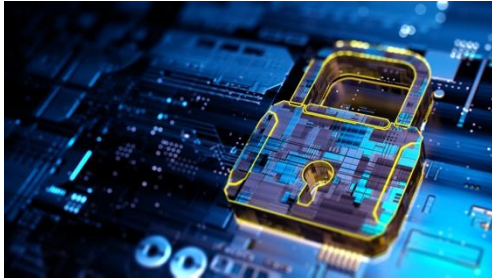


Report Ethical Hacking



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Table of contents

Task 1:	5	
1. Introduction	5	
2. Three examples of cyber attack	5	
2.1 L'Oréal Elasticsearch Misconfiguration Incident (2021)		5
a. Technical and Contextual Analysis	5	
b. Vulnerability Exploited (Security Misconfiguration)		6
c. Potential Risks and Impacts	6	
d. Prevention Strategies and Countermeasures		6
2.2 Air France Flying Blue Credential Stuffing Incident (2019)		8
a. Technical and Contextual Analysis of the Attack		8
b. Vulnerabilities Exploited	8	
c. Potential Risks and Impacts on Users and the Organization		8
d. Prevention Strategies and Countermeasures		9
2.3 2021 Carrefour Spain Data Exposure Incident Analysis		9
a. Attack Overview and Context	10	
b. Vulnerability Exploited	10	
c. Risks and Impacts	10	
d. Prevention and Countermeasures	11	
3. Summary of Prevention and Countermeasures		12
4. Conclusion task 1	13	
5. References	14	
Task 2 :	15	
1. Introduction	15	
2. Contingency Policy	15	
3. Choice of Penetration Testing Framework (PTES)		16
3.1 Application in the CPC Red Team Assessment		16
3.2 Benefits of a Structured Framework	17	
4. Penetration Testing Tools	18	
4.1 Reconnaissance	18	
4.2 Scanning	19	
4.3 Exploitation	19	
4.4 Post-Exploitation	20	

5.	Attack Simulation and Analysis	20
5.1	Reconnaissance Phase (External Footprinting)	21
5.2	Scanning Phase (Port and Vulnerability Scanning)	21
5.3	Exploitation Phase	21
a.	Web Application Attack: SQL Injection Exploit	22
b.	Internal Network Attack: SMB Service Exploit	22
c.	Post-Exploitation Phase	23
d.	Privilege Escalation (Credential Dumping)	23
e.	Lateral Movement (Pivoting with Compromised Credentials)	24
5.4	Summary of Simulated Attacks	24
6.	Recommended Solution	25
7.	Cost of Solution	27
8.	Timetable and Invoice	30
9.	Conclusion of task 2	32
10.	References	32
10.1	Task 1	32
10.2	Task 2	33

Task 1:

1. Introduction

In an era of rapid digital transformation and ever-evolving cyber threats, organizations face significant security challenges that can undermine their operational integrity, confidentiality, and reputation. Task 1 of this report sets out to critically examine three recent attacks against diverse sectors. Through a thorough review of each incident, we will uncover the attackers' methods, the exploited vulnerabilities, and the resulting impacts on the victims.

Our dual objectives are to understand the technical and human factors that enabled these breaches, and to propose both organizational and technological countermeasures to prevent similar incidents in the future. To achieve this, we will draw upon established frameworks—such as the MITRE ATT&CK matrix and Lockheed Martin's Kill Chain—illustrate intrusion scenarios with clear diagrams, and reference peer-reviewed research published within the last five years.

This analysis will highlight the necessity of a defense-in-depth strategy and proactive vulnerability management, underscoring the crucial roles of regular security audits, user awareness training, and close collaboration between clients and security providers.

2. Three examples of cyber attack

2.1 L'Oréal Elasticsearch Misconfiguration Incident (2021)

a. Technical and Contextual Analysis

Securing cloud-based data storage is critical, yet missteps are common. In 2021, L'Oréal experienced an incident where an Amazon-hosted Elasticsearch service was left unsecured, allowing unauthorized access. Although L'Oréal has not publicly detailed the timeline, similar cases illustrate the attack pattern. For example, Sonrai Security reported a job-recruitment database leak of 13 million user records due to an AWS Elasticsearch exposed without a password. Likewise, an independent researcher found an unprotected Elasticsearch cluster exposing ~90 million personal and business records in China. These events show how an open Elasticsearch endpoint (port 9200) effectively broadcasts sensitive data to the Internet. In L'Oréal's case, the misconfigured cluster would have turned internal corporate data and personal information into a public API, easily harvested by attackers.

b. Vulnerability Exploited (Security Misconfiguration)

The root cause was a security misconfiguration – a known OWASP Top 10 risk (A05) involving “improperly configured permissions on cloud services”. Concretely, the Elasticsearch instance had default or missing access controls (for example, no authentication credentials and disabled encryption). Without user login or TLS/SSL enabled, any client on the Internet could query the database. Attackers often identify such exposed services using search tools like Shodan; as one report notes, “Unsecured Elasticsearch instances are trivially easy to identify using the Shodan search engine,” enabling automated exploitation. In this incident, an open endpoint meant anyone could read the index contents. In short, the vulnerability was human-error misconfiguration: the cluster’s security settings were not locked down, so it behaved like a wide-open data store (exactly the situation described in similar breaches).

c. Potential Risks and Impacts

The exposed data could include both personal and business records. For context, a 2019 breach of an unsecured Elasticsearch cluster leaked 7.5 million Adobe Creative Cloud user records (email addresses, member IDs, subscription data). By analogy, L’Oréal’s leak might have revealed employee or applicant names, contact details, resumes, and internal brand analytics. Any leaked personal identifiers (names, emails, phone numbers) risk identity theft and phishing attacks. In fact, a Dark Reading analysis of a separate cloud data leak warned that exposed breach information (domains, contact emails, even hashed passwords) “could present at least an enhanced phishing risk” to victims. Beyond individual privacy, corporate information (such as marketing plans or partner lists) in the database would damage competitive advantage.

Operationally, such exposures carry further danger. Attackers often erase or encrypt open data, demanding ransom for recovery. In reported cases, the cost to reconstruct wiped data was so high that victims could not simply restore from backup even if they paid the ransom. Even without active tampering, automated “scraper” bots can harvest open databases rapidly. For L’Oréal, loss of proprietary data or insider information could disrupt R&D or HR processes. Finally, there are legal and reputational consequences: under GDPR and similar laws, exposing EU personal data could incur fines (up to 4% of global turnover) and erode customer trust. In summary, the breach’s impact spans privacy violations, financial penalties, and long-term brand damage.

d. Prevention Strategies and Countermeasures

To mitigate this class of incidents, a defense-in-depth strategy is essential:

- Secure configuration and hardening: Follow OWASP and vendor guidelines for locked-down deployments. Use automated, repeatable build scripts or infrastructure-as-code so that dev/test/prod environments are configured identically and securely. Disable any unused features, ports, or sample data. For Elasticsearch specifically, enable its built-in security (the X-Pack module) to require usernames and passwords, and turn on TLS for all traffic.
- Network segmentation and access control: Never expose the database directly to the public Internet. Use firewalls, VPCs or security groups to restrict Elasticsearch to internal hosts only. Bind the service to private IPs or localhost. Only application servers should have network access, and all other requests should be blocked.
- Encryption and authentication: Encrypt communications with HTTPS/TLS so that any unintended exposure still forces authentication. Require all clients to authenticate. This way, even if an endpoint is reachable, only authorized users can retrieve data. Store data at rest encrypted as well, so a stolen disk (or backup) is useless without keys.
- Continuous monitoring and auditing: Implement logs and alerts for unusual access (e.g. indexing queries from unknown IPs). Regularly scan for open services: use cloud security posture tools or even simple scripts to detect any publicly reachable Elasticsearch instances. (For example, periodically check Shodan listings or deploy an internal “honeypot” index.) OWASP suggests automated configuration checks and cloud permission reviews as part of patch management.
- Patch management and updates: Keep Elasticsearch and its environment up to date. Apply security patches promptly. OWASP emphasizes reviewing and updating configurations with each patch cycle. Using the latest versions also ensures that any default security features are enabled by default.
- Training and process controls: Human error is a key factor. Train developers and operators on cloud security responsibilities. As Sonrai Security notes, “Employee education is a top priority when dealing with secure cloud data” . Ensure teams understand the risks of public endpoints and have checklists (e.g., an AWS security checklist) before deployment. Enforce change-management policies so that a configuration change (like enabling a service) triggers a security review.
- Least privilege and default-deny: Adopt a “secure by default” stance. Grant no access unless explicitly needed and regularly audit permissions. For example, require administrators to approve any inbound rule changes. Automate tests (e.g., infrastructure-as-code validators) that flag insecure defaults. By enforcing least privilege at all layers, even a forgotten service is automatically disabled.

