An introduction to web application security through Python

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Agenda

- Introductions
- An introduction to what is Cyber Security
- OWASP and the OWASP Top 10
- Common vulnerabilities
  - With hands on labs
- Automated vulnerability tooling
- The real world applicability of what you've learnt

Introductions

- Who are we?

- Please ask questions whenever
- There are also a couple breaks spaced throughout

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- Who are we?
    - A bunch of hackers by trade

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Introductions

- Who are we?
  - A bunch of hackers by trade
  - But some of us are also passionate developers

- Please ask questions whenever
- There are also a couple breaks spaced throughout

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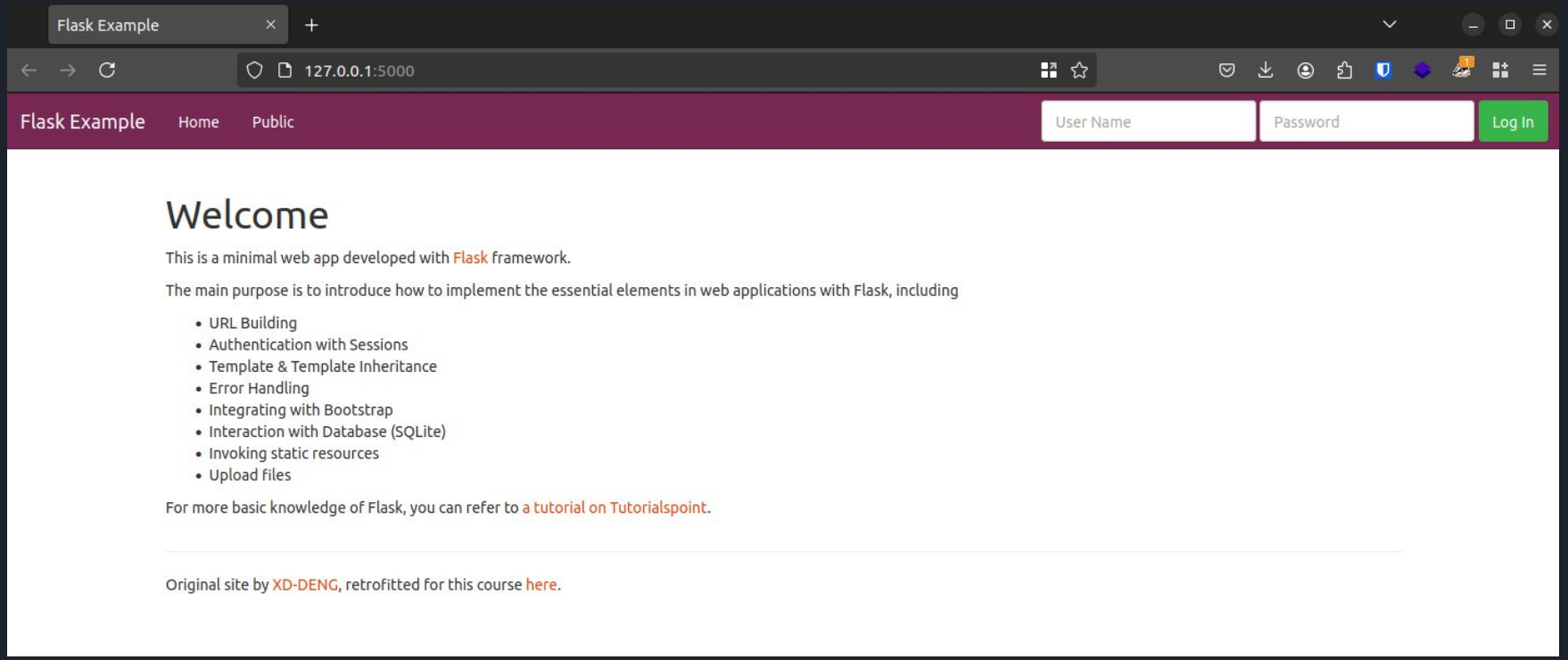
A legal disclaimer

~ Don’t hack shit without prior permission ~

What are we hacking

What are we hacking



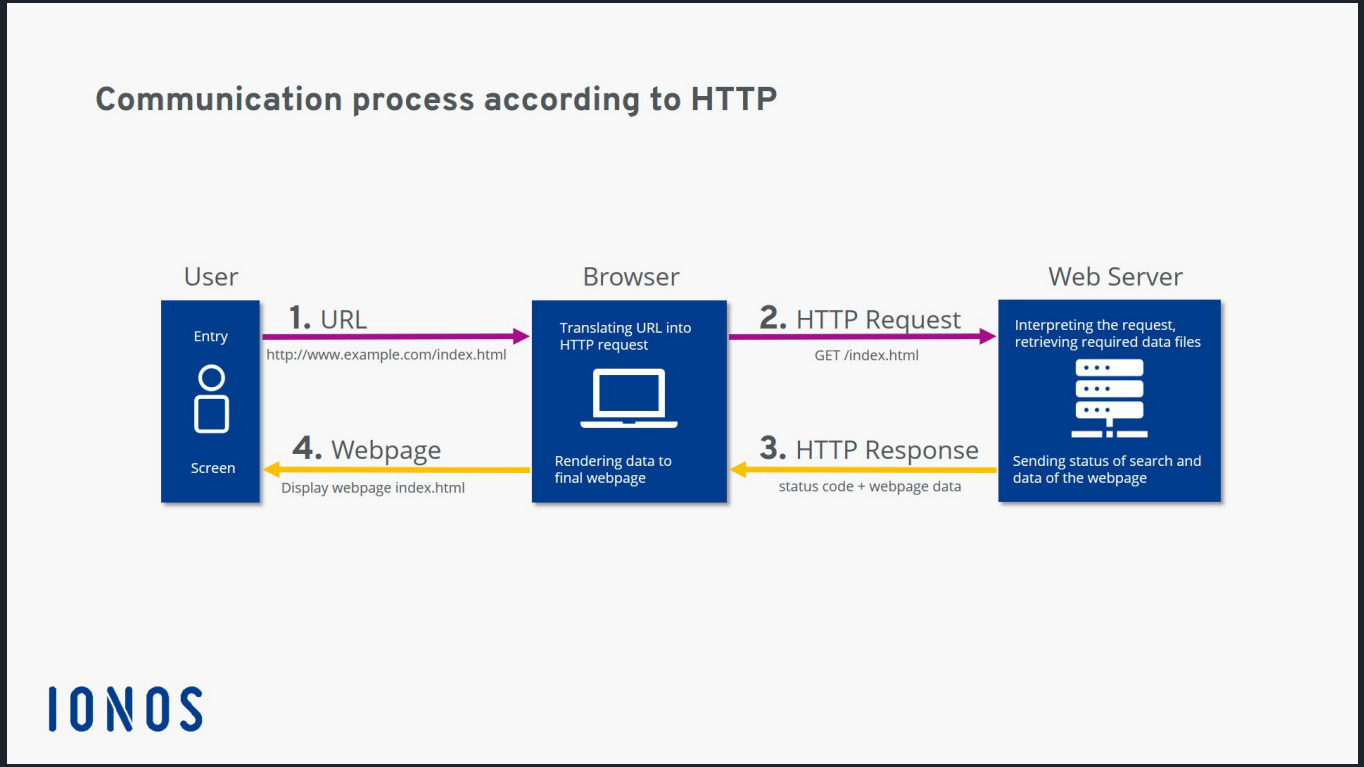
What are we hacking

- This is available as a hosted website which can be found here: https://lab.kpc.koldfusion.xyz

- Further to this, the source code for the lab can be found for download here: https://skelmis.co.nz/lab

How web browsers work – High Level

How web browsers work – High Level



High profile breaches

High profile breaches

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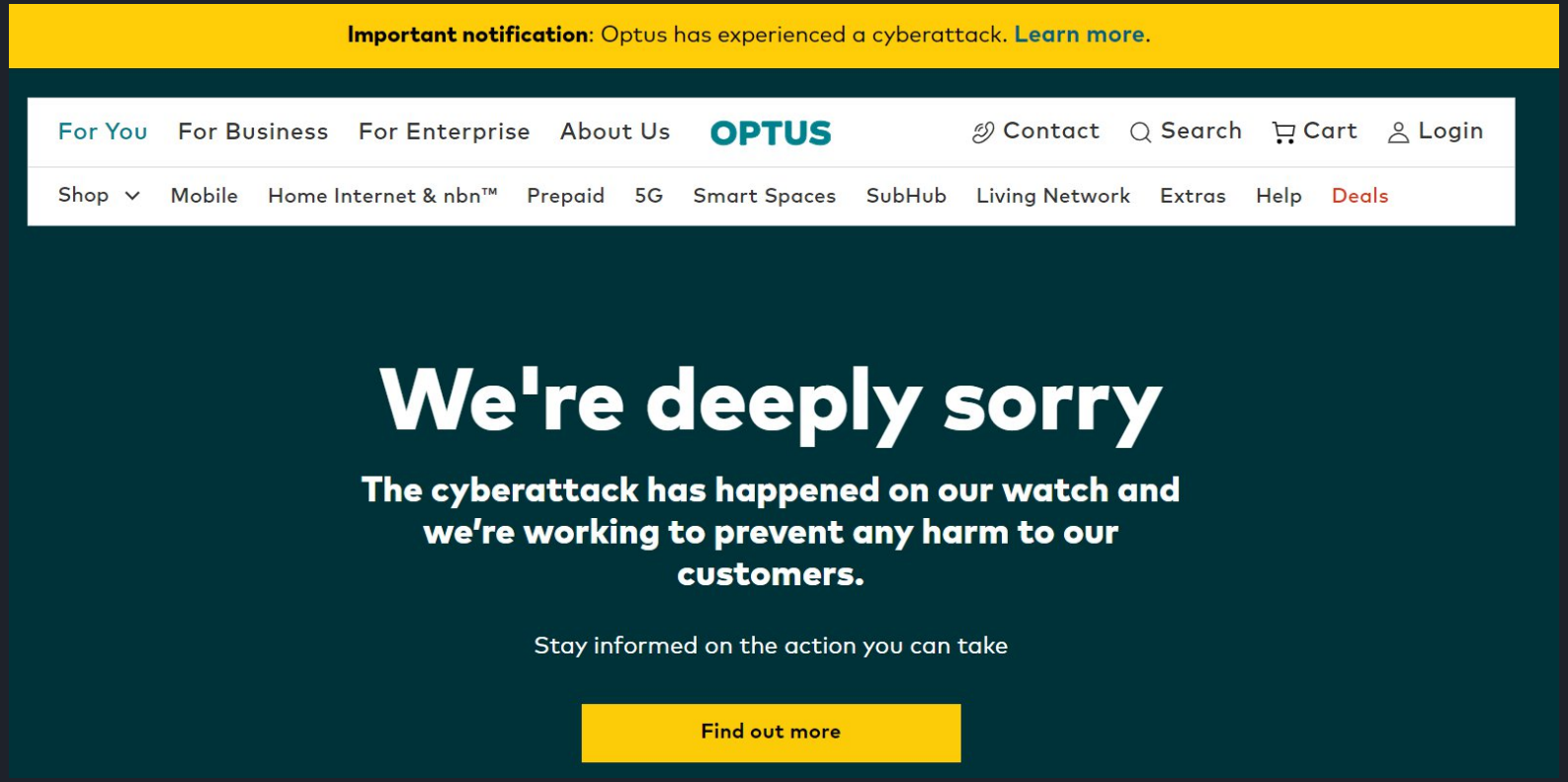


High profile breaches

- The takeaway? It happens
- You don’t need to be an expert to make a meaningful difference in most cases

What is OWASP

The OWASP web top ten

- Broken access control
- Cryptographic failures
- Injection
- Insecure Design
- Security misconfiguration
- Vulnerable and outdated components
- Identification and authentication failures
- Software and data integrity failures
- Security logging and monitoring failures
- Server side request forgery

