Security Test Engineer Syllabus

Version 1.0

International Software Testing Qualifications Board

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Revision History

Version	Date	Remarks
1.0	09-09-2024	Final version for GA approval

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Acknowledgements

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0. Introduction

0.1. Purpose of this Syllabus

This syllabus forms the basis for the International Software Test Qualification Security Test Engineer. The ISTQB® provides this syllabus as follows:

1. To member boards, to translate into their local language and to accredit training providers. Member boards may adapt the syllabus to their particular language needs and modify the references to adapt to their local publications.
2. To certification bodies, to derive examination questions in their local language adapted to the learning objectives for this syllabus.
3. To training providers, to produce courseware and determine appropriate teaching methods.
4. To certification candidates, to prepare for the certification exam (either as part of a training course or independently).
5. To the international software and systems engineering community, to advance the profession of software and systems test, and as a basis for books and articles.

0.2. Business Outcomes

This section lists the Business Outcomes expected of a candidate who has achieved the Security Test Engineer Specialist Level certification.

A Security Test Engineer Certified Tester can …

STE-BO1	Understand the fundamental security paradigms, and their impact on security testing
STE-BO2	Use and apply appropriate security test techniques and know their strengths and limitations
STE-BO3	Contribute to planning, designing, and executing security tests
STE-BO4	Understand how security testing standards and security best practices can be utilized for security testing
STE-BO5	Adjust and perform security testing activities accordingly to specific organization context
STE-BO6	Adjust and perform security testing activities accordingly to specific development methods and software development lifecycles
STE-BO7	Feed security testing results into an information security management system (ISMS) for an active security risk management

STE-BO8	Collect, evaluate, and aggregate test results, and write a detailed test report which includes all evidence and findings
STE-BO9	Based on a required security testing approach, identify proper requirements for tooling, and assist in the selection of security testing tools

0.3. Examinable Learning Objectives and Cognitive Level of Knowledge

Learning objectives support the business outcomes and are used to create the Certified Tester Security Test Engineer Level exams.

In general, all contents of this syllabus are examinable at a K1 level. That is, the candidate may be asked to recognize, remember, or recall a keyword or concept mentioned in any of the nine chapters. The specific learning objectives levels are shown at the beginning of each chapter, and classified as follows:

- K1: Remember
- K2: Understand
- K3: Apply
- K4: Analyze

Further details and examples of learning objectives are given in Appendix A.

All terms listed as keywords and security testing specific terms (Appendix D) just following the chapter headings shall be examinable (K1), even if they are not explicitly mentioned in the learning objectives.

0.4. The Security Test Engineer Certification Exam

The Security Test Engineer certification exam will be based on this syllabus. The other syllabus Security Test Analyst focuses on designing security tests that are later executed by the Security Test Engineer.

Answers to exam questions may require the use of material based on more than one section of this syllabus. All sections of the syllabus are examinable, except for the Appendices. Standards and books are included as references, but their content is not examinable, beyond what is summarized in the syllabus itself from such standards and books.

Refer to Exam Structures and Rules document for the Security Test Engineer document for further details.

The entry criterion for taking the Security Test Engineer exam is that candidates have an interest in software testing. However, it is recommended that candidates also have at least a minimal background in either software development, software testing or security testing.

Entry Requirement Note: The ISTQB® Foundation Level certificate shall be obtained before taking the Security Test Engineer certification exam.

Completion of an accredited training course is not a pre-requisite for the exam.

0.5. Accreditation

An ISTQB® Member Board may accredit training providers whose course material follows this syllabus. Training providers should obtain accreditation guidelines from the Member Board or body that performs the accreditation. An accredited course is recognized as conforming to this syllabus and is allowed to have an ISTQB® exam as part of the course.

The accreditation guidelines for this syllabus follow the general Accreditation Guidelines published by the Processes Management and Compliance Working Group.

0.6. Handling of Standards

Standards are referenced in the Security Test Engineer Syllabus (e.g., NIST, ISO, etc.). The purpose of these is to provide a framework or to provide a source of additional information if desired by the reader. Please note that the syllabus uses standards as a reference, and they are not intended for examination. Refer to chapter 4 for more information on the use of standards, best practices and norms.

0.7. Level of Detail

The level of detail in this syllabus allows for internationally consistent courses and exams. In order to achieve this goal, the syllabus consists of:

- General instructional objectives describing the intention of the Specialist Level
- A list of terms (keywords) that students must be able to recall
- Learning objectives for each knowledge area, describing the cognitive learning outcomes to be achieved
- A description of the key concepts, including references to recognized sources

The syllabus content is not a description of the entire knowledge area of security testing; it reflects the level of detail to be covered in Security Test Engineer training courses at Specialist level. It focuses on test concepts and techniques that can be applied to all software projects independent of the SDLC employed.