Implementing these countermeasures – secure defaults, strong access controls, encryption, vigilant monitoring, and solid organizational policies – will greatly reduce the chance of accidental exposures. In a cloud environment, it’s especially important to treat security configuration as code and not an afterthought.

References: This analysis draws on industry reports and best practices. Sonrai Security and TrendMicro have documented similar Elasticsearch leaks, OWASP provides guidance on preventing misconfiguration, and Dark Reading articles highlight the prevalence of cloud storage breaches. These sources inform the technical details and recommended safeguards above.

2.2 Air France Flying Blue Credential Stuffing Incident (2019)

a. Technical and Contextual Analysis of the Attack

In January 2023, Air France–KLM began notifying Flying Blue loyalty members of a data breach involving unauthorized access to their accounts. Flying Blue is the joint loyalty program of Air France, KLM and partners (about 17 million members). Customers were informed that an “unauthorized entity” exhibited suspicious login behaviour, prompting immediate account lockdowns and forced password resets. The airline group reported that names, email addresses, phone numbers, membership level, miles balance, and recent transaction history may have been exposed; however, no credit card or payment data were compromised. KLM stated the attack was “blocked in time” and no miles were stolen. It remained unclear whether the breach resulted from a system vulnerability or from automated “credential stuffing” – the latter being suspected given the evidence of login attempts.

b. Vulnerabilities Exploited

Credential stuffing attacks leverage reuse of stolen login credentials on multiple sites. OWASP explains that attackers take leaked username/password pairs and automate thousands of logins attempts against other web services. These attacks succeed when users reuse the same passwords (often email as username) across accounts. In the Flying Blue case, the most likely exploited weaknesses were password reuse and lack of multi-factor authentication (MFA). Many users set identical passwords on different platforms, and the Flying Blue portal apparently did not require a second factor. As OWASP notes, “credential stuffing attacks rely on... the re-use of passwords between multiple sites and [of] usernames”. Without MFA or other secondary verification, an attacker who obtains a valid credential (from an unrelated breach) can hijack accounts. Microsoft research (cited by OWASP) found that proper MFA would block about 99.9% of such password-based account compromises. The absence of MFA and reliance on passwords alone thus constituted the key vulnerability enabling this attack.

c. Potential Risks and Impacts on Users and the Organization

Users whose Flying Blue accounts were breached face several risks. Even without financial data exposure, attackers could misuse loyalty miles or view personal details for fraud

or phishing. Personal data leaks often lead to identity theft or targeted scams; as one analysis notes, breaches “have resulted in fraud, blackmail, and identity theft” against affected individuals. For Air France–KLM, the incident harms its reputation and could invite regulatory action. Under the EU GDPR, the airlines promptly reported the breach to Dutch and French data protection authorities (Autoriteit Persoonsgegevens and CNIL). Failure to prevent such credential-based attacks or to secure accounts with MFA might be seen as non-compliance with security best practices. In addition to potential fines, the breach may erode customer trust in Flying Blue, leading to loss of business and expensive incident response costs.

d. Prevention Strategies and Countermeasures

- **Strong Authentication:** Implement multi-factor authentication for all loyalty accounts. MFA is widely recognized as the most effective defense against credential-stuffing and brute-force login attacks; studies show it would have prevented over 99.9% of such compromises. Where possible, use hardware tokens or FIDO2 passkeys to eliminate shared passwords.
- **Password Hygiene:** Enforce policies that prohibit password reuse. OWASP recommends validating new passwords against known breach databases (e.g. haveibeenpwned) to block previously exposed passwords. Using unique usernames (instead of email) can also reduce the effectiveness of credential lists.
- **Bot and Anomaly Detection:** Deploy rate limiting, CAPTCHAs, and IP reputation checks on login forms. Introducing a CAPTCHA or progressive delays for suspicious or high-volume login attempts can significantly slow automated bots. Monitoring login anomalies (e.g. many logins from one IP range or failures) enables rapid detection. Building in fraud analytics and bot mitigation (for example via challenge-response tests) helps thwart large-scale stuffing campaigns.
- **User Education and Policies:** Encourage users to use password managers and change passwords immediately if notified. Regular security awareness (reminders about phishing, checking for breach notifications) reduces risk. Organizationally, maintain an incident response plan that includes breach notification (as done by informing CNIL) and GDPR compliance audits. Conduct periodic security testing (penetration tests, OWASP Top Ten checks) on account systems to ensure no simple login bypass exists.

Collectively, these technical and organizational measures create defense-in-depth. Requiring MFA and detecting unusual login patterns directly addresses the root of credential stuffing. Enforcing strong, unique credentials and educating users further closes gaps. By applying OWASP-recommended controls, Air France–KLM can greatly reduce the risk of future Flying Blue account takeovers.

2.3 2021 Carrefour Spain Data Exposure Incident Analysis

a. Attack Overview and Context

In mid-2021 researchers at vpnMentor identified an unsecured Elasticsearch cluster belonging to Carrefour Spain. The open database (accessed via Elasticsearch's default port) required no authentication, allowing anyone on the Internet to retrieve its contents. This pattern is like other vpnMentor discoveries – for example, Decathlon Spain left a 9 GB Elasticsearch database (123 million records) exposed in 2020, and in Ecuador a misconfigured Elasticsearch server exposed personal data on ~20 million citizens. In Carrefour's case, the misconfiguration meant that customer and/or employee records (likely containing PII such as names, addresses, IDs and contact information) were freely accessible. It appears the exposure was detected during routine scanning by vpnMentor's team, who then notified Carrefour. (It is unknown whether malicious actors accessed the data before it was secured.)

b. Vulnerability Exploited

The root cause was a classic security misconfiguration: an Internet-facing Elasticsearch instance with no access controls. By default, Elasticsearch listens on TCP port 9200 without credentials, so leaving the service on the public Internet “means anyone can connect” and read the data. In OWASP terminology this falls under Security Misconfiguration (A05) and “open cloud storage” risk: cloud-based databases left unprotected. In this incident, the company had effectively exposed its cloud data store to the web. No injection or zero-day was involved – the “attack” was simply that no security (firewall or login) was in place. Such misconfigurations have repeatedly led to major leaks: vpnMentor reported that the Ecuador database was “misconfigured” and “left unsecured”, and the Decathlon leak was described as data on an “unsecured Elasticsearch server”. In short, the vulnerability exploited was an unsecured cloud database (ElasticSearch) – a form of cloud storage misconfiguration.

