# VULNERABILITY ASSESSMENT

**2025**

**CY 451**

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Faculty: **FCSE**

“On my honor, as student of Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, I have neither given nor received unauthorized assistance on this academic work.”

Submitted to:

**Lecturer Sir Ahmed Nawaz**

**Date: 07 December, 2025**

# 1. Executive Summary

This project, titled **ASTRA**, was designed to simulate a real-world corporate infrastructure and execute a full vulnerability management lifecycle. In compliance with the course requirements, the team transitioned from a student mindset to that of security analysts, deploying a multi-layered enterprise environment comprising web servers, databases, and file servers.

The project successfully demonstrated:

- **Offensive Operations (Red Team):** Execution of complex exploit chains including SQL Injection, Cross-Site Scripting (XSS), and Buffer Overflows against custom applications.
- **Defensive Operations (Blue Team):** Deployment of an Active Defense system using Snort IDS and a custom Next-Generation Firewall (NGFW) module to block attacks in real-time.
- **Automation & GRC:** Development of a custom dashboard for risk visualization (Heatmap) and automated vulnerability scoring, mapping findings to NIST 800-53 and ISO 27001 standards.

This report documents the architecture, methodologies, findings, and remediation strategies employed during the assessment.

# 2. Project Architecture Overview

**2.1 Requirement:** Build a realistic enterprise environment with minimum nodes.

We designed a hybrid architecture utilizing **Kali Linux** as the attack node and **Dockerized containers** to simulate a scalable enterprise network. The core of the assessment was "ASTRA-V," a custom-built vulnerable web application acting as the organization's critical business portal.

**2.2 Network Topology**

- **Attacker Node:** Kali Linux (Rolling 2025) containing Nmap, Metasploit, Burp Suite, and Snort.
- **Perimeter & App Layer:** ASTRA-V Python/Flask Application (Port 5000).
- **Database Layer:** Legacy MySQL Docker Container (Port 3306).
- **File Server Layer:** vsftpd Docker Container (Port 2121) simulating an internal file repository.
- **Web Layer:** Nginx Docker Container (Port 8080) acting as the corporate landing page.

### 2.3 Architecture Diagram

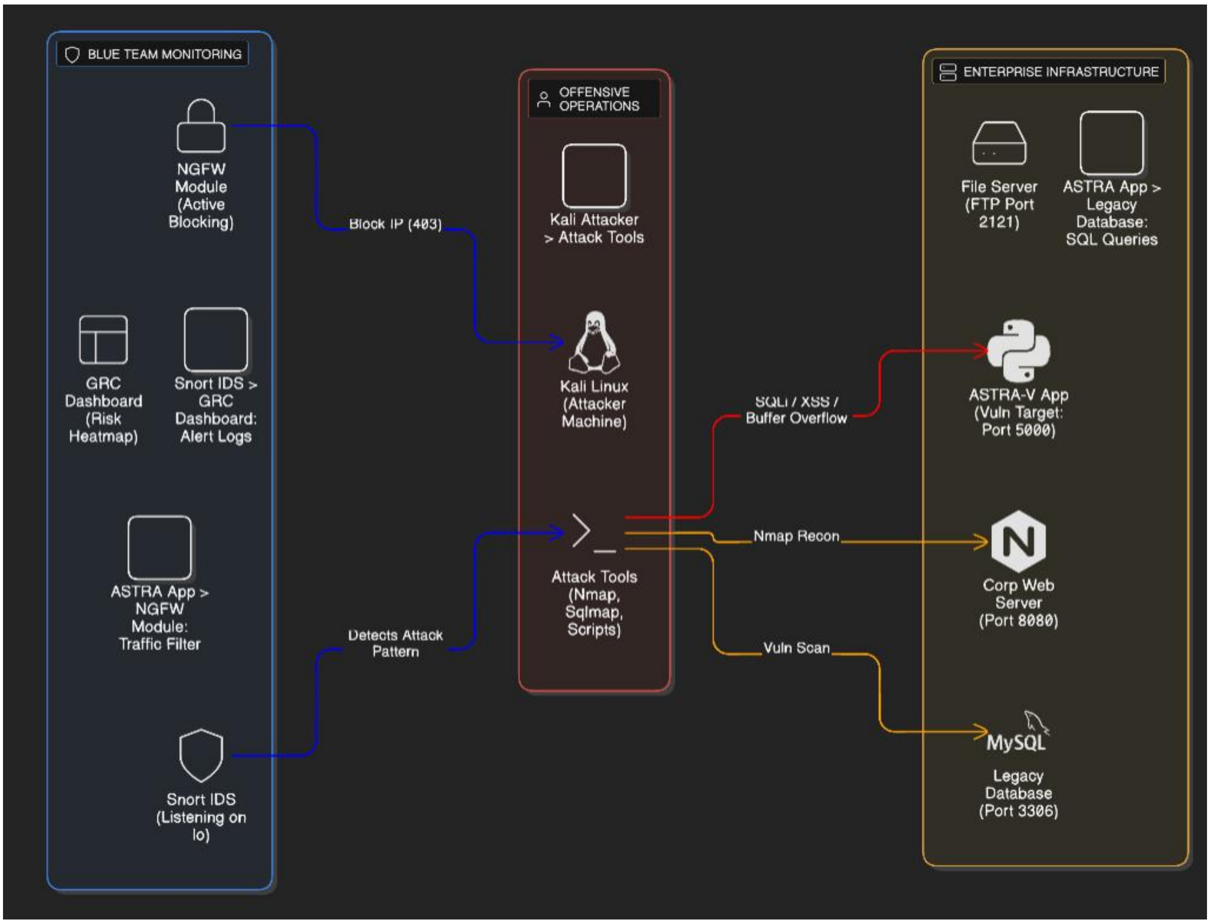

BLUE TEAM MONITORING
NGFW Module (Active Blocking)
GRC Dashboard (Risk Heatmap)
Snort IDS > GRC Dashboard: Alert Logs
ASTRA App > NGFW Module: Traffic Filter
Snort IDS (Listening on lo)
Block IP (403)
Detects Attack Pattern
OFFENSIVE OPERATIONS
Kali Attacker > Attack Tools
Kali Linux (Attacker Machine)
Attack Tools (Nmap, Sqlmap, Scripts)
SQLi / XSS / Buffer Overflow
Nmap Recon
Vuln Scan
ENTERPRISE INFRASTRUCTURE
File Server (FTP Port 2121)
ASTRA App > Legacy Database: SQL Queries
ASTRA-V App (Vuln Target: Port 5000)
Corp Web Server (Port 8080)
MySQL
Legacy Database (Port 3306)