0.8. How this Syllabus is Organized

There are nine chapters with examinable content. The top-level heading for each chapter specifies the training time for the chapter; timing is not provided below chapter level. For accredited training courses, the syllabus requires a minimum of 1290 minutes (about 22 hours) of instruction, distributed across the nine chapters as follows:

- Chapter 1: Security Paradigms – 135 minutes
- Chapter 2: Security Test Techniques - 150 minutes
- Chapter 3: The Security Test Process - 120 minutes

- Chapter 4: Standards and Best Practices - 195 minutes
- Chapter 5: Adjusting to the Organizational Context - 195 minutes
- Chapter 6: Adjusting to Software Development Lifecycle Models - 165 minutes
- Chapter 7: Security Testing as Part of an Information Security Management System - 105 minutes
- Chapter 8: Reporting Test Results - 135 minutes
- Chapter 9: Tooling – 90 minutes

1. Security Paradigms – 135 minutes (K3)

Keywords

availability, confidentiality, information sensitivity, integrity, security audit, security testing, security vulnerability

Learning Objectives for Chapter 1:

1.1 Asset Security Levels

STE-1.1.1 (K2) Explain different security levels of assets and their corresponding protection level

STE-1.1.2 (K2) Explain the relationship between information sensitivity and security testing

1.2 Security Audits

STE-1.2.1 (K2) Describe the role of security testing in the context of security audits

1.3 The Concept of Zero Trust

STE-1.3.1 (K2) Explain the concept of Zero Trust

STE-1.3.2 (K3) Apply Zero Trust concept in Security Testing

1.4 Open-Source Software

STE-1.4.1 (K2) Exemplify the concept of Open-Source Software (OSS) reuse in software development and its impacts on security testing

1.1. Asset Security Levels

An asset is anything that has value to the organization and which, therefore, requires protection. Assets enable organizations to operate business processes and decision making. Every information and data asset are vulnerable and thus should be protected. Assets are objects of information security. Assets can be people, information, software, hardware, functions, processes, and corporate reputation facilities [Chapple 2021]. Some examples:

- software assets: operating system, applications, databases
- information assets: business plans, documentation, invention, pictures, personal records
- hardware assets: computer systems, data storage, data communication devices
- physical assets: facilities.

1.1.1. Assets and Their Corresponding Protection Level

The value of an asset is determined by three pillars of information security (called CIA Triad): confidentiality, integrity, and availability [Stallings18].

Confidentiality seeks to prevent the unauthorized disclosure of information. A loss of confidentiality occurs when information is disclosed to an unauthorized party or system [Stallings18].

Integrity seeks to prevent data from being modified or deleted by an unauthorized party. [Stallings18].

Availability ensures that information is available when needed. [Stallings18].

The three pillars of information security can be classified into the following levels: high, medium, low. The higher the security level is, the higher is the requirement on protection level (safeguards) to be deployed. Safeguards are such as security functions and constraints, personnel security, and the security of physical structures, areas, and devices.

The loss of information confidentiality, integrity, or availability can have an impact on organizational operation, organizational assets, people, customers or even countries.

Asset classification defines asset sensitivity and confidentiality levels. This helps organizations to implement appropriate security controls and protection levels.

If the asset has low sensitivity, a protection level might be set to low security level, and security testing might not be necessary. The pillar suited for this is availability.
An example of low sensitivity can be when the availability of information is of greater importance to the big mass of people with traffic information.

If the asset has medium sensitivity, a protection level will be set to medium security level, and security testing will be necessary. The pillar suited for this is Integrity.
An example of medium sensitivity can be when people need accurate information from trusted sources such as authorities.

If the asset has high sensitivity, a protection level will be set to a high security level, and security testing will be a must. The pillar suited for this is Confidentiality.
An example of high sensitivity can be personal information about employees.

1.1.2. Information Sensitivity and Security Testing

Information sensitivity represents the degree to which information requires protection to ensure its confidentiality, integrity, and availability [NIST Glossary]. Since the consequences of breaching sensitive information can range from minor to disaster, a security test must be done before any breach occurs.

The purpose of security testing is to verify that an implementation protects data and maintains functionality as intended. The more protection an asset needs, the more security actions are needed according to higher protection level and perform tests on the solution.

