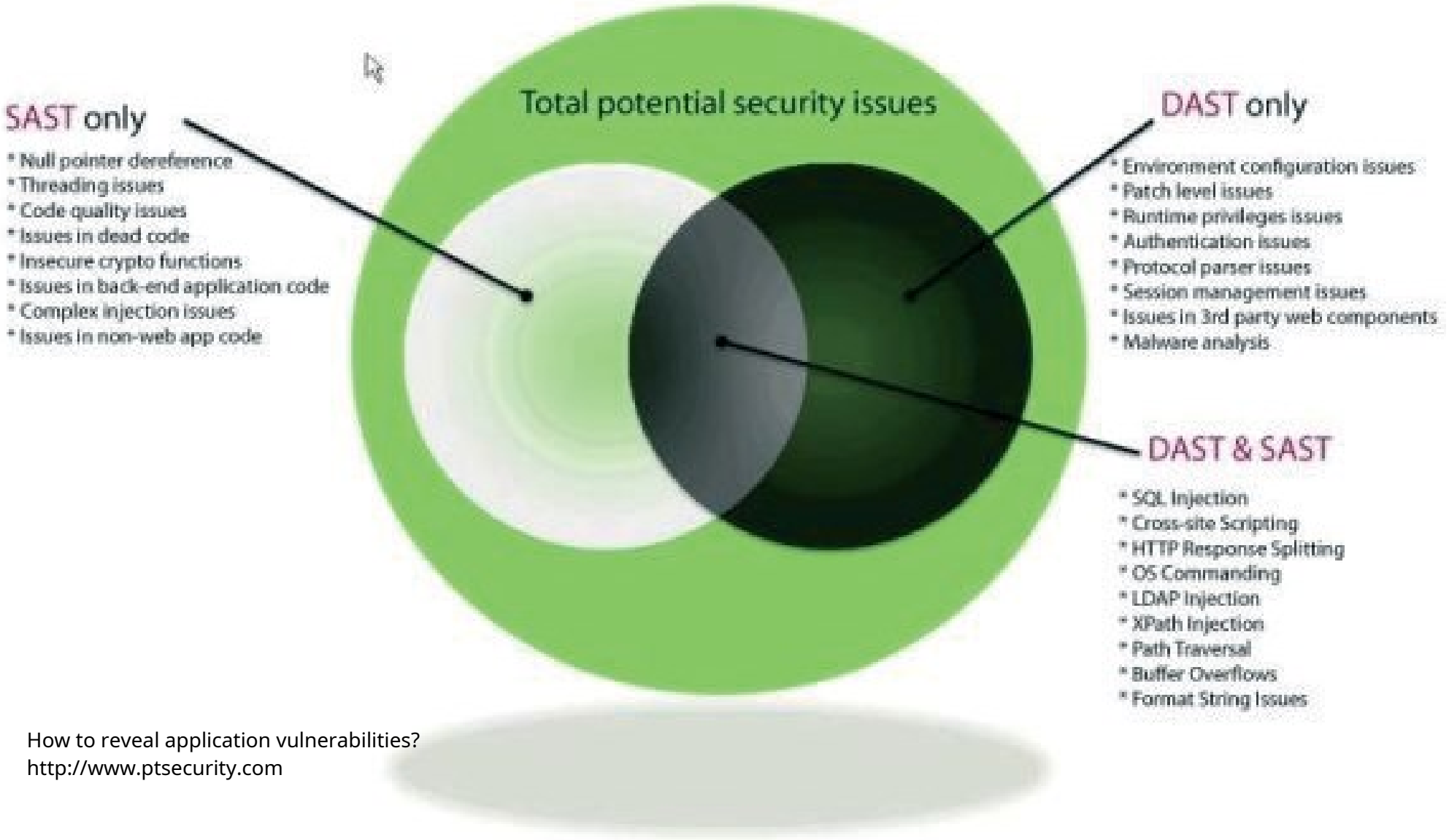
-**Correction**(Fix) **-** state of repair



Application security verification procedures

- Supervision ("Technical Reviews", "Code Reviews", "Inspections", ...)
  - testing tends to cause deadlock, monitoring looks for malfunction
- Static Application Security Testing (**SAST**) # white-box static
  - which does not require execution
  - access to the source code on the client and on the server
- Dynamic Application Security Testing (**DAST**) # black-box dynamic
  - requires execution
  - does not have access to the source code and operating environment on the server
- Interactive Application Security Testing (**IAST**) # white-box dynamic
  - dynamic with access to the source code and operating environment on the server
- Source code analysis - static or dynamic with access to the entire code

How to reveal application vulnerabilities?



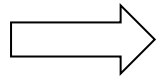
How to reveal application vulnerabilities?
http://www.ptsecurity.com

Supervision

Security Review, Code Reviews, Inspection

Revision, review (peer review)

- Variants



  - inspection
  - Team review
  - Walkthrough

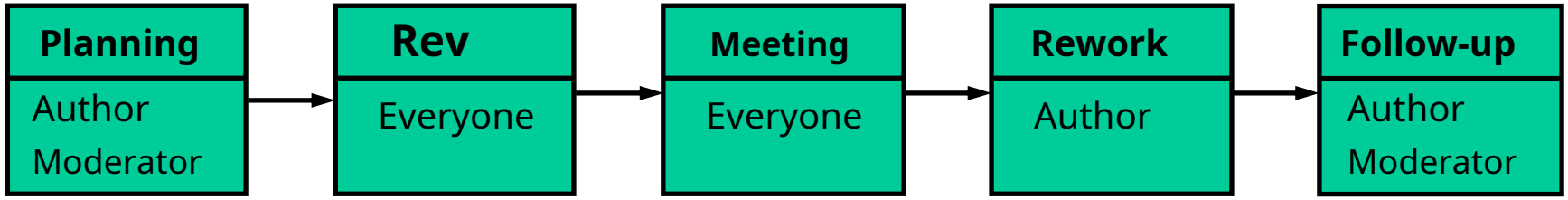
- Use it
  - finding defects earlier in the life cycle - up to 80% before testing
  - finding defects with less effort than testing
    - IBM - review 3.5 h/defect, test 15-25 h/defect
  - finding different defects than by testing - design and requirements problems
  - teaching developers - not to repeat the same mistakes

Inspection

- Formal process
  - Thorough coverage of separate roles
    - Moderator - leads the meeting, monitors problems
    - The reader - paraphrases (retells) the code, not the author
    - Recorder - records defects
    - Author - provides code context, explains, fixes after review
  - Checklists for specific objectives
  - Data collection for error tracking
  - Determining the need for subsequent inspections

- Extensive documentation of effectiveness
  - 16-20 defects/kLOC inspections vs. 3 defects/kLOC passes

Inspection process



- Planning
  - the author initiates, the moderator equips, the meeting prepares the inspection package
- Preparation
  - reviewers review, use checklists and analytical tools, mark defects
- Meeting
  - the reader recounts, the reviewers comment and question, the recorder records
  - the team concludes the code evaluation
- Processing
  - the author fixes
- Control (follow-up)
  - the moderator verifies the correctness of the changes, the author reports the code (check-in)

