# Compendium

# TDT4237 - Software Security

**Part Two**
OWASP Testing Guide

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# Contents

# Chapter 1

# Introduction to Security Testing

## 1.1 The OWASP Testing Guide

**OWASP:** The Open Web Application Security Project

The OWASP Testing Project has been in development for many years. With this project, we wanted to help people understand the what, why, when, where, and how of testing their web applications, and not just provide a simple checklist or prescription of issues that should be addressed. The outcome of this project is a complete Testing Framework, from which others can build their own testing programs or qualify other people's processes. The Testing Guide describes in details both the general Testing Framework and the techniques required to implement the framework in practice.

## 1.2 What, Why, When?

**What is Testing?**
What do we mean by testing? During the development life cycle of a web application, many things need to be tested. The Merriam-Webster Dictionary describes testing as:

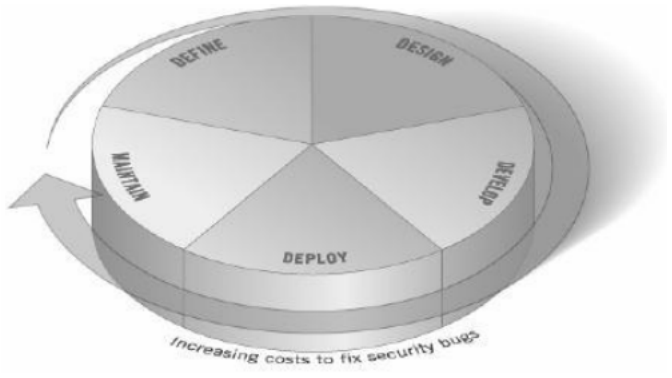
- To put to test or proof.
- To undergo a test.
- To be assigned a standing or evaluation based on tests.

Many outsiders regard security testing as a black art. This document's aim is to change that perception and to make it easier for people without in-depth security knowledge to make a difference.

**Why Testing?**
This document is designed to help organizations understand what comprises a testing program, and to help them identify the steps that they need to undertake to build and operate that testing program on their web applications. It is intended to give a broad view of the elements required to make a comprehensive web application security program. This guide can be used as a reference and as a methodology to help determine the gap between your existing practices and industry best practices. This guide allows organizations to compare themselves against industry peers, understand the magnitude of resources required to test and maintain their software, or prepare for an audit. The technical details about how to test an application, as part of a penetration test or code review, will be covered in later chapters.

**When to Test?**
Most people today don't test the software until it has already been created and is in the deployment phase of its life cycle (i.e., code has been created and instantiated into a working web application). This is generally a very ineffective and cost-prohibitive practice. One of the best methods to prevent security bugs from appearing in production applications is to improve the Software Development Life Cycle (SDLC) by including security in each of its phases.

An SDLC is a structure imposed on the development of software artifacts. If an SDLC is not currently being used in your environment, it is time to pick one! The following figure shows a generic SDLC model:

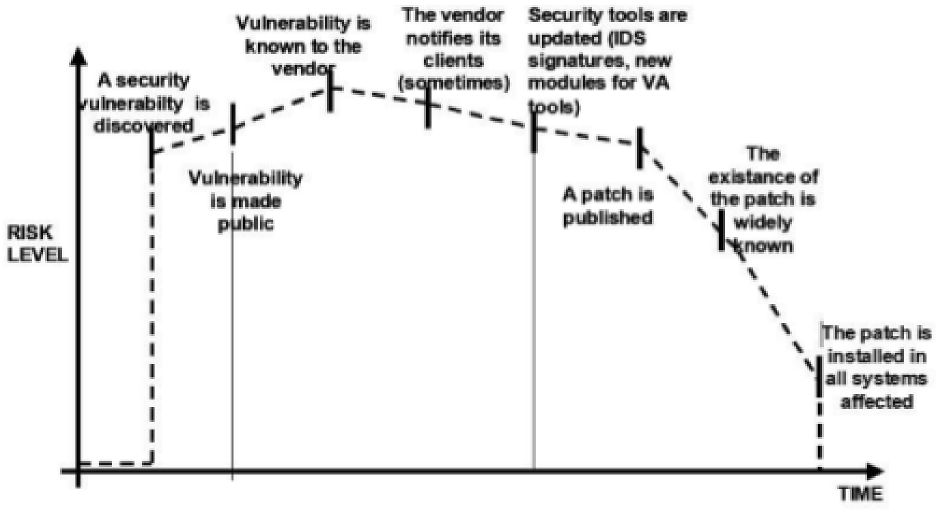


**What to Test?**
It can be helpful to think of software development as a combination of people, process, and technology. If these are the factors that "create" software, then it is logical that these are the factors that must be tested. Today most people generally test the technology or the software itself. An effective testing program should have components that test
**People** – to ensure that there is adequate education and awareness;
**Process** – to ensure that there are adequate policies and standards and that people know how to follow these policies;
**Technology** – to ensure that the process has been effective in its implementation.

## 1.3 Principles of Testing

**There is no silver bullet:** While it is tempting to think that a security scanner or application firewall will either provide a multitude of defenses or identify a multitude of problems, in reality there are no silver bullets to the problem of insecure software.

**Think strategically, not tactically:** The patch-and-penetrate model involves fixing a reported bug, but without proper investigation of the root cause. This model is usually associated with the window of vulnerability:


RISK LEVEL
A security vulnerabilty is discovered
Vulnerability is made public
Vulnerability is known to the vendor
The vendor notifies its clients (sometimes)
Security tools are updated (IDS signatures, new modules for VA tools)
A patch is published
The existance of the patch is widely known
The patch is installed in all systems affected
TIME

To prevent reoccurring security problems within an application, it is essential to build security into the Software Development Life Cycle (SDLC) by developing standards, policies, and guidelines that fit and work within the development methodology. Threat modeling and other techniques should be used to help assign appropriate resources to those parts of a system that are most at risk.

**Test early and test often:** When a bug is detected early within the SDLC, it can be addressed more quickly and at a lower cost. A security bug is no different from a functional or performance-based bug in this regard.

**Understand the scope of security:** It is important to know how much security a given project will require. The information and assets that are to be protected should be given a classification that states how they are to be handled (e.g., Confidential, Secret, Top Secret). Security testing cost money! You have to prioritize what's important for your system.

**Develop the right mindset:** Successfully testing an application for security vulnerabilities requires thinking "outside of the box." Normal use cases will test the normal behavior of the application when a user is using it in the manner that you expect. Good security testing requires going beyond what is expected and thinking like an attacker who is trying to break the application. This is one of the reasons why automated tools are actually bad at automatically testing for vulnerabilities.

**Understand the subject:** One of the first major initiatives in any good security program should be to require accurate documentation of the application. The architecture, data-flow diagrams, use cases, and more should be written in formal documents and made available for review.

**Use the right tools:** While we have already stated that there is no silver bullet tool. There is a range of open source and commercial tools that can automate many routine security tasks. These tools can simplify and speed up the security process. It is important to understand exactly what these tools can and cannot do.

**The devil is in the details:** It is critical not to perform a superficial security review of an application and consider it complete. Care should be taken to verify that every possible section of application logic has been tested, and that every use case scenario was explored for possible vulnerabilities.

**Use source code when available:** While black box penetration test results can be impressive and useful to demonstrate how vulnerabilities are exposed in production, they are not the most effective way to secure an application. If the source code for the application is available, it should be given to the security staff to assist them while performing their review. It is possible to discover vulnerabilities within the application source that would be missed during a black box engagement.

**Develop metrices:** An important part of a good security program is the ability to determine if things are getting better. It is important to track the results of testing engagements, and develop metrics that will reveal the application security trends within the organization.

**Document the test results:** To conclude the testing process, it is important to produce a formal record of what testing actions were taken, by whom, when they ware performed, and details of the test findings.

## 1.4 Testing Techniques

This section presents a high-level overview of various testing techniques that can be employed when building a testing program.

### 1.4.1 Manual Inspection and Reviews

Manual inspections are human-driven reviews that typically test the security implications of the people, policies, and processes, but can include inspection of technology decisions such as architectural designs. By asking someone how something works and why it was implemented in a specific way, it allows the tester to quickly determine if any security concerns are likely to be evident. Manual inspections and reviews are one of the few ways to test the software development life-cycle process itself and to ensure that there is an adequate policy or skill set in place. As with many things in life, when conducting manual inspections and reviews we suggest you adopt a trust-but-verify model.

**Advantages:**

- Requires no supporting technology
- Can be applied to a variety of situations
- Flexible
- Promotes teamwork
- Can be performed early in the SDLC

**Disadvantages:**

- Can be time consuming
- Supporting material not always available
- Requires significant human thought and skill to be effective!

### 1.4.2 Threat Modeling

Threat modeling has become a popular technique to help system designers think about the security threats that their systems/applications might face. Therefore, threat modeling can be seen as risk assessment for applications. In fact, it enables the designer to develop mitigation strategies for potential vulnerabilities and helps them focus their inevitably limited resources and attention on the parts of the system that most require it. To develop a threat model, we recommend taking a simple approach. This approach involves:

- **Defining and classifying the assets** – classify the assets into tangible and intangible assets and rank them according to business importance.
- **Exploring potential vulnerabilities** - whether technical, operational, or management.
- **Decomposing the application** – how the application works, its assets, functionality, and connectivity.
- **Exploring potential threats** – use threat scenarios and/or attack trees.
- **Creating mitigation strategies** – develop mitigating controls for each of the threats deemed to be realistic.

**Advantages:**

- Practical attacker's view of the system
- Flexible
- Early in the SDLC

**Disadvantages:**

- Relatively new technique
- Good threat models don't automatically mean good software

### 1.4.3 Source Code Review

Source code review is the process of manually checking a web application's source code for security issues. Many serious security vulnerabilities cannot be detected with any other form of analysis or testing. As the popular saying goes "if you want to know what's really going on, go straight to the source." Almost all security experts agree that there is no substitute for actually looking at the code. All the information for identifying security problems is there in the code somewhere.

**Advantages:**

- Completeness and effectiveness
- Accuracy
- Fast (for competent reviewers)

**Disadvantages:**

- Requires highly skilled security developers
- Can miss issues in compiled libraries
- Cannot detect run-time errors easily
- The source code actually deployed might differ from the one being analyzed

### 1.4.4 Penetration Testing

Penetration testing has been a common technique used to test network security for many years. It is also commonly known as black box testing or ethical hacking. Penetration testing is essentially the "art" of testing a running application remotely, without knowing the inner workings of the application itself, to find security vulnerabilities. Typically, the penetration test team would have access to an application as if they were users. The tester acts like an attacker and attempts to find and exploit vulnerabilities. Penetration testing tools have been developed that automate the process, but, again, with the nature of web applications their effectiveness is usually poor.

Gary McGraw summed up penetration testing well when he said:
**"If you fail asummed penetration test you know you have a very bad problem indeed. If you pass a penetration test you do not know that you don't have a very bad problem".**

**Advantages:**

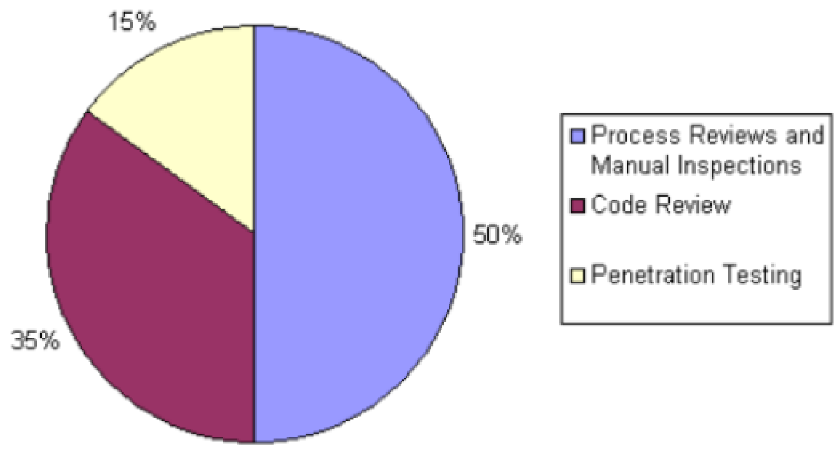
- Can be fast (and therefore cheap)
- Requires a relatively lower skill-set than source code review
- Tests the code that is actually being exposed

**Disadvantages:**

- Too late in the SDLC
- Front impact testing only!

### 1.4.5 Test Effort According to Test Technique

With so many techniques and so many approaches to testing the security of web applications, it can be difficult to understand which techniques to use and when to use them. The fact remains that all techniques should probably be used to ensure that all areas that need to be tested are tested. What is clear, however, is that there is no single technique that effectively covers all security testing that must be performed to ensure that all issues have been addressed. The following figure shows a typical proportional representation of test effort according to test technique:



## 1.5 Security Requirements

### 1.5.1 Test Derivation

**Testing Objectives**
One of the objectives of security testing is to validate that security controls function as expected. This is documented via **security requirements** that describe the functionality of the security control. At a high level, this means proving confidentiality, integrity, and availability of the data as well as the service. The other objective is to validate that security controls are implemented with few or no vulnerabilities. These are common vulnerabilities, such as the OWASP Top Ten, as well as vulnerabilities that are previously identified with security assessments during the SDLC, such as threat modeling, source code analysis, and penetration test.

**Security Requirement Documentation**
The first step in the documentation of security requirements is to understand the business requirements. A **business requirement document** could provide the initial, high-level information of the expected functionality for the application. For example, the main purpose of an application may be to provide financial services to customers or shopping and purchasing goods from an on-line catalogue. A security section of the business requirements should highlight the need to protect the customer data as well as to comply with applicable security documentation such as regulations, standards, and policies.

Applicable **industry standards** for security need also to be captured by the general security requirement checklist. For example, in the case of applications that handle customer credit card data, the compliance with the PCI DSS standard forbids the storage of PINs and CVV2 data.