Security testing helps to identify vulnerabilities, weaknesses, and it checks if proper security controls are implemented.

Security testing cannot guarantee that a system or organization will be free from exploitable defects. Such steps include conducting security testing to achieve the following objectives:

- Evaluating the effectiveness of existing security controls
- Discovering vulnerabilities and weaknesses
- Establishing a Security Test Strategy which includes confirmation tests for tracking the progress of any software patches and long-term upgrades

For the Security Test Engineer, a security risk assessment done from an information sensitivity perspective can be a rich source of information from which security tests can be planned and designed. In addition, a security risk assessment can be used to prioritize security tests such that risks and priorities can be determined and those with the highest levels targeted for more rigorous testing. Risk assessment is only a snapshot at the current point in time and may be based on limited information.

1.2. Security Audits

A security audit is an independent review and examination of the security of a company's information system by controlling how well it conforms to an established set of criteria. The audits are intended to determine the adequacy of system controls, ensure compliance with established security policy and procedures. But also, to detect breaches in security services, and recommend any changes that are indicated for countermeasures [NIST Glossary].

1.2.1. Security Audits and Security Testing

Security audits have the following characteristics:

- They can be performed by internal or external auditors.
- They focus on aspects of an organization’s security processes and controls, such as:
  - Physical components of the information system and the environment in which the information is stored
  - Applications and software, including security patches and configurations
  - Controls for user rights and privileges
  - Network vulnerabilities, including evaluations of the connection between different points within, and outside the organization’s network
  - How employees collect, share, and store information
  - Intrusion detection mechanisms
  - Response plans in the event of a breach
- They are a type of static test technique (described in chapter 2.1.2) which involves manual examination of work products or automated reviews with security audit tools.

- They investigate aspects of an organization's security procedures, policies and controls which are difficult to test dynamically.
- They check the effectiveness of installed security controls and identify where the criteria set by the organization have or have not been achieved at a particular point in time.
- They do not guarantee all vulnerabilities will be found but provide assurance that problem areas are identified and indicate where remedial action is needed.

Security audits should be part of the regular routine. They can be done as:

- One-time assessments for special circumstances, such as when the organization introduces a new software platform or a new integration. A test suite and audits should be done to discover any new risks and/or defects.
- Regularly scheduled audits to verify that security processes and procedures are being followed and that they are adequate for the current business climate and needs.

In some security audit approaches, testing is performed as part of the audit process to determine whether security controls are actually in place and working effectively. However, the scope of a security audit is much larger than security testing.

Security testing and auditing work together. Auditing identifies deficiencies and areas of importance to test. Security testing is the means by which it is proven or disproven that the security controls are actually in place and working effectively.

1.3. The Concept of Zero Trust

1.3.1. What is Zero Trust?

Zero Trust is a security model created out of a collection of concepts and ideas designed to minimize uncertainty in enforcing accurate, least privilege per-request access. Based on the principle of strict access controls and not trusting anyone by default, even everyone already inside the network perimeter.

Zero Trust model embodies a "trust nothing, verify everything, face of a network viewed as compromised" principle.

Increased use of on-line services has resulted in a corresponding increase in vulnerabilities and security attacks. The information is often spread across cloud vendors, which has resulted in perimeter-based security concepts becoming less effective in providing security for organizations, employers, users, and customers. Traditional perimeter-based security trusts anyone and anything inside the network. The problem with this approach is that once an attacker gains access to the network, they have access to all the assets inside.

Using the Zero Trust concept, information systems and services operate under the assumption that their networks are already compromised and that the network has no trusted space. The Zero Trust perspective causes the practice that moves security defenses from static, network-based perimeters to focus on users, assets, and resources [NIST Glossary].

Benefits of Zero Trust [Cloudflare]:

- Reduces an organization's attack surface.
- Minimizes the damage of an attack by restricting the breach to a small area and lowers the cost of recovery.
- Reduces the impact of user credential theft and phishing attacks by requiring multiple authentication factors.

1.3.2. Zero Trust concept in Security Testing

Today's networks are perimeter-less, migrating from flat deployments into dynamic, distributed, and hybrid environments. Organizations adapt to the growing complexity of their environment, which embraces hybrid workplaces, remote workers, interactions with other companies and suppliers, and needs to protect people, devices, applications, networks, and data wherever they might be located. The Zero Trust model with the assumption "trust nothing and always verify, drives the need for a complete paradigm shift in IT security where users, applications, and devices must undergo stringent validations before gaining access to an application or requested resource.