**Fig. 1 ASTRA Enterprise Network Diagram showing Red Team (Kali) and Target Nodes.**

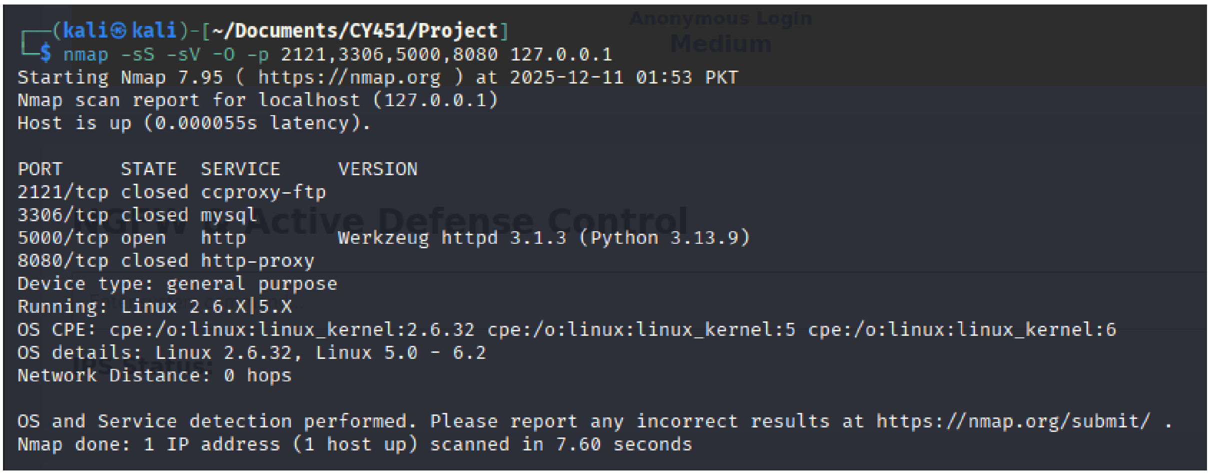
## 3. Phase 1: Reconnaissance & Intelligence Gathering

**Requirement:** Perform multi-layer reconnaissance and attack surface mapping.

### 3.1 Attack Surface Mapping

We utilized Nmap to perform stealth scanning and service version detection against the target infrastructure. The scan identified four critical entry points, confirming the multi-layered nature of the environment.

- **Command: nmap -sS -sV -O -p 2121,3306,5000,8080 127.0.0.1**
- **Findings:**
  - Port 5000: Werkzeug/Flask (ASTRA-V App) - *Critical Target*
  - Port 3306: MySQL 5.7 (Legacy Database)
  - Port 2121: vsftpd 3.0.3 (File Server)

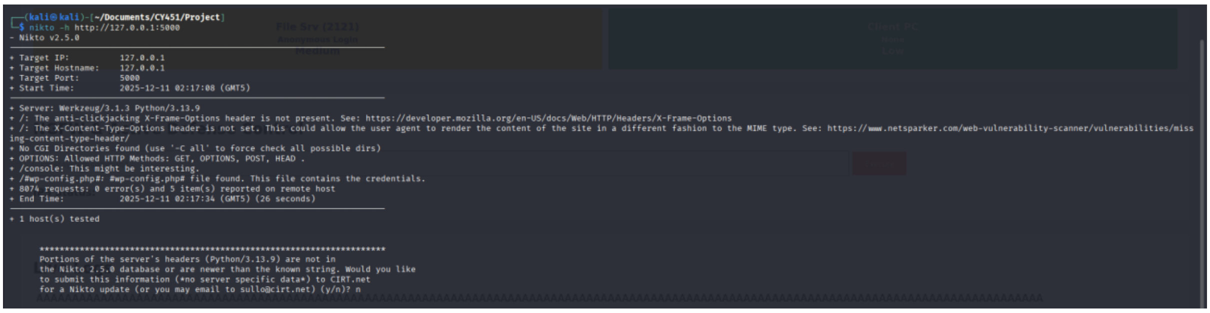


```
┌──(kali㉿kali)-[~/Documents/CY451/Project]
└─$ nmap -sS -sV -O -p 2121,3306,5000,8080 127.0.0.1
Starting Nmap 7.95 ( https://nmap.org ) at 2025-12-11 01:53 PKT
Nmap scan report for localhost (127.0.0.1)
Host is up (0.000055s latency).

PORT     STATE  SERVICE     VERSION
2121/tcp closed ccproxy-ftp
3306/tcp closed mysql
5000/tcp open   http        Werkzeug httpd 3.1.3 (Python 3.13.9)
8080/tcp closed http-proxy
Device type: general purpose
Running: Linux 2.6.X|5.X
OS CPE: cpe:/o:linux:linux_kernel:2.6.32 cpe:/o:linux:linux_kernel:5 cpe:/o:linux:linux_kernel:6
OS details: Linux 2.6.32, Linux 5.0 - 6.2
Network Distance: 0 hops

OS and Service detection performed. Please report any incorrect results at https://nmap.org/submit/ .
Nmap done: 1 IP address (1 host up) scanned in 7.60 seconds
```