Some OWASP links

- Primary site:
  - https://owasp.org/
- The OWASP Top 10 2021:
  - https://owasp.org/Top10/
- Cheat sheets:
  - https://cheatsheetseries.owasp.org/index.html

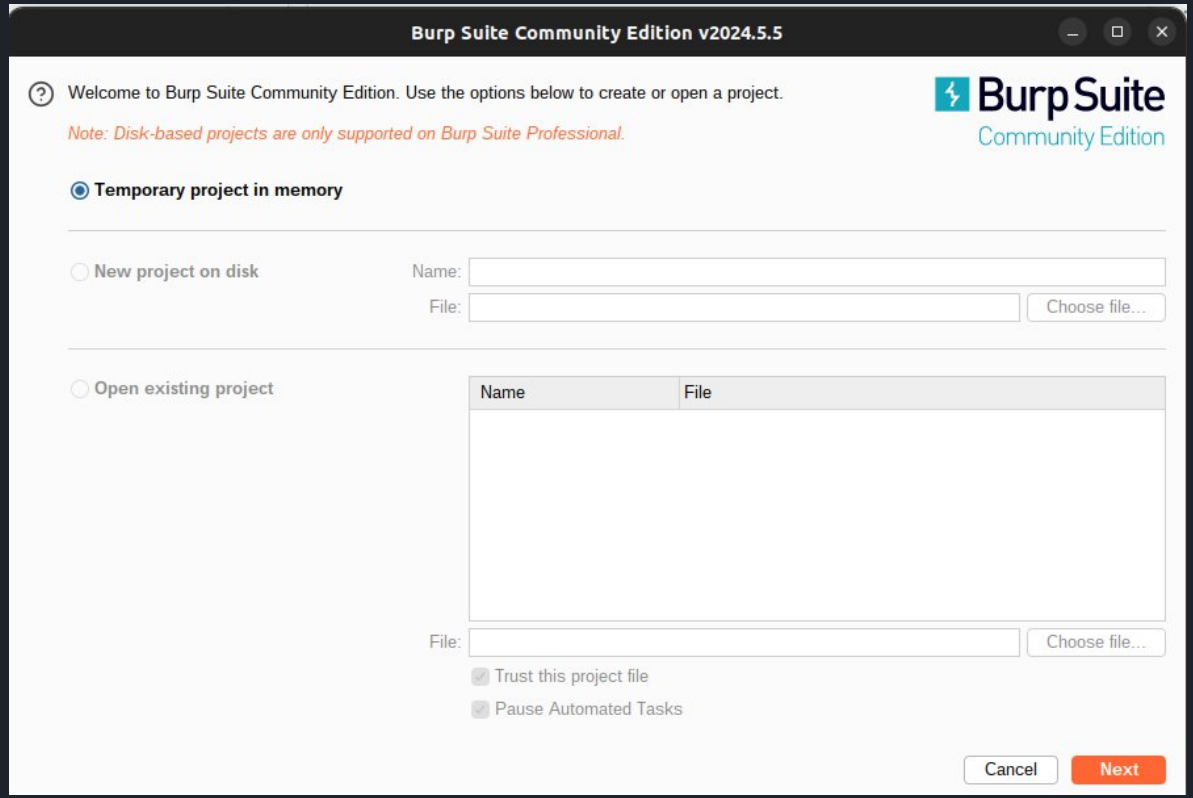
What we are going to cover

- Broken access control
- Broken authentication
- Cryptographic failures
- Injection
  - SQL Injection
  - Cross Site Scripting
  - Template Injection
- Security misconfiguration
- Security logging and monitoring failures
- Server side request forgery
- Path traversal

Initial website exploration

- Understanding the expected behavior of your target is often where we start an engagement

Initial website exploration - BurpSuite



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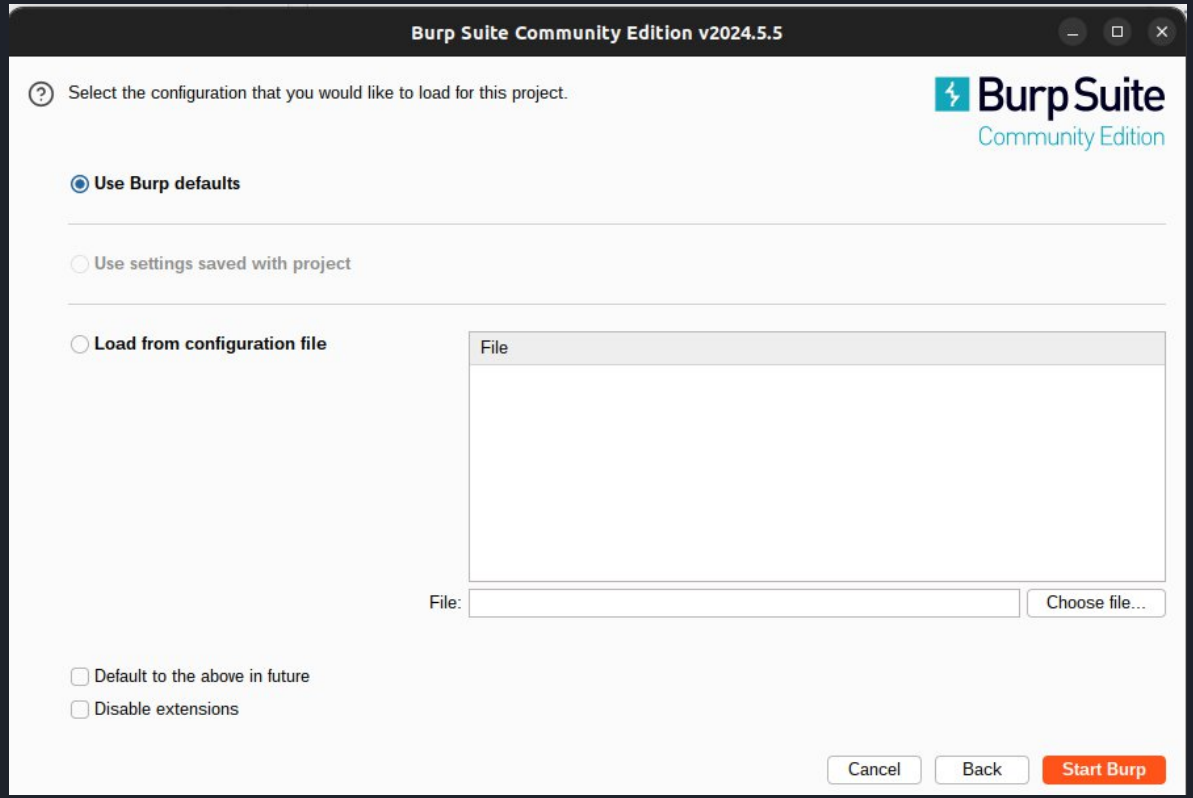

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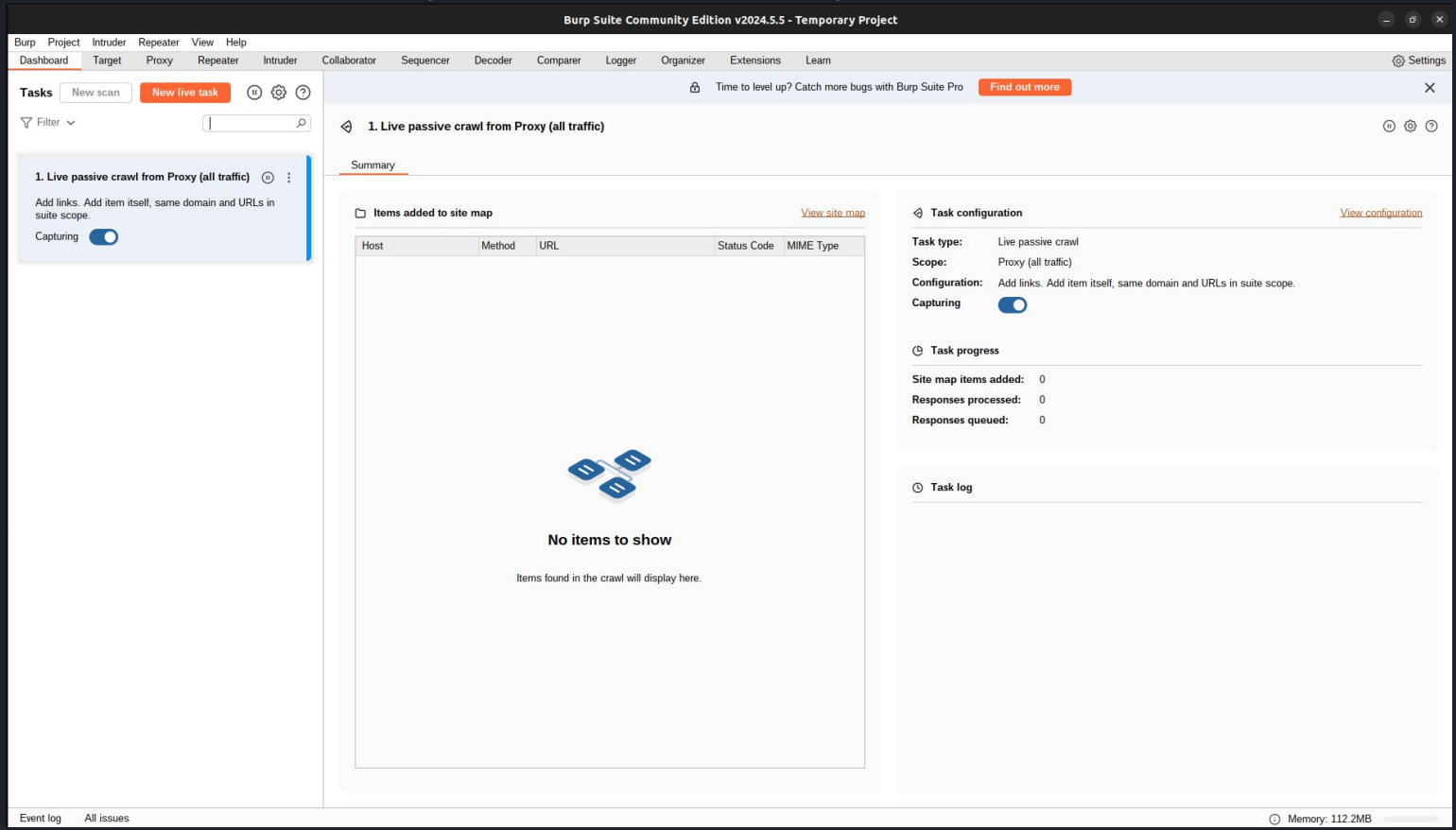