Zero Trust principles [Micro22] [Cloudflare]:

- Continuous monitoring and verification: always verify access for all resources. Logins and connections time out periodically, forcing users and devices to be continuously re-verified.
- "Least privilege access" principle: give users only as much access as they need.
- Multi-factor authentication (MFA): require more than one piece of evidence to authenticate a user; just entering a password is not enough to allow access.
- Security monitoring of device endpoints of the hardware accessing data, such as laptops, workstations, tablets, mobile devices: every remote endpoint can be the entry point for an attack.
- Micro-segmentation: divide security perimeters into small zones to achieve separate access for separate parts of the network.
- No lateral movement within networks without continuous validation: Zero Trust access is segmented and must be re-established periodically; an attacker cannot move across to other microsegments within the network. Once the attacker's presence is detected, the compromised segment or user account can be quarantined, and cut off from further access.
- Protection of the data across the files and content: encryption and access restrictions based on organizational policies.

The concept of Zero-Trust affects how security testing should be managed. This means narrowing down and focusing test cases on Zero Trust security mechanisms. Testing contributes to identifying the following possible weaknesses:

- Network: Zero-Trust microsegments, reducing damage and highlighting violations
  - Test for cross segment traffic both automatically and with user defined microsegments.
- Data: Zero Trust requires that data shall be transmitted in a secure encrypted way.

    - Test for endpoints that expose or store data using unencrypted methods.
- Identity: people, devices and processes can only do what they are allowed to do.
    - Test if people, devices and/or processes have more than the necessary access permissions that may compromise the assets in the network.
    - Check if unauthorized users can access segments of the network resources.
- Devices should run only secure software and be centrally monitored and managed.
    - Test if the device is protected with security software and perform penetration test.
- Limitation of the “blast radius”
    - Test performed on regular basis to show weaknesses to mitigate the risk of potential impact to limit the “blast radius” in case of an external or internal breach occurs.

1.4. Open-Source Software (OSS)

Open-source software is software developed and maintained via open collaboration, and is available, typically at no cost, for anyone to use, change and redistribute however they like.

1.4.1. The concept of OSS and its impacts on security testing

OSS is built on open source-code is open to be, used, modified, and shared by anyone. OSS is often distributed under licenses that comply with the definition of "Open-Source", as provided by the Open-Source Initiative (OSI). Open-source licenses allow software to be freely used, modified, and shared at no cost.

The main benefit of using OSS is code-transparency and the assumption that many volunteer developers have checked it to detect and resolve defects. The assumption is that this openness will lead to more people being involved in quickly identifying vulnerabilities and fixing defects.

However, the fact that these applications, libraries and other reusable objects (the code) are available all over the world presents a challenge, since anyone can update the code and potentially introduce vulnerabilities and attack vectors [Shacklett]. OSS generally has more attack vectors than closed software, because anyone can add intentional backdoors, propagate vulnerabilities through reuse, and exploit publicly disclosed vulnerabilities and human errors. Once a security vulnerability has been published, the users of that version of the software are at risk of an attack.

Using OSS means that every published exploit for a specific component could potentially affect thousands of systems. However, mitigating OSS vulnerabilities is much easier. When source code is available in executable versions, observation, reverse engineering, code reviews, disassembly and exploratory testing may be able to find security vulnerabilities [Stallings18].

The Security Test Engineer performs the following tasks:

- Identification of open-source vulnerabilities
- Performing code reviews as part of a shift-left development approach which targets the detection of defects early in the development process.

When it comes to testing OSS for application security, the Security Test Engineer thinks like a hacker or a malicious user. Test cases capture how an application behaves under different use and misuse scenarios and enables developers to put proper risk mitigations in place.

Code reviews are performed by developers and Security Test Engineers on both the producer's and consumer's sides to identify unsecure code.

Open Web Application Security Project (OWASP) has made automated vulnerability-detection tools available that are for free to open-source projects [OWASP Top 10]. NIST offers guidance for OSS security [NIST SP 800-161].