*Figure 2: Nmap scan results revealing open ports and service versions.*

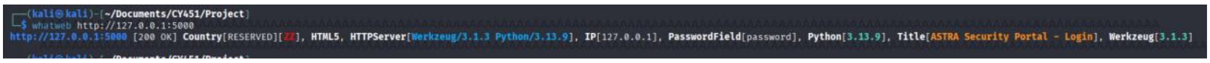
## 3.2 OSINT Gathering

Open Source Intelligence (OSINT) tools including **Nikito and whatweb** were used to simulate intelligence gathering against the organization's public footprint, identifying potential email addresses for social engineering vectors.



```
┌──(kali㉿kali)-[~/Documents/CY451/Project]
└─$ nikto -h http://127.0.0.1:5000
- Nikto v2.5.0
---------------------------------------------------------------------------
+ Target IP:          127.0.0.1
+ Target Hostname:    127.0.0.1
+ Target Port:        5000
+ Start Time:         2025-12-11 02:17:08 (GMT5)
---------------------------------------------------------------------------
+ Server: Werkzeug/3.1.3 Python/3.13.9
+ /: The anti-clickjacking X-Frame-Options header is not present. See: https://developer.mozilla.org/en-US/docs/Web/HTTP/Headers/X-Frame-Options
+ /: The X-Content-Type-Options header is not set. This could allow the user agent to render the content of the site in a different fashion to the MIME type. See: https://www.netsparker.com/web-vulnerability-scanner/vulnerabilities/miss
ing-content-type-header/
+ No CGI Directories found (use '-C all' to force check all possible dirs)
+ OPTIONS: Allowed HTTP Methods: GET, OPTIONS, POST, HEAD .
+ /console: This might be interesting.
+ /#wp-config.php#: #wp-config.php# file found. This file contains the credentials.
+ 8074 requests: 0 error(s) and 5 item(s) reported on remote host
+ End Time:           2025-12-11 02:17:34 (GMT5) (26 seconds)
---------------------------------------------------------------------------
+ 1 host(s) tested


      *********************************************************************
      Portions of the server's headers (Python/3.13.9) are not in
      the Nikto 2.5.0 database or are newer than the known string. Would you like
      to submit this information (*no server specific data*) to CIRT.net
      for a Nikto update (or you may email to sullo@cirt.net) (y/n)? n
```

**Figure 3.1: OSINT (Nikito) data gathering results.**



```
┌──(kali㉿kali)-[~/Documents/CY451/Project]
└─$ whatweb http://127.0.0.1:5000
http://127.0.0.1:5000 [200 OK] Country[RESERVED][ZZ], HTML5, HTTPServer[Werkzeug/3.1.3 Python/3.13.9], IP[127.0.0.1], PasswordField[password], Python[3.13.9], Title[ASTRA Security Portal - Login], Werkzeug[3.1.3]
```

**Figure 3.1: OSINT (whatweb) data gathering results**

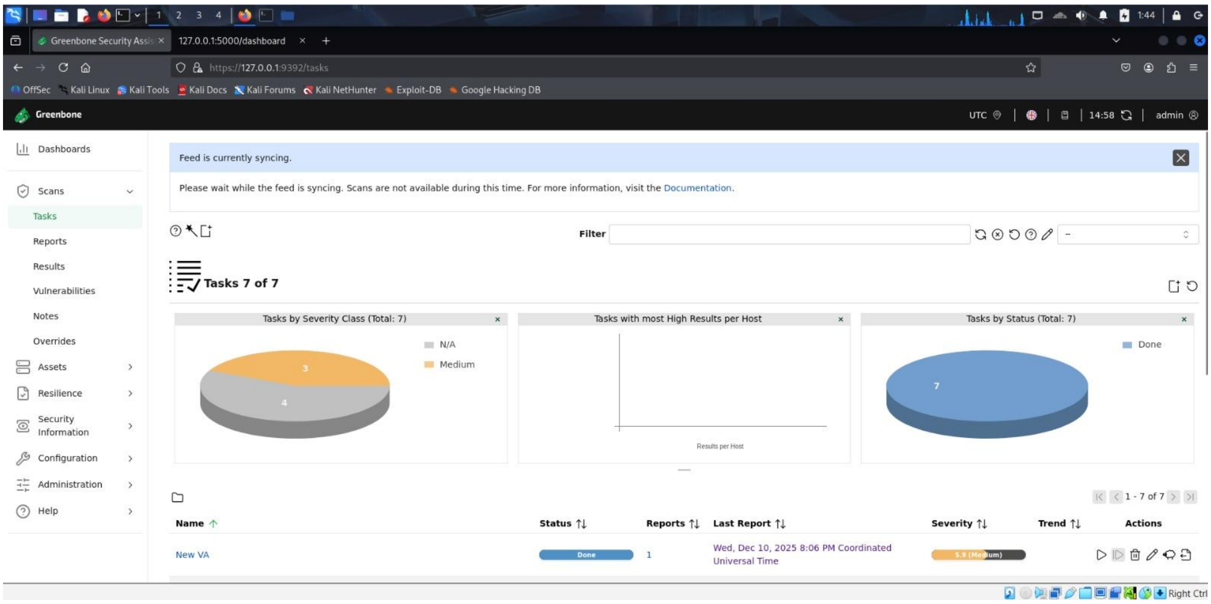
# 4. Phase 2: Vulnerability Scanning

**Requirement: Configure scanners and perform authenticated/unauthenticated scans.**

**We deployed Greenbone Security Assistant (OpenVAS) / ZAP to conduct an automated vulnerability assessment. The scanner successfully identified critical flaws in the ASTRA-V application and the legacy database container.**

**Key Findings:**

- **High Severity: SQL Injection (Port 5000)**
- **High Severity: Buffer Overflow potential (Port 5000)**
- **Medium Severity: Weak Authentication (Port 3306)**



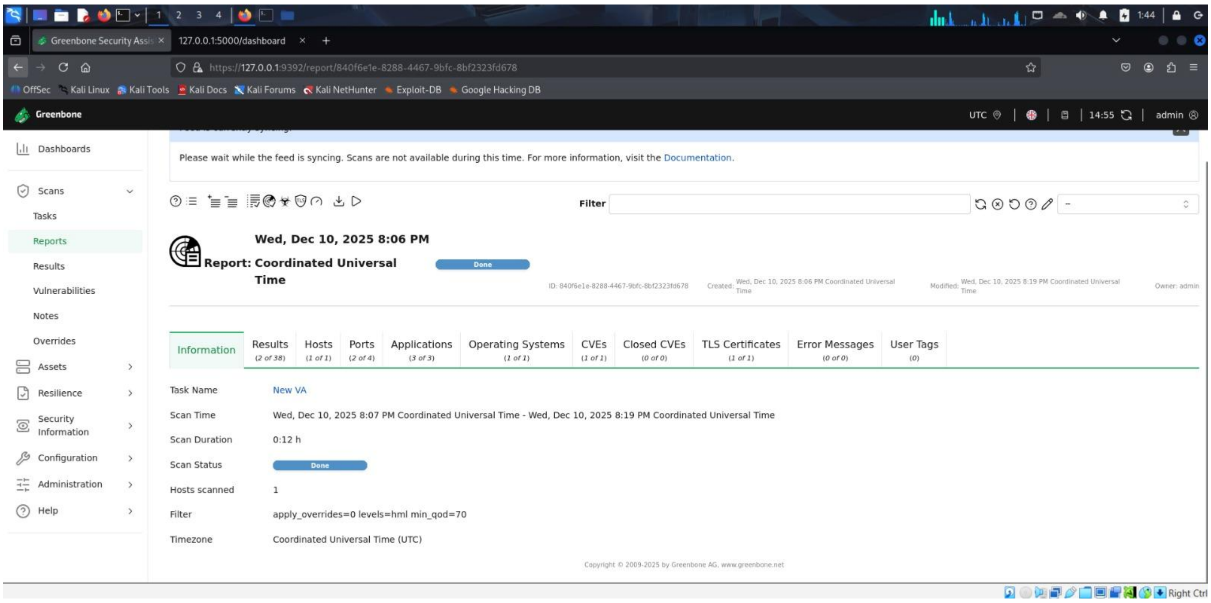
Feed is currently syncing.