Variants

- Team review
  - Team inspection ("light" inspection)
  - Persons: moderator, reviewers (who are not code authors)
  - Modules or smaller sets of classes
  - 1-2 hours, < 1 kLOC

- Walkthrough
  - The author leads the meeting and explains the code
  - A less formal process
  - Undefined process
  - No checklists or metrics

Other procedures

- Pair programming
  - Guide (driver) and observer (observer, navigator)
  - Change of roles and partners

- *Peer deskcheck*
  - Only one reviewer with the author
  - informal review
  - may include checklists and other procedures

- *Pass around* (circular addition?)
  - multiple, simultaneous *Peer deskcheck*
  - multiple reviewers (same code)

Static check

Static Analysis

Static analysis

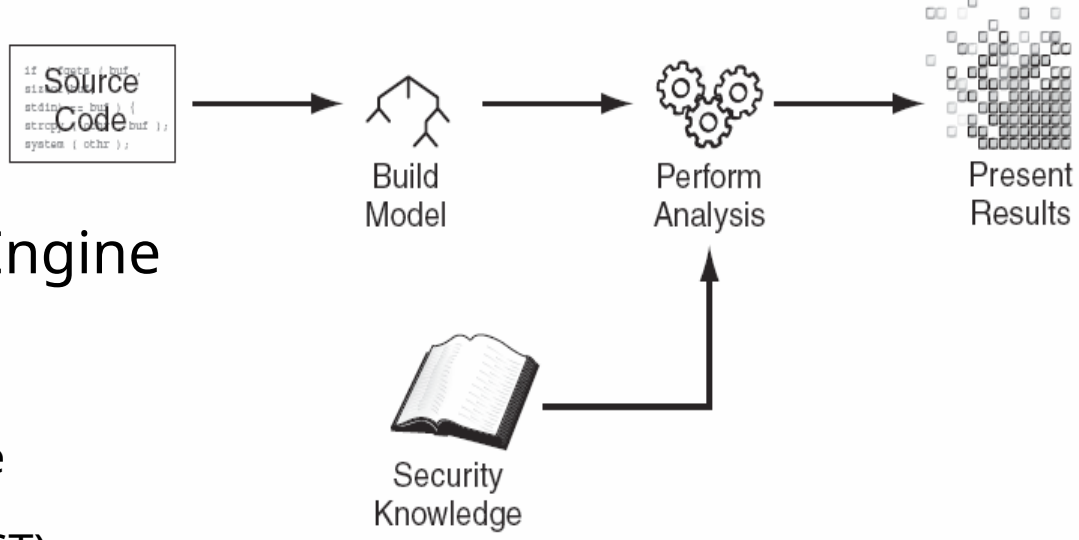
- SAST (Quick and Dirty)
  - Code analysis without execution
  - It covers everything but testing
  - Using the code analyzer
  - It can be part of a code review

- Limitations: false detection and false non-recognition
  - **False Positives**-non-existent bugs, powerlessness with complex code or external
  - **False Negatives**-failure to recognize bugs, complexity of code, weakness of rules

Types of static analysis

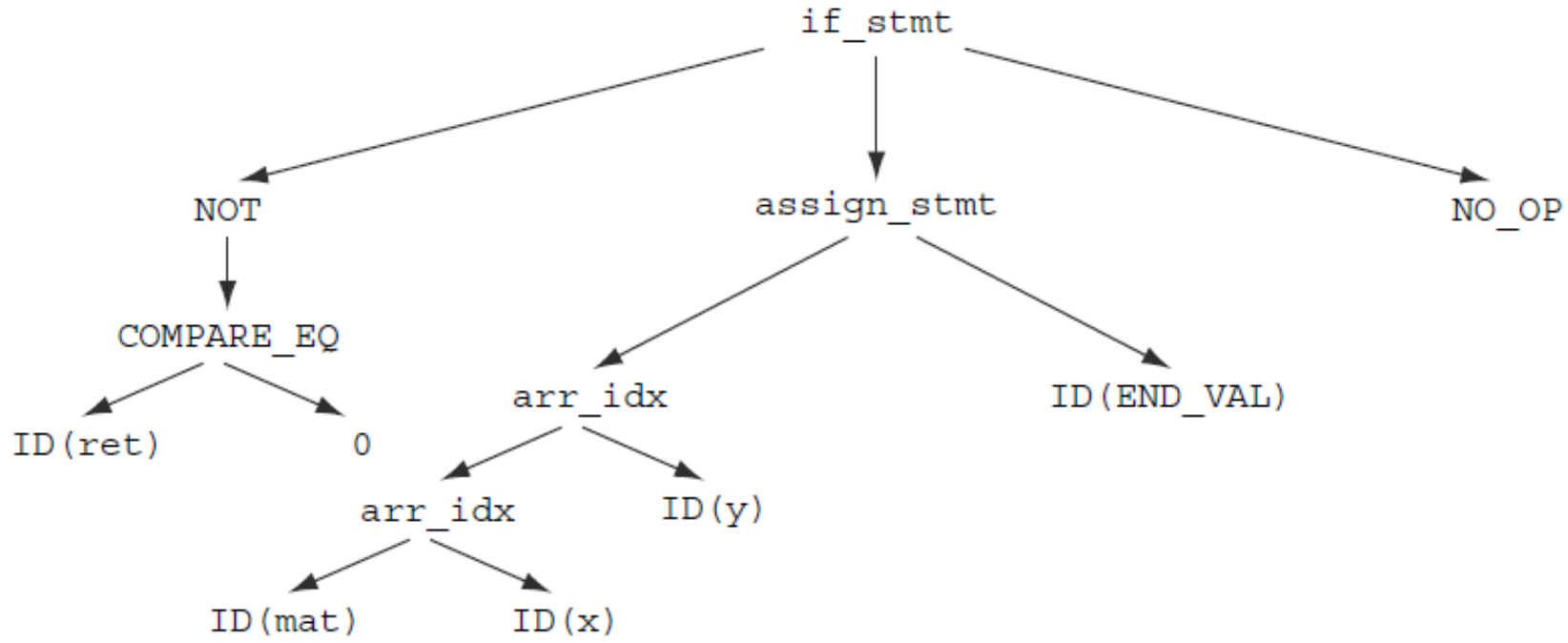
- Type checking - part of the programming language
  - ex. int i = "abc";
- Style checking - good practices
  - Rules - spaces/spaces, nomenclature, comments, ...
- Program understanding - inferring meaning
  - All method usage, global variable declaration finding, ...
- Property checking - ensuring that there is no bad behavior
  - For example memory leak : if (malloc() == NULL)
- Program verification (Program verification) - ensuring correct behavior
  - For example free(mem);
- Bug finding - detection of possible errors
  - Bug patterns

Mechanisms of static analysis



- Parser, Model Builder, Analysis Engine

- A parser for every programming language
  - generates an Abstract Syntax Tree (AST)



Lexical analysis and parsing

Example, program section

```
if (ret) // probably true
    mat[x][y] = END_VAL;
```

The corresponding sequence of symbols (tokens)