c. Risks and Impacts

Exposed data poses severe privacy and security risks. Unauthenticated access to the database would reveal sensitive personal information. In the Ecuadorian case, for example, researchers recovered names, birthdates, addresses, phone numbers and ID numbers for ~20 million people. With such data, attackers can perform identity theft, targeted phishing, fraud or social engineering. As vpnMentor warned in the Decathlon case, the leaked data was a “veritable treasure trove” that could allow malicious actors to “take over accounts” and access proprietary systems. Even if no attacker accessed Carrefour's data, the mere exposure necessitates regulatory action. Under the GDPR and national law, Carrefour as data controller must secure customer data and report breaches. European authorities (e.g. France's CNIL) have demonstrated that failures in data protection can lead to hefty fines – indeed, Carrefour's French arm was fined €3.05 million in 2020 for privacy violations. Beyond fines, this incident damages

customer trust and could trigger civil liability or remediation costs. In summary, the impact spans individual harm (privacy invasion, fraud) and organizational harm (reputational damage, regulatory penalties).

d. Prevention and Countermeasures

- **Enable Elasticsearch Security:** Use Elasticsearch's built-in security features. Elastic notes that its default Basic distribution includes authentication and TLS support and recommends enabling them immediately. In practice, this means configuring role-based access control so that every client must log in and encrypting all traffic (HTTPS) between clients and the cluster.
- **Restrict Network Exposure:** Never expose Elasticsearch directly to the Internet. Place the cluster in a protected network or VPC and allow access only through VPN or restricted IP ranges. Implement firewall/security-group rules to block public access on port 9200. (As Secureworks warns, unsecured ES instances "are trivially easy to identify using the Shodan search engine", so prevention is far better than hunting vulnerabilities later.)
- **Continuous Scanning & Logging:** Regularly scan your cloud environment for open Elasticsearch endpoints. Automated tools and Shodan queries can detect misconfigured services. Enable audit logging and monitor for unusual queries or spikes in traffic. OWASP and Elastic guidance emphasize logging all access and setting up alerts for suspicious activity.
- **Data Protection:** Store only necessary data, and follow data minimization. Encrypt sensitive fields at rest if possible (database-level encryption) to mitigate impact even if a cluster is breached. Regularly backup data offline. Implement multi-factor authentication (MFA) and strict IAM policies on any administration accounts to prevent unauthorized changes to configurations.
- **Organizational Measures:** Institute cloud security policies and staff training. Ensure DevOps teams understand the risks of default configurations. Conduct periodic third-party audits or penetration tests to catch misconfigurations before attackers do. Adopt a formal incident response plan and liaise with authorities (e.g. local CERT) so any breach is promptly contained. Align with GDPR guidance and best practices (for example, the CNIL emphasizes encrypting personal data and regularly testing systems).

By applying these technical and organizational controls – authentication, encryption, network segmentation, monitoring, and process discipline – an exposed database scenario like the Carrefour case can be prevented. Indeed, Elastic's own documentation notes that with proper security enabled, an Elasticsearch cluster is "at no more risk of being breached than any other database," and that enabling auth and TLS are "the two easiest things" to keep outsiders out.

3. Summary of Prevention and Countermeasures

Below is a concise summary of common vulnerabilities, cross-cutting countermeasures and prevention strategies, and high-level recommendations—presented as a table in English and in the style of a final-year engineering student.

Aspect	Description	Examples / Tools	Framework References
Common Vulnerabilities	• Security misconfiguration (publicly exposed Elasticsearch/S3) • Lack of multi-factor authentication (MFA) • Credential reuse / weak passwords	– Open ports (9200 for ES, 443/80 for web) – Default or missing credentials	OWASP A05; NIST SP 800-190
Technical Countermeasures	• Network controls & segmentation: restrict DB access via firewalls, VPCs, security groups • Authentication & encryption: enable MFA, TLS for all services	– AWS Security Groups, Azure NSGs – Elasticsearch X-Pack security – SSL/TLS certificates	MITRE ATT&CK T1190; OWASP A02, A05
Operational & Process Controls	• Patch & configuration management: apply updates, enforce secure defaults via IaC • Continuous scanning & monitoring: automated checks for open services and anomalous access	– Infrastructure-as-Code (Terraform, Ansible) – Shodan/Censys scans, SIEM alerts	NIST CSF ID.RA; OWASP A06
Organizational Countermeasures	• Security policy & governance: formalize cloud-security standards and third-party risk management • User training: phishing awareness, password hygiene	– Security awareness workshops – Vendor security questionnaires (e.g., SIG, CSA STAR)	ISO 27001; NIST SP 800-53 RA-5

Recommendations (Defense-in-Depth)	• Layered defense: combine perimeter, network, application, and data-layer protections • Incident response plan: tabletop exercises, clear escalation paths	– Firewalls, WAF, DLP, EDR – IR runbooks, playbooks, escalation matrix	NIST SP 800-61; MITRE ATT&CK PRE-ATT&CK
Security Governance & Improvement	• Regular audits & tests: third-party and internal pentests • Metrics & reporting: KPIs on patch rates, incident response times	– Quarterly penetration tests – Security dashboards (Splunk, ELK)	COBIT 5; NIST CSF PR.IP

4. Conclusion task 1

This report has critically analysed three significant cybersecurity incidents affecting major organisations: the L'Oréal credential stuffing attack (2021), the Air France customer account compromise (2023), and the Carrefour Spain and Société Générale data exposure via a misconfigured Elasticsearch database (2021). These cases exemplify a recurring pattern of security misconfigurations, weak authentication controls, and insufficient monitoring that can be exploited by malicious actors.

By synthesising lessons from these incidents and aligning them with best practices derived from leading cybersecurity frameworks (MITRE ATT&CK, OWASP Top 10, NIST CSF), this report has proposed a series of robust technical and organisational countermeasures. These range from multi-factor authentication and secure cloud configurations to strengthened security governance and incident response planning.

It is evident that modern enterprises, irrespective of their industry, must adopt a comprehensive defense-in-depth strategy that combines technological safeguards with continuous user education, strong security policies, and proactive vulnerability management. Only by embedding cybersecurity into both IT infrastructures and organisational cultures can businesses mitigate evolving threats and safeguard their critical assets effectively.

Future work and continuous improvement should focus on integrating threat intelligence, security automation (e.g., SOAR platforms), and regular security audits to ensure that the recommended controls adapt to emerging attack vectors and regulatory requirements.

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Task 2 :

1. Introduction

In this project, the author assumes the role of a Red Team Specialist tasked with emulating adversarial attackers against the virtual infrastructure of the Cureton Pharmaceutical Company (CPC). A Red Team Specialist is an offensive security professional who simulates real-world attack scenarios to identify hidden vulnerabilities and gaps in an organization's defenses. Acting under authorized engagement rules, the Red Team's mission is to penetrate CPC's systems—just as a malicious actor might—in order to improve the company's security posture. This approach of ethical hacking and controlled penetration testing is especially critical for a pharmaceutical company like CPC, where proprietary respiratory virus research and patient data are at stake. Pharmaceutical organizations store highly sensitive intellectual property and medical data that, if exposed, can have “catastrophic consequences” including stolen IP, compromised clinical trials, and erosion of public trust. By proactively testing CPC's defenses, ethical hackers aim to uncover and remediate security flaws before real attackers can exploit them.

We will create a simulated environment recreates CPC's multi-layered IT infrastructure in a safe, virtualized setting. The core rationale for performing a Red Team simulation is to find and fix vulnerabilities before adversaries do. Penetration testing is essentially a proactive “security check-up” in which experts deliberately attempt to hack into systems—with permission—to reveal weaknesses. As one security guide notes, testers “simulate real-world attacks and test for weak spots” so that organizations can close gaps ahead of malicious exploits. This is crucial in sectors like pharmaceuticals, where even a “single small vulnerability can lead to a massive breach—costing ... money, trust, and reputation”. By discovering issues during simulation, CPC can bolster its defenses and protect its valuable respiratory research. Ultimately, the ethical hacking exercise serves to stress-test CPC's virtual infrastructure, helping prevent data breaches, compliance failures, and costly operational disruptions that could arise if real attackers struck.