Another section of the checklist needs to enforce general requirements for compliance with the **organization information security standards and policies**. From the functional requirements perspective, requirement for the security control needs to map to a specific section of the information security standards. An example of such requirement can be: **"a password complexity of six alphanumeric characters must be enforced by the authentication controls used by the application."**

**Security Requirements Validation**
From the functionality perspective, the validation of security requirements is the main objective of security testing, while, from the risk management perspective, this is the objective of information security assessments. More

in depth, the security assessment objective is risk analysis, such as the identification of potential weaknesses in security controls that ensure the confidentiality, integrity, and availability of the data. Assuming encryption is used to protect the data, encryption algorithms and key lengths need to comply with the **organization encryption standards**. For example, a security requirement that can be security tested is verifying that only allowed ciphers are used (e.g., SHA-1, RSA, 3DES) with allowed minimum key lengths (e.g., more than 128 bit for symmetric and more than 1024 for asymmetric encryption).

From the security assessment perspective, security requirements can be validated at different phases of the SDLC by **using different artifacts and testing methodologies**. For example, threat modeling focuses on identifying security flaws during design, secure code analysis and reviews focus on identifying security issues in source code during development, and penetration testing focuses on identifying vulnerabilities in the application during testing/validation.

**Threats and Countermeasures Taxonomies**
A **threat and countermeasure classification** that takes into consideration root causes of vulnerabilities is the critical factor to verify that security controls are designed, coded, and built so that the impact due to the exposure of such vulnerabilities is mitigated.

The focus of a threat and countermeasure **categorization** is to define security requirements in terms of the threats and the root cause of the vulnerability. The root cause can be categorized as security flaw in design, a security bug in coding, or an issue due to insecure configuration. A threat and countermeasure categorization for vulnerabilities can also be used to document security requirements for secure coding such as secure coding standards. An example of a common coding error in authentication controls consists of applying an hash function to encrypt a password, without applying a seed to the value.

**Security Testing and Risk Analysis**
By combining the results of source code analysis and penetration testing it is possible to determine the likelihood and exposure of the vulnerability and calculate the risk rating of the vulnerability. For example, high and medium risk vulnerabilities can be prioritized for remediation, while low risk can be fixed in further releases. By considering the threat scenarios exploiting common vulnerabilities it is possible to identify potential risks for which the application security control needs to be security tested. By thinking in terms of threats and vulnerabilities, it is possible to devise a battery of tests that simulate such attack scenarios.

### 1.5.2 Positive Requirements

From the perspective of functional security requirements, the applicable standards, policies and regulations drive both the need of a type of security control as well as the control functionality. These requirements are also referred to as **"positive requirements"**, since they state the expected functionality that can be validated through security tests. Examples of positive requirements are:

- The application will lockout the user after six failed logon attempts.
- Passwords need to be six min characters, alphanumeric.

The validation of positive requirements consists of asserting the expected functionality and, as such, can be tested by re-creating the testing conditions, and by running the test according to predefined inputs and by asserting the expected outcome as a fail/pass condition. In order to validate security requirements with security tests, security requirements need to be function driven and highlight the expected functionality **(the what)** and implicitly the implementation **(the how)**. Examples of high-level security design requirements for authentication can be:

- Protect user credentials and shared secrets in transit and in storage
- Mask any confidential data in display (e.g., passwords, accounts)
- Lock the user account after a certain number of failed login attempts
- Do not show specific validation errors to the user as a result of failed logon
- Only allow passwords that are alphanumeric, include special characters and six

### 1.5.3 Negative Requirements

Security tests need also to be risk driven, that is they need to validate the application for unexpected behavior. These are also called **"negative requirements"**, since they specify what the application should not do. Examples of "should not do" (negative) requirements are:

- The application should not allow for the data to be altered or destroyed
- The application should not be compromised or misused for unauthorized financial transactions by a malicious user.

Negative requirements are more difficult to test, because there is no expected behavior to look for. This might require a threat analyst to come up with unforeseeable input conditions, causes, and effects. This is where security testing needs to be driven by risk analysis and threat modeling. The key is to document the threat scenarios and the functionality of the countermeasure as a factor to mitigate a threat. For example, in case of authentication controls, the following security requirements can be documented from the threats and countermeasure perspective:

- Encrypt authentication data in storage and transit to mitigate risk of information disclosure and authentication protocol attacks.
- Encrypt passwords using non reversible encryption such as using a digest (e.g., HASH) and a seed to prevent dictionary attacks.
- Lock out accounts after reaching a logon failure threshold and enforce password complexity to mitigate risk of brute force password attacks
- Display generic error messages upon validation of credentials to mitigate risk of account harvesting/enumeration.

Threat modeling artifacts such as **threat trees and attack libraries** can be useful to derive the negative test scenarios. A threat tree will assume **a root attack** and identify different **exploits of security controls** and necessary **countermeasures** that could be validated to be effective in mitigating such attacks.

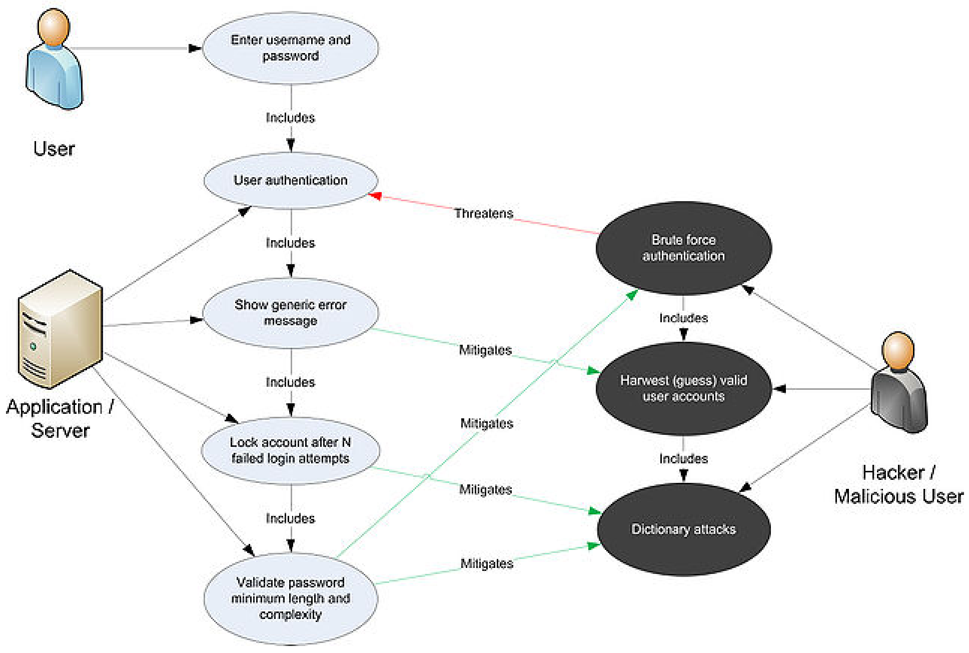
### 1.5.4 Use and Misuse Cases

Pre-requisite in describing the application functionality is to understand what the application is supposed to do and how. This can be done by describing use cases. **Use cases**, in the graphical form as commonly used in software engineering, show the interactions of actors and their relations, and help to identify the actors in the application, their relationships, the intended sequence of actions for each scenario, alternative actions, special requirements, and pre- and post-conditions.

Similar to use cases, **misuse and abuse cases** describe unintended and malicious use scenarios of the application. These misuse cases provide a way to describe scenarios of how an attacker could misuse and abuse the application. By going through the individual steps in a use scenario and thinking about how it can be maliciously exploited, potential flaws or aspects of the application that are not well-defined can be discovered. The key is to describe all possible or, at least, the most critical use and misuse scenarios. Misuse scenarios allow the analysis of the application from the **attacker's point of view**.

**Sequrity Requirements Derivation Through Use and Misuse Cases:**

- Step 1: Describe the Functional Scenario:
- Step 2: Describe the Negative Scenario:
- Step 3: Describe Functional and Negative Scenarios With Use and Misuse Case:
- Step 4: Elicit The Security Requirements. These security requirements need to be documented and tested.


User
Enter username and password
Includes
User authentication
Threatens
Brute force authentication
Includes
Show generic error message
Mitigates
Includes
Harwest (guess) valid user accounts
Application / Server
Mitigates
Lock account after N failed login attempts
Includes
Mitigates
Hacker / Malicious User
Includes
Dictionary attacks
Mitigates
Validate password minimum length and complexity

## 1.6 Security Tests Integrated in Developers and Testers Workflow

### 1.6.1 Developers' Security Testing Workflow

Security testing during the development phase of the SDLC represents the first opportunity for developers to ensure that individual software components that they have developed are security tested before they are integrated with other components and built into the application. Software components might consist of software artifacts such as functions, methods, and classes, as well as application programming interfaces, libraries, and executables. For security testing, developers can rely on the results of **the source code analysis** to verify statically that the developed source code does not include potential vulnerabilities and is compliant with the secure coding standards. **Security unit tests** can further verify dynamically (i.e., at run time) that the components function as expected.

### 1.6.2 Testers' Security Testing Workflow

After components and code changes are tested by developers and checked in to the application build, the most likely next step in the software development process workflow is to perform tests on the application as a whole entity. This level of testing is usually referred to as **integrated test** and **system level test**. These security tests on the application include both **white box testing**, such as source code analysis, and **black box testing**, such as penetration testing. **Gray box testing** is similar to Black box testing. In a gray box testing we can assume we have some partial knowledge about the session management of our application, and that should help us in understanding whether the logout and timeout functions are properly secured. A testing engineer who validates the security of the application in the integrated system environment might release the application for testing in the operational environment (e.g., **user acceptance tests**). The application **functional testing** is usually a responsibility of **QA testers**, while **white-hat hackers/security consultants** are usually responsible for **security testing**.

## 1.7 Security Test Data Analysis And Reporting

### 1.7.1 Goals for Security Test Metrices and Measurements

The definition of the goals for the security testing metrics and measurements is a pre-requisite for using security testing data for risk analysis and management processes. For example, a measurement such as the **total number of vulnerabilities found** with security tests might quantify the security posture of the application. These measurements also help to identify security objectives for software security testing: for example, reducing the number of vulnerabilities to an acceptable number (minimum) before the application is deployed into production.

From the perspective of the **effort required to fix** a defect, both security and quality defects can be measured in terms of developer hours to implement the fix, the tools and resources required to fix, and, finally, the cost to implement the fix.

Security testing data needs to support the security risk strategy at critical checkpoints during the SDLC. For example, vulnerabilities found in source code with source code analysis represent an initial measure of risk. Such **measure of risk (e.g., high, medium, low)** for the vulnerability can be calculated by determining the exposure and likelihood factors and, further, by validating such vulnerability with penetration tests. The risk metrics associated to vulnerabilities found with security tests empower business management to make **risk management decisions**, such as to decide whether risks can be accepted, mitigated, or transferred at different levels within the organization.

We need to lowering the cost of fixing the vulnerabilities, since it is less expensive to deal with the vulnerabilities when they are found (in the same phase of the SDLC), rather than fixing them later in another phase.

When security test data is reported it has to provide metrics to support the analysis. The scope of the analysis is the interpretation of test data to find clues about the security of the software being produced as well the effectiveness of the process. Some examples of clues supported by security test data can be:

Are vulnerabilities reduced to an acceptable level for release? Are all security test requirements being met? What are the major root causes of security issues? Which security activity is most effective in finding vulnerabilities? Which team is more productive in fixing security defects and vulnerabilities? Which percentage of overall vulnerabilities are high risks? Which tools are most effective in detecting security vulnerabilities?

### 1.7.2 Reporting Requirements

The security posture of an application can be characterized from the perspective of the effect, such as number of vulnerabilities and the risk rating of the vulnerabilities, as well as from the perspective of the cause (i.e., origin) such as coding errors, architectural flaws, and configuration issues.

When reporting security test data, the best practice is to include the following information, besides the categorization of each vulnerability by type:

- The security threat that the issue is exposed to
- The root cause of security issues (e.g., security bugs, security flaw)
- The testing technique used to find it
- The remediation of the vulnerability (e.g., the countermeasure)
- The risk rating of the vulnerability (High, Medium, Low)

### 1.7.3 Business Cases

For the security test metrics to be useful, they need to **provide value** back to the organization's security test data stakeholders, such as project managers, developers, information security offices, auditors, and chief information officers. The value can be in terms of the business case that each project stakeholder has in terms of role and responsibility.

**Project managers** look for data that allows them to successfully manage and utilize security testing activities and resources according to the project plan.

To compliance **auditors**, security test metrics provide a level of software security assurance and confidence that security standard compliance is addressed through the security review processes within the organization.

Finally, **Chief Information Officers (CIOs) and Chief Information Security Officers (CISOs)**, responsible for the budget that needs to be allocated in security resources, look for derivation of a **cost/benefit analysis** from security test data to make informed decisions on which security activities and tools to invest.

# Chapter 2

# Testing Framework

This section describes a typical testing framework that can be developed within an organization. It can be seen as a reference framework that comprises techniques and tasks that are appropriate at various phases of the software development life cycle (SDLC).

There are many development methodologies such as the Rational Unified Process, eXtreme and Agile development, and traditional waterfall methodologies. The intent of this guide is to suggest neither a particular development methodology nor provide specific guidance that adheres to any particular methodology. Instead, we are presenting a generic development model, and the reader should follow it according to their company process.

This testing framework consists of the following activities that should take place:

- Before Development Begins
- During Definition and Design
- During Development
- During Deployment
- Maintenance and Operations

## 2.1 Before Development Begins

Before application development has started:

**Review Policies and Standards**
Ensure that there are appropriate policies, standards, and documentation in place. Documentation is extremely important as it gives development teams guidelines and policies that they can follow. People can only do the right thing, if they know what the right thing is.