IF LPAREN ID(ret) RPAREN ID(mat) LBRACKET ID(x) RBRACKET LBRACKET ID(y) RBRACKET EQUAL ID(END_VAL) SEMI

Extracted by syntax rules, parsed according to grammar productions

```
if                          { return IF; }
(                           { return LPAREN; }
)                           { return RPAREN; }
[                           { return LBRACKET; }
]                           { return LBRACKET; }
=                           { return EQUAL; }
;                           { return SEMI; }
/[ \t\n]+/                  { /* ignore whitespace */ }
/\/\/.*/                    { /* ignore comments */ }
/[a-zA-Z][a-zA-Z0-9]*"/     { return ID; }
```

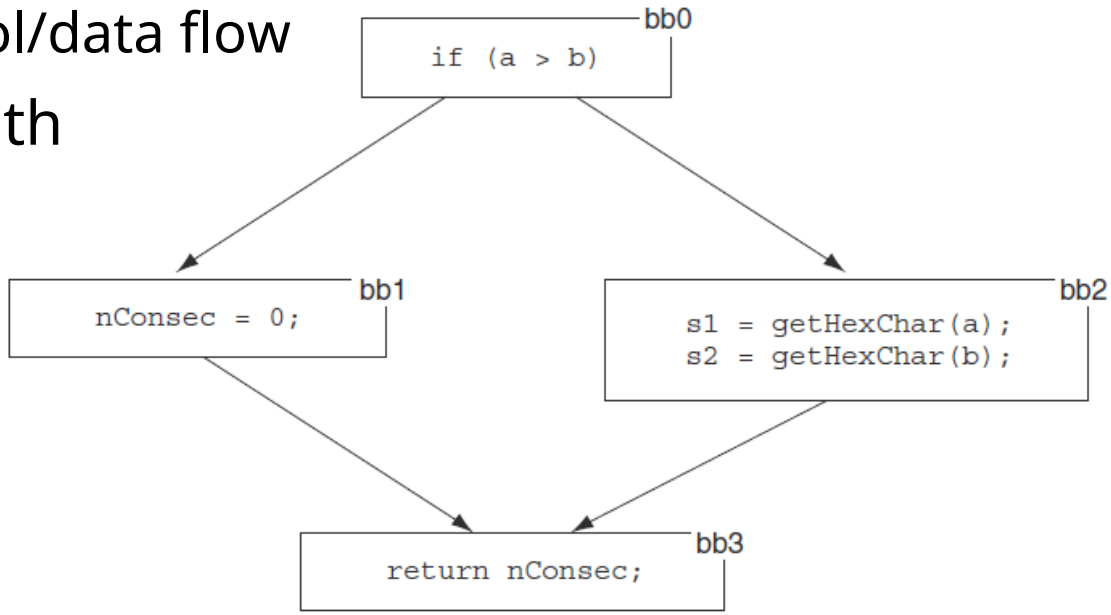
```
stmt := if_stmt | assign_stmt
if_stmt := IF LPAREN expr RPAREN stmt
expr := lval
assign_stmt := lval EQUAL expr SEMI
lval = ID | arr_access
arr_access := ID arr_index+
arr_idx := LBRACKET expr RBRACKET
```

Data Flow Analysis

- Collecting information about the data stream when the program is executed while it is stopped
- Semantic analysis - based on AST and symbol table

- Basic block - a sequence of statements that does not stop or branch except at the end
- Control Flow Analysis – control/data flow
- Control Flow Path - data path

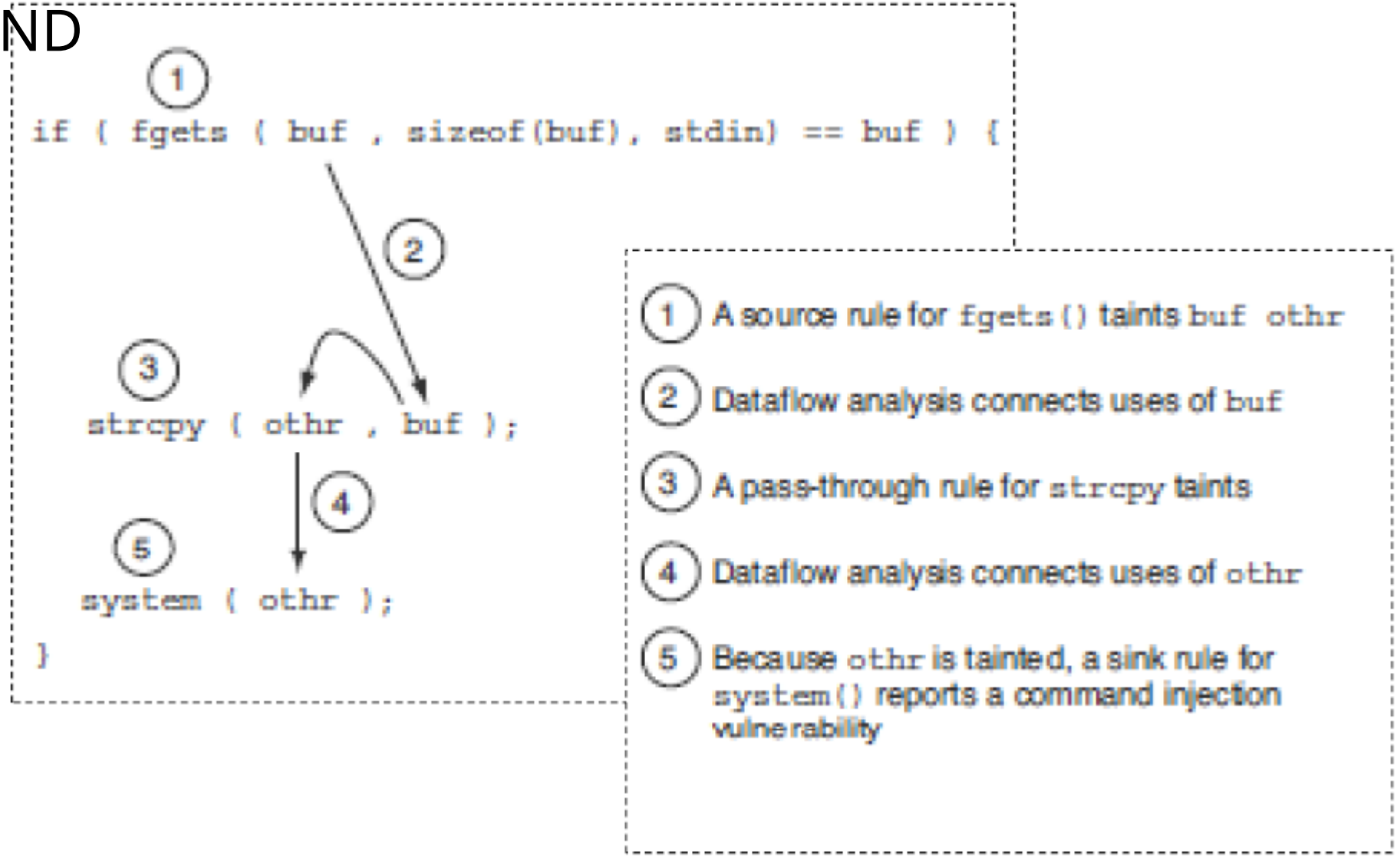
- Flow control chart
  - Control Flow Graph (CFG)
  - Example: graph with 4 basic blocks