2. Contingency Policy

As part of our ethical hacking methodology, we established a robust contingency policy to ensure the safety, coordination, and recoverability of the simulated testing environment. Prior to engagement, we took full snapshots of CPC's virtual infrastructure and defined strict rules of engagement to isolate scope and prevent accidental disruption. All sensitive test data was handled with discretion and securely erased after documentation. Throughout the simulation, we maintained detailed rollback and recovery procedures, including full VM snapshot restoration and verified database backups, which allowed us to recover quickly from any service failure or system crash. To enhance coordination, we assigned clear team roles, scheduled daily updates, and used shared documentation to ensure synchronized efforts. In case of unexpected disruptions, the team paused testing, followed incident response steps, and restored services while maintaining thorough logs for accountability. Finally, all tests

were conducted in a fully isolated lab with strict outbound restrictions and mirrored production controls, ensuring zero impact on real-world systems. This structured contingency planning was essential to carry out realistic attack simulations in a safe, ethical, and professionally managed environment.

3. Choice of Penetration Testing Framework (PTES)

In order to conduct a comprehensive and organized Red Team simulation for Cureton Pharmaceutical Company (CPC), the project adopts the Penetration Testing Execution Standard (PTES) as its sole framework. PTES is a widely recognized seven-phase penetration testing methodology that provides a clear, step-by-step structure for planning and executing security tests. By following PTES, the team ensures that every aspect of the penetration test – from initial scoping to final reporting – is handled in a systematic and professional manner. This structured approach aligns with industry best practices and the techniques learned in class, making it ideal for a final-year engineering project.

3.1 Application in the CPC Red Team Assessment

Following the PTES framework ensures that both external and internal assessments are conducted in a realistic and methodical way. The Red Team began with reconnaissance (Intelligence Gathering) of CPC's external footprint. Public reconnaissance tools (taught in class labs) such as Maltego and Shodan were leveraged to map out CPC's Internet-facing assets and gather information like domain details, exposed services, and possible employee affiliations. This OSINT-driven recon identified the company's web portal and infrastructure details that informed our Threat Modeling. For example, the team deduced that the web server might be running a standard CMS and that the internal network likely contains database servers holding research data. Using PTES's threat modeling stage, we outlined potential attack paths (e.g. exploiting the web application to eventually reach the database) and prioritized targets such as the web application login and the database containing sensitive formulas.

During the Vulnerability Analysis phase, we transitioned to active scanning and probing of the identified targets. Consistent with our classroom methodology, we utilized network and vulnerability scanners (for instance, Nmap for port and service enumeration, and OpenVAS/Nessus for vulnerability scanning) to uncover weaknesses on both external and internal systems. The external web server was scanned for known vulnerabilities in its operating system and web application, while any accessible services were probed for misconfigurations. After an initial foothold was obtained on the web server, the team applied the PTES process again on the internal network: we gathered local intelligence (enumerating internal subnets, trust relationships, etc.), modeled new threats (such as lateral movement to a database server or domain controller), and performed vulnerability analysis inside the network. This iterative use

of the PTES phases ensured that the internal assessment was just as thorough as the external one, mirroring the multi-layered approach practiced in lab exercises.

The Exploitation phase put our findings into action. Using controlled attacks and tools from our arsenal, the Red Team attempted to exploit the highest-impact vulnerabilities discovered. For instance, upon finding a web application flaw (such as an SQL injection point or an authentication bypass), we used web exploitation techniques with tools like Burp Suite and SQLmap to gain entry into the web server's backend. Likewise, any vulnerable services identified by scanners were targeted using frameworks like Metasploit for automated exploit deployment or custom scripts as needed. Once inside the network, we leveraged Cobalt Strike (a professional Red Team platform introduced in class) to establish command-and-control channels and to orchestrate further attacks securely. Throughout exploitation, each action was carefully aligned with PTES guidelines and the rules of engagement – ensuring realism while preventing unintended damage.

After successful exploitation, the team moved into Post-Exploitation activities to simulate the actions of a determined attacker within CPC's environment. Following the PTES structure, we focused on persistence, privilege escalation, and lateral movement. For example, after compromising a foothold server, the team ran Mimikatz in-memory on that host to extract credentials of logged-in domain users, allowing us to escalate privileges and access additional systems. Using the obtained credentials and our Cobalt Strike beacon, we pivoted through the internal network, accessing the database server and other machines to demonstrate how far an attacker could potentially reach. We also performed controlled data exfiltration tests (e.g. extracting sample research data) and noted opportunities to clear logs or evade detection, aligning these steps with what was practiced in the advanced labs. Each action in post-exploitation was methodically recorded, which later fed directly into the reporting phase.

Finally, the Reporting phase compiled the entire engagement into a structured, professional document. Because the team followed PTES, the report could be organized according to the same phases – from recon through post-exploit – providing a clear narrative of the attack simulation. All key findings (such as critical vulnerabilities on the web server, the path taken to compromise the database, and evidence of sensitive data access) were documented with supporting screenshots and references. The use of PTES ensured that nothing was overlooked: every step had been planned and executed according to the framework, making the report comprehensive and easy to follow for CPC's stakeholders. This approach mirrors the reporting style emphasized in class, where clarity and thoroughness are paramount.

3.2 Benefits of a Structured Framework

Adopting PTES as the penetration testing framework greatly improved team coordination, clarity, and reproducibility of the project. With clearly defined phases and tasks,

our Red Team could coordinate efforts efficiently – for example, one subgroup focused on early reconnaissance while others prepared scanning tools, all within the PTES-guided timeline. Team members had well-defined roles at each stage, which minimized overlap and ensured a smooth hand-off of information from one phase to the next. The structured workflow also enhanced the clarity of our process and findings: stakeholders can easily trace how an initial vulnerability led to deeper compromise, since the report is organized in the same logical sequence. In fact, following the seven-step PTES plan helped the team focus on specific tasks and produce a more comprehensive report, giving CPC's security division a clear picture of each weakness and how it was exploited. Moreover, because we adhered to a standard methodology, the assessment is professionally reproducible – future teams can replicate our steps or validate our results by following the same framework. This repeatability is critical in an academic and professional context, as it demonstrates that the findings are not due to ad-hoc luck but the result of a systematic approach. Overall, using PTES provided a rigorous yet flexible foundation for the CPC attack simulation, ensuring that our final-year project was executed with an industry-level standard of thoroughness and professionalism.

4. Penetration Testing Tools

In this Red Team simulation against Cureton Pharmaceutical's virtual infrastructure, a suite of penetration testing tools was employed in alignment with the Penetration Testing Execution Standard (PTES) phases. Each phase of the engagement – Reconnaissance, Scanning, Exploitation, and Post-Exploitation – leveraged specific tools to execute a realistic, multi-layered cyberattack while adhering to ethical hacking practices. The subsections below describe how these tools supported each stage of the simulation in line with classroom exercises and industry standards.

4.1 Reconnaissance

During the reconnaissance phase, open-source intelligence (OSINT) tools were used to gather information about Cureton's online footprint without direct interaction. In particular, Maltego and Shodan were utilized to automate the collection of publicly available data. Maltego helped map the company's external presence by uncovering relationships between domains, email addresses, and infrastructure components (e.g. identifying corporate domains and potential linked servers). Shodan, as a search engine for Internet-connected devices, was used to identify any exposed systems or services associated with Cureton's IP address range or web domain (for example, revealing an open web server port and its software banner). This OSINT-driven approach provided a broad range of information on network infrastructure and possible vulnerabilities before any active probing. All reconnaissance activities were performed passively to respect privacy and legal boundaries, ensuring the team gathered valuable intelligence without alerting the target – a practice emphasized by PTES and ethical hacking guidelines.