**Develop Measurement and Metrics Critera**
Before development begins, plan the measurement program. By defining criteria that need to be measured, it provides visibility into defects in both the process and product. It is essential to define the metrics before development begins, as there may be a need to modify the process in order to capture the data.

## 2.2 During Definition and Design

**Review Security Requirements**
Security requirements define how an application works from a security perspective. It is essential that the security requirements be tested. Testing in this case means testing the assumptions that are made in the requirements, and testing to see if there are gaps in the requirements definitions. When looking for requirements gaps, consider looking at security mechanisms such as: User Management (password reset etc.), Authentication, Authorization, Data Confidentiality, Integrity, Accountability, Session Management, Transport Security, Tiered System Segregation and Privacy.

**Review Design and Architecture**
Applications should have a documented design and architecture. By documented, we mean models, textual documents, and other similar artifacts. It is essential to test these artifacts to ensure that the design and architecture enforce the appropriate level of security as defined in the requirements. Identifying security flaws in the design phase is not only one of the most cost-efficient places to identify flaws, but can be one of the most effective places to make changes.

**Create And Review UML Models**
Once the design and architecture is complete, build Unified Modeling Language (UML) models that describe how the application works. In some cases, these may already be available. Use these models to confirm with the systems designers an exact understanding of how the application works. If

weaknesses are discovered, they should be given to the system architect for alternative approaches.

**Create And Review Threat Models**
Armed with design and architecture reviews, and the UML models explaining exactly how the system works, undertake a threat modeling exercise. Develop realistic threat scenarios. Analyze the design and architecture to ensure that these threats have been mitigated, accepted by the business, or assigned to a third party, such as an insurance firm. When identified threats have no mitigation strategies, revisit the design and architecture with the systems architect to modify the design.

## 2.3 During Development

Theoretically, development is the implementation of a design. However, in the real world, many design decisions are made during code development. These are often smaller decisions that were either too detailed to be described in the design, or in other cases, issues where no policy or standard guidance was offered. If the design and architecture were not adequate, the developer will be faced with many decisions. If there were insufficient policies and standards, the developer will be faced with even more decisions.

**Code Walkthroughs**
The security team should perform a code walkthrough with the developers, and in some cases, the system architects. A code walkthrough is a high-level walkthrough of the code where the developers can explain the logic and flow of the implemented code. It allows the code review team to obtain a general understanding of the code, and allows the developers to explain why certain things were developed the way they were. The purpose is not to perform a code review, but to understand at a high level the flow, the layout, and the structure of the code that makes up the application.

**Code Reviews**
Armed with a good understanding of how the code is structured and why certain things were coded the way they were, the tester can now examine the actual code for security defects. Static code reviews validate the code against a set of checklists, including:

- Business requirements for availability, confidentiality, and integrity.
- OWASP Guide or Top 10 Checklists for technical exposures.
- Specific issues relating to the language or framework in use.
- Any industry specific requirements, such as ISO standards, or other regulatory regimes.

## 2.4 During Deployment

**Application Penetration Testing**
Having tested the requirements, analyzed the design, and performed code review, it might be assumed that all issues have been caught. Hopefully, this is the case, but penetration testing the application after it has been deployed provides a last check to ensure that nothing has been missed.

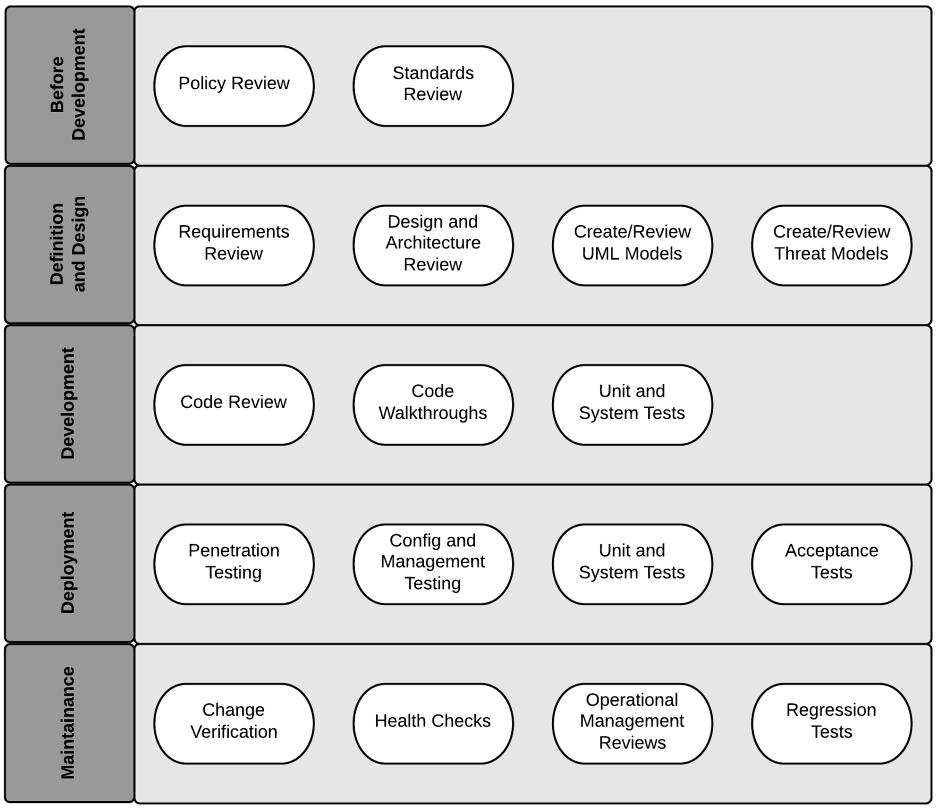
**Configuration Management Testing**
The application penetration test should include the checking of how the infrastructure was deployed and secured. While the application may be secure, a small aspect of the configuration could still be at a default install stage and vulnerable to exploitation.

## 2.5 Maintenance and Operations

**Conduct Operational Management Reviews**
There needs to be a process in place which details how the operational side of both the application and infrastructure is managed.

**Conduct Periodic Health Checks**
Monthly or quarterly health checks should be performed on both the application and infrastructure to ensure no new security risks have been introduced and that the level of security is still intact.

**Enusure Change Verification**
After every change has been approved and tested in the QA environment and deployed into the production environment, it is vital that, as part of the change management process, the change is checked to ensure that the level of security hasn't been affected by the change.


Before Development
Policy Review
Standards Review
Definition and Design
Requirements Review
Design and Architecture Review
Create/Review UML Models
Create/Review Threat Models
Development
Code Review
Code Walkthroughs
Unit and System Tests
Deployment
Penetration Testing
Config and Management Testing
Unit and System Tests
Acceptance Tests
Maintainance
Change Verification
Health Checks
Operational Management Reviews
Regression Tests

# Chapter 3

# Web Application Penetration Testing

## 3.1 Introduction to Penetration Testing

### What is Web Application Penetration Testing?

A penetration test is a method of evaluating the security of a computer system or network by simulating an attack. A Web Application Penetration Test focuses only on evaluating the security of a web application. The process involves an active analysis of the application for any weaknesses, technical flaws, or vulnerabilities.

### What is a vulnerability?

**A vulnerability** is a flaw or weakness in a system's design, implementation, or operation and management that could be exploited to violate the system's security policy.

**A threat** is a potential attack that, by exploiting a vulnerability, may harm the assets owned by an application (resources of value, such as the data in a database or in the file system).

**A test** is an action that tends to show a vulnerability in the application.

### What is the OWASP testing methodology?

**Penetration testing** will never be an exact science where a complete list of all possible issues that should be tested can be defined. Indeed, penetration testing is only an appropriate technique for testing the security of web applications under certain circumstances.

**The goal** is to collect all the possible testing techniques, explain them and keep the guide updated. The OWASP Web Application Penetration Testing method is based on the **black box** approach. The tester knows nothing or very little information about the application to be tested.

**The testing model consists of:**

- **Tester:** Who performs the testing activities
- **Tools and methodology:** The core of this Testing Guide project
- **Application:** The black box to test

## Active and Passive Mode

**Passive Mode:** in the passive mode, the tester tries to understand the application's logic, and plays with the application. Tools can be used for information gathering, for example, an HTTP proxy to observe all the HTTP requests and responses. At the end of this phase, the tester should understand all the access points (gates) of the application (e.g., HTTP headers, parameters, and cookies). The Information Gathering section explains how to perform a passive mode test.

**Ative Mode:** in this phase, the tester begins to test (the penetration testing) using the methodology described in the specific penetration category.

# Chapter 4

# Information Gathering

The first phase in security assessment is focused on collecting as much information as possible about a target application. Information Gathering is a necessary step of a penetration test. This task can be carried out in many different ways. By using public tools (search engines), scanners, sending simple HTTP requests, or specially crafted requests, it is possible to force the application to leak information, e.g., disclosing error messages or revealing the versions and technologies used.

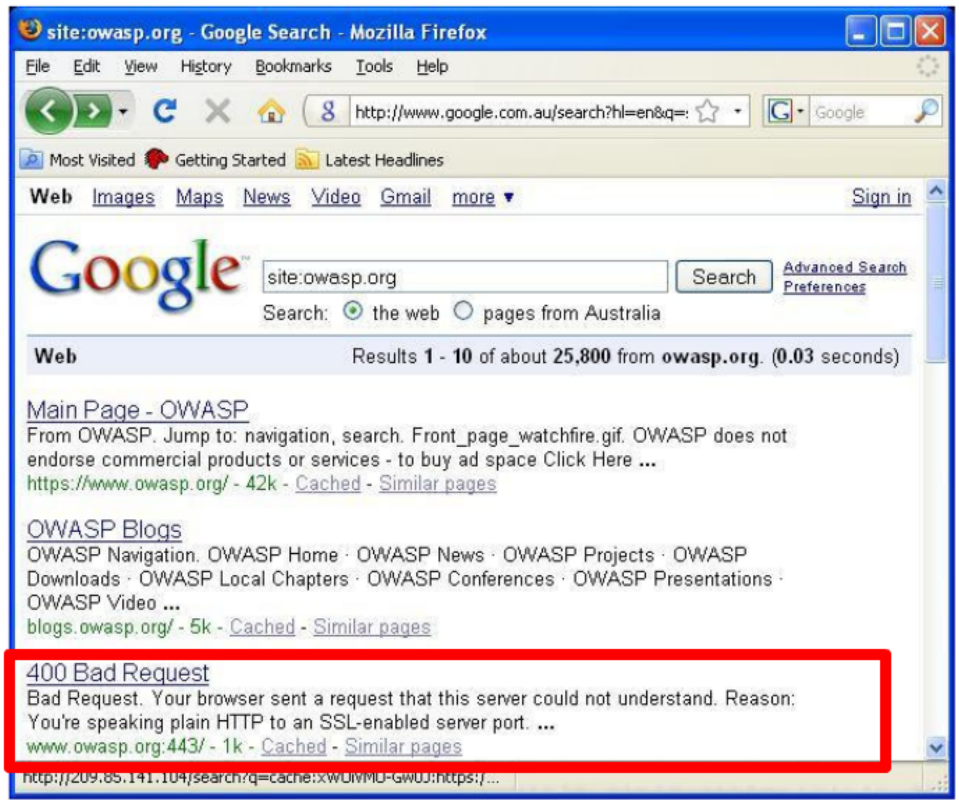
## 4.1 OWASP-IG-001 - Spiders, Robots, and Crawlers

This phase of the Information Gathering process consists of browsing and capturing resources related to the application being tested. Web spiders/robots/crawlers retrieve a web page and then recursively traverse hyperlinks to retrieve further web content.

**Black Box Testing** wget to retrieve information and Google Webmaster Tools to analyse the retrived information from wget. Wget is a reqursive information retrival tool that collects all information on the client side of an application.

## 4.2 OWASP-IG-002 - Search Engine Discovery/ Reconnaissance

Search engines, such as Google, can be used to discover issues related to the web application structure or error pages produced by the application that have been publicly exposed.


site:owasp.org - Google Search - Mozilla Firefox

http://www.google.com.au/search?hl=en&q=

site:owasp.org

Search: the web pages from Australia

Web Results **1** - **10** of about **25,800** from **owasp.org**. (**0.03** seconds)

Main Page - OWASP
From OWASP. Jump to: navigation, search. Front_page_watchfire.gif. OWASP does not endorse commercial products or services - to buy ad space Click Here ...
https://www.owasp.org/ - 42k - Cached - Similar pages

OWASP Blogs
OWASP Navigation. OWASP Home · OWASP News · OWASP Projects · OWASP Downloads · OWASP Local Chapters · OWASP Conferences · OWASP Presentations · OWASP Video ...
blogs.owasp.org/ - 5k - Cached - Similar pages

400 Bad Request
Bad Request. Your browser sent a request that this server could not understand. Reason: You're speaking plain HTTP to an SSL-enabled server port. ...
www.owasp.org:443/ - 1k - Cached - Similar pages

http://209.85.141.104/search?q=cache:xWUlvMU-GwUJ:https:/...

## 4.3 OWASP-IG-003 - Identify application entry points

Enumerating the application and its attack surface is a key precursor before any attack should commence. This section will help you identify and map out every area within the application that should be investigated once your enumeration and mapping phase has been completed.

Enumerating the application and its attack surface is a key precursor before any thorough testing can be undertaken, as it allows the tester to identify likely areas of weakness. This section aims to help identify and map out areas within the application that should be investigated once enumeration and mapping has been completed.

Before any testing begins, always get a good understanding of the application and how the user/browser communicates with it. As you walk through the application, pay special attention to all HTTP requests (GET and POST Methods, also known as Verbs), as well as every parameter and form field that are passed to the application. In addition, pay attention to when GET requests are used and when POST requests are used to pass parameters to the application. It is very common that GET requests are used, but when sensitive information is passed, it is often done within the body of a POST request. Note that to see the parameters sent in a POST request, you will need to use a tool such as an intercepting proxy (for example, OWASP's WebScarab) or a browser plug-in. Within the POST request, also make special note of any hidden form fields that are being passed to the application, as these usually contain sensitive information, such as state information, quantity of items, the price of items, that the developer never intended for you to see or change. This is typical data that an attacker can tamper with.