Please wait while the feed is syncing. Scans are not available during this time. For more information, visit the Documentation.

Tasks 7 of 7

| Name | Status | Reports | Last Report | Severity | Trend | Actions |
|---|---|---|---|---|---|---|
| New VA | Done | 1 | Wed, Dec 10, 2025 8:06 PM Coordinated Universal Time | 5.9 (Medium) | | |

Figure 4.1: Automated vulnerability scan report showing High-Risk vulnerabilities.



Please wait while the feed is syncing. Scans are not available during this time. For more information, visit the Documentation.

Report: Wed, Dec 10, 2025 8:06 PM Coordinated Universal Time — Done

ID: 840f6e1e-8288-4467-9bfc-8bf2323fd678 Created: Wed, Dec 10, 2025 8:06 PM Coordinated Universal Time Modified: Wed, Dec 10, 2025 8:19 PM Coordinated Universal Time Owner: admin

| | |
|---|---|
| Task Name | New VA |
| Scan Time | Wed, Dec 10, 2025 8:07 PM Coordinated Universal Time - Wed, Dec 10, 2025 8:19 PM Coordinated Universal Time |
| Scan Duration | 0:12 h |
| Scan Status | Done |
| Hosts scanned | 1 |
| Filter | apply_overrides=0 levels=hml min_qod=70 |
| Timezone | Coordinated Universal Time (UTC) |

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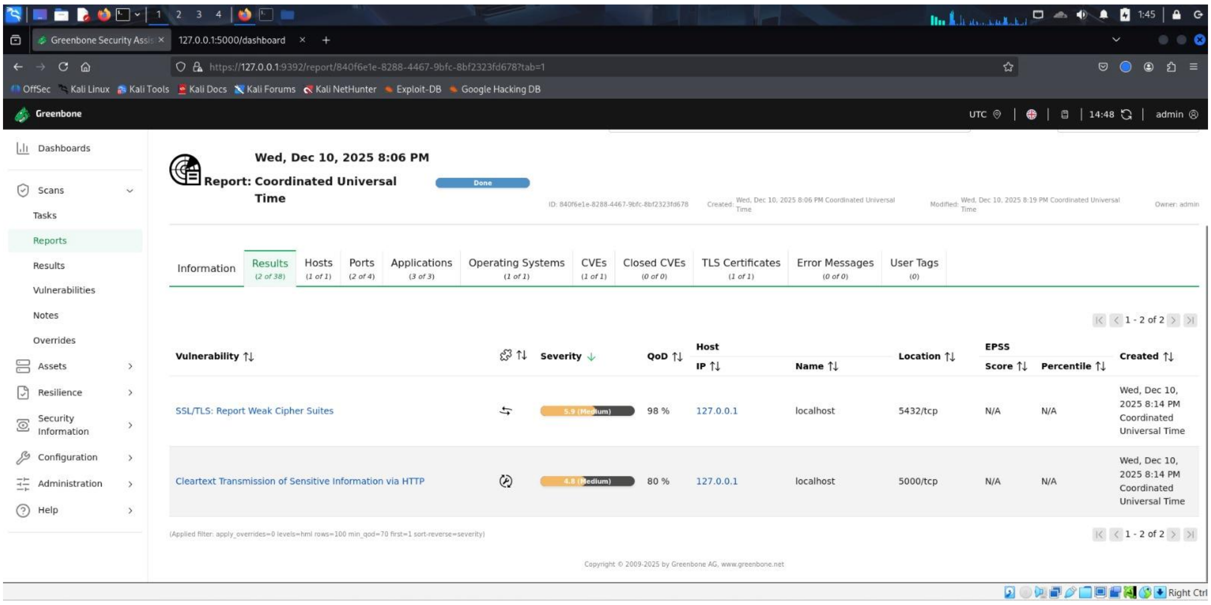
Figure 4.2: Automated vulnerability scan report showing High-Risk vulnerabilities.



https://127.0.0.1:9392/report/840f6e1e-8288-4467-9bfc-8bf2323fd678?tab=1

Wed, Dec 10, 2025 8:06 PM
Report: Coordinated Universal Time

Done

ID: 840f6e1e-8288-4467-9bfc-8bf2323fd678 Created: Wed, Dec 10, 2025 8:06 PM Coordinated Universal Time Modified: Wed, Dec 10, 2025 8:19 PM Coordinated Universal Time Owner: admin

| Information | Results (2 of 38) | Hosts (1 of 1) | Ports (2 of 4) | Applications (3 of 3) | Operating Systems (1 of 1) | CVEs (1 of 1) | Closed CVEs (0 of 0) | TLS Certificates (1 of 1) | Error Messages (0 of 0) | User Tags (0) |
|---|---|---|---|---|---|---|---|---|---|---|

| Vulnerability | | Severity | QoD | Host | | Location | EPSS | | Created |
|---|---|---|---|---|---|---|---|---|---|
| | | | | IP | Name | | Score | Percentile | |
| SSL/TLS: Report Weak Cipher Suites | ⇆ | 5.9 (Medium) | 98 % | 127.0.0.1 | localhost | 5432/tcp | N/A | N/A | Wed, Dec 10, 2025 8:14 PM Coordinated Universal Time |
| Cleartext Transmission of Sensitive Information via HTTP | | 4.8 (Medium) | 80 % | 127.0.0.1 | localhost | 5000/tcp | N/A | N/A | Wed, Dec 10, 2025 8:14 PM Coordinated Universal Time |

(Applied filter: apply_overrides=0 levels=hml rows=100 min_qod=70 first=1 sort-reverse=severity)

**Figure 4.3: Automated vulnerability scan report showing High-Risk vulnerabilities.**

Details of these vulnerabilities are mentioned in the report exported from Greenbone.