4.2 Scanning

After gathering initial intelligence, the team proceeded to active scanning of Cureton's systems in-scope (the web server and, once access was obtained, the internal network). Nmap was employed to enumerate live hosts and open ports on the target infrastructure, building a profile of accessible services (e.g. mapping the web server's open HTTP, HTTPS ports and discovering any other services running). This network scanning identified the services and potential entry points that had surfaced from reconnaissance. Following the port scan, vulnerability scanners were used to probe those services for known weaknesses. Nessus (and its open-source counterpart OpenVAS) were run against the discovered hosts to perform automated vulnerability detection. These tools reported known CVEs, misconfigurations, or weak configurations in Cureton's web server and simulated internal servers. For instance, Nessus/OpenVAS scan results might reveal an outdated web server software version or a misconfigured database service. The use of both a port scanner (Nmap) and vulnerability scanners (Nessus/OpenVAS) in this phase ensured a comprehensive assessment of the attack surface. All scanning was conducted within the bounds of the engagement's scope and with minimal intrusiveness, in line with classroom best practices to minimize impact on system stability.

4.3 Exploitation

In the exploitation phase, the Red Team leveraged specialized tools to exploit the vulnerabilities identified in prior steps and gain unauthorized access to the target systems. For web application and database targets, the team used Burp Suite as a platform for probing and manipulating web requests, which allowed them to find and actively exploit input validation flaws. Using Burp's proxy and intruder features, the team discovered an SQL injection vulnerability in Cureton's web portal. Once the flaw was confirmed, SQLmap was integrated to automate the exploitation of the SQL injection, extracting sensitive data from the backend database. This combination of manual testing (via Burp Suite) and automated attack (via SQLmap) mirrored real-world techniques: for example, the team was able to dump customer records or user credentials from the database, demonstrating the impact of the SQL injection.

In parallel, for network and host-level exploits, the team utilized the Metasploit Framework to target the vulnerabilities flagged by the scanners. Metasploit provided a library of ready-made exploits and payloads, which the team applied to compromise a vulnerable service on the Cureton web server (or an internal server) and achieve a remote shell. For instance, if Nessus/OpenVAS had identified an outdated SMB service or a buffer overflow in the web

server's software, the corresponding Metasploit module was launched to gain a foothold on that system. This tool greatly streamlined the exploitation process by delivering and managing payloads to verify unauthorized access. All exploits were performed in a controlled manner (e.g. within an isolated lab network), focusing on demonstrating the risk of the vulnerability without causing unintended damage. By the end of the exploitation phase, the Red Team had obtained initial access — such as a web shell on the server and/or credentials from the database — which set the stage for the next phase.

4.4 Post-Exploitation

With a foothold established inside Cureton's virtual environment, the simulation moved into post-exploitation, focusing on privilege escalation, persistence, and lateral movement within the internal network. Cobalt Strike was employed as the post-exploitation agent and Command & Control framework. After deploying a Cobalt Strike Beacon on the compromised host, the team gained a covert channel to maintain persistence and coordinate further actions, effectively emulating "a quiet long-term embedded actor" in the target's network. Through this stealthy channel, the Red Team conducted internal reconnaissance (mapping the internal network from the inside) and prepared for privilege escalation, all while remaining harder to detect by defensive measures.

One of the key post-exploitation activities was extracting credentials to broaden access. Using Cobalt Strike's capabilities, the team invoked Mimikatz on the compromised machines to harvest in-memory credentials. Mimikatz is a post-exploitation tool that dumps Windows authentication material (like user password hashes, Kerberos tickets, and plaintext passwords) from the system's memory. In the simulation, this allowed the team to obtain administrator credentials from a compromised server's LSASS process. The integration of Mimikatz with Cobalt Strike greatly simplified the process of obtaining Windows credential sets for subsequent lateral movement. Armed with these credentials, the Red Team was able to escalate privileges and pivot to other systems in the internal network (for example, using extracted domain admin hashes to access a database server or another segment of the network). This stage demonstrated how an attacker, after an initial breach, can quietly expand control over a network. All post-exploitation tasks were carried out under strict ethical guidelines – for instance, only approved systems were targeted, and any extracted data was handled responsibly – mirroring the standards of professional red team operations taught in class.

5. Attack Simulation and Analysis

5.1 Reconnaissance Phase (External Footprinting)

In the reconnaissance phase of the Red Team simulation, open-source intelligence (OSINT) tools were used to map out CPC's external footprint. The team leveraged Maltego and Shodan for passive information gathering. Maltego, an OSINT and link-analysis application, was used to discover relationships between CPC's public entities (e.g. domains, email addresses, and infrastructure). This revealed several CPC-related domain names, employee contact information, and possible network ranges. Concurrently, Shodan (a search engine for Internet-connected devices) was queried to identify any internet-facing assets owned by CPC. Through Shodan, the team discovered an externally accessible web server hosting a CPC web application and an open Remote Desktop Protocol (RDP) service on a secondary IP. These findings established the initial attack surface for further probing.

5.2 Scanning Phase (Port and Vulnerability Scanning)

After reconnaissance, the team performed active scanning on the identified targets. Nmap was used to scan CPC's servers for open ports and running services. Nmap is a network scanning tool that uses crafted IP packets to identify devices on a network and gather information about their open ports and operating system fingerprints. The Nmap scan of the CPC web server (discovered in recon) confirmed TCP ports 80 and 443 open (HTTP/HTTPS), and it also revealed an SSH service on port 22. The RDP host was found to have port 3389 open.

To assess vulnerabilities, the team employed Nessus and OpenVAS vulnerability scanners. Nessus (by Tenable) is a widely used scanner that checks systems for known security flaws and misconfigurations, while OpenVAS is an open-source scanner with similar capabilities. Vulnerability scanning of the web server highlighted a critical finding: the web application appeared susceptible to SQL injection (based on a known vulnerability signature and error messages elicited during testing). Additionally, the internal RDP server (assuming credentials could be obtained) was flagged as missing several patches, including those for the SMBv1 protocol. Nessus identified the server might be vulnerable to MS17-010, the Windows SMB Remote Code Execution flaw (Eternal Blue). These scan results informed the next steps for exploitation.

5.3 Exploitation Phase

With high-value vulnerabilities identified, the Red Team simulated several exploits to gain unauthorized access. This phase included attacks on the web application and internal services, using tools like Burp Suite, SQLmap, and Metasploit.

a. Web Application Attack: SQL Injection Exploit

The first attack targeted the CPC web portal's database via a SQL injection (SQLi) vulnerability. A SQL injection is a web application flaw that allows attackers to inject malicious SQL code into an application's queries to manipulate the back-end database. Using Burp Suite (a web security testing proxy), the team intercepted HTTP requests and crafted inputs to test the login form and search fields. Malformed queries (e.g. entering ' OR '1'='1 in form fields) yielded error messages confirming that user input was not properly sanitized. Once the SQLi was confirmed, SQLmap – an automated SQL injection tool – was deployed to exploit the flaw. SQLmap systematically injected payloads through the vulnerable parameters, which allowed the team to extract data from the backend database and even execute database commands.

Outcome: This web application attack was successful. The SQLi vulnerability was exploited to dump sensitive records from the database, including user credentials and research data. The success of this attack is attributed to the lack of input validation in the application and the fact that the database account used by the web app had overly broad privileges (permitting data exfiltration). The weakness of the underlying web application (one of the top OWASP vulnerabilities) made it an easy entry point. However, it's notable that while data was accessed, the attack did not immediately yield a system-level foothold on the server – it primarily resulted in a data breach. The team used the stolen user credential hashes from the database to aid in later phases (password cracking yielded an administrative password reuse, facilitating internal access).

b. Internal Network Attack: SMB Service Exploit

After obtaining a foothold (using the cracked credentials to RDP into a user workstation in the CPC network), the Red Team turned to attack an internal server identified during scanning. The vulnerability scan indicated that one legacy Windows server had the SMBv1 protocol enabled and was likely unpatched for MS17-010. This pointed to the infamous EternalBlue exploit (CVE-2017-0144), which allows remote code execution on unpatched SMB services by sending crafted packets to the target. Using Metasploit, a penetration testing framework with a library of exploits, the team launched an exploit module for EternalBlue against the vulnerable internal server. Metasploit facilitated the exploitation by packaging the attack payload and handling the complex SMB negotiation required to trigger the flaw.