- Taint Analysis
  - Identification of variables *soiled* by user input
  - Monitoring their propagation according to possibly vulnerable functions (*son*)
  - If they are not disinfected before the drain - vulnerability
- The rules of blob propagation
  - Source rules - data entry
    - Orders *read(), getenv(), getpass(), gets().*
  - Sink rules - locations that should not receive dirty data
    - Example, Java *Statement.executeQuery()*, C *strcpy()*
  - Pass-through rules
    - If it is *string* soiled and *trim(string)* will be dirty
  - Cleanse rules - input validation
  - Entry-point rule - similar to the source, e.g. *main(...)*

Example of static analysis

- AND



Advantages and disadvantages of static analysis

- Advantages
  - Full code coverage (code coverage) - in theory
  - The potential to confirm the absence of entire classes of bugs
  - It catches *bugs* different compared to dynamic analysis

- Weaknesses
  - High false detection rate
  - Difficult test shaping
  - Complexity of construction (tool) - "parser for every language"
    - not enough when using additional frameworks or libraries
  - Not having the entire source code in practice (OS, shared libraries, DLLs, ...)

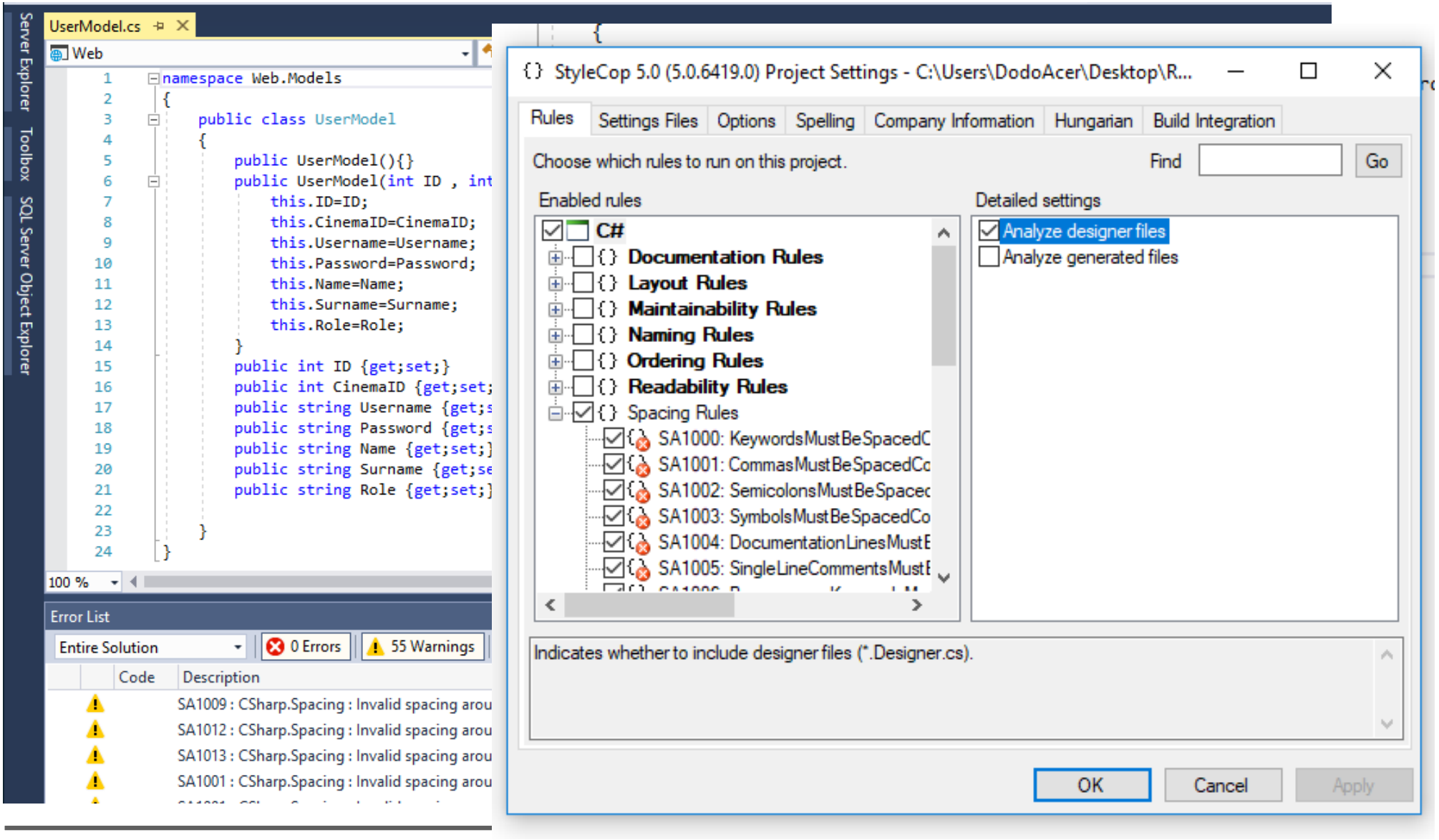
Tools for static analysis

- https://www.owasp.org/index.php/Source_Code_Analysis_Tools

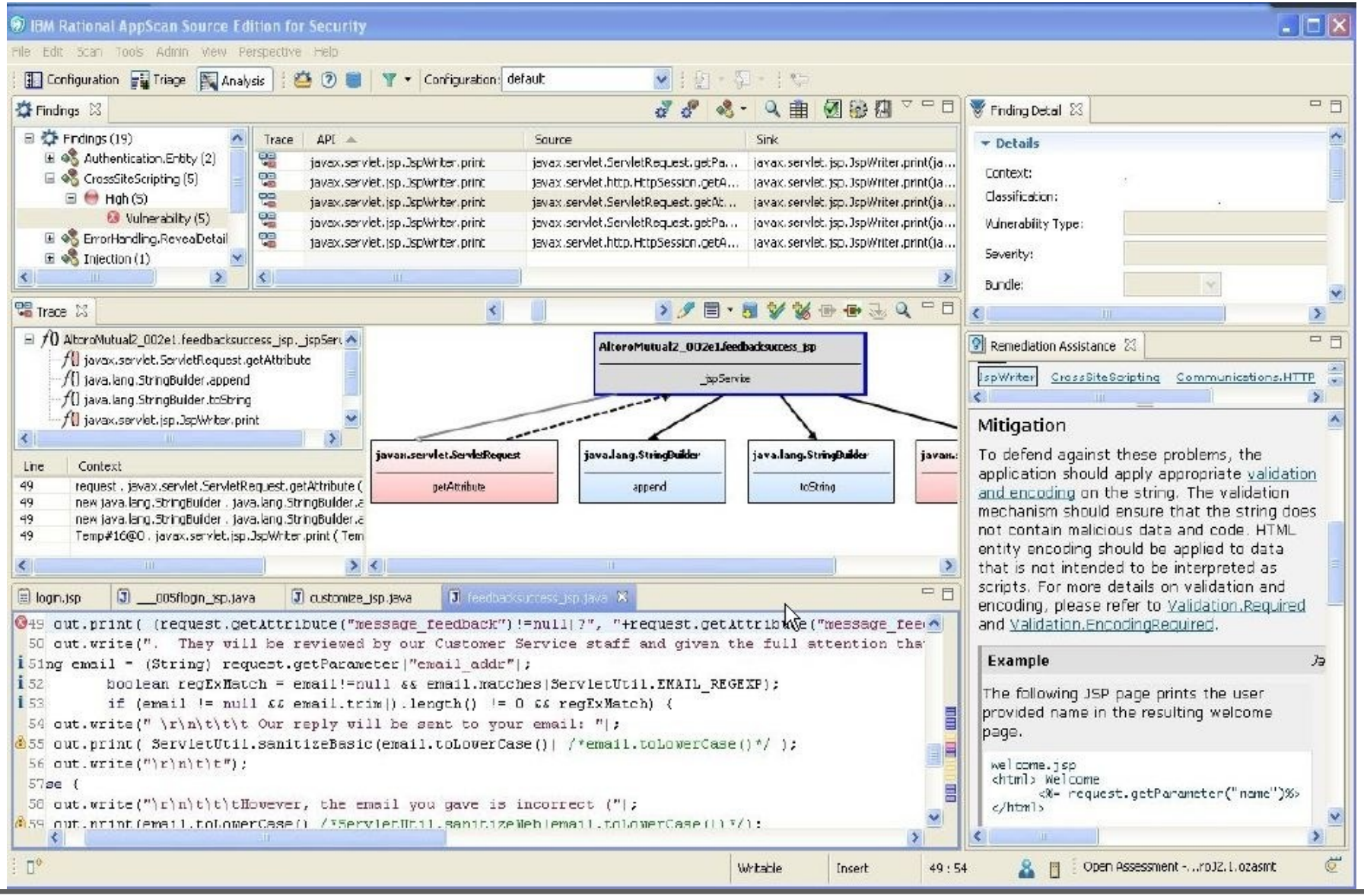
- StyleCophttps://github.com/StyleCop/StyleCop - C#
- CodeSmarthttp://www.axtools.com/ - C#, C++, VB.NET
- NDependhttp://www.ndepend.com/ - C#, jDepend for Java

- VS Code Analysis (FxCop, Roslyn analyzers) - C#, C/C++, ...
- PMD - Java, C, C++, C#, Groovy, PHP, Ruby, Fortran, JavaScript, PLSQL, ...
- Fortify Source Code Analyzer - 25 languages
- Checkstyle - Java
- Klocwork K7 Suite - Java
- FindBugs, Find Security Bugs - Java
- Coverity Prevent - C#, clang, gcc