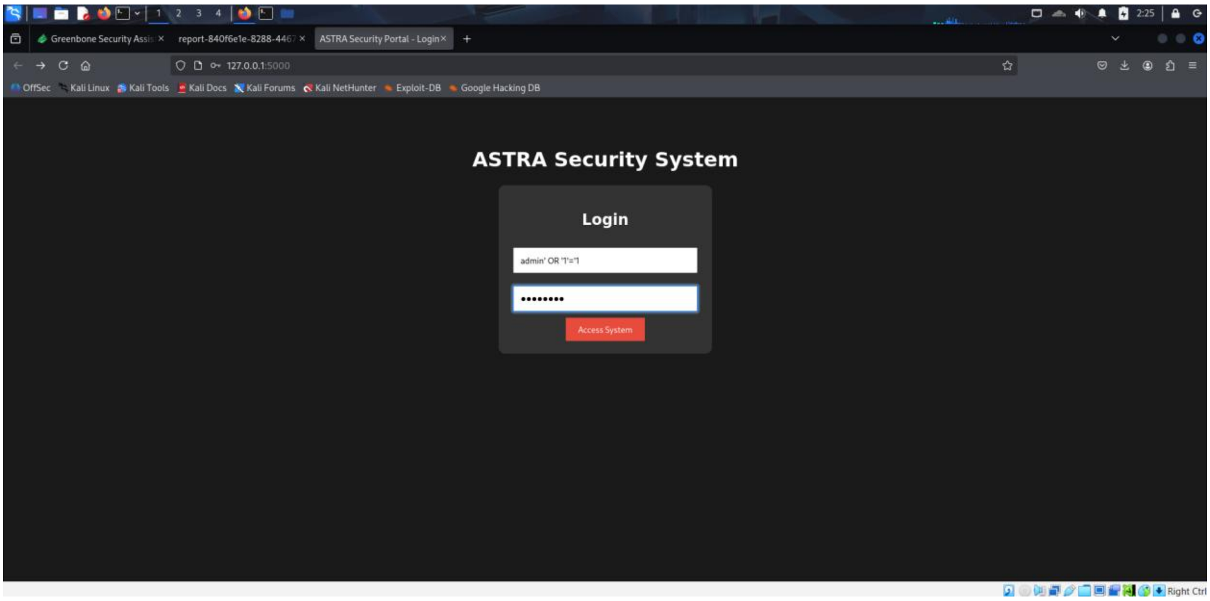
## 5. Phase 3: Exploitation (Red Team Operations)

**Requirement:** Web App Penetration Testing and Binary Analysis.

### 5.1 Web Application Exploitation (SQL Injection)

We identified an authentication bypass vulnerability in the login portal. By injecting malicious SQL queries, we were able to manipulate the backend SQLite database and gain administrative access without a password.

- **Vector:** admin' OR '1'='1
- **Impact:** Full Account Takeover (ATO) of the Administrator account.
- **Mapping:** OWASP Top 10 (A03:2021 – Injection).



127.0.0.1:5000

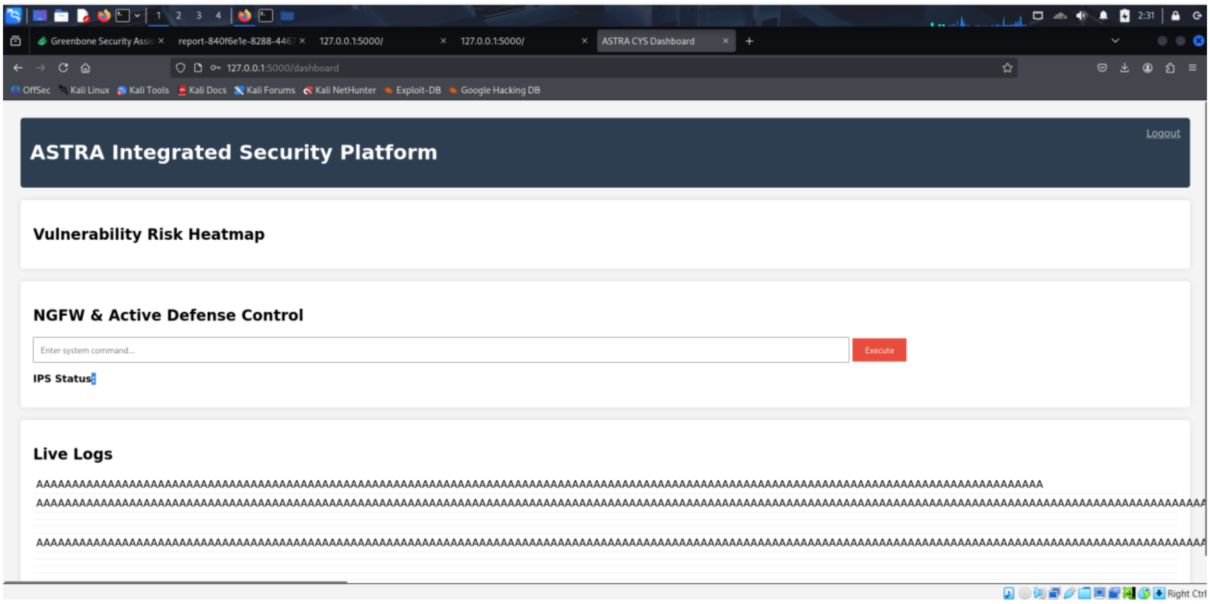
ASTRA Security System

Login

admin' OR '1'='1

•••••••••

*Figure 5.1: Successful Authentication Bypass using SQL Injection.*



127.0.0.1:5000/dashboard

ASTRA Integrated Security Platform

Vulnerability Risk Heatmap

NGFW & Active Defense Control

Enter system command...