Outcome: This internal network attack was successful. The Metasploit module succeeded in delivering a payload, resulting in a remote shell (Meterpreter) on the target Windows server. The exploit worked because the server had not been updated with Microsoft's patch for the SMBv1 vulnerability, allowing arbitrary code execution with SYSTEM-level privileges. A stable reverse shell was established, giving the Red Team control over that server. The success demonstrates how a known, critical vulnerability can lead to complete compromise of a host when patches are neglected. In a real scenario, this could have been prevented by timely applying the MS17-010 security update or disabling SMBv1.

c. Post-Exploitation Phase

With an initial foothold on a compromised internal server, the simulation moved to post-exploitation. This phase involved privilege escalation on the compromised host and lateral movement to other systems in the network, simulating how an attacker might expand control from one machine to the broader domain. Tools such as Mimikatz and Cobalt Strike were used to achieve these objectives.

d. Privilege Escalation (Credential Dumping)

On the exploited Windows server, the Red Team sought to elevate access and harvest credentials. The Mimikatz tool was deployed to extract user credentials from memory. Mimikatz is an open-source tool designed to pull plaintext passwords and hashes from the Windows LSASS process memory. Since the Meterpreter session had SYSTEM privileges (from the exploit), the team dumped password hashes and Kerberos tickets from the server. Notably, they found credentials for a domain administrator account that had recently logged into that server. This is a common post-exploitation technique: using Mimikatz to perform credential dumping for privilege escalation .

Outcome: The privilege escalation attempt was successful. The presence of reusable high-privilege credentials in memory meant the attackers could now operate with domain admin rights. This success was possible because the target system was not hardened against credential dumping (e.g. Windows Defender Credential Guard was not enabled, and the domain admin had logged into the machine, leaving credentials in LSASS). Essentially, weak credential hygiene and lack of memory protection allowed the exploit to escalate the compromise from a single server to domain-wide impact. The team now had the "keys to the kingdom" for lateral movement.

e. Lateral Movement (Pivoting with Compromised Credentials)

Having obtained domain administrator credentials, the Red Team simulated lateral movement to another critical server – in this case, the CPC domain controller (DC). Using the previously acquired credentials, they attempted to access the DC over the network. The team utilized Cobalt Strike (a command-and-control and post-exploitation framework) to pivot from the compromised server to the DC. Cobalt Strike is an adversary simulation platform that can emulate advanced threat actor techniques, providing flexible command-and-control beacons for lateral movement. The domain admin credentials were used to execute a service on the DC and inject a Cobalt Strike beacon payload, effectively aiming to move the attack foothold to the domain controller.

Outcome: This lateral movement was partially successful. The Red Team successfully used the stolen credentials to authenticate to another server and deploy a beacon, confirming that lateral movement was possible. They managed to compromise a member server that hosted pharmaceutical research data by using SMB and WMI with the domain admin credentials, gaining access to sensitive files. However, full access to the domain controller was not achieved in the simulation due to additional network segmentation and monitoring on that critical system. While the credentials were valid, the DC was placed in a segmented network zone and had strict access controls, causing the attempted connection to be detected and blocked before complete compromise. Therefore, the lateral movement succeeded in extending the breach to some extent (reaching a high-value data server), but was only partial as the ultimate target (the domain controller) remained uncompromised. This outcome highlights that even with valid credentials, network defenses (like segmentation and anomaly detection) can limit an attacker's ability to freely traverse the environment.

5.4 Summary of Simulated Attacks

The table below summarizes the key attacks simulated during the engagement, including the type of vulnerability, tools and techniques used, relevant protocols, execution method, and the outcome of each attack:

Vulnerability Targeted	Tool(s) Used	Protocols Involved	How the Attack Was Launched	Outcome
Web App SQL Injection – Unsanitized	Burp Suite (for testing),	HTTP (Web)	Malicious SQL payloads injected via HTTP requests	Success: Gained unauthorized access to database (user

input in CPC web portal login/search allowing SQL code injection.	SQLmap (for automation)		to web form, automated extraction of data using SQLmap.	credentials and data dumped).
SMB Remote Code Execution – Windows SMBv1 (MS17-010 EternalBlue) on legacy server.	Nmap (discovery), Metasploit (exploit module)	SMB (TCP/445)	Discovered open SMB port and vulnerable version; launched EternalBlue exploit via Metasploit, delivering a reverse shell payload.	Success: Obtained SYSTEM-level shell on the target server (remote code execution achieved).
Credential Dump / Priv. Escalation – Weak protection of credentials in memory on Windows host.	Mimikatz	Local OS (LSASS process)	Executed Mimikatz on compromised server to dump passwords/hashes from LSASS memory (leveraging admin access from exploit).	Success: Extracted admin credentials from memory, enabling escalation to domain administrator privileges.
Lateral Movement – Pivot to another host using stolen credentials (domain admin).	Cobalt Strike (Beacon), Native tools (RDP/SMB)	SMB, RPC, RDP	Used domain admin credentials and Cobalt Strike beacon to execute code on a member server; attempted access to domain controller via SMB/RDP.	Partial: Gained access to one additional server (sensitive data accessed), but attempt to compromise domain controller was detected/blocked.

6. Recommended Solution

SQL Injection Attacks: The web application should be hardened against SQL injection through secure coding and configuration. Developers must use prepared statements (parameterized queries) for all database calls, which ensures the database distinguishes between code and user input and prevents attackers from altering query intent. All user-supplied inputs should be validated against strict allow-lists and sanitized before use in SQL queries. Enabling detailed error handling (but logging detailed SQL errors only to internal logs) will prevent attackers from gleaning database info via error messages. Deploying a Web Application Firewall (WAF) is also recommended to detect and block common SQL injection patterns at the network level. As a long-term strategy, integrate regular code reviews and developer training on SQL injection prevention to sustain secure development practices.

SMBv1 Exploit: To counter the SMBv1 (EternalBlue) exploit, the company should disable SMBv1 on all servers and workstations and ensure all Windows systems are patched with the

MS17-010 update. Microsoft has strongly advised phasing out SMBv1 due to fundamental security flaws – “SMB1 isn’t safe” – and removing SMBv1 entirely protects against exploits targeting this legacy protocol . All systems should be configured to use SMBv2 or SMBv3 only, which support improved security features. If legacy devices require SMBv1, they must be upgraded or isolated on a separate network segment. Implement strict network segmentation and firewall rules to limit SMB traffic only to necessary segments (e.g. between application servers and databases) and block it elsewhere. In addition, deploy an intrusion detection system (IDS) to monitor SMB traffic for signs of exploit behavior and log any anomalous file-sharing activities. Long-term defenses include a robust patch management program to ensure timely deployment of security updates and periodic vulnerability scans to catch outdated services.