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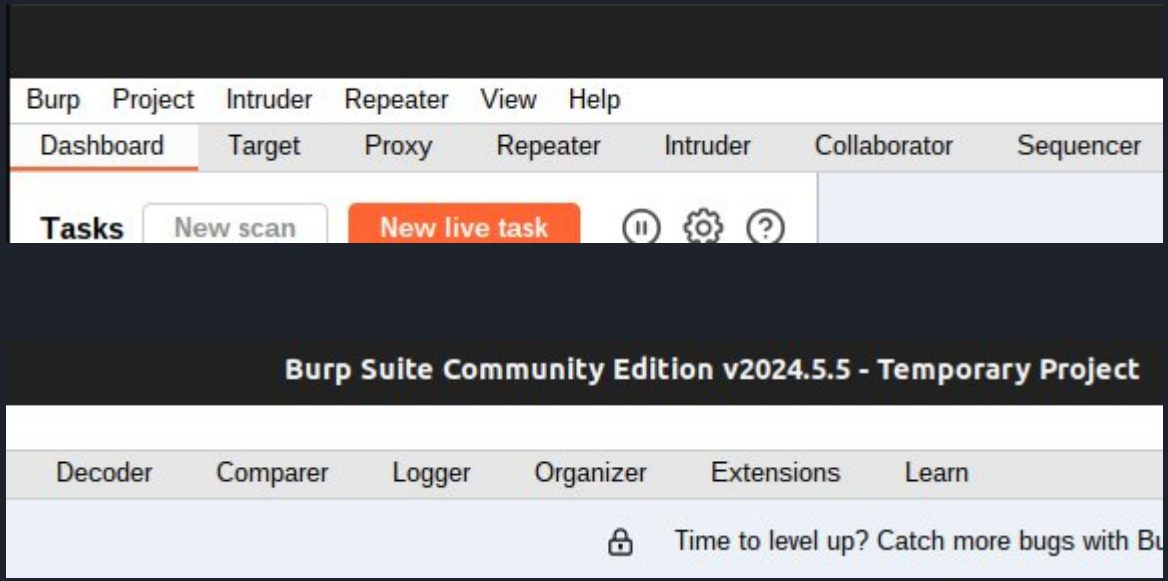

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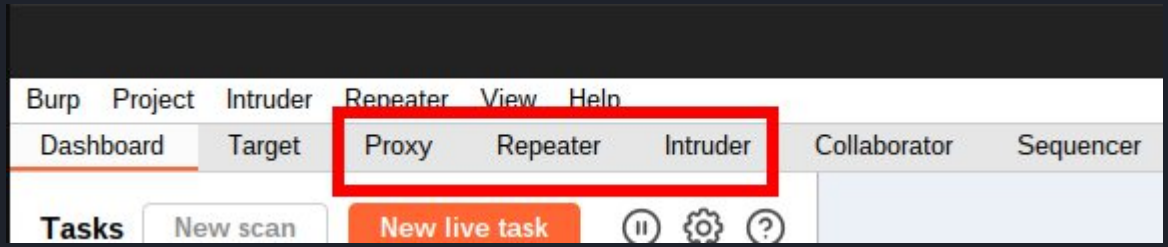

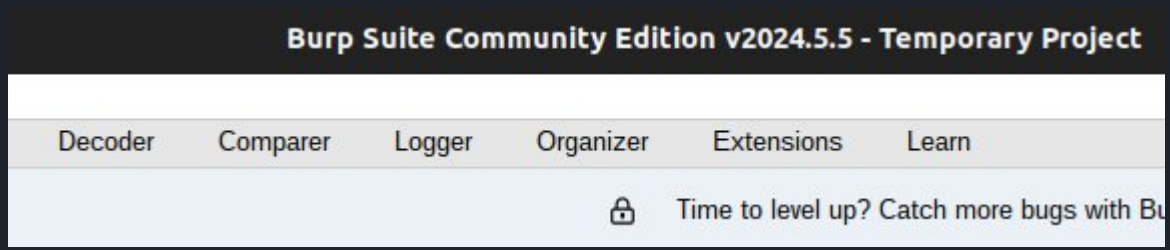

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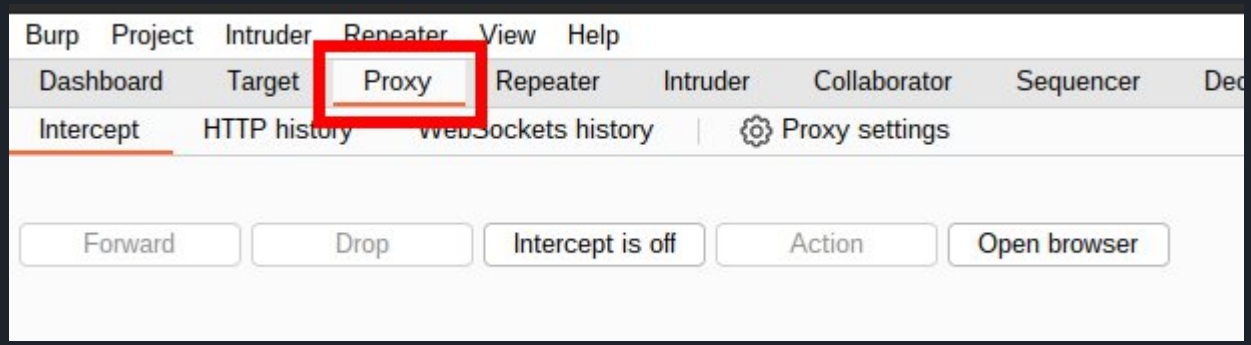

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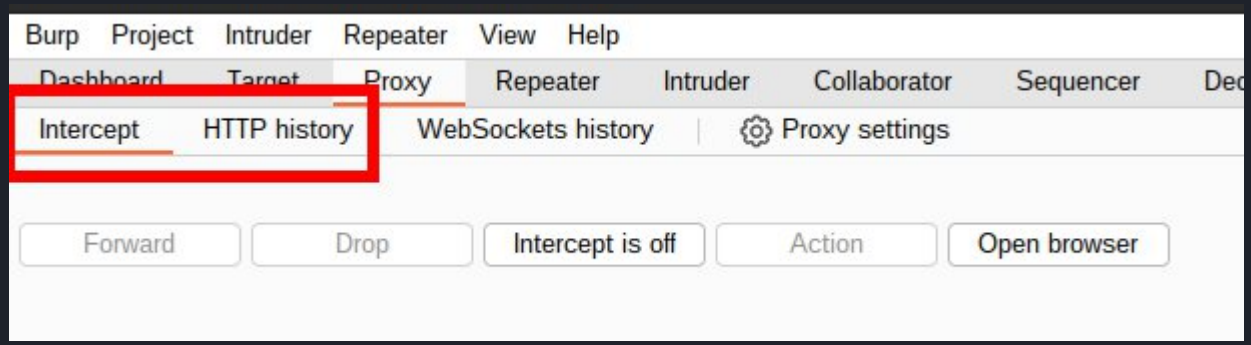

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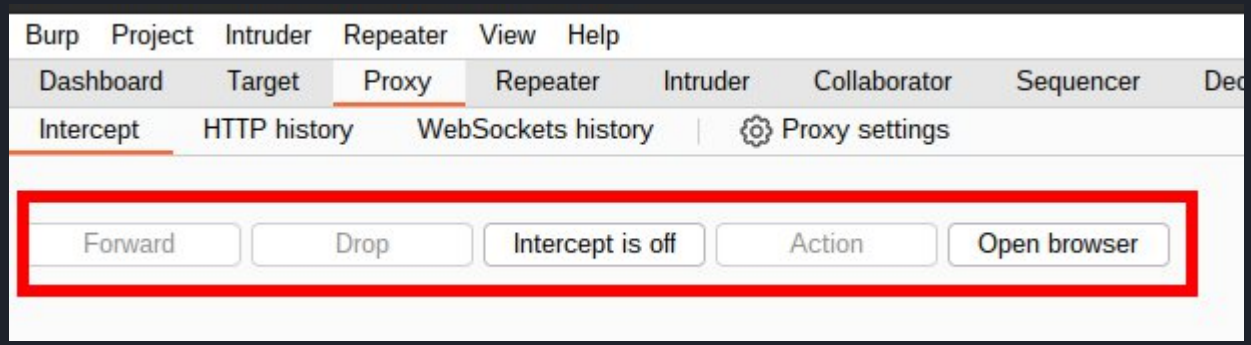

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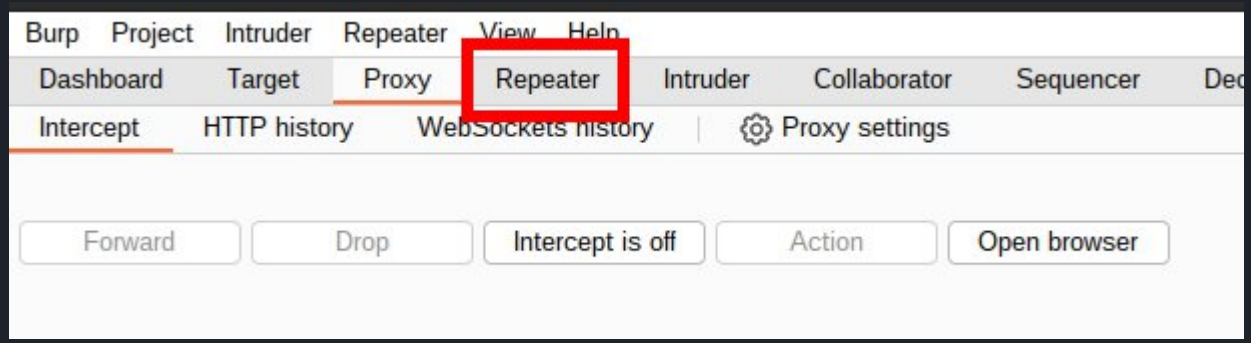

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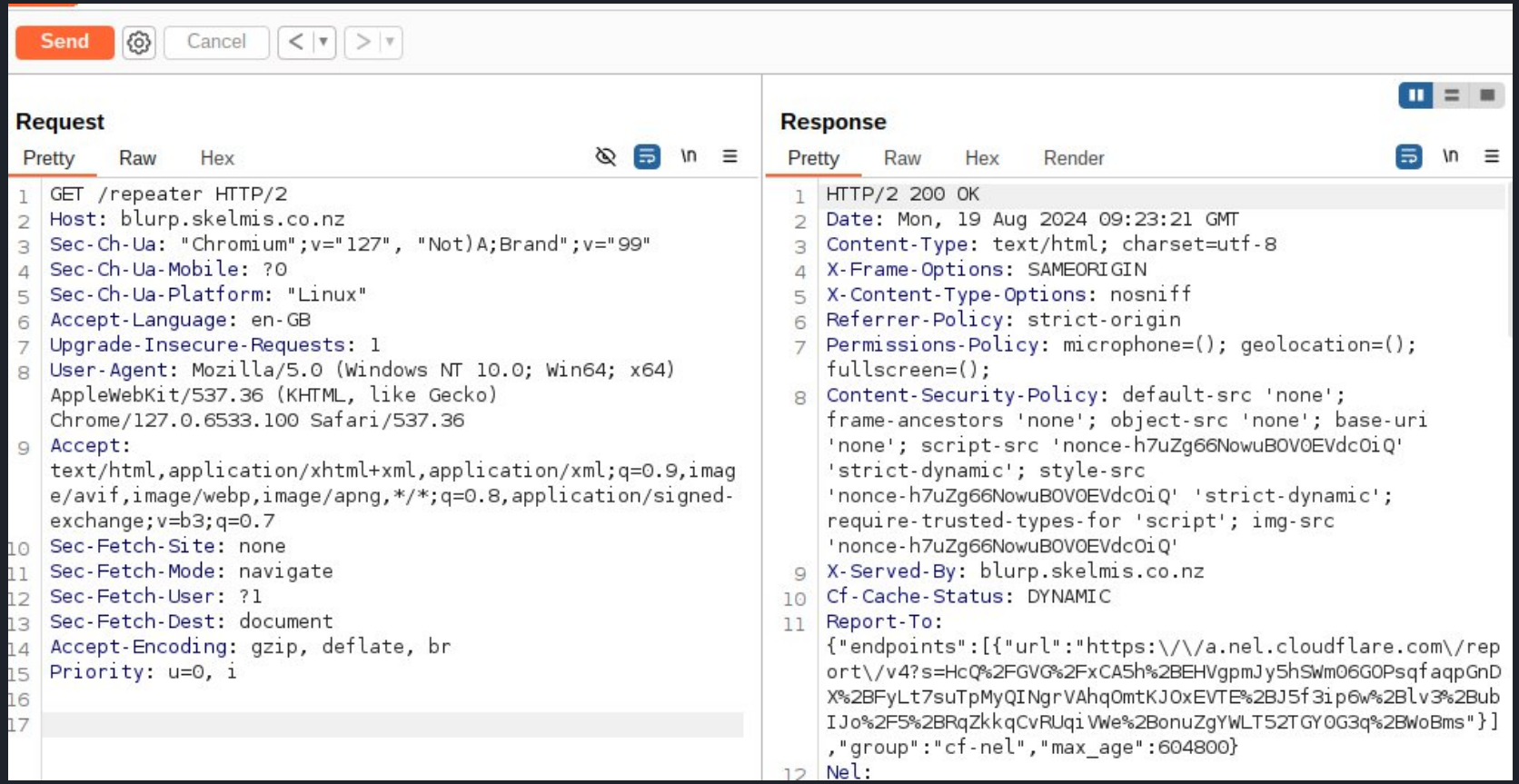