Example:

This example shows a POST request that would log you into an application.
**A simplified POST request:**

- **POST** https://x.x.x.x/KevinNotSoGoodApp/authenticate.asp?service=login
- **Host:** x.x.x.x
- **Cookie:** SESSIONID = dGhpcyBpcyBhIGJhZCBhcHAgdGhhdCBz-ZXRzIHByZWRpY3RhYmxlIGNvb2tpZXMgYW5kIG1pbmUgaXMg MTIzNA==
- **CustomCookie**=00my00trusted00ip00is00x.x.x.x00

**Body of the POST message:**

- user=admin&pass=pass123&debug=true&fromtrustIP=true

## 4.4 OWASP-IG-004 - Testing Web Application Fingerprint

Application fingerprint is the first step of the Information Gathering process; knowing the version and type of a running web server allows testers to determine known vulnerabilities and the appropriate exploits to use during testing.

Web server fingerprinting is a critical task for the Penetration tester. Knowing the version and type of a running web server allows testers to determine known vulnerabilities and the appropriate exploits to use during testing. There are several different vendors and versions of web servers on the market today. Knowing the type of web server that you are testing significantly helps in the testing process, and will also change the course of the test. This information can be derived by sending the web server specific commands and analyzing the output, as each version of web server software may respond differently to these commands. By knowing how each type of web server responds to specific commands and keeping this information in a web server fingerprint database, a penetration tester can send these commands to the web server, analyze the response, and compare it to the database of known signatures.

**HTTP header field ordering:** The first method consists of observing the ordering of the several headers in the response. Every web server has an inner ordering of the header.

**Malformed requests test:** Another useful test to execute involves sending malformed requests or requests of nonexistent pages to the server.

**Automated Testing:** The tests to carry out in order to accurately fingerprint a web server can be many. Luckily, there are tools that automate these tests. "httprint" is one of such tools. httprint has a signature dictionary that allows one to recognize the type and the version of the web server in use. An example of on line tool that often delivers a lot of information on target Web Server, is Netcraft. With this tool we canv retrieve information about operating system, web server used, Server Uptime, Netblock Owner, history of change related to Web server and O.S.

## 4.5 OWASP-IG-005 - Application Discovery

Application discovery is an activity oriented to the identification of the web applications hosted on a web server/application server. This analysis is important because often there is not a direct link connecting the main application backend. Discovery analysis can be useful to reveal details such as web applications used for administrative purposes. In addition, it can reveal old versions of files or artifacts such as undeleted, obsolete scripts, crafted during the test/development phase or as the result of maintenance.

## 4.6 OWASP-IG-006 - Analysis of Error Codes

During a penetration test, web applications may divulge information that is not intended to be seen by an end user. Information such as error codes can inform the tester about technologies and products being used by the application. In many cases, error codes can be easily invoked without the need for specialist skills or tools, due to bad exception handling design and coding. Clearly, focusing only on the web application will not be an exhaustive test. It cannot be as comprehensive as the information possibly gathered by performing a broader infrastructure analysis.

## Chapter 5

# Configuration Management Testing

Often analysis of the infrastructure and topology architecture can reveal a great deal about a web application. Information such as source code, HTTP methods permitted, administrative functionality, authentication methods and infrastructural configurations can be obtained.

## 5.1 SSL/TLS Testing

The http clear-text protocol is normally secured via an SSL or TLS tunnel, resulting in https traffic. In addition to providing encryption of data in transit, https allows the identification of servers (and, optionally, of clients) by means of digital certificates.

In order to detect possible support of weak ciphers, the ports associated to SSL/TLS wrapped services must be identified. These typically include port 443 which is the standard https port, however this may change because a) https services may be configured to run on non-standard ports, and b) there may be additional SSL/TLS wrapped services related to the web application. In general a service discovery is required to identify such ports. Vulnerability Scanners, in addition to performing service discovery, may include checks against weak ciphers.

## 5.2 DB Listener Testing

The Data base listener is a network daemon. It waits for connection requests from remote clients. This daemon can be compromised and hence can affect the availability of the database.

It listens for connection requests and handles them accordingly. The listener, by default, listens on port 1521(different ports may be used depending on the configuration). It is good practice to change the listener from this port to another arbitrary port number. If this listener is "turned off" remote access to the database is not possible. If this is the case, one's application would fail also creating a denial of service attack.

Potential areas of attack

- Stop the Listener – create a DoS attack.
- Set a password and prevent others from controlling the Listener - Hijack the DB.

- Write trace and log files to any file accessible to the process owner of tnslnsr - Possible informationleakage.
- Obtain detailed information on the Listener, database, and application configuration.

## 5.3 Infrastructure Configuration Management Testing

Proper configuration management of the web server infrastructure is very important in order to preserve the security of the application itself. If elements such as the web server software, the back-end database servers, or the authentication servers are not properly reviewed and secured, they might introduce undesired risks or introduce new vulnerabilities that might compromise the application itself.

In order to test the configuration management infrastructure, the following steps need to be taken:

- The different elements that make up the infrastructure need to be determined in order to understand how they interact with a web application and how they affect its security.
- All the elements of the infrastructure need to be reviewed in order to make sure that they don't hold any known vulnerabilities.
- A review needs to be made of the administrative tools used to maintain all the different elements.
- The authentication systems, if any, need to reviewed in order to assure that they serve the needs of the application and that they cannot be manipulated by external users to leverage access.
- A list of defined ports which are required for the application should be maintained and kept under change control.

## 5.4 Application Configuration Management Testing

Proper configuration of the single elements that make up an application architecture is important in order to prevent mistakes that might compromise the security of the whole architecture.

**Sample/known files and directories**
Many web servers and application servers provide, in a default installation, sample applications and files that are provided for the benefit of the developer and in order to test that the server is working properly right after installation. However, many default web server applications have been later known to be vulnerable.

**Comment review**
It is very common, and even recommended, for programmers to include detailed comments on their source code in order to allow for other programmers to better understand why a given decision was taken in coding a given function. Programmers usually do it too when developing large web-based applications. However, comments included inline in HTML code might reveal to a potential attacker internal information that should not be available to them. Sometimes, even source code is commented out since a functionality is no longer required, but this comment is leaked out to the HTML pages returned to the users unintentionally. Comment review should be done in order to determine if any information is being leaked through comments.

**Configuration review** The web server or application server configuration takes an important role in protecting the contents of the site and it must be carefully reviewed in order to spot common configuration mistakes. Obviously, the recommended configuration varies depending on the site policy, and the functionality that should be provided by the server software. In most cases, however, configuration guidelines (either provided by the software vendor or external parties) should be followed in order to determine if the server has been properly secured. It is impossible to generically say how a server should be configured, however, some common guidelines should be taken into account:

- Only enable server modules that are needed for the application. This reduces the attack surface since the server is reduced in size and complexity as software modules are disabled.
- Handle server errors with custom-made pages instead of with the default web server pages. Specifically make sure that any application errors will not be returned to the end-user and that no code is leaked through these since it will help an attacker.
- Make sure that the server software runs with minimised privileges in the operating system.
- Make sure the server software logs properly both legitimate access and errors.
- Make sure that the server is configured to properly handle overloads and prevent Denial of Service attacks. Ensure that the server has been

performance tuned properly.

**Logging**
Logging is an important asset of the security of an application architecture, since it can be used to detect flaws in applications as well as sustained attacks from rogue users. In both cases (server and application logs) several issues should be tested and analysed based on the log contents:

- Are the logs stored in a dedicated server?
- Can log usage generate a Denial of Service condition?
- How are they rotated? Are logs kept for the sufficient time?
- Do the logs contain sensitive information?
- How are logs reviewed? Can administrators use these reviews to detect targeted attacks?
- How are log backups preserved?
- Is the data being logged data validated (min/max length, chars etc) prior to being logged?

## 5.5 Testing for File Extensions Handling

File extensions are commonly used in web servers to easily determine which technologies / languages / plugins must be used to fulfill the web request.

Determining how web servers handle requests corresponding to files having different extensions may help to understand web server behaviour depending on the kind of files we try to access. For example, it can help understand which file extensions are returned as text/plain versus those which cause execution on the server side. The latter are indicative of technologies / languages / plugins which are used by web servers or application servers, and may provide additional insight on how the web application is engineered. For example, a ".pl" extension is usually associated with server-side Perl support.

The following file extensions should NEVER be returned by a web server, since they are related to files which may contain sensitive information, or to files for which there is no reason to be served.

- .asa
- .inc

The following file extensions are related to files which, when accessed, are either displayed or downloaded by the browser. Therefore, files with these extensions must be checked to verify that they are indeed supposed to be served (and are not leftovers), and that they do not contain sensitive information.

- **.java:** No reason to provide access to Java source files
- **.txt:** Text files
- **.zip, .tar, .gz, .tgz, .rar, ...:** (Compressed) archive files
- **.pdf:** PDF documents
- **.doc, .rtf, .xls, .ppt, ...:** Office documents
- **.bak, .old** and other extensions indicative of backup files (for example: for Emacs backup files)

## 5.6 Old, Backup and Unreferenced Files

While most of the files within a web server are directly handled by the server itself it isn't uncommon to find **unreferenced and/or forgotten files** that can be used to obtain important information about either the infrastructure or the credentials. Most common scenarios include the presence of renamed old version of modified files, inclusion files that are loaded into the language of choice and can be downloaded as source, or even automatic or manual backups in form of compressed archives.

An important source of vulnerability lies in **files which have nothing to do with the application**, but are created as a consequence of editing application files, or after creating on-the-fly backup copies, or by leaving in the web tree old files or unreferenced files. Performing in-place editing or other administrative actions on production web servers may inadvertently leave, as a consequence, backup copies.

As a result, these activities generate files which a) are not needed by the application, b) may be handled differently than the original file by the web server.

For example, **if we make a copy of login.asp named login.asp.old**, we are allowing users to download the source code of login.asp; this is because, due to its extension, login.asp.old will be typically served as text/plain, rather than being executed. In other words, accessing login.asp causes the execution of the server-side code of login.asp, while accessing login.asp.old causes the content of login.asp.old (which is, again, server-side code) to be plainly returned to the user – and displayed in the browser. This may pose security risks, since sensitive information may be revealed. Generally, exposing server side code is a bad idea; not only are you unnecessarily exposing business logic, but you may be unknowingly revealing application-related information which may help an attacker, not to mention the fact that there are too many scripts with embedded username/password in clear text (which is a careless and very dangerous practice).

Other causes of unreferenced files are due to design or configuration choices when they allow diverse kind of application- related files such as data files, configuration files, log files, to be **stored in filesystem directories** that can be accessed by the web server. These files have normally no reason to be in a filesystem space which could be accessed via web, since they should be accessed only at the application level, by the application itself (and not by the casual user browsing around!).

**Countermeasures** To guarantee an effective protection strategy, testing should be compounded by a security policy which clearly forbids dangerous practices, such as:

- Editing files in-place on the web server / application server filesystem. This is a particular bad habit, since it is likely to unwillingly generate backup files by the editors. It is amazing to see how often this is done, even in large organizations.
- Check carefully any other activity performed on filesystems exposed by the web server, such as spot administration activities. For example, if you occasionally need to take a snapshot of a couple of directories (which you shouldn't, on a production system...), you may be tempted to zip/tar them first. Be careful not to forget behind those archive files!
- Appropriate configuration management policies should help not to leave around obsolete and unreferenced files.
- Applications should be designed not to create (or rely on) files stored under the web directory trees served by the web server. Data files, log files, configuration files, etc. should be stored in directories not accessible by the web server, to counter the possibility of information disclosure

## 5.7 Infrastructure and Application Admin Interfaces

Administrator interfaces may be present in the application or on the application server to allow certain users to undertake privileged activities on the site. Tests should be undertaken to reveal if and how this privileged functionality can be accessed by an unauthorized or standard user. An application may require an administrator interface to enable a privileged user to access functionality that may make changes to how the site functions. Such changes may include:

- User account provisioning
- Site design and layout
- Data manipultion
- Configuration changes

In many instances, such interfaces are usually implemented with little thought of how to separate them from the normal users of the site.

## 5.8 Testing for HTTP Methods and XST

HTTP offers a number of methods that can be used to perform actions on the web server. Many of theses methods are designed to aid developers in deploying and testing HTTP applications. These HTTP methods can be used for nefarious purposes if the web server is misconfigured. Additionally, Cross Site Tracing (XST), a form of cross site scripting using the servers HTTP TRACE method, is examined.

the Hypertext Transfer Protocol (HTTP) allows several other methods. Here are the following eight methods: **GET, POST, PUT, DELETE, TRACE, HEAD, OPTIONS and CONNECT**

Some of these methods can potentially pose a security risk for a web application, as they allow an attacker to modify the files stored on the web server and, in some scenarios, steal the credentials of legitimate users. More specifically, the methods that should be disabled are the following:

- **PUT:** This method allows a client to upload new files on the web server.
- **DELETE:** This method allows a client to delete a file on the web server.
- **CONNECT:** This method could allow a client to use the web server as a proxy
- **TRACE:** This method simply echoes back to the client whatever string has been sent to the server, and is used mainly for debugging purposes.

# Chapter 6

# Authentication Testing

Authentication is the act of establishing or confirming something (or someone) as authentic, that is, that claims made by or about the thing are true. Authenticating an object may mean confirming its provenance, whereas authenticating a person often consists of verifying her identity. Authentication depends upon one or more authentication factors. In computer security, authentication is the process of attempting to verify the digital identity of the sender of a communication. A common example of such a process is the logon process. Testing the authentication schema means understanding how the authentication process works and using that information to circumvent the authentication mechanism.