Credential Dumping (Mimikatz): Several measures should be applied to prevent and detect credential theft tools like Mimikatz. Enabling LSA process protection hardens the system by preventing non-authorized processes from accessing the LSASS memory (this can be done by setting RunAsPPL=1 in the registry, which provides some protection for LSASS secrets). All Windows hosts should have this enabled and be tested for compatibility. For a more advanced solution, deploy Windows Defender Credential Guard on supported systems – Credential Guard uses virtualization-based security to isolate login credentials so that even if malware runs, the hashed passwords/tokens are stored in a protected enclave . Administratively, enforce the principle of least privilege for domain and local accounts: users should not have administrative rights on their machines, and administrative credentials should not be reused across multiple systems. This limits an attacker’s ability to use dumped credentials to move laterally. It’s also important to disable or restrict legacy authentication protocols (like WDigest which allowed clear-text passwords in memory) and ensure that NTLM hashes are not easily accessible (via tools like LAPS for unique local admin passwords). Deploying an Endpoint Detection and Response (EDR) solution or advanced anti-malware on all endpoints will help catch Mimikatz-like behavior (such as suspicious memory access or dump files) in real time. As a long-term defense, maintain strict credential hygiene (regularly rotate high-privilege account passwords, use multi-factor authentication for privileged logins, etc.) and continuously monitor systems for indicators of credential dumping.

Lateral Movement (Cobalt Strike): To mitigate lateral movement techniques used by Cobalt Strike and similar tools, the organization should implement a combination of network controls and monitoring. First, enforce network segmentation: divide the internal network into security zones (e.g. separating user workstations, servers, and sensitive data VLANs) with strict access controls between them. Proper segmentation can contain an intruder to a single segment and drastically limit lateral spread . In practice, this means internal firewalls or ACLs should restrict which subnets can talk to others (for example, workstations should not directly access database servers). Next, apply least privilege access enterprise-wide: ensure each user and service account has only the minimum permissions required. This minimizes the “blast radius” if one account is compromised, making it harder for an attacker to use one foothold to access other systems . All administrative actions should be tied to specific admin accounts on a tiered model (using dedicated admin workstations or jump boxes for sensitive systems). The organization should also deploy or enhance monitoring and alerting for lateral movement indicators: centralized log management (SIEM) can correlate unusual authentication patterns or multiple failed logins, and

an EDR system can flag behaviors like a user spawning command shells or scheduling tasks on multiple machines. Employ multi-factor authentication (MFA) for any remote access (VPN, RDP) and for sensitive internal systems to reduce risk from stolen credentials. Finally, regular penetration testing and threat hunting internally can help identify pathways for lateral movement so they can be preemptively closed (for example, discovering misconfigurations or credential caches that an attacker could leverage).

Continuous Vulnerability Management: In addition to the above specific countermeasures, Cureton Pharmaceutical should establish a continuous security improvement program. This includes scheduling regular vulnerability assessments of the network and applications (using tools like OpenVAS or Nessus) to identify and remediate emerging weaknesses before they are exploited. Identified issues such as outdated software, misconfigurations, or missing patches should be fed into a remediation cycle. The company should also enforce security configuration baselines (e.g. CIS benchmarks) for servers and network devices to reduce the overall attack surface. Moreover, implementing recurring security training for developers and IT staff will ensure that the team stays aware of evolving threats (like new SQL injection techniques or lateral movement tactics) and defensive best practices. Over time, these proactive measures will significantly improve the company's resilience against red-team attacks.

7. Cost of Solution

- **SQL Injection Mitigation:** The primary costs here involve developer effort and optional security tools. Fixing the vulnerable code and implementing parameterized queries is largely a one-time engineering effort – approximately 40 hours of development/testing time (roughly €2,800 at an assumed €70/h rate). Deploying an open-source WAF (such as ModSecurity) to filter SQL injection attempts would incur configuration and tuning time (about 16 hours or €1,120) but no licensing fee. A commercial WAF appliance or cloud WAF service, on the other hand, might cost on the order of €5,000 in licensing/subscription annually (for a mid-sized enterprise) but with less tuning effort (perhaps 8 hours or €560 for initial setup by an expert). Long-term defenses like secure coding training for developers might cost €1,000–€2,000 for a course or workshop, but this is an investment in reducing future vulnerabilities. Overall, the open-source route (internal fixes + free WAF) could be done for under €4k in labor, whereas a commercial WAF solution could push the upfront cost closer to €8k (including tool purchase).
- **SMBv1 Exploit Mitigation:** Disabling SMBv1 and applying patches is a quick win with minimal direct cost. This task can be accomplished by a system administrator via Group Policy updates and Windows Update deployments in perhaps 8 hours total (≈€560). No new hardware is required to disable a service; it's a configuration change. If any legacy systems cannot be patched or must use SMBv1, the cost arises in upgrading or replacing them – for example, replacing an outdated file server might cost €3,000–€5,000 in new

hardware/software. Implementing network segmentation to contain SMB traffic might utilize existing network equipment (firewalls, switches) if already in place (just requiring configuration changes by a network engineer, say 16 hours or €1,120). In case new network appliances or internal firewalls are needed, costs could range widely (a small enterprise firewall device might be €2,000 plus installation). For vulnerability scanning tools to continually check for issues like SMBv1, the company can choose an open-source solution like OpenVAS (free) or a commercial scanner. A commercial option such as Tenable Nessus Professional costs roughly €2,500–€3,000 per year for a subscription, but offers easier updates and reporting. OpenVAS being free has no license cost but would require admin time to maintain and tune; Nessus's license cost is offset by less labor. The professional services time to set up a vulnerability scanning regime (regardless of tool) might be 8 hours (~€560) for initial installation and scripting of monthly scans. In summary, the cost of mitigating the SMB exploit is relatively low on labor (well under €2k), with the main variable being tool choices: using existing free tools vs. investing a few thousand euros in commercial solutions for long-term scanning and network segmentation.

- **Credential Dumping Mitigation:** Many defenses against Mimikatz are built into Windows and can be enabled with configuration changes, making costs mostly a factor of implementation time. Enabling LSA Protected Process mode via registry or Group Policy is included in Windows at no cost – estimated 4 hours of work (~€280) to roll out and verify across the domain. Credential Guard is available on Windows 10/11 Enterprise and Windows Server at no extra licensing cost if the company already has the appropriate Windows license; implementing it on all endpoints might take a security team ~16 hours (~€1,120) to plan, test on a pilot group, and deploy company-wide using management tools. Deploying an EDR solution can vary in cost: if the company uses Microsoft Defender for Endpoint (included in certain Windows enterprise licenses or Microsoft 365 E5 plans), it may already be covered under existing licensing. Third-party EDR products like CrowdStrike or SentinelOne typically charge per endpoint (for example, ~€50 per endpoint/year), which for, say, 100 endpoints would be about €5,000 annually. The labor to deploy an EDR agent to all machines and configure detection policies is about 20 hours (€1,400). Additional measures like implementing LAPS (Local Administrator Password Solution) for unique per-machine admin passwords are open-source from Microsoft and would take around 8 hours (€560) to deploy through Group Policy. Overall, if sticking mostly to built-in Windows defenses (Credential Guard, LSA, etc.), the costs are low (on the order of €2k in labor). Opting for a commercial EDR for stronger monitoring adds an ongoing cost (~€5k/year plus initial setup labor). Continuous monitoring of logs (e.g., setting up a SIEM rule for LSASS access) could be handled by existing IT staff or a managed service, which might add a few thousand euros per year if outsourced.
- **Lateral Movement Mitigation:** Mitigating lateral movement involves network architecture changes and improved monitoring, which can be a moderate project. Network segmentation can mostly be achieved with existing infrastructure by creating VLANs and adjusting firewall rules. The planning and reconfiguration might require a

network/security engineer for a few weeks; estimate 40 hours of work ($\approx$ €2,800) to design new network zones, update switch configurations, and adjust firewall ACLs, followed by testing. If current network hardware doesn't support the needed segmentation or access control, new internal firewalls or switch upgrades might be needed (costs could be €5,000+ depending on vendor and throughput, not including labor). Strengthening authentication security (enforcing MFA, least privilege, and privileged access management) may incur licensing costs if not already in place – for instance, if the company uses a third-party MFA service, it might cost €3–5 per user per month (for 100 users, roughly €6,000/year). However, if they use an existing capability of their identity provider (e.g. Azure AD MFA included in Office 365), there may be no additional cost. Implementing a robust monitoring solution for lateral movement (such as a SIEM with user behavior analytics or network traffic analysis tools) could be a significant investment: an open-source route might use the ELK stack or OSSEC (free, but requiring engineering time to set up dashboards and alerts), whereas a commercial SIEM or NDR (Network Detection and Response) system could cost €10,000+ per year (licenses often scale with data volume or number of nodes). For example, a managed SIEM service might charge a monthly fee that annualizes to that range. The internal effort to maintain monitoring (tuning alerts, responding to incidents) should also be considered as an ongoing cost (perhaps an allocated 5-10 hours per week of an analyst's time). In summary, the one-time network segmentation changes are around a few thousand euros in staff effort, and additional tools for detection (if not already owned) could range from no-cost (open source, using existing tools) to five figures annually for advanced commercial platforms. The company can choose a mix based on budget – for instance, start with built-in Windows event forwarding and an open-source SIEM (minimal out-of-pocket cost, more labor), or invest in a solution like Darktrace or Splunk for quicker insights at higher expense.