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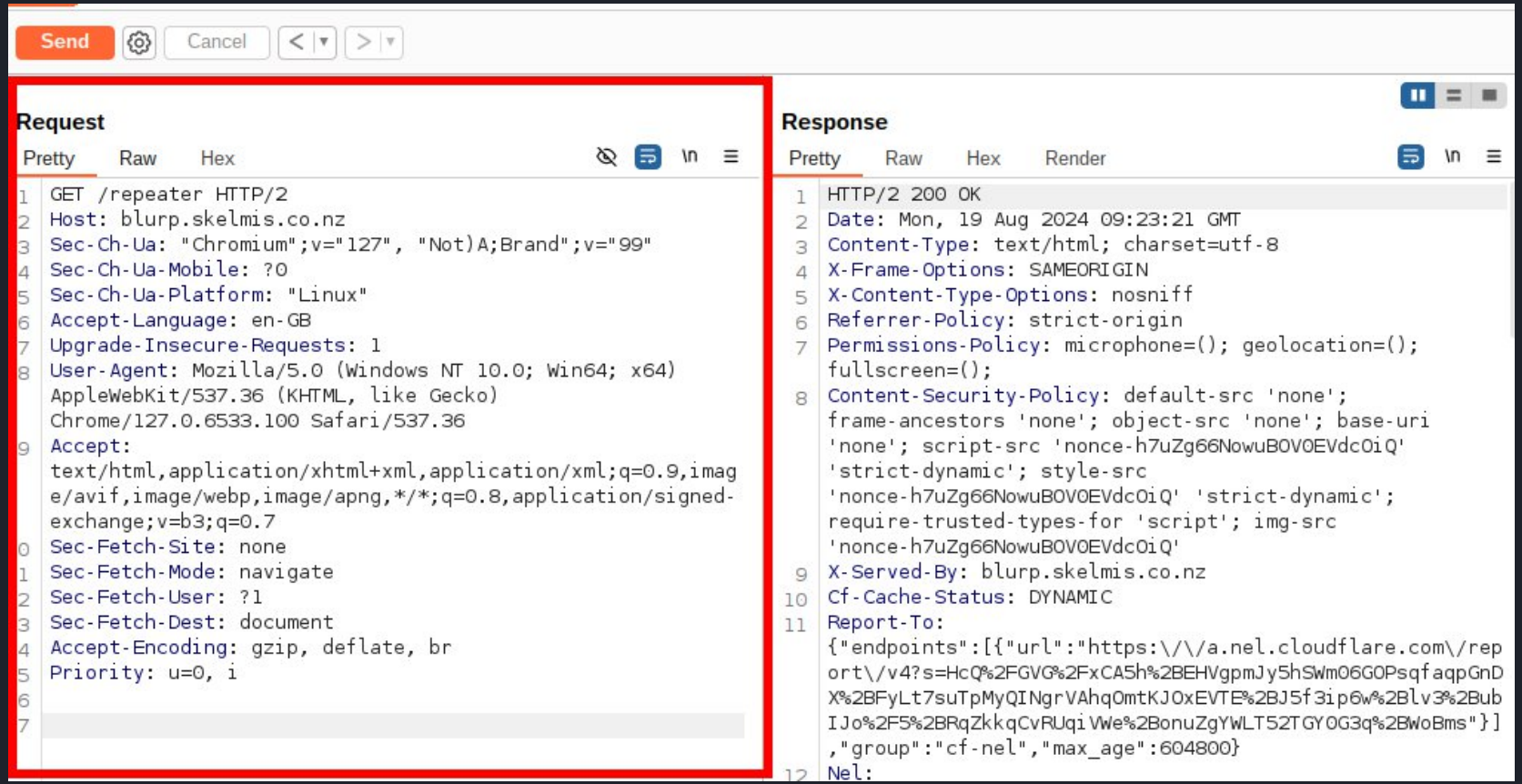

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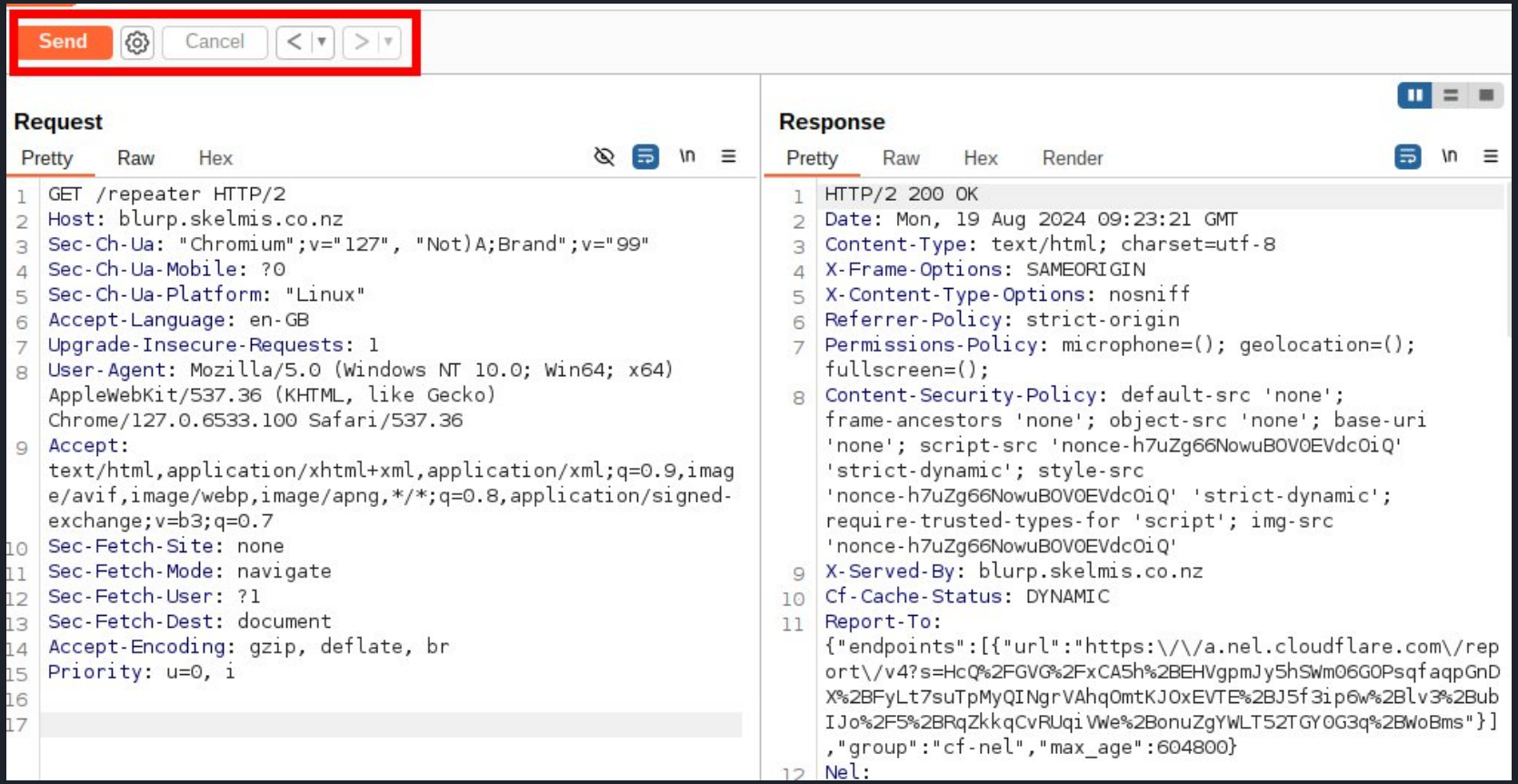

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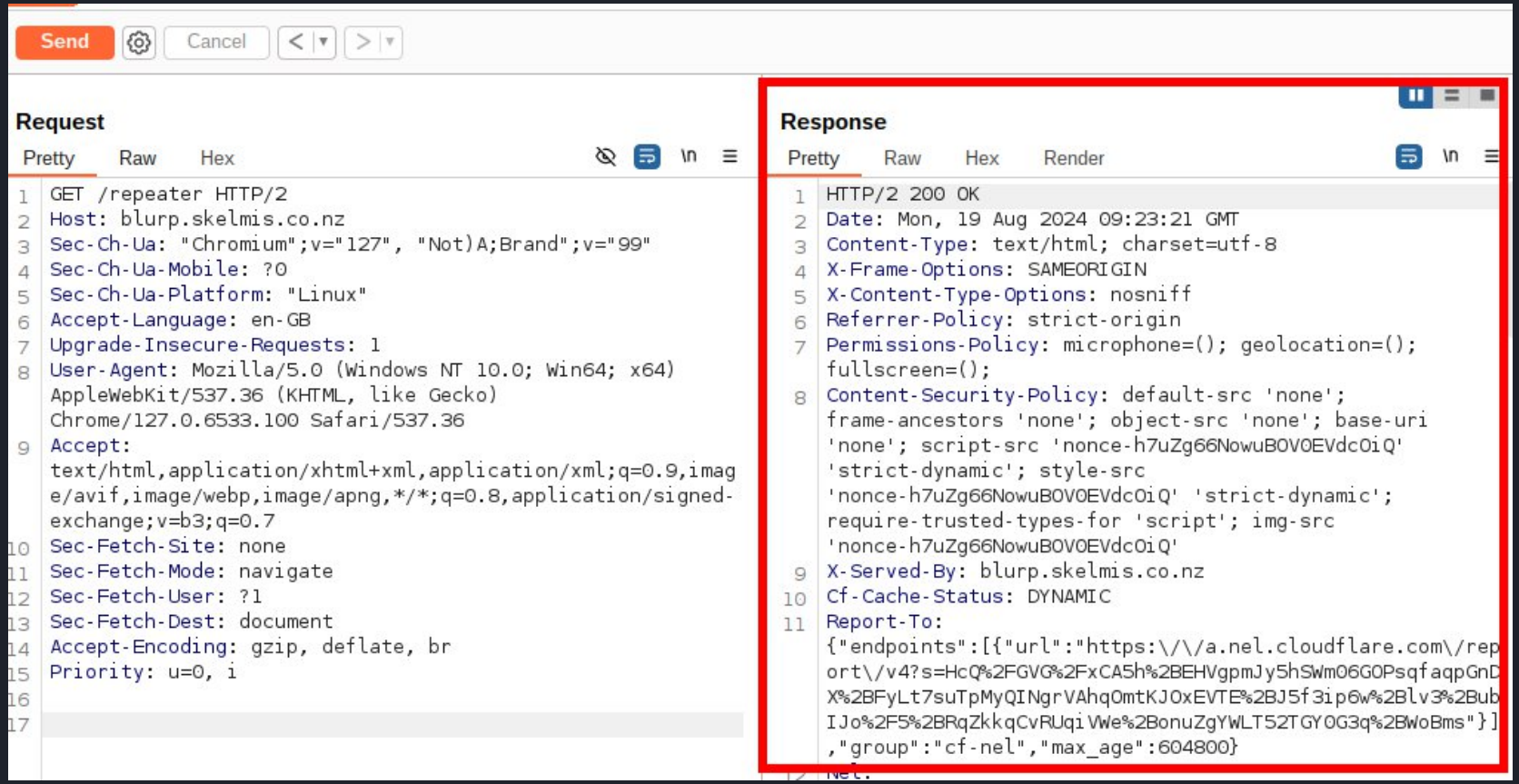