2. Security Test Techniques - 150 minutes (K3)

Test Keywords

authentication, authorization, firewall, fuzz test, system hardening, destructive testing, non-destructive testing

Information Security Keywords

buffer overflow, defense in depth, honeypot, identification, Intrusion Detection System (IDS), port scanning, vulnerability scanning, Web Application Firewall (WAF)

Learning Objectives for Chapter 2:

2.1 Applying Security test types according to a test context

STE-2.1.1 (K2) Give examples for security test types according to black-box, grey-box, or white-box security context

STE-2.1.2 (K2) Give examples for security test types according to dynamic security testing or static security testing

2.2 Applying Security test types according to a project and technical context

STE-2.2.1 (K3) Apply security test cases, based on a given security test approach, along with identified functional and structural security risks

STE-2.2.2 (K2) Describe how to do recertification testing and reconciliation testing for identities and permissions

STE-2.2.3 (K2) Describe how to test Identity and access management control

STE-2.2.4 (K2) Describe how to test data protection control

STE-2.2.5 (K2) Describe how to test protective technology

2.1. Applying Security Test Types according to a test context

2.1.1. Black-Box, White-Box and Grey-Box Security Testing

Test types for the test basis are classified as black-box testing, grey-box testing and white-box testing [ISTQB FL]. The ISTQB glossary [ISTQB Glossary] defines black-box testing and white-box testing.

Grey-box Security Testing is defined in [NIST] as “a test methodology that assumes some knowledge of the internal structure and implementation detail of the assessment object”. The Security Test Engineer

has access to some information about the software under test (SUT) (e.g., a subset of a network addressing map, a subset of architecture documentation, a user access, an access to an internal machine).

White-box Testing is based on an analysis of the internal structure of the component or system [ISTQB Glossary]. The Security Test Engineer has access to all needed information about the SUT during test:

- Information on the architecture of the SUT
- Information about the source code
- Information on data flows in SUT
- Information about network design and zone structure
- Information about password requirements
- Information about firewall rules
- Information on authentication
- Log storage and management information

Black-box testing is based on an analysis of the specifications of a component system, there is no information about SUT internal structure.

The choice of test techniques is based on the objectives of the security test approach as well as the availability of code. The Security Test Engineer should decide, amongst other things, on the level of depth of the tests and whether to focus on external or internal threats.

2.1.2. Static and Dynamic Security Testing

Both static and dynamic testing are used in security testing to secure the product throughout its entire lifecycle.

Static Security Testing

From the Security Test Engineer's perspective, among the work products that can be reviewed during static security testing are:

- Security risk analysis documents
- Security requirements

When looking for requirements gaps, the following security mechanisms should be considered:

- User Management
- Authentication

- Authorization
- Confidentiality
- Integrity
- Accountability
- Session Management
- Transport Security
- Tiered System Segregation
- Legislative and standards compliance including privacy, government and industry standards
- Technical architectural security documentation
- Source code
- Configuration set up and infrastructure/operational set up

Dynamic Security Testing

Compared to static security testing, the aim of dynamic security testing is to check that the SUT correctly implements and uses security functions as required or specified and that these security functions cannot be bypassed while using the system or application.

Dynamic security testing can be performed by:

- Using black-box testing to evaluate security functions by checking that the results are as expected when particular inputs are submitted.
- Penetration test: Tries to find vulnerabilities that could be exploited.

It is recommended to execute dynamic security testing in the following manner in the following environments, if possible:

- The development environment
  This is the first opportunity for the Security Test Engineer to execute security tests. In this environment, the Security Test Engineer verifies that the security implementation conforms to security requirements, e.g., the correct development of a password creation (control of the minimal size, control the mandatory types of characters, etc.).
- The test and pre-production environment
  Often known as a staging or acceptance test environment, this environment should be as close to the production environment as possible and should contain all the intended security measures that will be applied in the production environment.
- The production environment
  This is the most critical environment. The Security Test Engineer must take care not to disable the SUT and should conduct security audits to keep the system secure. The objective of testing on the production environment is to check that newly discovered and known vulnerabilities are fixed.

Using a Dynamic Application Security Test (DAST) tool enables conditions to be automatically detected that might lead to security vulnerabilities (see chapter 9). DAST can be included in a CI/CD (Continuous Integration/Continuous Delivery) pipeline at the following stages:

- During the test after a build, it functions as a dynamic security scanner to detect security defects
- During production it functions as a vulnerability scanner.