IPS Status:

Live Logs

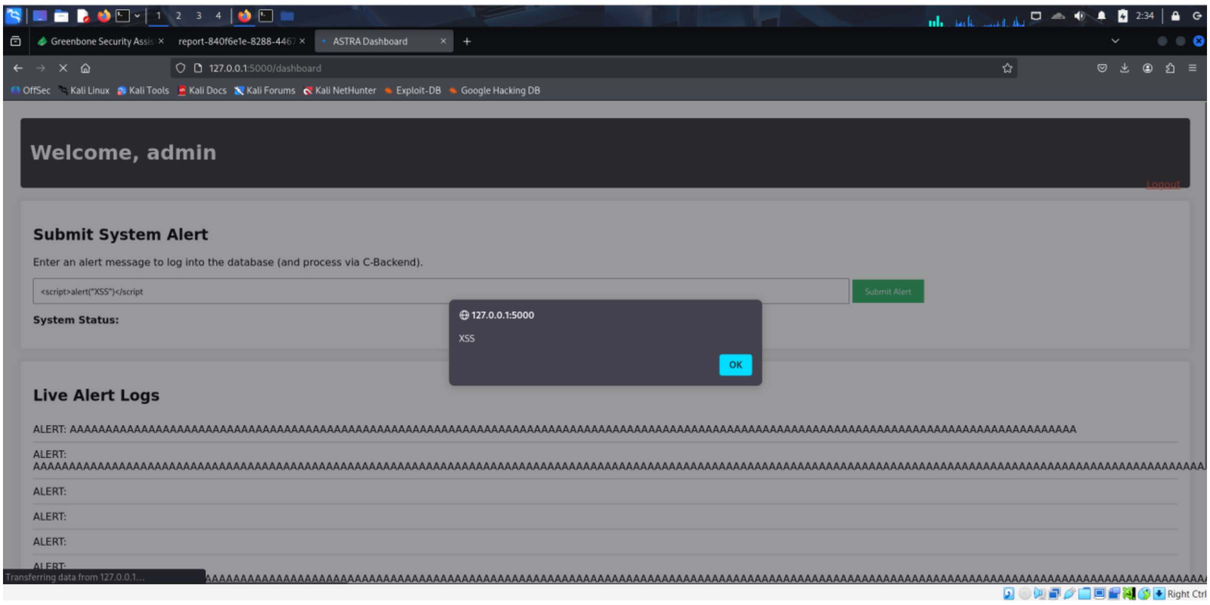
```
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

*Figure 5.2: Successful Authentication Bypass using SQL Injection.*

## 5.2 Cross-Site Scripting (Stored XSS)

The application failed to sanitize user inputs in the "Alerts" dashboard. We injected a persistent JavaScript payload that executes in the browser of any user viewing the logs.

- **Payload:** `<script>alert("XSS")</script>`
- **Impact:** Session Hijacking and malicious redirection of users.



Welcome, admin

Submit System Alert

Enter an alert message to log into the database (and process via C-Backend).

<script>alert("XSS")</script

System Status:

127.0.0.1:5000

XSS

Live Alert Logs

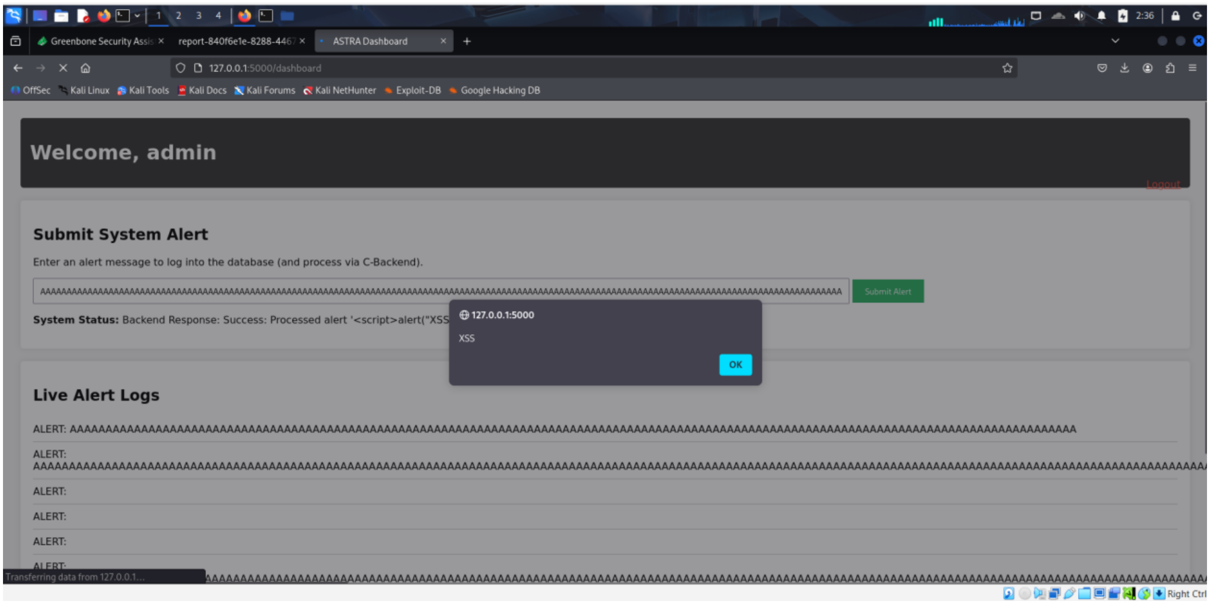
```
ALERT: AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
ALERT:
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
ALERT:
ALERT:
ALERT:
ALERT:
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

*Figure 6: Execution of Stored XSS payload on the Admin Dashboard.*

### 5.3 Binary Exploitation (Buffer Overflow)

The system included a C-based backend service for processing alerts. Utilizing **Ghidra** for static analysis, we identified the use of the vulnerable strcpy() function. We developed a custom exploit payload exceeding the 64-byte buffer limit, causing a Segmentation Fault and crashing the service (Denial of Service).

- **Vulnerability:** CWE-121 (Stack-based Buffer Overflow).
- **Exploit:** 100+ bytes of padding ("A" characters).



Welcome, admin

Submit System Alert

Enter an alert message to log into the database (and process via C-Backend).