Initial website exploration

- In that spirit, go do the following proxying via Burp:
  - Create a couple users
  - Upload some images to multiple accounts
  - Create some private notes
  - Have a general explore of the site

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Broken Access Control

Broken Access Control

- Generally websites expect users to only do certain actions
  - For example, you may only change your own password

- Broken access control refers to scenarios that break this expectation, some examples may include:
  - Viewing, editing and modifying other users data
  - Executing admin functions as an everyday user
  - Accessing privileged resources

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Lab Exercise

Try to delete other user's images

How to abuse the issue

1. Log into the site as any user
2. Upload an image
3. Right click the “Delete” button and copy the URL
4. Log out of the user
5. Navigate to the URL, observing it has still deleted the image

Mitigation's

- Deny access by default
- Models should enforce ownership / authorisation before allowing row modifications
- Disable features such as directory listing on web server
- Log anytime an access policy is triggered
- Rate limit all the things

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Broken Authentication

Broken Authentication

- Websites need to understand the concept of a ‘user’
- This requires things such as:
  - A password
  - Multi factor authentication
  - Session management
  - Forgot password flows

Broken Authentication

- Broken authentication in this case refers to scenarios that abuses those requirements, some examples may include:
  - Allowing automated attacks against user accounts
  - Exposing insecure session management details
  - Failing to enforce secure standards user’s should adhere to

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Lab Exercise

Attempt to use your session after logging out

Hint

- You can find cookies in browsers via:
  - Press F12
  - Storage -> Cookies
  - Click on the correct domain

How to abuse the issue

- Log in to the website
- Within your browser, navigate to cookie storage
- Copy the session cookies name and value
- Log out of the website, observing the cookie has been removed
- Manually re-add the cookie using the stored values

Mitigation's

- Implement and require multi-factor authentication
- Ensure default credentials do not exist
- Implement weak password checks
- Implement account lockout policies
- Ensure authentication routes are sufficiently hardened

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Cryptographic Failures

What is Cryptography?

- Simply, Cryptography is the implementation of techniques to ensure secure communication, storage, and transmission of datats.

But why should I care?

- Failure to securely store or transmit data may result in attackers gaining access to things such as:
  - Personal Identifiable Information
  - Credentials
    - (Example of cleartext breaches Rockyou, GoDaddy, DailyQuiz)
  - The ability to intercept and ‘see’ requests you make

Okay, so what do I need to consider?

- Are your cryptographic algorithms old and/or weak?
- Are your cryptographic algorithms using weak secret keys?
- Are you using secure source of randomness?
- Are you using a Salt?
- Are you using a pepper?
- Is data transmitted in clear text (HTTP/HTTPS)?
- Are you hashing or encrypting data?

Cryptographic Failures

- However, if we can ask you to take one thing away from this

Cryptographic Failures

- However, if we can ask you to take one thing away from this

Cryptographic Failures

- There are cryptographic standards for a reason... Banana Water is bad

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Injection

Injection

- Injection occurs when user supplied data ends up in commands and/or queries unvalidated
- Some examples of the end vulnerabilities include:
  - SQL injection (SQLi)
  - NoSQL injection
  - OS command injection
  - Cross site scripting (XSS)
  - Object Relational Mapping (ORM) leakage

Injection

- Examples of how these vulnerabilities occur include:
  - User supplied data is not validated or sanitised by the application
  - User supplied data is used directly within an interpreter
  - Malicious data is used within ORM to extract additional, sensitive records
  - Hostile data is directly used or concatenated into SQL queries

Cross Site Scripting (XSS)

- XSS occurs when data enters a web application through an untrusted source and is executed on the client side

- Often this takes the form of JavaScript which the web browser will execute
  - The following payload is a simple example:
    <script>alert(“This is XSS”)</script>

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Lab Exercise

Get XSS via a simple <script> tag injection

Example payload:

<script>alert(“This is XSS”)</script>

How to abuse the issue

- Log in to the website as a user
- Navigate to the private page
- Enter <script>alert(1)<script> as a note
- Refresh the page

Mitigation's

- Frameworks often ship with great mitigation features, use them
- Sanitize all the things
- Ensure sensitive data exists in cookies with HTTPOnly set
- Implement a Content Security Policy inline with your sites requirements
- Use a web application firewall (WAF)

SQL Injection (SQLi)

- A SQLi attack often consists of malicious data being added to SQL queries in order to coerce the data into doing things
- Some of the things an attacker can do via this are:
  - Read sensitive data from the database such as password hashes
  - If allowed, modify data within the database
  - Execute administration operations on the database such as shutdown requests
  - In some cases, issue commands directly to the operating system

SQL Injection (SQLi)

- An example vulnerable query can be seen below:

```
def main(username):  new *
    query = f"SELECT * FROM users WHERE username = '{username}'"
```

SQL Injection (SQLi)

- An example vulnerable query can be seen below:

```
def main(username):  new *
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```

- With an example malicious payload being:
  - ‘ OR 1=1 --C

- This payload returns all users instead of just the matching user

SQL Injection (SQLi) – Time based

- If the application doesn't return the results of the query, what do we do?
- Well SQL supports a sleep operation alongside conditional checks, so we can build the following payload:
  - IF(SUBSTRING(version(), 1, 1)=1, SLEEP(5), null)
- Where:
  - If the first character returned from version() is 1 then sleep for five seconds
  - Using this we can easily extract information even if its not directly returned to us within the response

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Lab Exercise

Given your understanding of the site,
attempt to find a SQL injection vulnerability

Example payload:
‘ OR 1=1 --C

How to abuse the issue

- Navigate to the website
- When attempting to log in, set the username to the following:
  - ‘ OR 1=1 --C

- Automated tooling also exists
- SqlMap:
  - https://sqlmap.org/
  - sqlmap -u http://localhost:5000 --forms

Mitigation's

- Frameworks often ship with great mitigation features, use them
- Use parameterized queries, stored procedures or prepared statements
- Enforce the principal of least privilege
- Only allow expected characters for fields
- Use a web application firewall (WAF)

Server Side Template Injection (SSTI)

- Common web applications generate dynamic HTML for responses using technology such as Jinja2
- Often this content contains dynamic attributes, such as usernames or emails
- Attackers can use this to provide malicious payloads which a web application may execute within the server if not properly validated

Server Side Template Injection (SSTI)

- An example of vulnerable Jinja2 can be seen below:
  - output = Environment(..).from_string(“Hello” + name).render()
- With which an attacker controlling the name may be able to run anything that Jinja2 supports
- Some examples include:
  - Including arbitrary content within output
  - Dump all current variables
  - Execute arbitrary code on the server

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Lab Exercise

Gain template injection within the notes field

Example payload:

```
{{ 7*7 }}
```

How to abuse the issue

- Navigate to the website
- When creating a note, add the following payload:
  - {{ 7*7 }}

Mitigation's

- Frameworks often ship with great mitigation features, use them
- Remove the functional need for users to interact with templating logic that executes code
- Only allow expected characters for fields
- Use a web application firewall (WAF)

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Security Misconfiguration

Security Misconfiguration

- Security misconfiguration often ties into the idea of a defense in depth approach to security
- Some examples of this include:
  - Missing rate limiting / application hardening
  - Unnecessary features are enabled / configured
  - Default accounts are still enabled and unmodified
  - Verbose error messages revealing system details
  - Sensitive data stored in local storage

Security Headers

- Security headers are a great example of:
  - Defense in depth
  - And also easy security wins

Security Headers

- For example, let's compare two requests:

```
HTTP/2 200 OK
Date: Tue, 23 Jul 2024 06:44:34 GMT
Content-Type: text/html; charset=utf-8
Cf-Cache-Status: DYNAMIC
Report-To:
{"endpoints":[{"url":"https:\/\/a.nel.cloudflare.com
JzGKC66%2B4tiQgxS6%2B7w0xgmn7mRzoG9HgrKgnVE0mh04fgl8
u2lJWGssns0v%2F60f5n7CHZyqZQ%3D"}],"group":"cf-nel",
Nel: {"success_fraction":0,"report_to":"cf-nel","max
Server: cloudflare
Cf-Ray: 8a79b3dc8bf9a886-SYD
Alt-Svc: h3=":443"; ma=86400
```

```
HTTP/2 200 OK
Date: Mon, 19 Aug 2024 06:38:54 GMT
Content-Type: text/html; charset=utf-8
X-Frame-Options: SAMEORIGIN
X-Content-Type-Options: nosniff
Referrer-Policy: strict-origin
Permissions-Policy: microphone=(); geolocation=();
Content-Security-Policy: default-src 'none'; frame-
base-uri 'none'; script-src 'nonce-RfILB4fbBzIcMd18
'nonce-RfILB4fbBzIcMd18cpJdcg' 'strict-dynamic'; re
img-src 'nonce-RfILB4fbBzIcMd18cpJdcg'
X-Served-By: blurp.hla.sh
Cf-Cache-Status: DYNAMIC
Report-To:
{"endpoints":[{"url":"https:\/\/a.nel.cloudflare.co
%2B7RHyI95H3RE9i%2Bx3Pm2XbXWaYsPD7Tn4%2BJg8lE63Cfw0
x%2BSbQ7bMtshKXi44n9m5oIAgUcM8%3D"}],"group":"cf-ne
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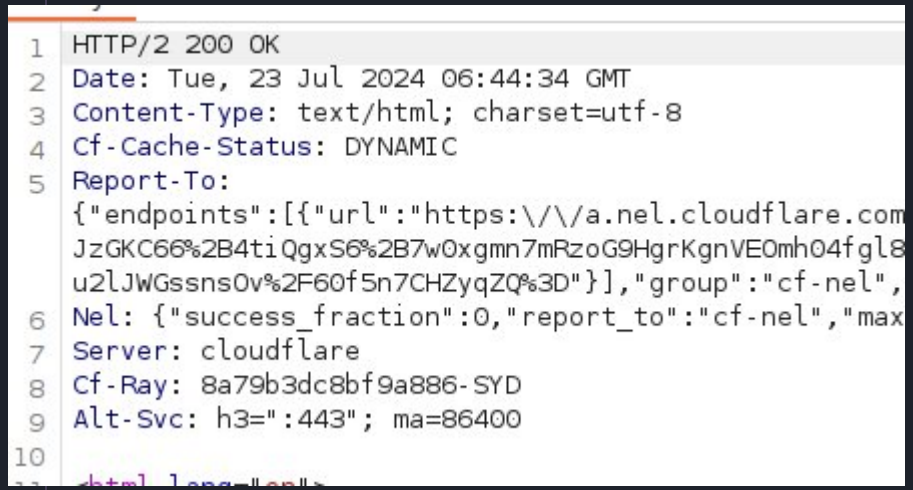