## 6.1 Credentials Transport Over An Encrypted Channel

Testing for credentials transport means to verify that the user's authentication data are transferred via an encrypted channel to avoid being intercepted by malicious users. The analysis focuses simply on trying to understand if the data travels unencrypted from the web browser to the server, or if the web application takes the appropriate security measures using a protocol like HTTPS. The HTTPS protocol is built on TLS/SSL to encrypt the data that is transmitted and to ensure that user is being sent towards the desired site. Clearly, the fact that traffic is encrypted does not necessarily mean that it's completely safe. The security also depends on the encryption algorithm used and the robustness of the keys that the application is using, but this particular topic will not be addressed in this section.

Nowadays, the most common example of this issue is the login page of a web application. In order to log into a web site, usually, the user has to fill a simple form that transmits the inserted data with the POST method. What is less obvious is that this data can be passed using the HTTP protocol, that means in a non-secure way, or using HTTPS, which encrypts the data.

It is strongly suggested to use the POST method instead og GET. This is because when the GET method is used, the url that it requests is easily available from, for example, the server logs exposing your sensitive data to information leakage.

https://www.
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## 6.2 User Enumeration

The scope of this test is to verify if it is possible to collect a set of valid usernames by nteracting with the authentication mechanism of the application. This test will be useful for the brute force testing, in which we verify if, given a valid username, it is possible to find the corresponding password. Often, web applications reveal when a username exists on system, either as a consequence of a misconfiguration or as a design decision. For example, sometimes, when we submit wrong credentials, we receive a message that states that either the username is present on the system or the provided password is wrong.

In some cases, we receive a message that reveals if the provided credentials are wrong because an invalid username or an invalid password was used. Sometimes, we can enumerate the existing users by sending a username and an empty password.

**Testing for nonexisting username**
Generally the application should respond with the same error message and length to the different wrong requests. If you notice that the responses are not the same, you should investigate and find out the key that creates a difference between the 2 responses. For example:

Client request: Valid user/wrong password – Server answer:'The password is not correct'

Client request: Wrong user/wrong password – Server answer:'User not recognized'

**URI Probing**
Sometimes a web server responds differently if it receives a request for an existing directory or not. For instance in some portals every user is associated with a directory, if we try to access an existing directory we could receive a web server error. A very common error that we can receive from web server is:

- **403 Forbidden error code**
- **404 Not found error code**
- http://www.foo.com/account1 - we receive from web server: 403 Forbidden
- http://www.foo.com/account2 - we receive from web server: 404 file Not Found

In first case the user exists, but we cannot view the web page, in second case instead the user “account2” doesn't exist. Collecting this information we can enumerate the users.

**Guessing Users**
In some cases the userIDs are created with specific policies of administrator or company. Other possibilities are userIDs associated with credit card numbers, or in general a numbers with a pattern. For example we can view a user with a userID created in sequential order:

CN000100, CN000101, .....

## 6.3 Guessable User Account

Today's web applications typically run on popular open source or commercial software that is installed on servers and requires configuration or customization by the server administrator. In addition, most of today's hardware appliances, i.e., network routers and database servers, offer web-based configuration or administrative interfaces.

In addition, it is typical to find generic accounts, left over from testing or administration, that use common usernames and passwords and are left enabled in the application and its infrastructure. These default username and password combinations are widely known by penetration testers and malicious attackers, who can use them to gain access to various types of custom, open source, or commercial applications.

In addition, weak password policy enforcements seen in many applications allow users to sign up using easy to guess usernames and passwords, and may also not allow password changes to be undertaken.

**The root cause of this problem can be identified as:**

- Inexperienced IT personnel, who are unaware of the importance of changing default passwords on installed infrastructure components.
- Programmers who leave backdoors to easily access and test their application and later forget to remove them.
- Application administrators and users that choose an easy username and password for themselves.
- Applications with built-in, non-removable default accounts with a pre-set username and password.
- Applications which leak information as to the validity of usernames during either authentication attempts, password resets, or account signup.

An additional problem stems from the use of blank passwords, which are simply the result of a lack of security awareness or a desire to simplify administration.

Note that the application being tested may have an account lockout, and multiple password guess attempts with a known username may cause the account to be locked. If it is possible to lock the administrator account, it may be troublesome for the system administrator to reset it

**Approach for testing:**

- Try the following usernames - "admin", "administrator", "root", "system", "guest", "operator", or "super". These are popular among system administrators and are often used. In addition try an empty password or one of the following "password", "pass123", "password123", "admin", or "guest" with the above accounts or any other enumerated accounts.
- Application administrative users are often named after the application or organization.
- When performing a test for a customer, attempt using names of contacts you have received as usernames with any common passwords.
- Viewing the User Registration page may help determine the expected format and length of the application usernames and passwords.
- Attempt using all the above usernames with blank passwords.
- Review the page source and javascript either through a proxy or by viewing the source. Look for any references to users and passwords in the source.
- Look for account names and passwords written in comments in the source code. Also look in backup directories, etc for source code that may contain comments of interest.
- Try to extrapolate from the application how usernames are generated. For example, can a user create their own username or does the system create an account for the user based on some personal information or a predictable sequence?

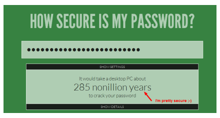
## 6.4 Brute Force

Brute-forcing consists of systematically enumerating all possible candidates for the solution and checking whether each candidate satisfies the problem's statement. Here is several types of bruteforce attacks:

**Dictionary Attack**
Dictionary-based attacks consist of automated scripts and tools that will try to guess username and passwords from a dictionary file. A dictionary file can be tuned and compiled to cover words probably used by the owner of the account that a malicious user is going to attack. The attacker can gather information (via active/passive reconnaissance, competitive intelligence, dumpster diving, social engineering) to understand the user, or build a list of all unique words available on the website.

**Search Attacks**
Search attacks will try to cover all possible combinations of a given character set and a given password length range. This kind of attack is very slow because the space of possible candidates is quite big.

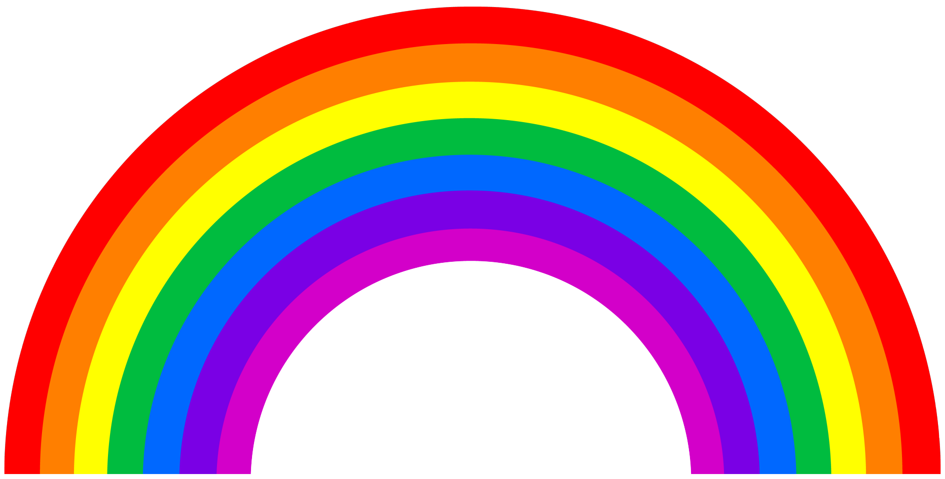
**Rule-based search attacks**
To increase combination space coverage without slowing too much of the process it's suggested to create good rules to generate candidates. For example "John the Ripper" can generate password variations from part of the username or modify through a preconfigured mask words in the input (e.g. 1st round "pen" – 2nd round "p3n" – 3rd round "p3np3n").



••••••••••••••••••••••••

It would take a desktop PC about
285 nonillion years
to crack your password

Nowadays, a common attacks are based on Rainbow Tables, a special type of lookup table used in recovering the plaintext password from a ciphertext generated by a one-way hash. Tables are specific to the hash function they were created for e.g., MD5 tables can only crack MD5 hashes. The more powerful RainbowCrack program was later developed that can generate and use rainbow tables for a variety of character sets and hashing algorithms, including LM hash, MD5, SHA1, etc.



## 6.5 Bypassing Authentication Schema

While most applications require authentication for gaining access to private information or to execute tasks, not every authentication method is able to provide adequate security. There are several methods to bypass the authentication schema in use by a web application:

- Direct page request (forced browsing)
- Parameter Modification
- Session ID Prediction
- SQL Injection

## 6.6 Vulnerable remember password and reset

Most web applications allow users to reset their password if they have forgotten it, usually by sending them a password reset email and/or by asking them to answer one or more ”security questions”.

A great majority of web applications provide a way for users to recover (or reset) their password in case they have forgotten it. The exact procedure varies heavily among different applications, also depending on the required level of security, but the approach is always to use an alternate way of verifying the identity of the user. One of the simplest (and most common) approaches is to ask the user for his/her e-mail address, and send the old password (or a new one) to that address. This scheme is based on the assumption that the user's email has not been compromised and that is secure enough for this goal.

Alternatively (or in addition to that), the application could ask the user to answer one or more ”secret questions”, which are usually chosen by the user among a set of possible ones. The security of this scheme lies in the ability to provide a way for someone to identify themselves to the system with answers to questions that are not easily answerable via personal information lookups. As an example, a very insecure question would be “your mother's maiden name” since that is a piece of information that an attacker could find out without much effort. An example of a better question would be “favorite grade-school teacher” since this would be a much more difficult topic to research about a person whose identity may otherwise already be stolen.

Another common feature that applications use to provide users a convenience, is to cache the password locally in the browser (on the client machine) and having it 'pre-typed' in all subsequent accesses. While this feature can be perceived as extremely friendly for the average user, at the same time it introduces a flaw, as the user account becomes easily accessible to anyone that uses the same machine account.

## 6.7 Browser Cache Management

In this phase, we check that the logout function is properly implemented, and that it is not possible to “reuse” a session after logout. We also check that the application automatically logs out a user when that user has been idle for a certain amount of time, and that no sensitive data remains stored in the browser cache.

**Logout function:**
The first step is to test the presence of the logout function. Check that the application provides a logout button and that this button is present and well visible on all pages that require authentication. A logout button that is not clearly visible, or that is present only on certain pages, poses a security risk, as the user might forget to use it at the end of his/her session. The second step consists in checking what happens to the session tokens when the logout function is invoked. For instance, when cookies are used a proper behavior

is to erase all session cookies, by issuing a new Set-Cookie directive that sets their value to a non-valid one (e.g.: “NULL” or some equivalent value) and, if the cookie is persistent, setting its expiration date in the past, which tells the browser to discard the cookie. The first (and simplest) test at this point consists of logging out and then hitting the ’back’ button of the browser, to check whether we are still authenticated. If we are, it means that the logout function has been implemented insecurely, and that the logout function does not destroy the session IDs. It should be noted that this test only applies to session cookies, and that a persistent cookie that only stores data about some minor user preferences (e.g.: site appearance) and that is not deleted when the user logs out is not to be considered a security risk.

**Timeout logout:**
The most appropriate logout time should be a right balance between security (shorter logout time) and usability (longer logout time) and heavily depends on the criticality of the data handled by the application. A 60 minute logout time for a public forum can be acceptable, but such a long time would be way too much in a home banking application.

**Cached pages:**
Logging out from an application obviously does not clear the browser cache of any sensitive information that might have been stored. Therefore, another test that is to be performed is to check that our application does not leak any critical data into the browser cache. In order to do that, we can use WebScarab and search through the server responses that belong to our session, checking that for every page that contains sensitive information the server instructed the browser not to cache any data. Such a directive can be issued in the HTTP response headers.

**As a general rule, we need to check that:**

- The logout function effectively destroys all session token, or at least renders them unusable
- The server performs proper checks on the session state, disallowing an attacker to replay some previous token.
- A timeout is enforced and it is properly checked by the server. If the server uses an expiration time that is read from a session token that is sent by the client, the token must be cryptographically protected.

## 6.8 Captcha

**CAPTCHA (”Completely Automated Public Turing test to tell Computers and Humans Apart”)** is a type of challenge-response test used by many web applications to ensure that the response is not generated by a computer. CAPTCHA implementations are often vulnerable to various kinds of attacks even if the generated CAPTCHA is unbreakable. This section will help you to identify these kinds of attacks.