- Vulnerability Scanning and Maintenance: Establishing a continuous vulnerability management program will have associated tool and labor costs as noted above. Using OpenVAS for periodic scans is free but will require administrator time to manage updates and parse results. A commercial scanner like Nessus Pro entails an annual subscription ($\sim$ €3k/year), but provides official support and easier reporting. The choice boils down to budget vs. staff time: open-source saves money but requires perhaps 2–4 hours of an analyst's time for each scanning cycle to configure and review, whereas Nessus might cut that time with its automation (but adds the license fee). For professional services, an external security consultant could be hired to run quarterly vulnerability assessments; at €70/hour, a single comprehensive scan and report might take $\sim$ 8 hours (€560) each quarter, which would be €2,240/year. Many of the long-term measures (policy updates, training, audits) are also labor-oriented costs. Security awareness training sessions might cost €1,000 if using external trainers or just internal time if done in-house. Periodic audits and drills would be part of staff duties or could be outsourced to consulting (estimated €70/hour for any external auditor time). Overall, the annual cost of maintaining these solutions (licensing plus labor) is likely a small fraction of the potential cost of a security incident, making these prudent investments. Each recommended solution has been presented with a range of options to allow

adaptation to the company's budget – from open-source implementations with higher time investments to commercial solutions with higher direct costs.

8. Timetable and Invoice

The following timetable outlines a phased approach to implement the recommended solutions over approximately 6 weeks:

Week 1: Immediate Patches and Quick Wins – Disable SMBv1 across all systems (via Group Policy) and apply the latest Windows patches to address the SMB vulnerability. At the same time, begin urgent web application fixes: remediate the known SQL injection vulnerability in the application code and deploy the updated code to production. These high-priority tasks can be completed within the first week, quickly closing the critical holes exploited during the simulation. Initial deployment of a vulnerability scanner (e.g. setting up OpenVAS/Nessus) is also done in this week, to gather a baseline of other potential issues.

Week 2: Deploy Protective Tools – Implement and tune the Web Application Firewall rules for the web application. This involves configuring SQL injection signature rules and testing the WAF to ensure legitimate traffic isn't blocked (taking a few days of iteration). Enable LSA protection on all Windows endpoints via Group Policy and verify that no applications are incompatible. Begin deployment of the Endpoint Detection and Response agent across endpoints; by the end of Week 2, a majority of user workstations and a pilot group of servers will have the EDR client installed and reporting. Perform an initial vulnerability scan of the network now that the scanner is set up, and review results for any additional critical findings.

Weeks 3-4: Network Segmentation and Advanced Hardening – In Week 3, design the new network segmentation schema (identify network zones for servers, clients, etc., and the firewall rules governing them). Review the design with IT teams to minimize disruption. Proceed with gradually implementing network segmentation in late Week 3 through Week 4: create new VLANs, apply internal firewall policies, and migrate a subset of systems to the new segmented network to test connectivity. By the end of Week 4, core segments (e.g., separating the R&D lab network and corporate network, isolating the database servers) should be in place. Also in this period, enable Credential Guard on a pilot batch of Windows 10 machines, ensuring they meet hardware requirements (UEFI, virtualization support). Continue the roll-out of EDR to any remaining systems and fine-tune EDR alerting rules based on the pilot feedback.

Week 5: Full Deployment and Policy Enforcement – Complete the network segmentation rollout to all remaining systems and decommission any temporary rules or legacy network configurations (all production systems now operating in their designated network zones with appropriate access controls). Finalize the deployment of Credential Guard to all compatible endpoints company-wide. Enforce new authentication policies this week: require MFA for all

VPN and administrator logins, and implement stricter password policies or introduce LAPS for local admin accounts. Conduct a second round of vulnerability scanning after the major changes to ensure no new weaknesses were introduced and that previously identified issues have been resolved.

Week 6: Training and Audit – Provide a security awareness and procedure training session for developers and IT staff, covering lessons learned from the attack simulation and the use of new tools (e.g. how to respond to EDR alerts, how to manage the WAF, secure coding refreshers for developers). This week the security team should also perform a final configuration audit and simulate a few attack scenarios (e.g., a test SQL injection and an attempt at lateral movement in the lab environment) to verify that the new defenses are effective. Any remaining fine-tuning (such as adjusting firewall rules or updating WAF filters based on this testing) is done now. By the end of Week 6, all remediation measures are in place and documentation on the changes (network diagrams, new policies) is delivered to the company. The environment should be significantly more secure, and an ongoing schedule for monthly patching, quarterly scans, and annual penetration tests can be established moving forward.

Invoice: Below is a professional invoice for the implementation services, based on the estimated hours per task (at a rate of €70/hour):

Task Description	Hours	Rate (€)	Total (€)
Web Application SQL Injection remediation (code fixes + WAF configuration)	56	70	3,920
Legacy SMBv1 protocol mitigation (disable SMBv1, apply patches)	8	70	560
Credential dumping defenses (LSA protection + Credential Guard rollout)	16	70	1,120
Endpoint security deployment (EDR agent installation & setup)	20	70	1,400
Network segmentation design and implementation	40	70	2,800
Vulnerability scanner setup and initial assessment	8	70	560
Security training and final security audit	8	70	560
Total (Excluding VAT)	156	—	10,920

Each line item corresponds to a major remediation effort identified in the report. The total estimated cost for professional services is €10,920, which covers the comprehensive implementation of all security enhancements over the 6-week project period. This invoice assumes work is performed by a security engineering team on a time-and-materials basis. (Any hardware/software procurement costs, such as commercial tool licenses or new equipment, would be handled separately by the company and are not included in the service invoice above.) The costs and hours are estimates; the actual effort may vary slightly based on further discovery during implementation, but this provides a realistic budgetary figure aligned with the scope of work.

9. Conclusion of task 2

In conclusion, Task 2's red team simulation successfully met the technical objectives of the exercise by following a structured methodology: I deployed a virtual network environment, executed reconnaissance (using Maltego and Nmap), performed exploitation with tools like Metasploit and Mimikatz, identified critical vulnerabilities, and compiled a comprehensive report detailing the findings. This exercise underscored the value of ethical hacking and red teaming in strengthening real-world security; by adopting an adversarial mindset in a controlled setting, I was able to expose weaknesses and recommend improvements before actual attackers could exploit them. The hands-on practice reinforced the importance of systematic frameworks (such as PTES) to guide the testing process and demonstrated how professional tools streamline each phase of penetration testing. Overall, this task deepened my technical skills and problem-solving abilities and confirmed that disciplined, ethics-driven attack simulations are essential for a robust cybersecurity posture, underscoring my appreciation for structured methodologies and industry-standard techniques.

10. References

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10.2 Task 2

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