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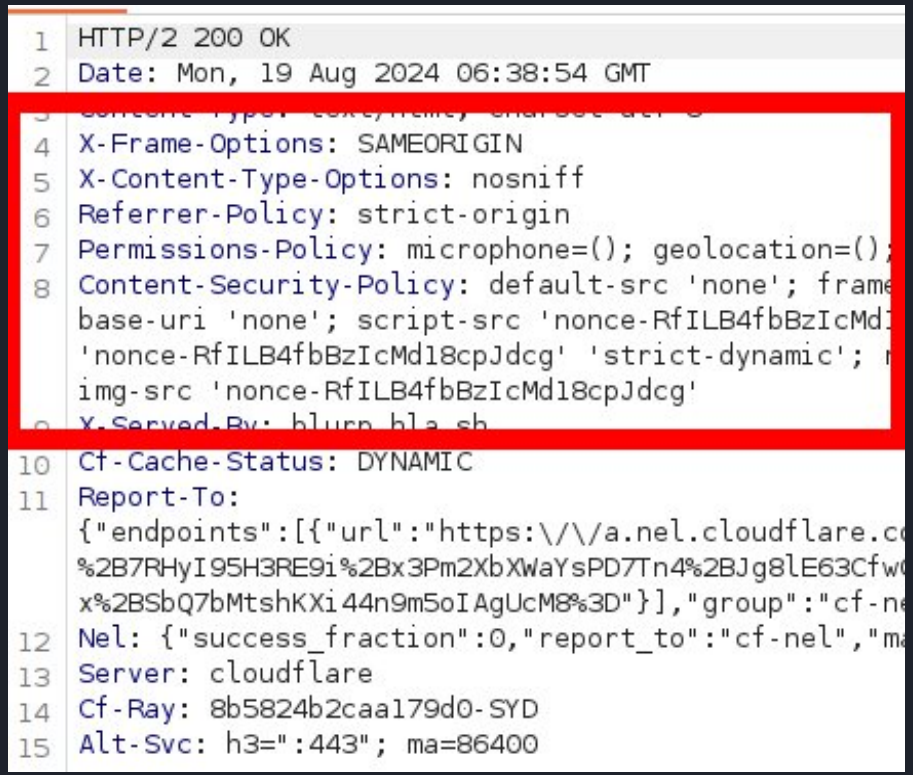

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Referrer-Policy: strict-origin
Permissions-Policy: microphone=(); geolocation=();
Content-Security-Policy: default-src 'none'; frame
base-uri 'none'; script-src 'nonce-RfILB4fbBzIcMd
'nonce-RfILB4fbBzIcMd18cpJdcg' 'strict-dynamic';
img-src 'nonce-RfILB4fbBzIcMd18cpJdcg'
X-Served-By: blurp.bla.sh
Cf-Cache-Status: DYNAMIC
Report-To:
{"endpoints":[{"url":"https:\/\/a.nel.cloudflare.c
%2B7RHyI95H3RE9i%2Bx3Pm2XbXWaYsPD7Tn4%2BJg8lE63Cfw
x%2BSbQ7bMtshKXi44n9m5oIAgUcM8%3D"}],"group":"cf-n
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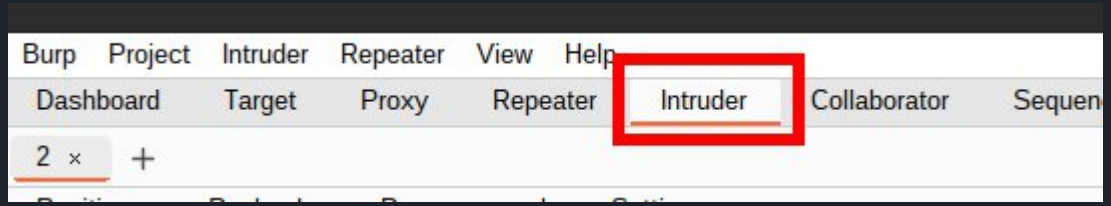

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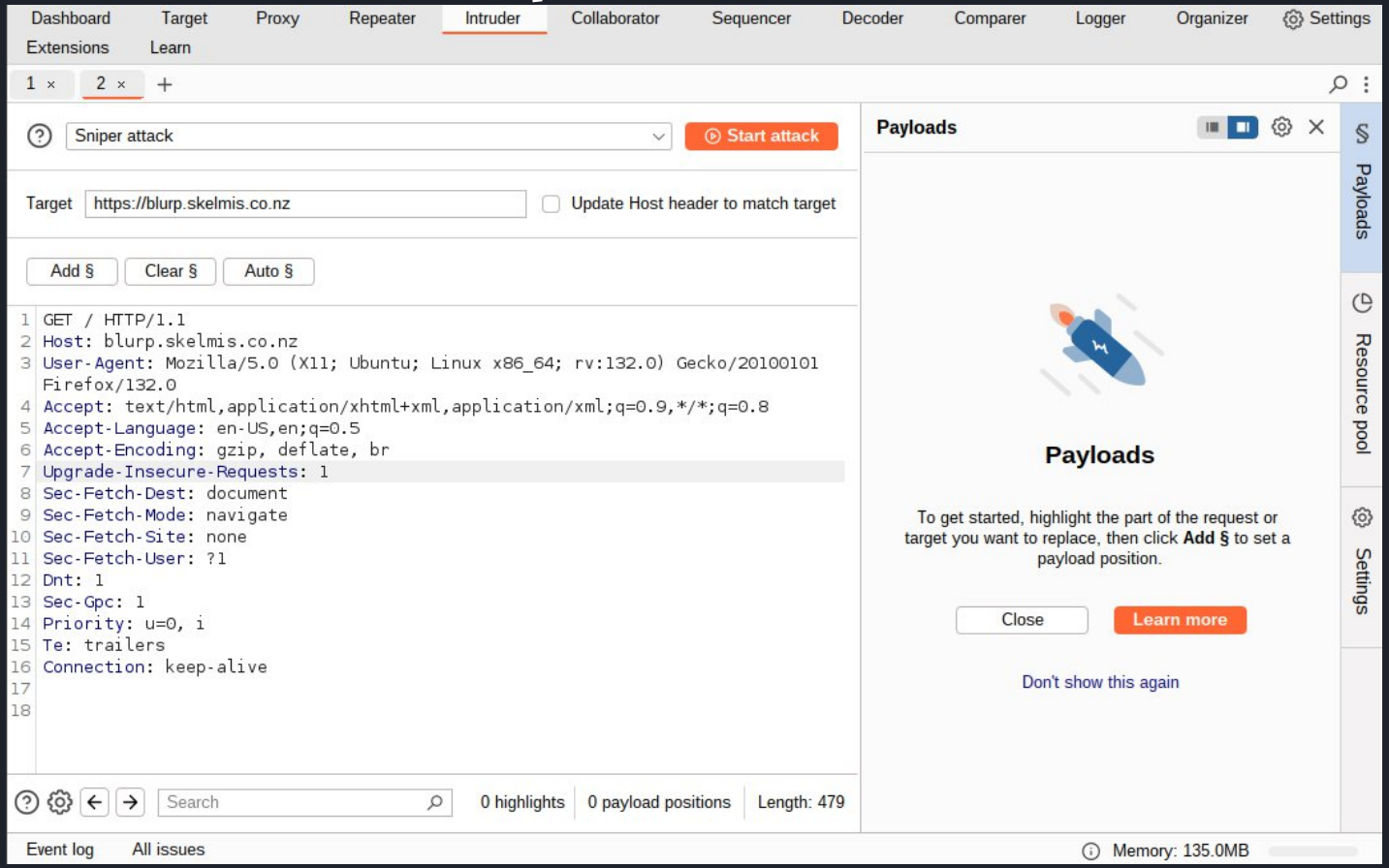

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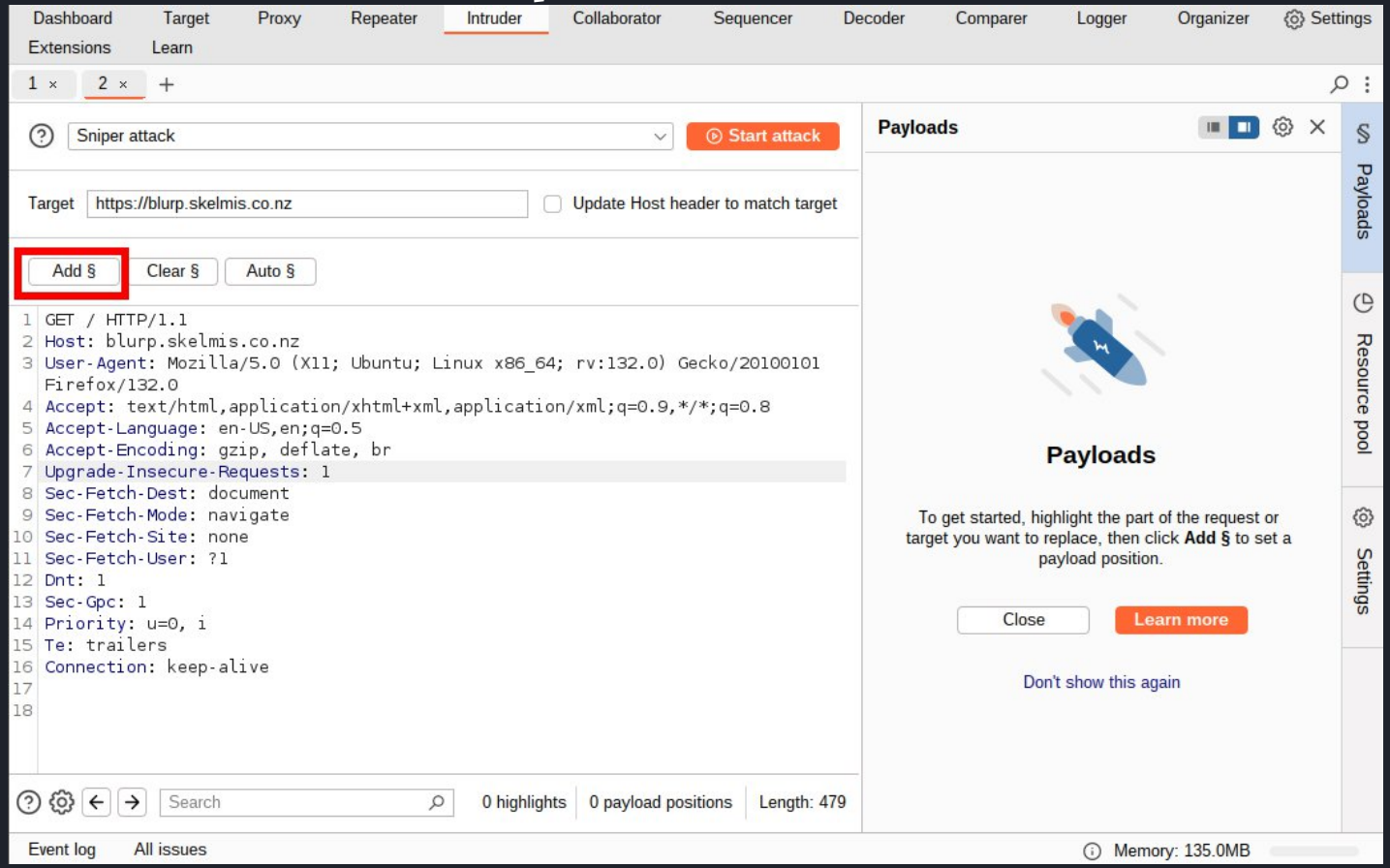