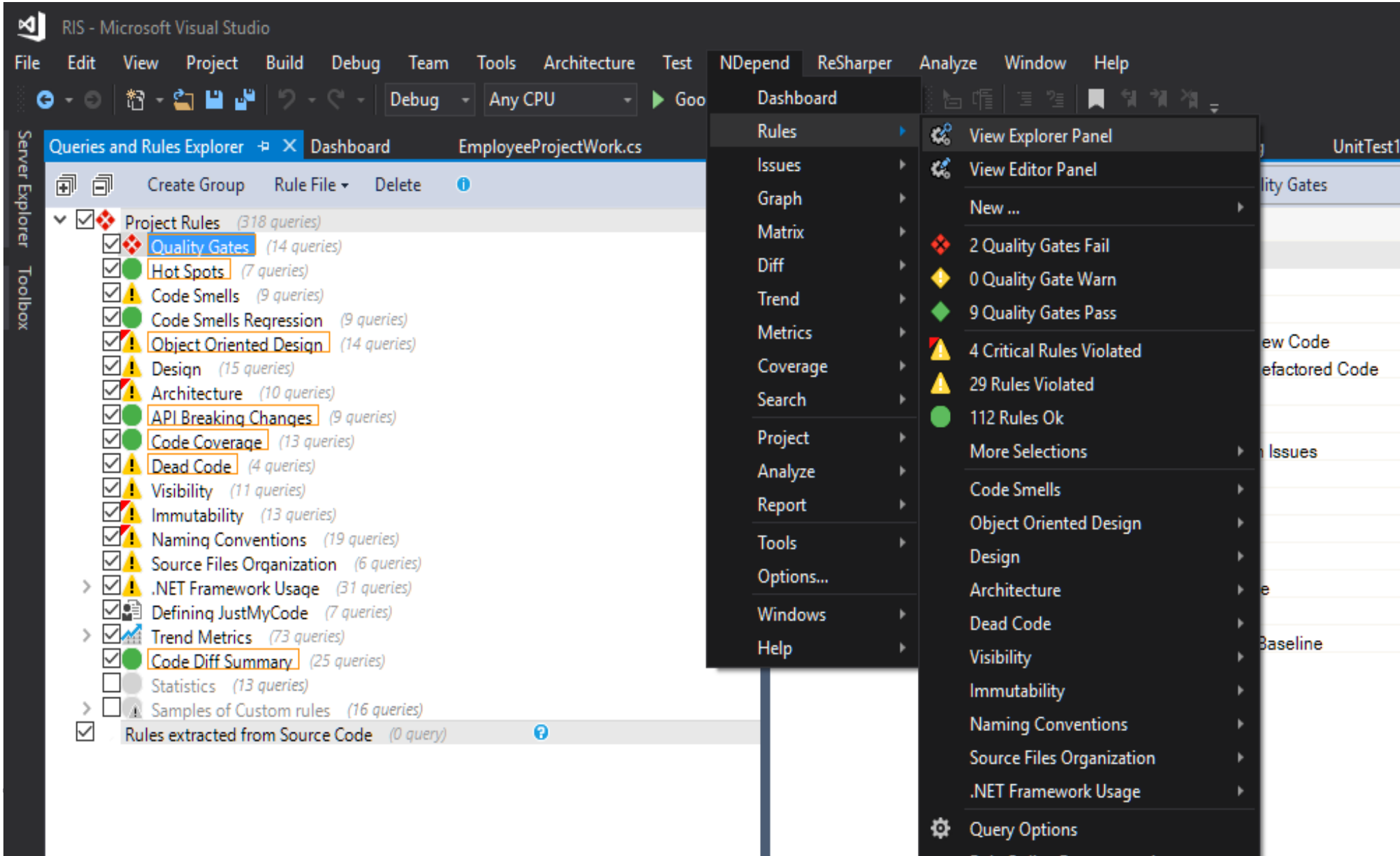
Example: StyleCop



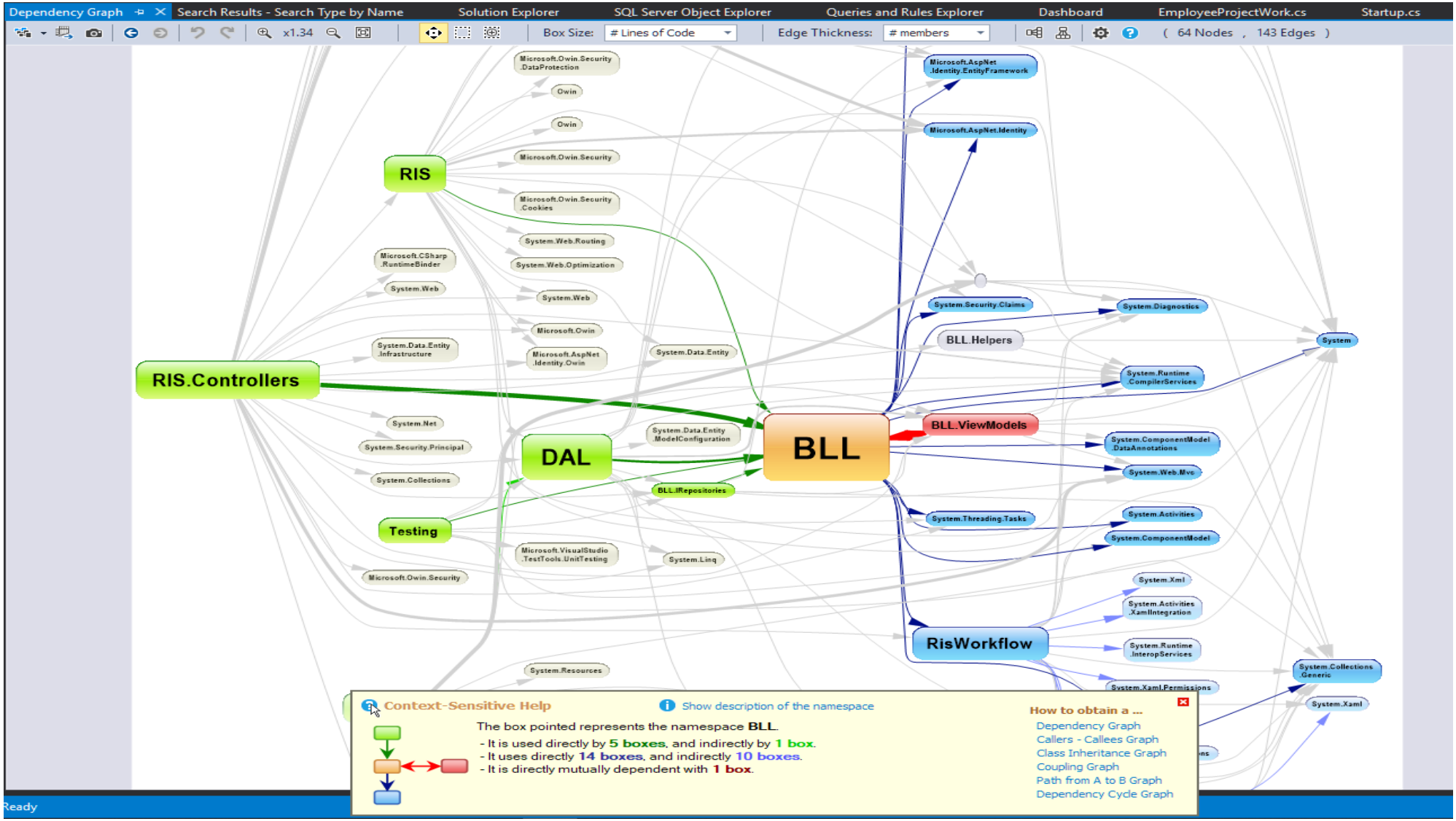
Example: IBM Rational Appscan Source Edition for Security



Example: NDepend



Example: application component dependency



Dynamic check

Dynamic Analysis

Fuzzing

Penetration Testing

Fuzzing - "combing" (eng. fuzz = hair)

- DAST (The Good, the Bad and the Ugly)
  - fault injection into the application (fuzzing, fuzz testing)
  - sending incorrect, unexpected or random data to the program input
  - similar to regression, only with bad data
  - "combing" applications, protocols, files
- Advantages:
  - simplicity, platform, language independence
- Disadvantages:
  - application to a narrow set of vulnerabilities, eg. *Buffer overflows, Integer overflows,...*
  - complex application to technologies (Web 2.0, JSON, Flash, HTML 5.0, Jscript)
  - relatively long duration (permutations of incorrect data samples)

- Glupo = Dumb (mutational) fuzzing
  - enough less knowledge about the goal and the tools
  - pseudorandom anomalies of correct data
  - repercussions
    - more analysis needed
    - redundancy of findings

Standard HTTP GET request

GET /index.html HTTP/1.1

Anomalous requests

AAAAAA...AAAA /index.html HTTP/1.1

GET ///////index.html HTTP/1.1

GET %n%n%n%n%n%n.html HTTP/1.1

GET /AAAAAAAAAAAA.html HTTP/1.1

GET /index.html HTTTTTTTTTTTTP/1.1

GET /index.html HTTP/1.1.1.1.1.1.1.1

- Smart (generational) fuzzing
  - data generated based on the model
  - requires in-depth knowledge of the target and specialized tools
  - purposeful anomalies by knowledge of formats, standards, ... (PDF, RFC)
  - repercussions
    - less need for analysis