2.2. Applying Security Testing

Security test design can be based on the following sources:

- Regulations, standards, and laws (e.g., new regulation requiring that cars have a security test before approval)
- A completed risk analysis
- Available threat models
- An ad-hoc origin categorization of security risks (see [ISTQB_ATTA_SYL])
- A security test approach
- Security requirements of security functions and mechanisms
- Systems and products in the software development lifecycle
- The security testers own experience and testing skills
- Previous incidents where security was (almost) breached

The following are attributes of a security test that should be considered during security test design:

- Required (mandatory) by regulations or laws
- Prioritized by security test approach, identified security risks and threat models
- Traced to defined security requirements
- Defined according to the intended testers (e.g., developers, functional testers, security testers)
- Defined according to security defect profiles and known vulnerabilities
- Designed to be automated, if applicable
- Destructive or not destructive
- Intrusive or not intrusive (e.g. is the objective to break a system from within or to bring down a system via a DDOS)

The basic workflow of security test design is:

1. Analysis of the security test approach (at project level)
2. Analysis of security risks analysis, threat models and requirements (at project level)
3. Application of security test techniques

In most cases, an efficient security test design is based on a mix of the above sources. Depending on the type of project, it is important to ensure that a security test is performed in every stage of the SUT's software development lifecycle.

2.2.1. Addressing Security Risks in Test Design

A key principle is that the Security Test Engineer should be able to create and implement security test cases based on any identified security risk, security requirement, threat and experience.

Security testing can be based on external security risks in the operational environment (threats on a system or product), a security testing approach, and other sources such as threat models. Security risks can also be seen as functional and structural in nature (i.e., risks due to lack of "security by design").

During the security test case design activity, the Security Test Engineer must identify whether a test is destructive or not destructive. If a test is identified as destructive it must be ensured, that this does not have any negative impacts on other test activities, environments or business.

In the following, common security risks and vulnerabilities at functional and structural level are described, along with appropriate security test techniques.

Functional Security Controls Risks or Vulnerabilities

Tests are designed to verify and validate that controls are in place, that they work correctly, and are effective in detecting and preventing unauthorized actions.

Security test techniques are based on functional security controls requirements and requirements for functional access controls.

Structural Access Controls Risks or Vulnerabilities

Tests for these controls are based on how user rights have been established for data access, functional access and privacy levels. Structural access controls are typically applied by a system administrator, security administrator or database administrator. In some cases, access rights are a configuration option in an application. In other cases, access rights are applied at a system infrastructure level.

Operating System Access Risks or Vulnerabilities

Once access is gained to the operating system, an attacker can control processes, data and network access, which may enable malware to be inserted.

Platform Risks or Vulnerabilities

Each computing platform has its own set of security vulnerabilities.

Security test techniques are based on the Security Test Engineer's experience (e.g., in dealing with vulnerabilities) and the testing of security procedures (e.g., testing maintenance of security condition).

External and internal Threats

Some threats, such as exploiting application or programming language vulnerabilities, can be detected, tested and their impact limited. Internal threats are executed by internal employees, external threats are executed by external people (e.g. hackers).

Security test techniques are based on exploratory testing (e.g., to find potential targets and useful injection points/attack vectors) and the Security Test Engineer's experience.

2.2.2. Recertification testing and reconciliation testing

Understanding Identity and Access Management (IAM) Concerns

The business services provided by organizations are increasing in complexity. They are deployed as "system of systems" and hosted in hybrid environments consisting of elements which are in-house, supplied by partners, supplied by customers, and in the cloud. In this distributed environment, the management of user accounts and user rights is security critical. For example:

- The user must have the right privileges, and no more
- Rights must be revoked after an employee has left the company
- Rights management must be compliant with regulations e.g., General Data Protection Regulation (GDPR)

Identity and Access Management (IAM) is an activity to manage and maintain user accounts and rights by defining who (identity) is willing to access what (role) for a specific resource. IAM lists two sub-processes, which are directly related to security testing:

- Reconciliation
  The comparison and updating of user access, rights and privileged accounts (via change requests and approving chains) to an authoritative trusted identity management database
- Recertification
  Regular reviews of accounts and related rights and privileges to verify if they are still required

Reconciliation is necessary to ensure that all applications accesses are synchronized with the same "trusted source". Levels within the reconciliation process are:

- Full: Comparison of all accounts and user access attributes with the identity and access management system, with the purpose of identifying any differences
- Incremental: Compare only the changes to accounts and rights created, updated, or deleted
- Automatic: Where applications are used which have the ability to schedule automatic comparisons of any security-relevant changes made

Recertification consists in auditing a user account and access privileges to determine if they are still justified, consistent with the organization's internal policies, and compliant with regulations. This involves a continuous audit being performed to ensure that users only have access to what they need and what they have permission for. The assessment could be:

- Manual
  - Extract and collate accounts information
  - Present information
  - Review by managers
- Automated
  - Messages are sent to managers to issue recertification requests
  - This has the advantage of being able to plan audits on a regular basis.