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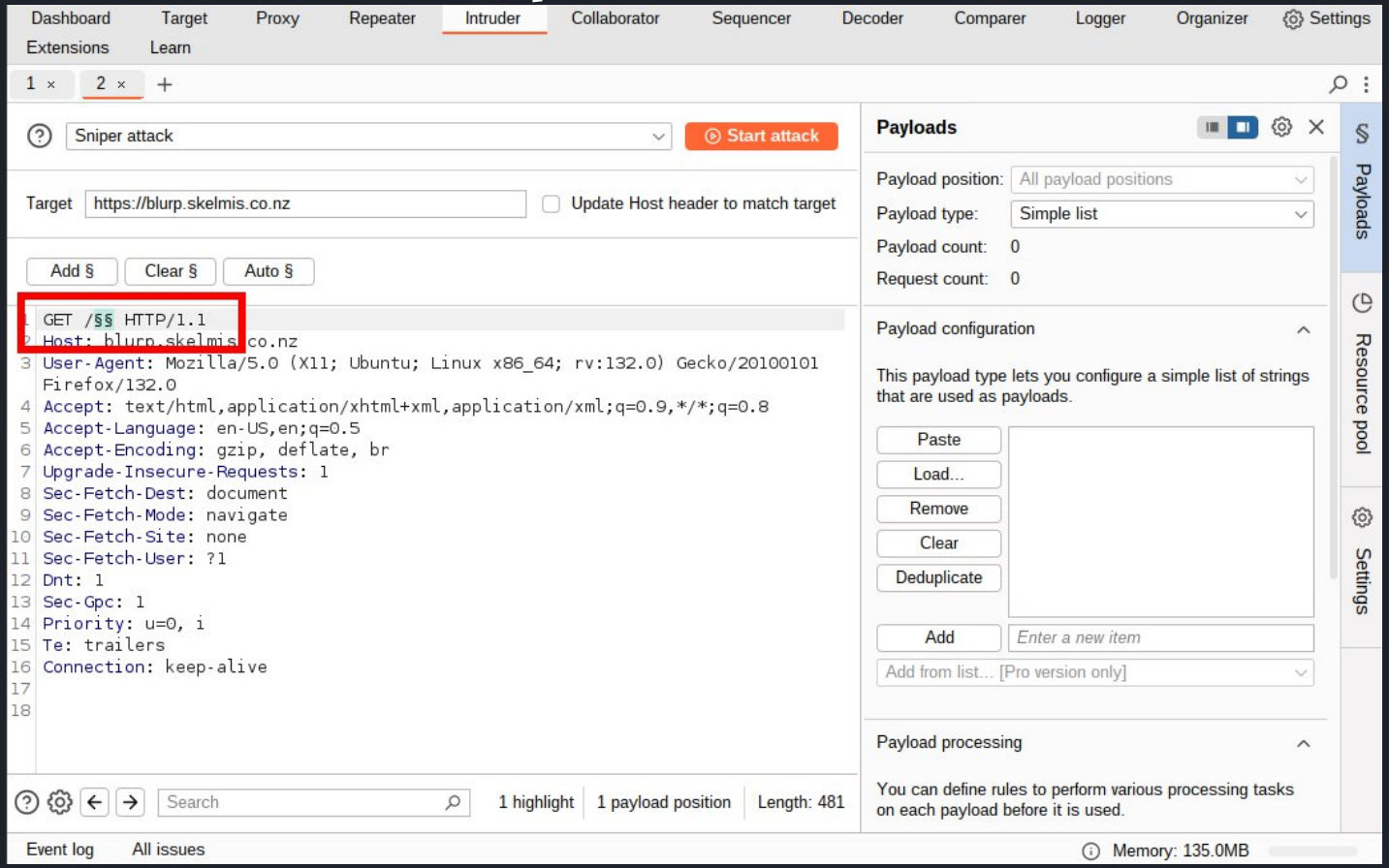

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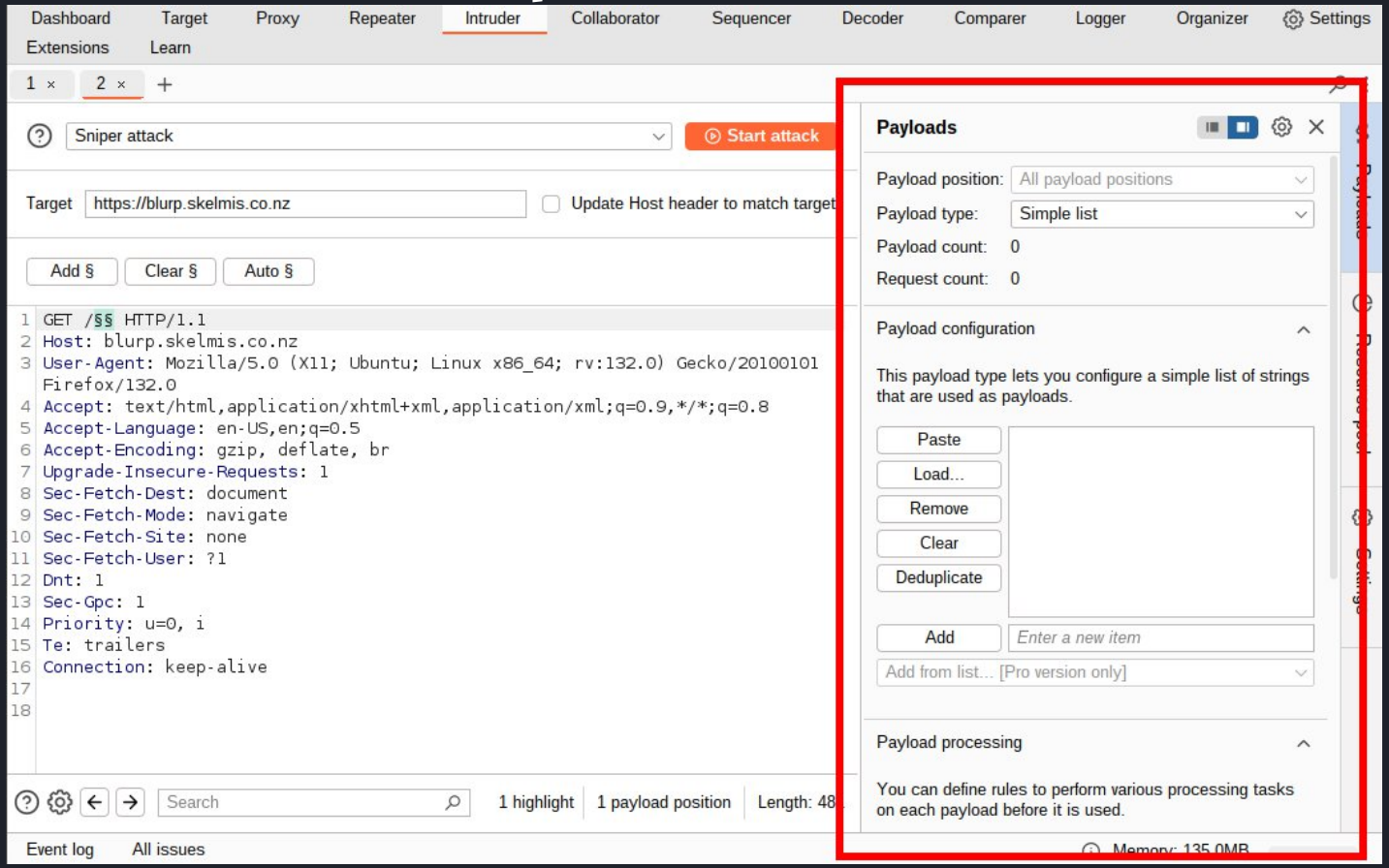
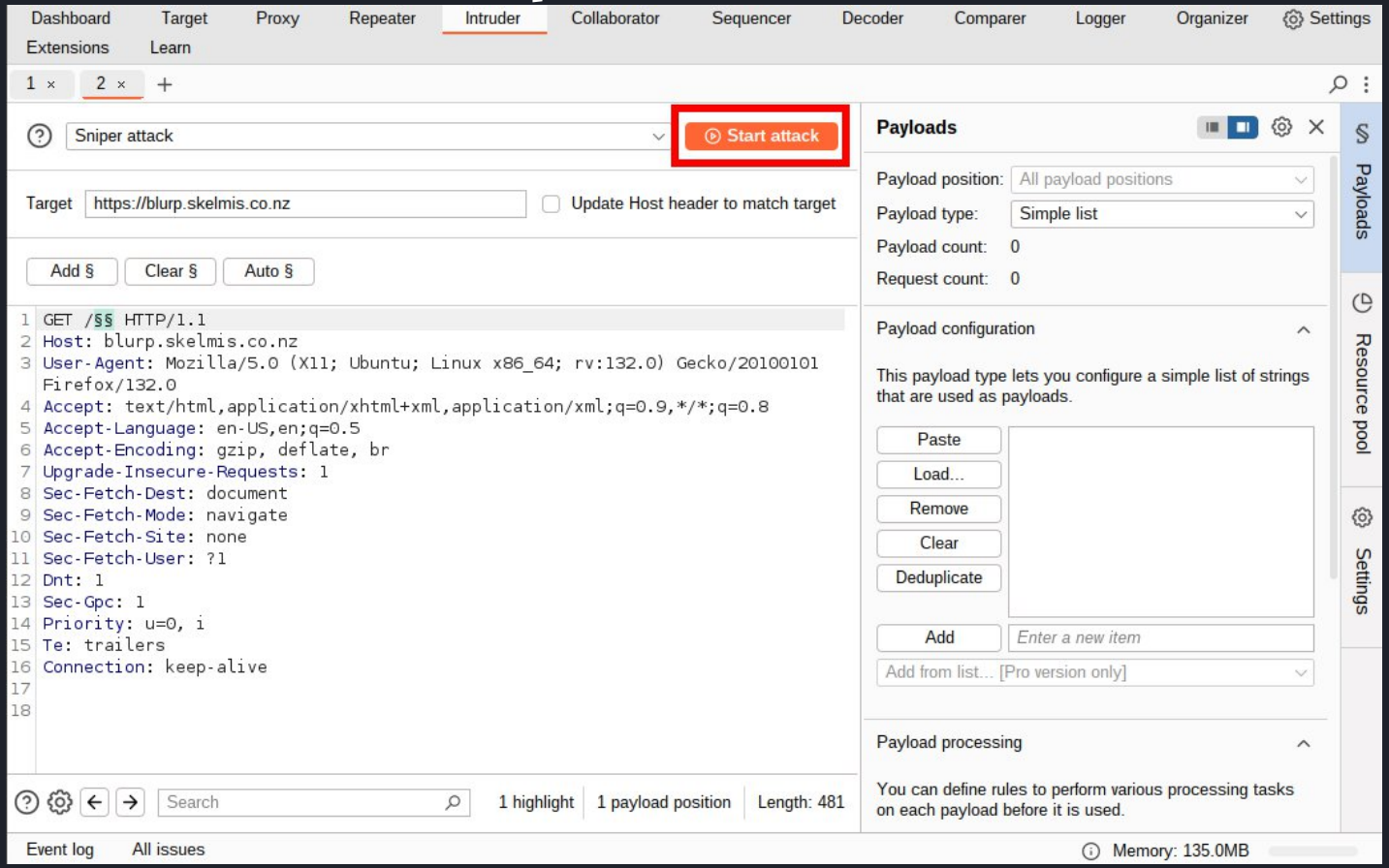