Although CAPTCHA is not an authentication control, its use can be very efficient against:

- enumeration attacks (login, registration or password reset forms are often vulnerable to enumeration attacks - without CAPTCHA the attacker can gain valid usernames, phone numbers or any other sensitive information in a short time)
- automated sending of many GET/POST requests in a short time where it is undesirable (e.g., SMS/MMS/email flooding), CAPTCHA provides a rate limiting function
- automated creation/using of the account that should be used only by humans (e.g., creating webmail accounts, stop spamming)
- automated posting to blogs, forums and wikis, whether as a result of commercial promotion, or harassment and vandalism
- any automated attacks that massively gain or misuse sensitive information from the application

These vulnerabilities are quite common in many CAPTCHA implementations:

- generated image CAPTCHA is weak, this can be identified (without any complex computer recognition systems) only by a simple comparison with already broken CAPTCHAs
- generated CAPTCHA questions have a very limited set of possible answers
- the value of decoded CAPTCHA is sent by the client (as a GET parameter or as a hidden field of POST form). This value is often: **1)** encrypted by simple algorithm and can be easily decrypted by observing of multiple decoded CAPTCHA values. **2)** hashed by a weak hash function (e.g., MD5) that can be broken using a rainbow table
- possibility of replay attacks: **1)** the application does not keep track of what ID of CAPTCHA image is sent to the user. Therefore, the attacker can simply obtain an appropriate CAPTCHA image and its ID, solve it, and send the value of the decoded CAPTCHA with its corresponding ID (the ID of a CAPTCHA could be a hash of the decoded CAPTCHA or any unique identifier) **2)** the application does not destroy the session when the correct phrase is entered - by reusing the session ID of a known CAPTCHA it is possible to bypass CAPTCHA protected page

## 6.9 Multiple Factors Authentication

“Multiple Factors Authentication System” (MFAS) is a critical task for the Penetration tester. Generally the aim of a two factor authentication system is to enhance the strength of the authentication process. This goal is achieved by checking an additional factor, or “something you have” as well as “something you know”, making sure that the user holds a hardware device of some kind in addition to the password. The hardware device provided to the user may be able to communicate directly and independently with the authentication infrastructure using an additional communication channel; this particular feature is something known as “separation of channels”. Bruce Schneier in 2005 observed that some years ago “the threats were all passive: eavesdropping and offline password guessing. Today, the threats are more active: phishing and Trojan horses”. Actually the common threats that a MFAS in a Web environment should correctly address include:

1. Weak Credentials (Credentials Password guessing and Password Bruteforcing attacks)
2. Credential Theft (Phishing, Eavesdropping, MITM e.g. Banking from compromised network)
3. Session based attacks (Session Riding, Session Fixation)
4. Trojan and Malware attacks (Banking from compromised clients)
5. Password Reuse (Using the same password for different purposes or operations, e.g. different transactions)

The typical IT professional’s advise is: “If you are not happy with your current authentication solution, just add another authentication factor and it will be all right”.

MFAS solutions add “something you have” to the authentication process. This component is usually a:

- One-time password (OTP) generator token.
- Grid Card, Scratch Card, or any information that only the legitimate user is supposed to have in his wallet
- Crypto devices like USB tokens or smart cards.
- Randomly generated OTPs transmitted through a GSM SMS messages.

## 6.10 Race Conditions

A race condition is a flaw that produces an unexpected result when the timing of actions impact other actions. An example may be seen on a multithreaded application where actions are being performed on the same data. Race conditions, by their very nature, are difficult to test for.

Race conditions may occur when a process is critically or unexpectedly dependent on the sequence or timings of other events. In a web application environment, where multiple requests can be processed at a given time, developers may leave concurrency to be handled by the framework, server, or programming language. The following simplified example illustrates a potential concurrency problem in a transactional web application and relates to a joint savings account in which both users (threads) are logged into the same account and attempting a transfer.

**Account A has 100 credits**

**Account B has 100 credits**

Both User 1 and User 2 want to transfer 10 credits from Account A to Account B. If the transaction was correct the outcome should be:

**Account A has 80 credits**

**Account B has 120 credits**

However, due to concurrency issues, the following result could be obtained:

**User 1 checks the value of Account A (=100 credits)**

**User 2 checks the value of Account A (=100 credits)**

**User 2 takes 10 credits from Account A (=90 credits) and put it in Account B (=110 credits)**

**User 1 takes 10 credits from Account A (Still believed to contain 100 credits) (=90 credits) and puts it into Account B (=120 credits).**

**Result: Account A has 90 credits**

**Account B has 120 credits**

However, testing can be focused on specific transactional areas of the application, where time-of-read to time-of-use of specific data variables could be adversely affected by concurrency issues.

# Chapter 7

# Session Management Testing

At the core of any web-based application is the way in which it maintains state and thereby controls user-interaction with the site. Session Management broadly covers all controls on a user from authentication to leaving the application. HTTP is a stateless protocol, meaning that web servers respond to client requests without linking them to each other. Even simple application logic requires a user's multiple requests to be associated with each other across a "session". Most popular web application environments, such as ASP and PHP, provide developers with built-in session handling routines. Some kind of identification token will typically be issued, which will be referred to as a "Session ID" or Cookie.

What the hell are you doing?!!
Me looking for internet cookies
AGENT-X COMICS
WWW.AGENT-X.COM.AU

## 7.1 Session Management Schema

This describes how to analyse a Session Management Schema, with the goal to understand how the Session Management mechanism has been developed and if it is possible to break it to bypass the user session. It explains how to test the security of session tokens issued to the client's browser: how to reverse engineer a cookie, and how to manipulate cookies to hijack a session.

In order to avoid continuous authentication for each page of a website or service, web applications implement various mechanisms to store and validate credentials for a pre-determined timespan. These mechanisms are known as Session Management and, while they're most important in order to increase the ease of use and user-friendliness of the application.

Cookies are used to implement **session management**. In a nutshell, when a user accesses an application which needs to keep track of the actions and identity of that user across multiple requests, a cookie (or more than one) is generated by the server and sent to the client. The client will then send the cookie back to the server in all following connections until the cookie expires or is destroyed. The data stored in the cookie can provide to the server a large spectrum of information about who the user is, what actions he has performed so far, what his preferences are, etc. therefore providing a state to a stateless protocol like HTTP.

A typical example is provided by an **online shopping cart**. Throughout the session of a user, the application must keep track of his identity, his profile, the products that he has chosen to buy, the quantity, the individual prices, the discounts, etc. Cookies are an efficient way to store and pass this information back and forth (other methods are URL parameters and hidden fields).

Due to the importance of the data that they store, cookies are therefore vital in the overall security of the application. Being able to tamper with cookies may result in hijacking the sessions of legitimate users, gaining higher privileges in an active session, and in general influencing the operations of the application in an unauthorized way.

Usually the main steps of the attack pattern are the following:

- **Cookie collection:** collection of a sufficient number of cookie samples;
- **Cookie reverse engineering:** analysis of the cookie generation algorithm;
- **Cookie manipulation:** forging of a valid cookie in order to perform the attack. This last step might require a large number of attempts, depending on how the cookie is created (cookie brute-force attack).

- **Cookie overflow:** Strictly speaking, this attack has a different nature. Instead of getting a valid cookie, our goal is to overflow a memory area, thereby interfering with the correct behavior of the application and possibly injecting (and remotely executing) malicious code.

### 7.1.1 Cookie Collection and Session Analysis

The first step required in order to manipulate the cookie is obviously to understand how the application creates and manages cookies. For this task, we have to try to answer the following questions:

**How many cookies are used by the application?**
Surf the application. Note when cookies are created. Make a list of received cookies, the page that sets them (with the set-cookie directive), the domain for which they are valid, their value, and their characteristics.

**Which parts of the application generate and/or modify the cookie?**
Surfing the application, find which cookies remain constant and which get modified. What events modify the cookie?

**Which parts of the application require this cookie in order to be accessed and utilized?**
Find out which parts of the application need a cookie. Access a page, then try again without the cookie, or with a modified value of it. Try to map which cookies are used where. A spreadsheet mapping each cookie to the corresponding application parts and the related information can be a valuable output of this phase.

The session tokens (Cookie, SessionID or Hidden Field) themselves should be examined to ensure their quality from a security perspective. They should be tested against criteria such as their randomness, uniqueness, resistance to statistical and cryptographic analysis and information leakage.

### 7.1.2 Token structure and Information Leakage

The first stage is to examine the structure and content of a Session ID provided by the application. A common mistake is to **include specific data** in the Token instead of issuing a generic value and referencing real data at the server side. If the Session ID is **clear-text**, the structure and pertinent data may be immediately obvious as the following:
**Clear-text:** 192.168.100.1:owaspuser:password:15:58
**Hybrid:** owaspuser:192.168.100.1: a7656fafe94dae72b1e1487670148412

If part or the entire token appears to be encoded or hashed, it should be compared to various techniques to check for obvious obfuscation. Having identified the type of obfuscation, it may be possible to decode back to the original data.

```
Hex    3139322E3136382E3130302E313A6F7761737070757365723A70617373776F72643A31353A3538
Base64 MTkyLjE2OC4xMDAuMTpvd2FzcHVzZXI6cGFzc3dvcmQ6MTU6NTg=
MD5    01c2fc4f0a817afd8366689bd29dd40a
```

A simple analysis of the tokens should immediately reveal any obvious patterns. For example, a 32 bit token may include 16 bits of static data and 16 bits of variable data. This may indicate that the first 16 bits represent a fixed attribute of the user – e.g. the username or IP address. If the second 16 bit chunk is incrementing at a regular rate, it may indicate a sequential or even time-based element to the token generation.The following areas should be addressed during the single and multiple Session ID structure testing:

- What parts of the Session ID are static?
- What clear-text confidential information is stored in the Session ID? E.g. usernames/UID, IP addresses
- What easily decoded confidential information is stored?
- What information can be deduced from the structure of the Session ID?
- What portions of the Session ID are static for the same login conditions?
- What obvious patterns are present in the Session ID as a whole, or individual portions?

### 7.1.3 Session ID Predictability and Randomness

Analysis of the variable areas (if any) of the Session ID should be undertaken to establish the existence of any recognizable or predictable patterns. In analyzing Session ID sequences, patterns or cycles, static elements and client dependencies should all be considered as possible contributing elements to the structure and function of the application:

- Are the Session IDs provably random in nature?
- Do the same input conditions produce the same ID on a subsequent run?
- Are the Session IDs provably resistant to statistical or cryptanalysis?
- What elements of the Session IDs are time-linked?
- What portions of the Session IDs are predictable?

- Can the next ID be deduced, given full knowledge of the generation algorithm and previous IDs

### 7.1.4 Cookie Reverse Engineering

Now that we have enumerated the cookies and have a general idea of their use, it is time to have a deeper look at cookies that seem interesting. Which cookies are we interested in? A cookie, in order to provide a secure method of session management, must combine several characteristics, each of which is aimed at protecting the cookie from a different class of attacks. These characteristics are summarized below:

1. **Unpredictability:** a cookie must contain some amount of hard-to-guess data. The harder it is to forge a valid cookie, the harder is to break into legitimate user's session. If an attacker can guess the cookie used in an active session of a legitimate user, he/she will be able to fully impersonate that user (session hijacking). In order to make a cookie unpredictable, random values and/or cryptography can be used.
2. **Tamper resistance:** a cookie must resist malicious attempts of modification. If we receive a cookie like IsAdmin=No, it is trivial to modify it to get administrative rights, unless the application performs a double check (for instance, appending to the cookie an encrypted hash of its value)
3. **Expiration:** a critical cookie must be valid only for an appropriate period of time and must be deleted from disk/memory afterwards, in order to avoid the risk of being replayed. This does not apply to cookies that store non-critical data that needs to be remembered across sessions (e.g., site look-and-feel)
4. **"Secure" flag:** a cookie whose value is critical for the integrity of the session should have this flag enabled in order to allow its transmission only in an encrypted channel to deter eavesdropping.

The approach here is to **collect a sufficient number of instances of a cookie** and start looking for **patterns** in their value. The exact meaning of "sufficient" can vary from a handful of samples, if the cookie generation method is very easy to break, to several thousands, if we need to proceed with some mathematical analysis.

It is important to pay particular attention to the **workflow of the application**, as the state of a session can have a heavy impact on collected cookies: a cookie collected before being authenticated can be very different from a cookie obtained after the authentication.

Another aspect to keep into consideration is **time**: always record the exact time when a cookie has been obtained, when there is the possibility that time plays a role in the value of the cookie (the server could use a timestamp as part of the cookie value).

**Analyzing the collected values**, try to figure out all variables that could have influenced the cookie value and try to vary them one at the time. Passing to the server modified versions of the same cookie can be very helpful in understanding how the application reads and processes the cookie.

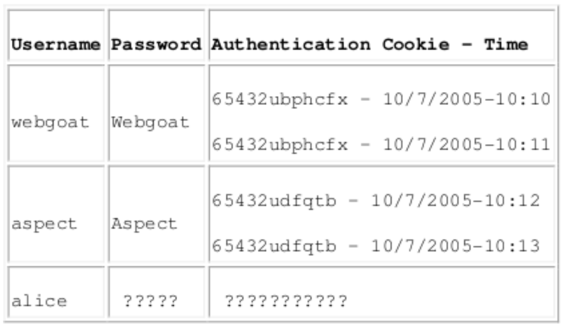
### 7.1.5 Brute Force Attacks

Brute force attacks inevitably lead on from questions relating to predictability and randomness. The variance within the Session IDs must be considered together with application session durations and timeouts. If the variation within the Session IDs is relatively small, and Session ID validity is long, the likelihood of a successful brute-force attack is much higher. A long Session ID (or rather one with a great deal of variance) and a shorter validity period would make it far harder to succeed in a brute force attack.