Within a large organization, with systems hosted on a wide range of environments, IAM becomes complex because of the need to manage several applications, each with accesses to be granted and revoked according to a user's movements (arrival, leave, transfer). In some organizations, user accounts and privileges are managed outside of a formal IAM process to save time. This is a critical issue from a security point of view because orphan and unused accounts may result in exploitation by an attacker.

How to Perform Recertification Test and Reconciliation Test for Identities and Permissions Mechanisms

Reconciliation tests and recertification tests must be performed to avoid inconsistencies in user accounts across all the applications which the user has access to. This includes aspects such as login credentials and privileges.

The following test conditions apply:

- New account management
- Modification of account credentials and privileges
- Relocation of an account, including removal of application access and adding access to new applications
- Review of all accounts

Test objectives can be:

- Attempting to switch, change or access another role
- Reviewing the granularity of the roles and the needs behind the permissions given
- Verifying that the identity requirements for user registration are aligned with business and security requirements.

Security test techniques for recertification and reconciliation include:

- Reviewing the documentation for the recertification and reconciliation processes
- Checking if registrations have been vetted by a human prior to provisioning, or whether they are automatically granted when particular criteria have been met
- Verifying, vetting and authorizing of de-provisioning requests
- Checking that account modification is effective
- Performing fuzz testing on possible roles to be sure that the system rejects fuzzed roles
- Reviewing role permissions after gathering all applied modifications.

Note that the [OWASP Test Guide] provides a list of security testing objectives and test techniques related with IAM testing.

2.2.3. Testing Identification, Authentication and Authorization

Understanding the Relationship Between Authentication and Authorization

The sensitive assets of an organization must be protected and must only be accessible to an authorized person who has been previously authenticated. Identification is the very first step of gaining access to a resource. It is the process of asserting an identity.

Authentication is based on the verification of a user identifier and a token to answer the questions:

- Who is the user? (user identifier)
- Is the user really who they pretend to be? (token, such as password or certificate)

Different implementations of authentication mechanisms might be used depending on the level of protection to be given against attacks to hijack an authentication or to steal the token.

Authorization is used for the following purposes:

- To verify if the authenticated user has the rights to perform an action
- To determine which level of access should be allowed to the system resources

There is a strong relation between authentication and authorization based on the principle that a non-authenticated user must not have privileges or have restricted privileges on the system.

The subjects “Authentication, Authorization and Accounting” give rise to the abbreviation “AAA”, which is a framework which helps to control and track access within a computer network. Accounting is the third “A” in the AAA framework which considers the logging, tracking of and activities of a user.

How to Test Authentication and Authorization Mechanisms

Security test techniques (penetration tests) for authentication mechanisms could include:

- Testing for default credentials
- Testing for weak password policy
- Searching for leaked information using Open-Source Intelligence (OSINT)
- Brute force tests using dictionary and rainbow tables (precomputed table of reversed password hashes) to perform attacks which attempt to discover user passwords. The first steps might be, for example, to try “123456”, “111111”, date of birth, name of pet, etc.

Security testing authorization mechanisms

- Security test techniques (penetration tests) for authorization mechanisms could include:

- Exploiting a lack of input filtering, such as injecting SQL requests to be authenticated without any known login/password or causing input buffer overflow to get admin access to a shell session.
- Entering unauthorized URI (../../ in an FTP account) or URL (site address/admin) to try to gain access to sensitive data
- Testing for horizontal and vertical privilege escalation violations.

Note that the [OWASP Test Guide] provides a list of security test techniques for testing authentication and authorization.

2.2.4. Encryption

Understanding Encryption

An encryption mechanism might be used to avoid divulging sensitive data, even if it can be accessed when stored somewhere or exchanged between a client and a server. Encryption is a process of encoding data, (such as plain text), into cyphered data (e.g., cyphered text), using a cryptographic algorithm and “secrets. The secret is shared and only known to the authorized users. The goal is to use encryption that is strong enough to prevent an attacker, who may have succeeded in stealing encrypted data, from recovering the plain text. The use of cryptographic algorithms helps to ensure the confidentiality and the integrity of sensitive assets and to prevent them from being manipulated.

The primary and typically used cryptographic protocol types are:

- Symmetric encryption: based on the use of a shared secret key
- Asymmetric encryption: based on the use of private, public key and certificates, managed via a Public Key Infrastructure.

How to Test Common Encryption Mechanisms

Some cryptographic mechanisms are known to be weak, especially due to the short length of the secret keys. Other mechanisms might be vulnerable because they are either not implemented using best practices, or they embed coding defects (such as buffer overflow).