    - less duplication of findings

Tools for dynamic analysis

- https://www.owasp.org/index.php/Category:Vulnerability_Scanning_Tools

- CERT Basic Fuzzing Framework (BFF) and Failure Observation Engine (FOE)
  - Open source https://github.com/CERTCC/certfuzz

- Peach Fuzzer - *automated security testing platform*
- WebScarab - analysis of applications that use HTTP/HTTPS, *intercepting proxy*
- Burp - web applications, buffer overflow, CSS, SQL injection, …
- Fuddly - *fuzzing and data manipulation framework (for GNU/Linux)*
- Hongfuzz - *general fuzzer*

- *Profilers, …*

Penetration testing (Pen Test), ethical hacking

- assessment of system or network security by simulating a malicious attack
- person, team, preferably external consultants
- written permission of the owner (implementation of illegal activities)

- Purpose
  - Confirmation of the functionality of security controls
  - Timely detection of security flaws
  - Prevention of security incidents
  - Investment justification
  - Compliance with regulatory requirements

Approach to penetration testing

- Types of verification according to the availability of information
  - without available information (eng. *black-box test*) - as a real attack
  - with all information (eng. *white-box test*) - the worst case, when the attacker knows everything, or the simulation of an attack by an internal attacker
  - with partially available information (eng. *gray-box test*) - hybrid

- Test starting point criterion
  - External - from a remote location (Internet) to publicly available systems
  - Internal - from the intranet, simulation of an incident of unauthorized access to the internal network infrastructure