### 7.1.6 Cookie Manipulation

Once you have squeezed out as much information as possible from the cookie, it is time to start to modify it. The methodologies here heavily depend on the results of the analysis phase, but we can provide some examples:

**Example 1: Guessable Cookie**
An example of a cookie whose value is easy to guess and that can be used to impersonate other users can be found in OWASP WebGoat, in the "Weak Authentication cookie" lesson. In this example, you start with the knowledge of two username/password couples (corresponding to the users 'webgoat' and 'aspect'). The goal is to reverse engineer the cookie creation logic and break into the account of user 'alice'. Authenticating to the application using these known couples, you can collect the corresponding authentication cookies.



| Username | Password | Authentication Cookie - Time |
|---|---|---|
| webgoat | Webgoat | 65432ubphcfx - 10/7/2005-10:10<br>65432ubphcfx - 10/7/2005-10:11 |
| aspect | Aspect | 65432udfqtb - 10/7/2005-10:12<br>65432udfqtb - 10/7/2005-10:13 |
| alice | ????? | ??????????? |

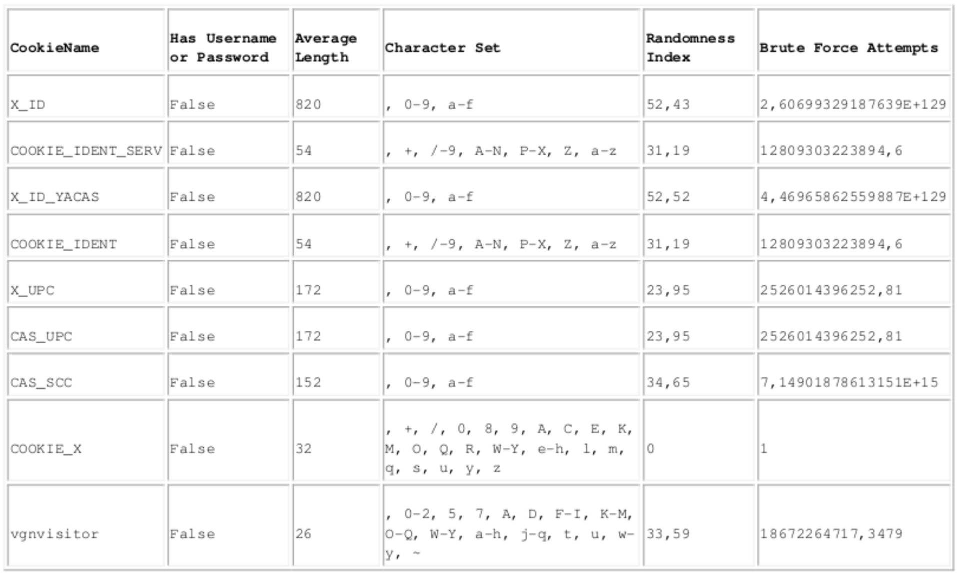
First of all, we can note that the authentication cookie remains constant for the same user across different logons, showing a first critical vulnerability to replay attacks: if we are able to steal a valid cookie (using for example a XSS vulnerability), we can use it to hijack the session of the corresponding user without knowing his/her credentials. Additionally, we note that the "webgoat" and "aspect" cookies have a common part: "65432u". So let's see the letter following each letter in "webgoat":

```
1st char: “w” + 1 =“x”
2nd char: “e” + 1 = “f”
3rd char: “b” + 1 = “c”
4th char: “g” + 1= “h”
5th char: “o” + 1= “p”
6th char: “a” + 1= “b”
7th char: “t” + 1 = “u”
```

We obtain "xfchpbu", which inverted gives us exactly "ubphcfx". The algorithm fits perfectly also for the user 'aspect', so we only have to apply it to user 'alice'. Bingo! Now can the application identifies us as "alice" instead of "webgoat".

### 7.1.7 Brute Force

The use of a brute force attack to find the right authentication cookie, could be a heavy time consuming technique. Foundstone Cookie Digger can help to collect a large number of cookies, giving the average length and the character set of the cookie. In advance, the tool compares the different values of the cookie to check how many characters are changing for every subsequent login. If the cookie values do not remain the same on subsequent logins, Cookie Digger gives the attacker longer periods of time to perform brute force attempts. In the following table we show an example in which we have collected all the cookies from a public site, trying 10 authentication attempts. For every type of cookie collected you have an estimate of all the possible attempts needed to "brute force" the cookie.



| CookieName | Has Username or Password | Average Length | Character Set | Randomness Index | Brute Force Attempts |
|---|---|---|---|---|---|
| X_ID | False | 820 | , 0-9, a-f | 52,43 | 2,60699329187639E+129 |
| COOKIE_IDENT_SERV | False | 54 | , +, /-9, A-N, P-X, Z, a-z | 31,19 | 12809303223894,6 |
| X_ID_YACAS | False | 820 | , 0-9, a-f | 52,52 | 4,46965862559887E+129 |
| COOKIE_IDENT | False | 54 | , +, /-9, A-N, P-X, Z, a-z | 31,19 | 12809303223894,6 |
| X_UPC | False | 172 | , 0-9, a-f | 23,95 | 2526014396252,81 |
| CAS_UPC | False | 172 | , 0-9, a-f | 23,95 | 2526014396252,81 |
| CAS_SCC | False | 152 | , 0-9, a-f | 34,65 | 7,14901878613151E+15 |
| COOKIE_X | False | 32 | , +, /, 0, 8, 9, A, C, E, K, M, O, Q, R, W-Y, e-h, l, m, q, s, u, y, z | 0 | 1 |
| vgnvisitor | False | 26 | , 0-2, 5, 7, A, D, F-I, K-M, O-Q, W-Y, a-h, j-q, t, u, w-y, ~ | 33,59 | 18672264717,3479 |

### 7.1.8 Overflow

Since the cookie value, when received by the server, will be stored in one or more variables, there is always the chance of performing a boundary violation of that variable. Overflowing a cookie can lead to all the outcomes of buffer overflow attacks. A Denial of Service is usually the easiest goal, but the execution of remote code can also be possible. Usually, however, this requires some detailed knowledge about the architecture of the remote system, as any buffer overflow technique is heavily dependent on the underlying operating system and memory management in order to correctly calculate offsets to properly craft and align inserted code.

## 7.2 Cookies Attributes

Cookies are often a key attack vector for malicious users (typically targeting other users) and, as such, the application should always take due diligence to protect cookies. In this section, we will look at how an application can take the necessary precautions when assigning cookies and how to test that these attributes have been correctly configured.

As you can imagine, there are many different types of applications that need to keep track of session state across multiple requests. The primary one that comes to mind would be an online store. As a user adds multiple items to a shopping cart, this data needs to be retained in subsequent requests to the application. Cookies are very commonly used for this task and are set by the application using the Set-Cookie directive in the application's HTTP response, and is usually in a name=value format. Once an application has told the browser to use a particular cookie, the browser will send this cookie in each subsequent request. A cookie can contain data such as items from an online shopping cart, the price of these items, the quantity of these items, personal information, user IDs, etc. D ue to the sensitive nature of information in cookies, they are typically encoded or encrypted in an attempt to protect the information they contain.

Let's take a look at what attributes can be set for a cookie. The following is a list of the attributes that can be set for each cookie and what they mean:

- **Secure** - This attribute tells the browser to only send the cookie if the request is being sent over a secure channel such as HTTPS. If the application can be accessed over both HTTP and HTTPS, then there is the potential that the cookie can be sent in clear text.
- **HttpOnly** - This attribute is used to help prevent attacks such as cross-site scripting, since it does not allow the cookie to be accessed via a client side script such as JavaScript.
- **Domain** - This attribute is used to compare against the domain of the server in which the URL is being requested.
- **Path** - In addition to the domain, the URL path can be specified for which the cookie is valid. If the domain and path match, then the cookie will be sent in the request.
- **Expires** - This attribute is used to set persistent cookies, since the cookie does not expire until the set date is exceeded. This persistent cookie will be used by this browser session and subsequent sessions until the cookie expires. Once the expiration date has exceeded, the browser will delete the cookie.

## 7.3 Session Fixation

## 7.4 Exposed Session Variables

## 7.5 CSRF

CSRF is an attack which forces an end user to execute unwanted actions on a web application in which he/she is currently authenticated. With a little help of **social engineering** (like sending a link via email/chat), an attacker may force the users of a web application to execute actions of the attacker's choosing. A successful CSRF exploit can compromise end user data and operation, when it targets a normal user.

# Chapter 8

# Authorization Testing

# Chapter 9

# Business Logic Testing

Testing for business logic flaws in a multi-functional dynamic web application requires thinking in unconventional ways. This type of vulnerability cannot be detected by a vulnerability scanner and relies upon the skills and creativity of the penetration tester. In addition, this type of vulnerability is usually one of the hardest to detect, but, at the same time, usually one of the most detrimental to the application, if exploited. Attacks on the business logic of an application are dangerous, difficult to detect, and are usually specific to the application being tested.

**Business logic may include:**

- **Business rules** that express business policy (such as channels, location, logistics, prices, and products);
- **Workflows** based on the ordered tasks of passing documents or data from one participant (a person or a software system) to another.

Business logic can have security flaws that allow a user to do something that isn't allowed by the business. For example, if there is a limit on reimbursement of $1000, could an attacker misuse the system to request more money than it is intended? Or, perhaps, users are supposed to do operations in a particular order, but an attacker could invoke them out of sequence. Or can a user make a purchase for a negative amount of money?

**Example 1:**
Setting the quantity of a product on an e-commerce site as a negative number may result in funds being credited to the attacker. The countermeasure to this problem is to implement stronger data validation, as the application permits negative numbers to be entered in the quantity field of the shopping cart.

**Example 2:**
Another more complex example pertains to a commercial financial application that a large institution uses for their business customers. When a user is created by an administrator account, a new userid is associated with this new account. The userids that are created are predictable. For example, if an admin from a fictitious customer of ”Spacely Sprockets” creates two accounts consecutively, their respective userids will be 115 and 116. To make things worse, if two more accounts are created and their respective userids are 117 and 119, then it can be assumed that another company's admin has created a user account for their company with the userid of 118.

**Creating Raw Data for Designing Logical Tests**

- **All application business scenarios:** Checkout, Browse, Product ordering, Search for a product, etc.
- **Workflows**
- **Different user roles:** Manager, Staff, Administrator, CEO, etc.
- **Different groups or departments:** Purchasing, Marketing, Engineering, etc.
- **Access Rights of Various User Roles and Groups**
- **Privilege Table**

Chapter 10

# Data Validation Testing

The most common web application security weakness is the failure to properly validate input coming from the client or environment before using it. Data validation is the task of testing all the possible forms of input, to understand if the application sufficiently validates input data before using it.

## 10.1 Cross Site Scripting (XSS)

In Cross Site Scripting (XSS) testing, we test if it is possible to manipulate the input parameters of the application so that it generates malicious output. We find an XSS vulnerability when the application does not validate our input and creates an output that is under our control.

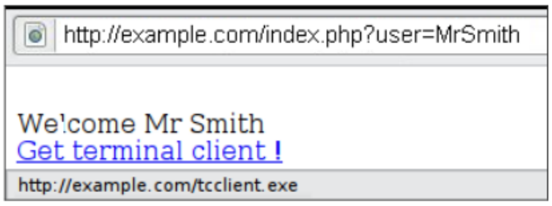
### 10.1.1 Refelcted Cross Site Scripting

Reflected XSS attacks are also known as **type 1 or non-persistent XSS** attacks, and are the most frequent type of XSS attacks found nowadays. When a web application is vulnerable to this type of attack, it will pass unvalidated input sent through requests to the client. The common modus operandi of the attack includes a design step, in which the attacker creates and tests an offending URI, a social engineering step, in which she convinces her victims to load this URI on their browsers, and the eventual execution of the offending code — using the victim's credentials.

One of the important matters about exploiting XSS vulnerabilities is **character encoding**. In some cases, the web server or the web application could not be filtering some encodings of characters, so, for example, the web application might filter out a script tag, but might not filter %3cscript%3e which simply includes another encoding of tags.

**Example:**

consider a site that has a welcome notice " Welcome %username% " and a download link.


http://example.com/index.php?user=MrSmith

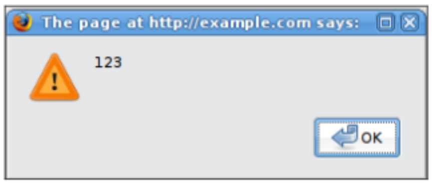
Welcome Mr Smith
Get terminal client !

http://example.com/tcclient.exe

To analyze it, the tester will play with the user variable and try to trigger the vulnerability. Let's try to click on the following link and see what happens:

```
http://example.com/index.php?user=<script>alert(123)</script>
```

If no sanitization is applied this will result in the following popup:


The page at http://example.com says:

123

This indicates that there is an XSS vulnerability and it appears that the tester can execute code of his choice in anybody's browser if he clicks on the tester's link.

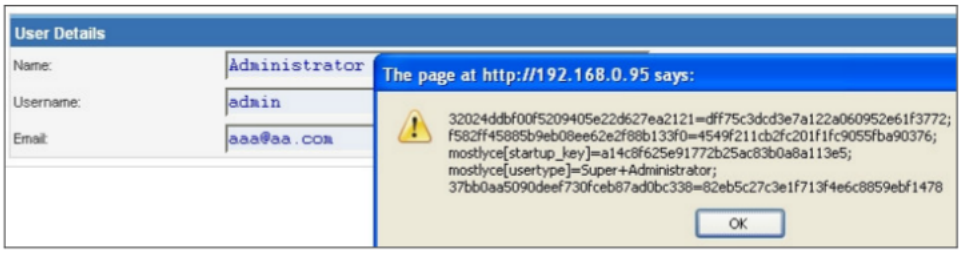
### 10.1.2 Stored Cross Site Scripting

Stored Cross Site Scripting (XSS) is the most dangerous type of Cross Site Scripting. Web applications that allow users to store data are potentially exposed to this type of attack. Stored XSS occurs when a web application gathers input from a user which might be malicious, and then stores that input in a data store for later use. The input that is stored is not correctly filtered. As a consequence, the malicious data will appear to be part of the web site and run within the user's browser under the privileges of the web application. Stored XSS does not need a malicious link to be exploited. A successful exploitation occurs when a user visits a page with a stored XSS.

The first step is to identify all points where user input is stored into the back-end and then displayed by the application. Typical examples of stored user input can be found in: User/Profiles page, shopping cart, file managers, application settings/preferences, etc.

**Example:**

```
aaa@aa.com"><script>alert(document.cookie)</script>
aaa@aa.com%22%3E%3Cscript%3Ealert(document.cookie)%3C%2Fscript%3E
```



User Details

Name: Administrator

Username: admin

Email: aaa@aa.com

The page at http://192.168.0.95 says:

```
32024ddbf00f5209405e22d627ea2121=dff75c3dcd3e7a122a060952e61f3772;
f582ff45885b9eb08ee62e2f88b133f0=4549f211cb2fc201f1fc9055fba90376;
mostlyce[startup_key]=a14c8f625e91772b25ac83b0a8a113e5;
mostlyce[usertype]=Super+Administrator;
37bb0aa5090deef730fceb87ad0bc338=82eb5c27c3e1f713f4e6c8859ebf1478
```

### 10.1.3 DOM based Cross Site Scripting

Not all XSS bugs require the attacker to control the content returned from the server, but can rather abuse poor JavaScript coding practices to achieve the same results. The results are the same as a typical XSS bug, only the means of delivery is different. In comparison to other cross site scripting vulnerabilities (reflected and stored XSS), where an unsanitized parameter is passed by the server, returned to the user and executed in the context of the user's browser, a DOM based cross site scripting vulnerability controls the flow of the code by using elements of the Document Object Model (DOM) along with code crafted by the attacker to change the flow.