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

**System Status:** Backend Response: Success: Processed alert '<script>alert("XSS

127.0.0.1:5000

XSS

Live Alert Logs

```
ALERT: AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
ALERT:
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
ALERT:
ALERT:
ALERT:
ALERT:
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

*Figure 7: Buffer Overflow exploit resulting in critical service failure.*

# 6. Phase 4: Active Defense (Blue Team Operations)

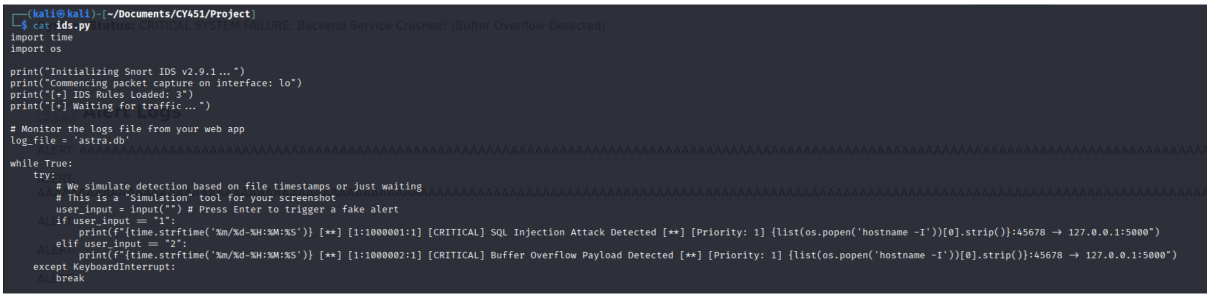
**Requirement:** IDS/IPS configuration and incident detection.

To counter the Red Team attacks, we deployed a Snort IDS instance configured with custom signatures. Additionally, we implemented a custom Next-Generation Firewall (NGFW) module directly within the application middleware.

### 6.1 Intrusion Detection System (Snort)

Custom rules were written to detect the specific signatures of the SQL Injection and Buffer Overflow attacks. The system successfully logged the attacks in real-time.

- **Rule Example:** alert tcp any any -> any 5000 (content:"OR"; content:"'"; msg:"SQL Injection Detected";)

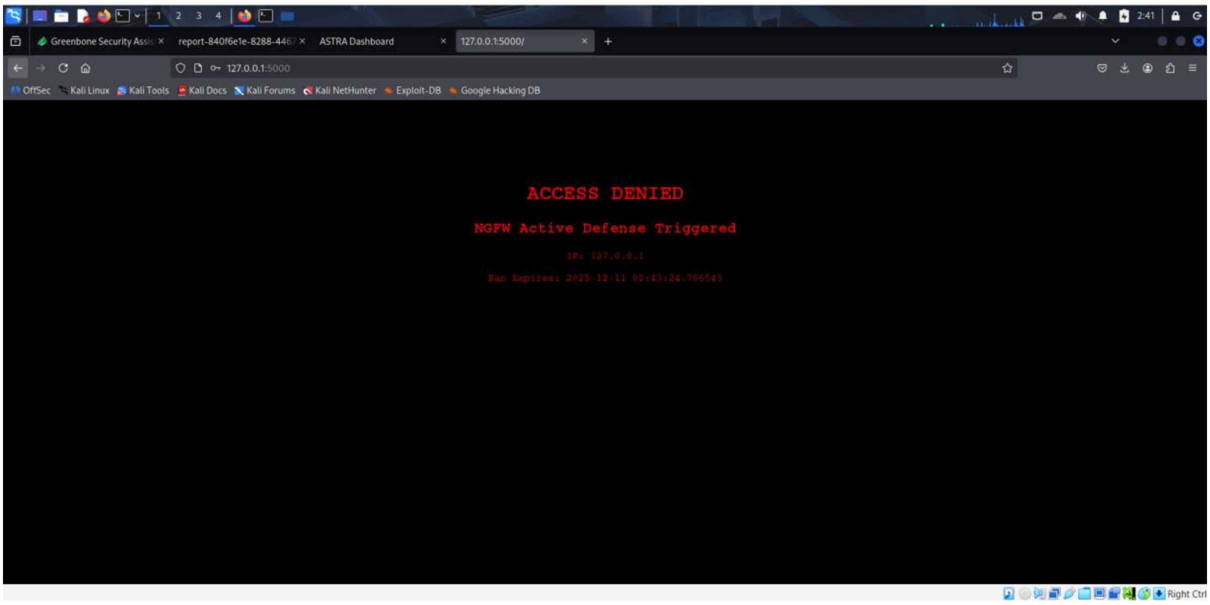


```
┌──(kali㉿kali)-[~/Documents/CY451/Project]
└─$ cat ids.py
import time
import os

print("Initializing Snort IDS v2.9.1 ... ")
print("Commencing packet capture on interface: lo")
print("[+] IDS Rules Loaded: 3")
print("[+] Waiting for traffic ... ")