- Other criteria
  - Range, stealth, techniques, aggressiveness

Performing a penetration test

- **Research**(Eng.*reconnaissance*), scouting
  - the examiner tries to collect as much information as possible.
  - passive - publicly available information (eg data from social networks, Google)
  - active - research tools (e.g.*nslookup*), to determine certain parameters
- **Scanning**(Eng.*scanning*)
  - the tester scans open ports (*port scanning*) using tools (e.g. Nmap)
  - goal - enumeration of services, versions of enumerated services and OS (*OS and service fingerprinting*).
  - vulnerability scan (*vulnerability scanning*), automated tools (e.g. OpenVAS)
- **Gaining access**(Eng.*obtaining access*)
  - exploitation of vulnerabilities, either manually or with a tool (e.g. Metasploit),
  - depending on the agreement with the owner, some vulnerabilities will not be exploited (eg server crash)
- **Access retention**(Eng.*maintaining access*)
  - examiner installs malicious*backdoor*and*rootkit*programs for further access to the system
  - this and the next phase are not usually carried out in practice, but represent a scenario of a real attack
- **Erasing traces**(Eng.*erasing records*)
  - the examiner attempts to delete log entries that would indicate their unauthorized access

Tools	Basic functionality	Phase
Harvester	Researching publicly available information using search engines, social networks, etc.	Research
Nmap	Network research and port scanning.	Scanning
QualysGuard (Network)	Network scan for known vulnerabilities.	Scanning
QualysGuard (WAS)	Vulnerability scanning of web applications.	Scanning
ASPauditor	Identification of vulnerable and poorly configured ASP.NET servers.	Scanning
Nobody	Scanning web servers for various vulnerabilities, such as dangerous ones files etc.	Scanning
REC	A multifunctional tool for penetration testing of web applications.	Scanning
Sqlmap	SQL injection vulnerability detection and exploitation.	Conducting an attack
Metasploit	A multifunctional platform for exploiting vulnerabilities.	Conducting an attack
HTTP DoS	Denial of service at the application layer.	Conducting an attack
Hydra	Remote password cracking.	Conducting an attack
Wireshark	Recording and analysis of network traffic.	Conducting an attack

Example: Nmap and QualysGuard

```
root@bt :~# nmap -sS -sV 22.22.22.22 Host is up
(0.0027s latency).
Not shown: 992 filtered ports PORT
                STATE    SERVICE          VERSION
21/tcp          open     ftp              Microsoft      ftp
25/tcp          open     smtp?
80/tcp          open     http             Microsoft IIS httpd 6.0
110/tcp         open     pop3             Microsoft Windows 2003 POP3 Service1.0 Microsoft
443/tcp         open     ssl/http         IIS httpd 6.0
3389/tcp open            microsoft-rdp Microsoft Terminal Service
```

Summary of Vulnerabilities

Vulnerabilities Total	24	Security Risk (Avg)	5.0

by Severity

Severity	Confirmed	Potential	Information Gathered	Total
5	1	0		
4	0	0		
3	0	0		
2	1	0		
1	0	0		
Total	2	0		

5 Biggest Categories

Category	Confirmed	Potential
Information gathering	0	0
TCP/IP	0	0
Windows	2	0
Web server	0	0
CGI	0	0
Total	2	0

5 Microsoft Windows Remote Desktop Protocol Remote Code Execution

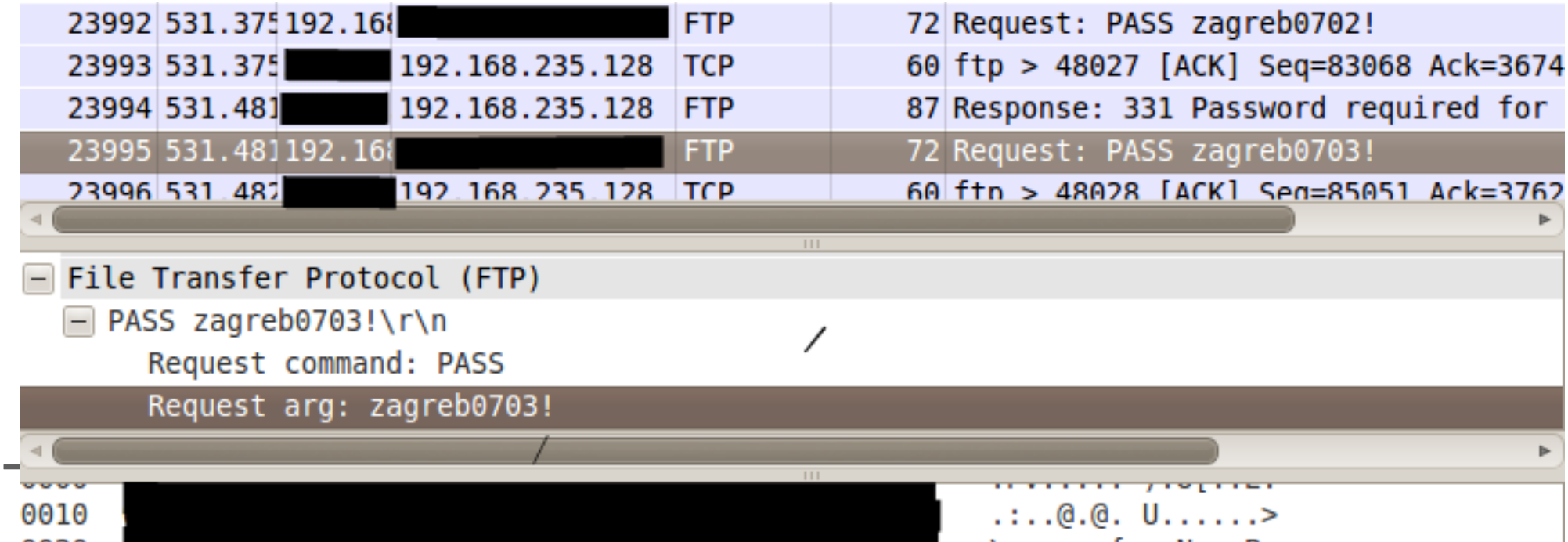
QID:	90783
Category:	Windows
CVE ID:	CVE-2012-0002, CVE-2012-0152
Vendor Reference:	MS12-020
Bugtraq ID:	-
Service Modified:	03/29/2012
User Modified:	-

Example: Hydra, Wireshark

- Dictionary attack with the Hydra tool

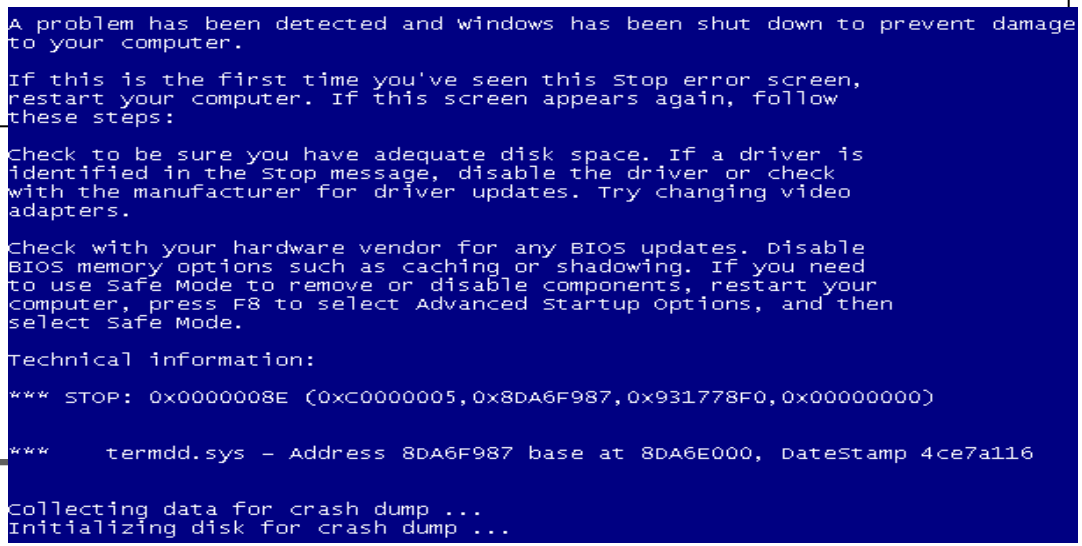
```
[STATUS] 446.66 tries/min, 187152 tries in 06:59h, 0 todo in 00:01h [STATUS] attack finished for
22.22.22.22 (waiting for children to finish) 1 of 1 target successfully completed, 0 valid passwords
found
Hydra (http://www.thc.org/thc-hydra) finished at 2012-06-10 17:20:30
```