An attacker may append # <script>alert('xss')</script>to the affected page URL which would, when executed display the alert box. In this instance, the appended code would not be sent to the server as everything after the # character is not treated as part of the query by the browser but yet as a fragment. In this example the code is immediately executed and an alert of "xss" is displayed in the page. Unlike the more common types of cross site scripting (persistent and non-persistent), in which the code is sent to the server and redisplayed to the user, this is immediately executed in the user's browser.

### 10.1.4 Cross Site Flashing

**RELEVANT?**

## 10.2 SQL Injections (SQLi)

A SQL injection attack consists of insertion or "injection" of a SQL query via the input data from the client to the application. A successful SQL injection exploit can read sensitive data from the database, modify database data (Insert/Update/Delete), execute administration operations on the database (such as shutdown the DBMS), recover the content of a given file existing on the DBMS file system and, in some cases, issue commands to the operating system.

SQL Injection attacks can be divided into the following three classes:

- **Inband:** data is extracted using the same channel that is used to inject the SQL code. This is the most straightforward kind of attack, in which the retrieved data is presented directly in the application web page.
- **Out-of-band:** data is retrieved using a different channel (e.g., an email with the results of the query is generated and sent to the tester).
- **Inferential:** there is no actual transfer of data, but the tester is able to reconstruct the information by sending particular requests and observing the resulting behaviour of the DB Server.
- **Blind:** if the application hides the error details, then the tester must be able to reverse engineer the logic of the original query.

**SQL Injection Detection**
The first step in this test is to understand when our application connects to a DB Server in order to access some data. Typical examples of cases when an application needs to talk to a DB include: Authentication forms, search engines, E-Commerce sites, etc.

The very first test usually consists of adding a single **quote (')** or a **semicolon (;)** to the field under test. The first is used in SQL as a string terminator and, if not filtered by the application, would lead to an incorrect query. The second is used to end a SQL statement and, if it is not filtered, it is also likely to generate an error.

**Union Query SQL Injection**
Another test involves the use of the UNION operator. This operator is used in SQL injections to join a query, purposely forged by the tester, to the original query. The result of the forged query will be joined to the result of the original query, allowing the tester to obtain the values of fields of other tables.

**Blind SQL Injection**
We have pointed out that there is another category of SQL injection, called Blind SQL Injection, in which nothing is known on the outcome of an operation. For example, this behavior happens in cases where the programmer has created a custom error page that does not reveal anything on the structure of the query or on the database. (The page does not return a SQL error, it may just return a HTTP 500).

**Stored Procedure Injections** When using dynamic SQL within a stored procedure, the application must properly sanitize the user input to eliminate the risk of code injection. If not sanitized, the user could enter malicious SQL that will be executed within the stored procedure.

## 10.3 XML Injection

We talk about XML Injection testing when we try to inject an XML doc to the application: if the XML parser fails to make an appropriate data validation the test will results positive. After lookking at a application, the tester will have some information about XML structure, so it will be possible to try to inject XML data and tags (Tag Injection).

**Discovery**
The first step in order to test an application for the presence of a XML Injection vulnerability, consists of trying to insert XML metacharacters. A list of some XML metacharacters is:

- Single quote '
- Double quote "
- Angular pharenthesis ¡ ¿
- Comment tag ¡!– / –¿

- Ampersand &

## 10.4 SSI Injection

Web servers usually give to the developer the possibility of adding small pieces of dynamic code inside static HTML pages, without having to play with full-fledged server-side or client-side languages. This feature is incarnated by the Server-Side Includes (SSI), a very simple extension that can enable an attacker to inject code into HTML pages, or even perform remote code execution.

Putting an SSI directive into a static HTML document is as easy as writing a piece of code like to print out the current time or like to include the content of a file. We could guess if SSI are supported just looking at the content of the target web site we are testing: if it makes use of **.shtml** files then SSI are probably supported, as this extension is used to identify pages containing these directives.

## 10.5 Buffer Overflow

### 10.5.1 Heap Overflow

Heap is a memory segment that is used for storing dynamically allocated data and global variables. Each chunk of memory in heap consists of boundary tags that contain memory management information. When a heap-based buffer is overflown, the control information in these tags is overwritten, and when the heap management routine frees the buffer, a memory address overwrite take place leading to an access violation.

### 10.5.2 Stack Overflow

Stack overflows occur when variable size data is copied into fixed length buffers located on the program stack without any bounds checking. The key to testing an application for stack overflow vulnerabilities is supplying overly large input data as compared to what is expected.

# Chapter 11

# Denial of Service Testing

The most common type of denial of service (DoS) attack is the kind used on a network to make a server unreachable by other valid users. The fundamental concept of a network DoS attack is a malicious user flooding enough traffic to a target machine, that it renders the target incapable of keeping up with the volume of requests it is receiving.

## 11.1 Testing for SQL Wildcard Attacks

SQL Wildcard Attacks are about forcing the underlying database to carry out CPU-intensive queries by using several wildcards. This vulnerability generally exists in search functionalities of web applications. Successful exploitation of this attack will cause Denial of Service. SQL Wildcard attacks might affect all database back-ends but mainly affect SQL Server because the MS SQL Server **LIKE operator** supports extra wildcards.

Craft a query which will not return a result and includes several wildcards. You can use one of the example inputs below. Send this data through the search feature of the application. If the application takes more time generating the result set than a usual search would take, it is vulnerable.

```
'%_[^!_%/%a?F%_D)_(F%)_%([)({}%){()}£$&N%_)$*£()$*R"_)][%](%[x])%a][$*"£$-9]_%'

'%64_[^!_%65/%aa?F%64_D)_(F%64)_%36([)({}%33){()}£$&N%55_)$*£()$*R"_)][%55](%66[x])%ba
][$*"£$-9]_%54' bypasses modsecurity

_[r/a)_ _(r/b)_ _(r-d)_

%n[^n]y[^j]l[^k]d[^l]h[^z]t[^k]b[^q]t[^q][^n]!%

%_[aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa[! -z]@$!_%
```

**How to craft search strings for testing:**

- Queries should return as few results as possible or even none at all. In this way, we can be sure that we actually forced the database server to search all records.
- During the OR combinations, every OR statement should be different, otherwise the database will optimize it. Changing one character is enough.
- In Microsoft SQL Server, every character after an open bracket [ causes unusually long execution time.
- Longer queries will generally result in longer execution time. Craft the longest possible query allowed by the application.
- Starting with % and ending with % will generally cause longer running queries.
- Some search implementations may cache search results. During the testing, every search query should be slightly different to avoid this.
- Performance is always about experimenting. Try different combinations to find the most expensive queries for that particular target system and data.

## 11.2 Locking Customer Accounts

In this test we check whether an attacker can lock valid user accounts by repeatedly attempting to log in with a wrong password. The first test that must be performed is to test that an account does indeed lock after a certain number of failed logins. To determine valid account names, a tester should look to find places where the application discloses the difference between valid and invalid logins. Common places this would occur are:

- **The login page** – Using a known login with a bad password, look at the error message returned to the browser.
- **New account creation page** – If the application allows people to create a new account that includes the ability to choose their account name, it may be possible to discover other accounts in this manner. What happens if you try to create a new account using an account name that is already known to exist?
- **Password reset page** – If the login page also has a function for recovering or resetting a password for a user, look at this function as

well. Does this function give different messages if you attempt to reset or recover an account that does not exist in the system?

## 11.3 Buffer Overflows

Any language where the developer has direct responsibility for managing memory allocation, most notably C and C++, has the potential for a buffer overflow.

The following is a simplified example of vulnerable code in C:

```
void overflow (char *str) {
   char buffer[10];
   strcpy(buffer, str); // Dangerous!
}

int main () {
  char *str = "This is a string that is larger than the buffer of 10";
  overflow(str);
}
```

If this code example were executed, it would cause a segmentation fault and dump core. The reason is that strcpy would try to copy 53 characters into an array of 10 elements only, overwriting adjacent memory locations.

## 11.4 User Input As a Loop Counter

In this test we check whether it is possible to force the application to loop through a code segment that needs high computing resources, in order to decrease its overall performance. Like the previous problem of User Specified Object Allocation, if the user can directly or indirectly assign a value that will be used as a counter in a loop function, this can cause performance problems on the server. The following is an example of vulnerable code in Java:

```
public class MyServlet extends ActionServlet {
   public void doPost(HttpServletRequest request, HttpServletResponse response)
                throws ServletException, IOException {
       . . .
       String [] values = request.getParameterValues("CheckboxField");
      // Process the data without length check for reasonable range - wrong!
       for ( int i=0; i<values.length; i++) {
              // lots of logic to process the request
       }
       . . .
```

As we can see in this simple example, the user has control over the loop counter. If the code inside the loop is very demanding in terms of resources, and an attacker forces it to be executed a very high number of times, this might decrease the performance of the server in handling other requests, causing a DoS condition.

## 11.5 Failure to Relese Resources

With this test, we check that the application properly releases resources (files and/or memory) after they have been used.

Possible examples include:

- An application **locks a file for writing**, and then an exception occurs but does not explicitly close and unlock the file.
- **Memory leaking** in languages where the developer is responsible for memory management such as C and C++.
- Use of **DB connection** objects where the objects are not being freed if an exception is thrown. A number of such repeated requests can cause the application to consume all the DB connections, as the code will still hold the open DB object, never releasing the resource.

The following is an example of vulnerable code in Java. In the example, both the Connection and the CallableStatement should be closed in a finally block.

```
try {
   Connection conn = DAOFactory.getConnection();
   CallableStatement  calStmt = conn.prepareCall(…);
   … …
   calStmt.executeUpdate();
   calStmt.close();
   conn.close();
}  catch (java.sql.SQLException e) {
   throw AcctCreationException (...);
}
```

# Chapter 12

# Web Services Testing

**SOA (Service Orientated Architecture)/Web services applications** are up-and-coming systems which are enabling businesses to interoperate and are growing at an unprecedented rate. Webservice "clients" are generally not user web front-ends but other backend servers. Webservices are exposed to the net like any other service but can be used on HTTP, FTP, SMTP, MQ among other transport protocols. The Web Services Framework utilizes the HTTP protocol (as standard Web Application) in conjunction with XML, SOAP, WSDL and UDDI technologies:

- **The "Web Services Description Language" (WSDL)** is used to describe the interfaces of a service.
- The "Simple Object Access Protocol" (SOAP) provides the means for communication between Web Services and Client Applications with XML and HTTP.
- **"Universal Description, Discovery and Integration" (UDDI)** is used to register and publish Web Services and their characteristics so that they can be found from potential clients.

The vulnerabilities in web services are similar to other vulnerabilities, such as SQL injection, information disclosure, and leakage, but web services also have unique XML/parser related vulnerabilities,

## 12.1 WS Information Gathering

**Zero Knowledge**
Normally you will have a WSDL path to access the Web Service, but if you have zero knowledge about it, you will have to use UDDI to find a specific service.

**WSDL endpoints**
When a tester accesses the WSDL, he can determine an access point and available interfaces for web services. These interfaces or methods take inputs using SOAP over HTTP/HTTPS. If these inputs are not defined well at the source code level, they can be compromised and exploited.

## 12.2 HTTP GET Parameters/REST Testing

Many XML applications are invoked by passing them parameters using HTTP GET queries. These are sometimes known as "REST-style" Web Services **(REST = Representational State Transfer)**. These Web Services can be attacked by passing malicious content on the HTTP GET string.

## 12.3 Replay Testing

This section describes testing replay vulnerabilities of a web service. The threat for a replay attack is that the attacker can assume the identity of a valid user and commit some nefarious act without detection. A replay attack is a "man-in-the-middle" type of attack where a message is intercepted and replayed by an attacker to impersonate the original sender. For web services, as with other types of HTTP traffic, a sniffer such as Ethereal or Wireshark can capture traffic posted to a web service and using a tool like WebScarab, a tester can resend a packet to the target server. An attacker can attempt to resend the original message or change the message in order to compromise the host server.

**NOT FINISHED. IS THE CHAPTER VERY RELEVANT?**

Chapter 13

# AJAX Testing

**AJAX**, an acronym for **Asynchronous JavaScript and XML**, is a web development technique used to create more responsive web applications. It uses a combination of technologies in order to provide an experience that is more like using a desktop application. This is accomplished by using the XMLHttpRequest object and JavaScript to make asynchronous requests to the web server, parsing the responses and then updating the page DOM HTML and CSS.

Testing AJAX applications can be challenging because developers are given a tremendous amount of freedom in how they communicate between the client and the server. In traditional web applications, standard HTML forms submitted via GET or POST requests have an easy-to-understand format, and it is therefore easy to modify or create new well-formed requests. AJAX applications often use different encoding or serialization schemes to submit POST data making it difficult for testing tools to reliably create automated test requests.

Asynchronous Javascript and XML (AJAX) is one of the latest techniques used by web application developers to provide a user experience similar to that of a local application. Since AJAX is still a new technology, there are many security issues that have not yet been fully researched.

**Some of the security issues in AJAX include:**

- Increased attack surface with many more inputs to secure
- Exposed internal functions of the application
- Client access to third-party resources with no built-in security and encoding mechanisms
- Failure to protect authentication information and sessions

- Blurred line between client-side and server-side code, resulting in security mistakes

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