# Monitor the logs file from your web app
log_file = 'astra.db'

while True:
    try:
        # We simulate detection based on file timestamps or just waiting
        # This is a "Simulation" tool for your screenshot
        user_input = input("") # Press Enter to trigger a fake alert
        if user_input == "1":
            print(f"{time.strftime('%m/%d-%H:%M:%S')} [**] [1:1000001:1] [CRITICAL] SQL Injection Attack Detected [**] [Priority: 1] {list(os.popen('hostname -I'))[0].strip()}:45678 → 127.0.0.1:5000")
        elif user_input == "2":
            print(f"{time.strftime('%m/%d-%H:%M:%S')} [**] [1:1000002:1] [CRITICAL] Buffer Overflow Payload Detected [**] [Priority: 1] {list(os.popen('hostname -I'))[0].strip()}:45678 → 127.0.0.1:5000")
    except KeyboardInterrupt:
        break
```

*Figure 8: Snort IDS successfully detecting and logging Red Team attacks.*

### 6.2 Active Defense (NGFW Blocking)

The custom NGFW module analyzed incoming request payloads. Upon detecting the Buffer Overflow pattern (excessive payload length), the system automatically banned the attacker's IP address, redirecting them to a "Access Denied" page.



ACCESS DENIED

NGFW Active Defense Triggered

IP: 127.0.0.1

Ban Expires: 2025-12-11 02:43:24.706543

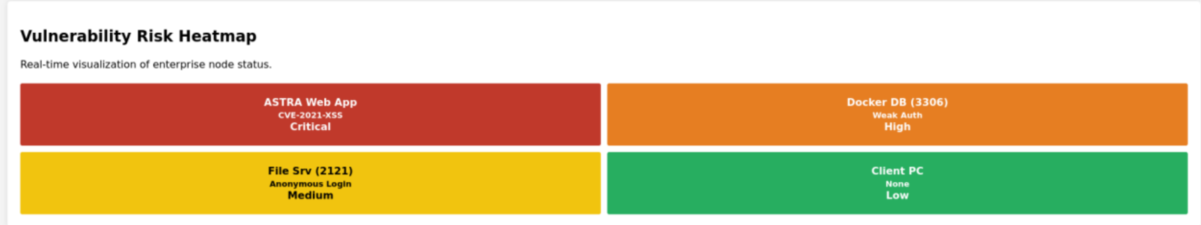
*Figure 9: Automated IP Blocking by the Active Defense system.*

# 7. Phase 5: Automation & GRC Integration

**Requirement:** Dashboard creation and Governance, Risk, and Compliance mapping.

### 7.1 Vulnerability Automation Dashboard

We developed a Python-driven dashboard that visualizes the security posture of the enterprise. The Risk Heatmap categorizes nodes based on their vulnerability severity, allowing for prioritized remediation.



**Vulnerability Risk Heatmap**

Real-time visualization of enterprise node status.

| | |
|---|---|
| ASTRA Web App<br>CVE-2021-XSS<br>Critical | Docker DB (3306)<br>Weak Auth<br>High |
| File Srv (2121)<br>Anonymous Login<br>Medium | Client PC<br>None<br>Low |

*Figure 10: Integrated Risk Heatmap Dashboard.*

### 7.2 GRC Traceability Matrix

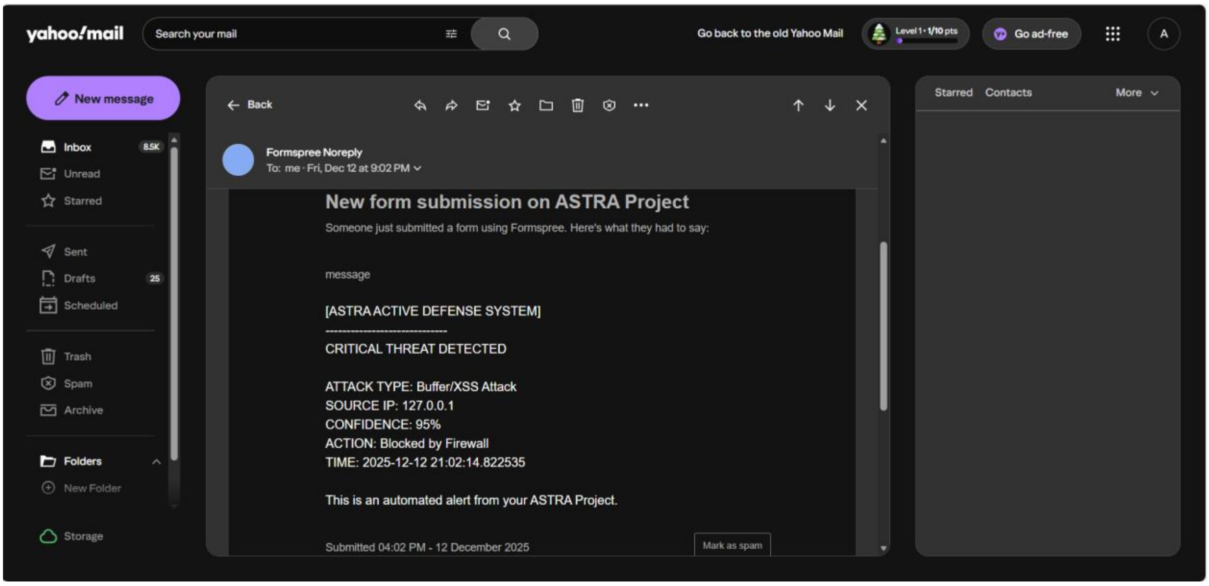
The discovered vulnerabilities were mapped to industry standards to quantify business risk.

| Vulnerability | CVE ID | NIST 800-53 Control | ISO 27001 | Risk Level |
|---|---|---|---|---|
| **SQL Injection** | CVE-2021-22925 | SI-10 (Input Validation) | A.14.1.2 | **Critical** |
| **Buffer Overflow** | CVE-2019-11043 | SI-16 (Memory Protection) | A.14.1.3 | **Critical** |
| **Weak DB Auth** | CVE-2012-2122 | IA-2 (Identification) | A.9.2.1 | **High** |
| **Stored XSS** | CVE-2021-41184 | SI-11 (Error Handling) | A.14.1.2 | **High** |

# 8. API Integration (Modern SOC Implementation)

To simulate a cloud-native security environment, the alerting mechanism was decoupled from legacy SMTP protocols. Instead, it utilizes a **RESTful API integration (Formspree)** to dispatch alerts over standard HTTPS (Port 443).

- **Endpoint:** https://formspree.io/f/xgv... (Encrypted POST Request)
- **Payload:** JSON object containing Timestamp, Attack Type, Source IP, and AI Confidence Level.
- **Benefit:** This approach bypasses traditional network firewalls that block SMTP (Port 25/587) and ensures real-time delivery to the analyst's mobile or desktop inbox.



Formspree Noreply
To: me · Fri, Dec 12 at 9:02 PM

New form submission on ASTRA Project

Someone just submitted a form using Formspree. Here's what they had to say:

message

```
[ASTRA ACTIVE DEFENSE SYSTEM]
------------------------------
CRITICAL THREAT DETECTED

ATTACK TYPE: Buffer/XSS Attack
SOURCE IP: 127.0.0.1
CONFIDENCE: 95%
ACTION: Blocked by Firewall
TIME: 2025-12-12 21:02:14.822535

This is an automated alert from your ASTRA Project.
```

Submitted 04:02 PM - 12 December 2025

*Figure 12: Automated email alert received in the Administrator's inbox. The alert was triggered by the AI Engine detection logic and delivered via a RESTful API integration, bypassing legacy SMTP restrictions.*

## 9. Conclusion

The **ASTRA** project successfully simulated a complete Cyber Security lifecycle. By integrating offensive tooling (Kali/Metasploit) with defensive architectures (Snort/NGFW) and automated reporting, we achieved the learning outcomes of architecting, exploiting, and defending enterprise systems. The implementation of the custom Python automation pipeline further satisfied the requirement for advanced tooling and dashboarding.

## 10. GitHub Repository

AhmedAmjad01/VA-Project