- Authentication data during the attack captured by the Wireshark tool



Example: Metasploit

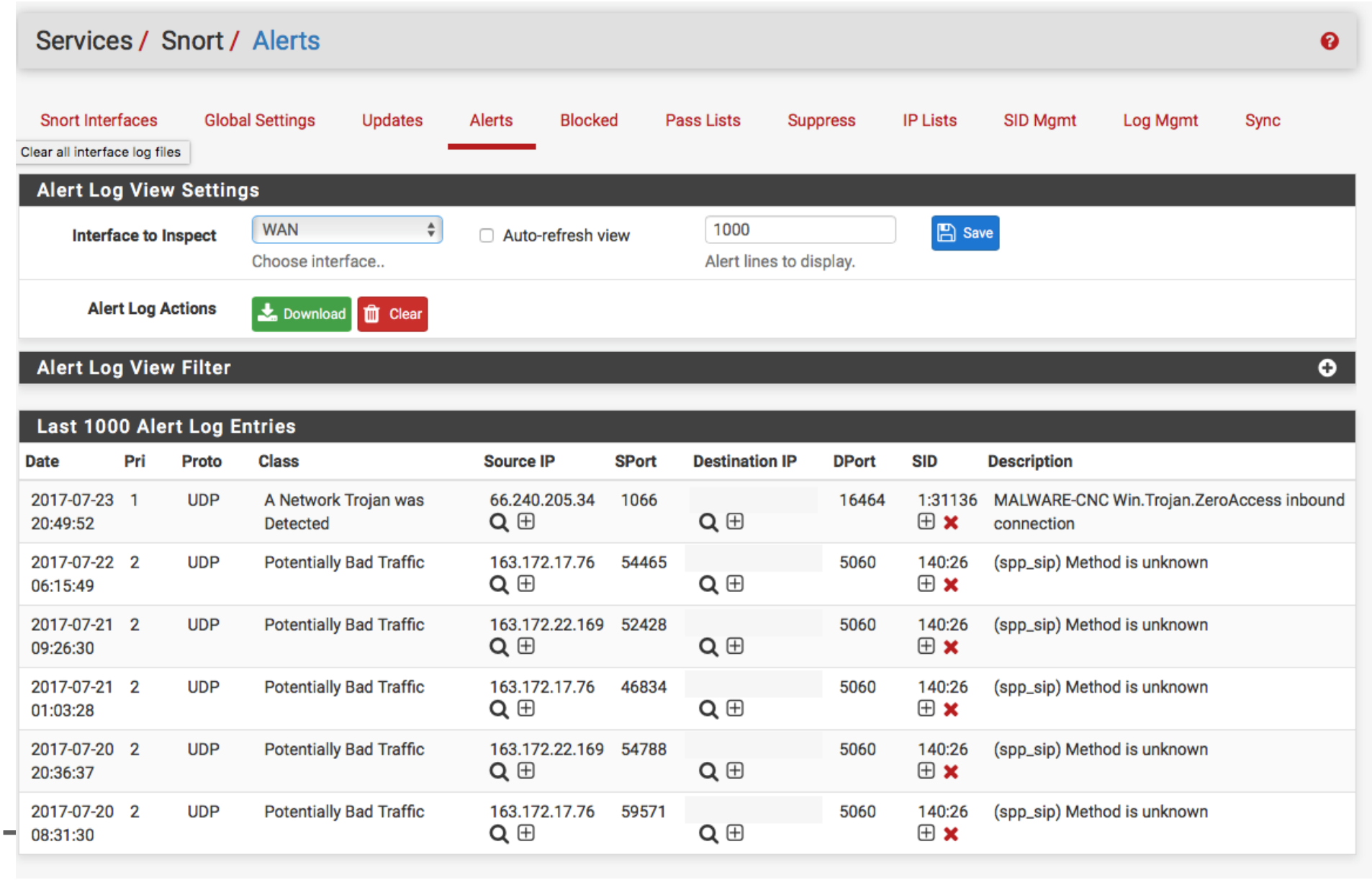
```
msf > use auxiliary/dos/windows/rdp/ms12_020_maxchannelids msf
auxiliary(ms12_020_maxchannelids) > show options Module
        options    (auxiliary/dos/windows/rdp/ms12_020_maxchannelids): Current
   To us            Setting            Required     Description
   - - - -      - - - - - - - - - - - - - -     - - - - - - - -     - - - - - - - - - - -
   RHOST                                yes          The  target    address
   REPORT       3389                    yes          The  target    port
msf auxiliary(ms12_020_maxchannelids) > set RHOST 11.11.11.11 RHOST =>
11.11.11.11
msf auxiliary(ms12_020_maxchannelids) > exploit
[*] 11.11.11.11:3389 - Sending MS12-020 Microsoft Remote Desktop Use-After-Free DoS

[*] 11.11.11.11:3389 - 210 bytes sent [*]
11.11.11.11:3389 - Checking RDP with [+]
11.11.11.11:3389 seems down
```



Tools for penetration testing and intrusion detection

- Pentest
  - https://www.owasp.org/index.php/Category:Penetration_Testing_Tools
  - Aircrack-ng - WIFI scanner - open source
  - Burp Suite - web vulnerability scanner
  - Cain & Abel - "password recovery tool" - packet sniffer, password cracker, ...
  - Ettercap - suite for man in the middle attacks - open source
  - John The Ripper - password cracker
  - Nessus - vulnerability scanner - free trial
  - Kismet - network detector, packet sniffer, IDS - freeware
  - Zed Attack Proxy (**REC**) - web application security scanner - Apache 2 License
- ID/PS
  - https://www.comparitech.com/net-admin/network-intrusion-detection-tools/
  - **Snort**, OSSEC, ..., Solarwinds Log and Event Manager, ...

Example: Snort



References

- OWASP Category: Vulnerability Scanning Tools
- OWASP Code Review Guide
- OWASP Testing Guide

- More tools…
  - http://sectools.org/
  - https://www.owasp.org/index.php/Appendix_A:_Testing_Tools
  - Software Security Assessment Tools Review, 2009