An introduction to Burp Intruder



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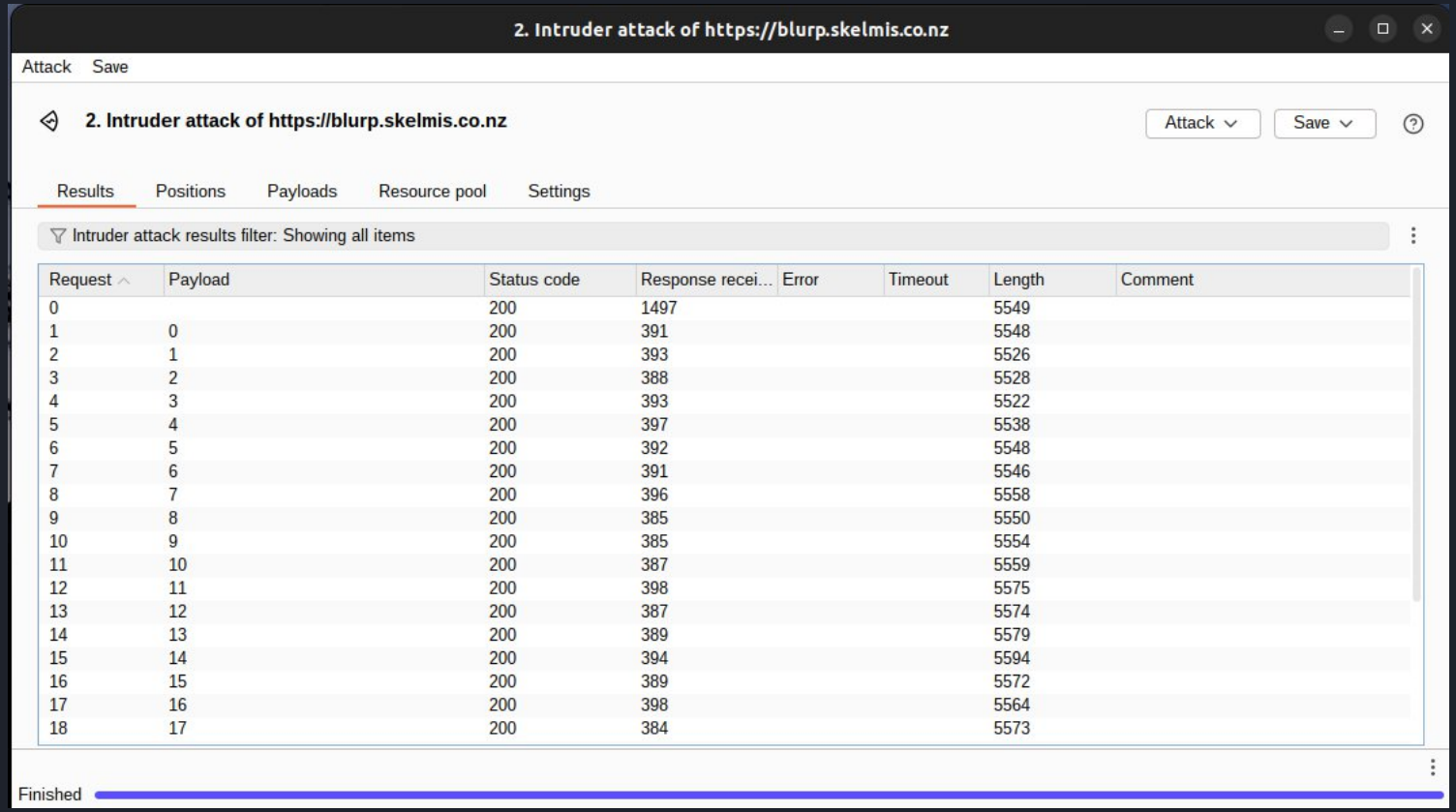


</>

Lab Exercise

Attempt to get into the account called default

How to abuse the issue

- Navigate to the GitHub
- Download the file titled “passwords.txt”
- Capture a log in request using Burp Suite
- Send the request to intruder
- Set the username to “default”
- Use the password file as an input list
- Start the attack and wait until the correct password is found

Mitigation's

- Ensure default accounts are not present
- Have easy and repeatable hardening processes present to reduce deployment friction
- Send security directives such as security headers
- Have automated processes present to verify the presence and effectiveness of controls in all environments

</>

Security Logging and Monitoring Failures

Security Logging and Monitoring Failures

- Logging primarily exists to tell us what kind of actions have occurred in a given product

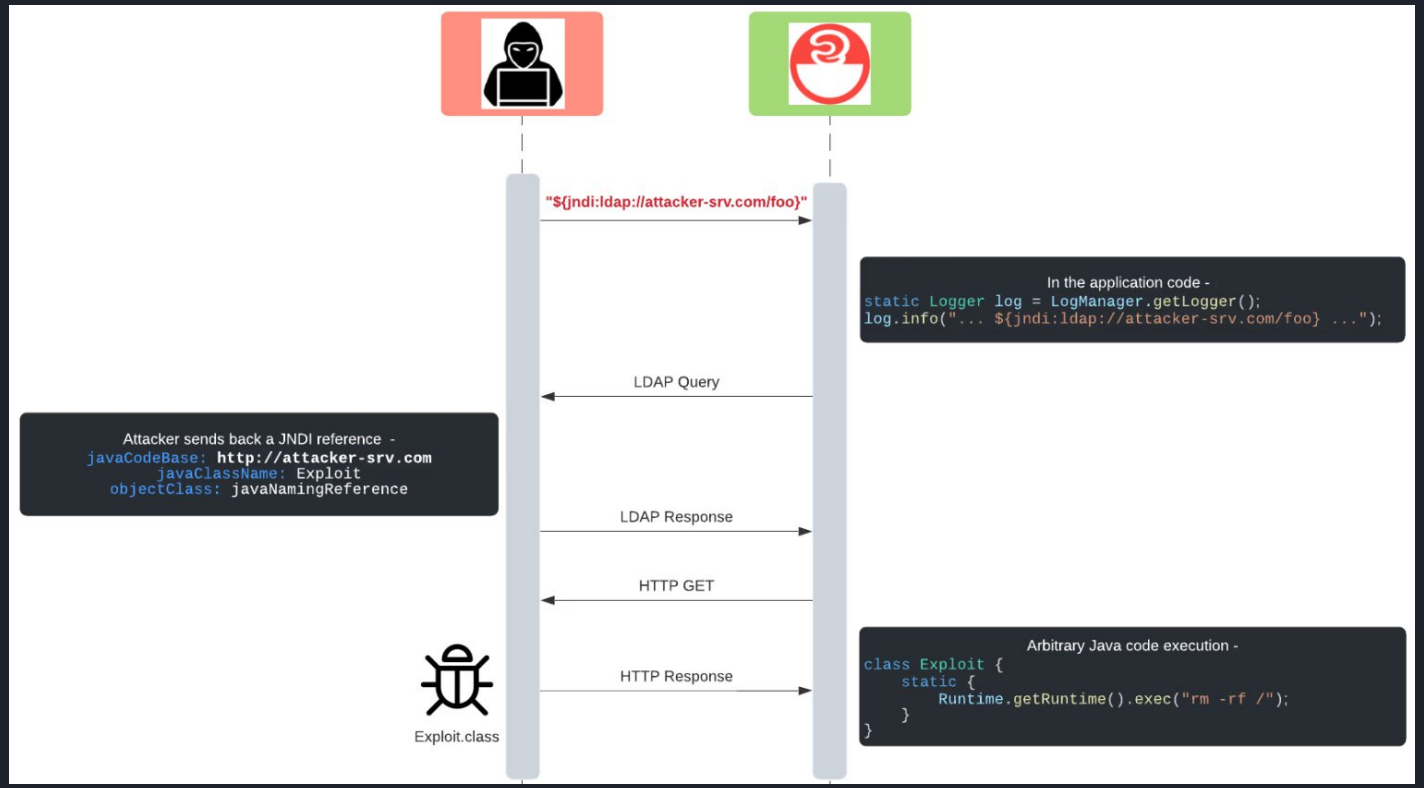
- For example:
  - User X logged in at Y
  - Alerting if a server goes down
  - User X did Z high value transaction
  - Alerting if an attack is currently underway

Security Logging and Monitoring Failures

- On the flip side, here’s a few actions which would be considered as a failure:
  - The following slides items don’t occur
  - Logs are only stored locally
  - Logs are not monitored for suspicious activity
  - Warnings or errors generate no / inadequate / unclear log messages

Security Logging and Monitoring Failures

Security Logging and Monitoring Failures



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Lab Exercise

Are the logs sufficient and do they log sensitive things?

How to abuse the issue

- Run the website locally and do some interactions
- Observe the logs created

- It logs username’s which provides observability
- It also logs passwords which is quite bad

Mitigation's

- Don’t log sensitive information
- Log enough information to recreate the ‘full picture’
- Use centralized logging services
- Ensure logs with user input present are generated such that log injection is mitigated
- Establish monitoring to alert on suspicious events
- Establish (or adopt) an incident response and recovery playbook

</>

Server Side Request Forgery

Server Side Request Forgery (SSRF)

- SSRF occurs when an application fetches resources from a remote resource without validating user supplied data

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- SSRF occurs when an application fetches resources from a remote resource without validating user supplied data

- In essence, the following code:

```
1  import httpx
2
3  url = input("Please provide a URL: ")
4  response = httpx.get(url)
5
```

Mitigation's

- Ensure adequate network segmentation is in place
- Sanitize and validate all client supplied data
- Enforce URL schema, port and destinations if users can provide them
- Disable HTTP redirection
- Don’t send raw responses to end users

</>

Path Traversal

Path Traversal

- Path traversal can be considered very similar to SSRF, however instead of web resources being returned it is file content

- Can be used for purposes such as:
  - Retrieving application source code
  - Retrieving credentials (think .env files)
  - Access to any file on the server the attacker wants

Path Traversal

- In essence, the following code is vulnerable code:

```
def main(request):
    file = request.query.get("file")
    with open(file) as f:
        return f.read()
```

- With an example payload being:
  - **https://localhost/?file=../../../../../../../../etc/passwd**

</>

Lab Exercise

Attempt to read local files

How to abuse the issue

- While using the site, observe the /images route use's file names
- Send a request that looks something like as follows:
  - /images?path=../app.py

Mitigation's

- Ensure adequate file storage segmentation is in place
- Sanitize and validate all client supplied data
- Attempt to work without user input where possible. This may mean using ID’s mapping to files server side

</>

Insecure File Upload

Insecure File upload

- Applications often take input, with files sometimes being present as an input. This presents a big attack surface, with some examples listed below:
  - Upload web shells
  - Denial of service via ZIP files
  - Denial of service via huge files
  - Upload and distribute malware
  - Upload scripting payloads for account takeover
  - Incur unexpected and excessive costs for website owner

Insecure File upload

- For example, the following SVG is a valid image and JavaScript payload:

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE svg PUBLIC "-//W3C//DTD SVG 1.1//EN" "http://www.w3.org/
Graphics/SVG/1.1/DTD/svg11.dtd">

<svg version="1.1" baseProfile="full" xmlns="http://www.w3.org/2000/
svg">
   <script type="text/javascript">
      alert("XSS all the things");
   </script>
</svg>
```

</>

Lab Exercise

Upload a file type you're not meant to

How to abuse the issue

- When reading the source code, we can see the site checks to see if “jpg” is in the file name
- So to bypass, the following file name would work:
  - Cat.jpg.png

Mitigation's

- Store files on a dedicated service such as S3
- Validate extensions correctly
- Validate the content-type and file signature is expected
- Sanitize file names, or have the application generate one itself
- Implement content validation based off of the file type
- Ensure local files only have minimal permissions set
- Enforce maximum file sizes

Let’s Recap

- Vulnerabilities can be bad, and come in many shapes and forms
- Your unlikely to make a system perfect, but any improvements increase your applications security
- You also learnt about a bunch of vulnerabilities and learnt to exploit them

Static analysis

- Automated tooling to detect common vulnerabilities
- Fast, free and easy to run
- Perfect for integrating into CI/CD pipelines

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Lab time

~ Use Bandit on the lab code base ~

pip install bandit

Example command:

bandit –r .

Real world impact

- The things taught today are highly applicable

Real world impact

- The things taught today are highly applicable
- If you look a bit, vulnerabilities will likely fall into your lap

Real world impact

- Here’s a few of my public vulnerabilities

CVE's I am attributed on

- CVE-2024-37893: MFA bypass in OAuth flow may lead to compromise of Firefly III data
- CVE-2024-32868: Improper lockout mechanisms may lead to bypass in Zitadel
- CVE-2024-30248: Raw SVG loading may lead to complete data compromise from Piccolo admin page
- CVE-2023-47128: SQL Injection via named transaction savepoints in Piccolo
- CVE-2023-46238: Stored XSS leading to a one click silent account takeover in Zitadel
- CVE-2023-41885: Piccolo time based user enumeration
- CVE-2023-33170: Security Feature Bypass In ASP.NET and Visual Studio – Race Condition

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Thanks for coming

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