Tests of encryption mechanisms should include:

- Conformance tests (security requirements-based test) of encryption mechanisms implementation
- Tests for “by-design” vulnerabilities
- Tests for “by-construction” vulnerabilities
- Tests for “by-configuration” vulnerabilities

Note that [OWASP Test Guide] provides a list of security tests for checking weak cryptographic implementations.

2.2.5. Testing protective technologies

Security Test Engineers need to understand the nuances of different lines of defense so that appropriate tests can be designed to verify and validate their effectiveness.

How to Test System Hardening

Testing the effectiveness of system hardening can be accomplished in a variety of ways. System hardening restricts the access of the system to the right roles, opens only the needed services, and monitors application updates. Therefore, to test the effectiveness of system hardening, tests should be designed to detect whether the system hardening measures are working, applied in the right places, and in the right ways. It is also relevant to test for system hardening protections that are too restrictive and might be excessive compared with the security risks.

Some system hardening tests may be based on review or audit, while others may be based on the ability of certain user groups to perform certain actions, or to access certain data.

How to Test Firewalls

Due to the number of protocols, their different options and the complexity of the networks to be protected, it is difficult to configure a firewall efficiently and consistently. Tests for firewall effectiveness should include:

- Performing a configuration audit to check the firewall configuration
- Port scanning to verify if the security policy is well implemented
- Using malformed network packets and network fuzz testing to exploit an unexpected behavior
- Fragmentation attacks to bypass filtering features with the objective of carrying out an attack behind the firewall
- Targeting the WAF by encoding and compressing data or obfuscating it to hide the malicious information that represents the attack. Web Application Firewall Evaluation Criteria [WAFEC] can be used to test the effectiveness of a WAF.

How to Test with Intrusion Detection Tools

Scenario-based detection is based on a known scenario or “signature”. It is easy to bypass because only known attacks are detected. Tests could include the following evasion techniques:

- Character encoding or modification of data (e.g., adding white space, end of lines, etc.)
- IP fragmentation, transmission control protocol (TCP) segmentation
- Encryption, obfuscation
- URL encoding

Behavior-based detection is based on a model of the system behavior and generates a large number of false positive and false negative results. A false negative result is any alert that should have been reported but wasn’t. False negatives can occur when a new attack is developed that an IDS is not aware

of, or perhaps a rule might be written in such a way as to detect some attacks but miss those not specified in the model.

The accuracy of this detection method should be maintained. It is possible for an attacker to deviate from the normal IDS behavior, which results in a new specification for intrusive behavior. Complementary tests should use malicious traffic in order to add new intrusive specifications to be considered as authorized traffic.

How to Test with Malware Scanning Tools

Developers of malware use different techniques to protect their code against reverse-engineering and detection by anti-malware software. Some of these techniques include:

- Exploiting system library functions used by anti-malwares
- String obfuscation to disable the understanding of malicious code behavior
- Code permutation
- Insertion of non-used code
- Dynamic loading of functions and libraries (e.g., to limit the analysis of the malicious code)
- Automatic update of applications

From the functional testing perspective, signature based anti-malware tools could be used to test the effectiveness of anti-malware without developing real malicious pieces of code. Other types of malicious files must be tested regarding the type of applications.

The testing of behavior-based anti-malware is difficult because there is no clear understanding and definition of what malicious behavior is. Ideas for testing can benefit from techniques used by developers of malwares:

- Unsigned execution files that try to use system calls to make system changes
- Trying to launch unusual processes with granted rights
- Attempting to copy execution files in unauthorized locations
- Trying to call unusual system APIs

An important consideration when implementing a new anti-malware application (either based on signature or behavior) or upgrading an existing anti-malware application is to test the implementation on a representative platform before deploying it to the entire organization.

Testing Data Obfuscation

Strict configuration control between the obfuscated data and keys used for the obfuscation is needed to ensure the correct versions of keys are used. Otherwise, the data cannot be un-obfuscated for use.

Since private data could be involved in some tests, data obfuscation may be used for testing purposes to render production data used in a system test environment anonymously. Sensitive data, such as user

information used by a health information system, must not be divulged to testers. Tests could include “brute force” or “dictionary” attacks to attempt to get plain data from obfuscated data

Tests to verify obfuscation of code could include:

- Reverse-engineering of byte code
- Brute force attacks, because some obfuscation mechanisms are vulnerable

3. The Security Test Process - 120 minutes (K3)

Test Keywords

risk, test environment, test plan, test process

Learning Objectives for Chapter 3:

3.1 The Security Test Process

STE-3.1.1 (K2) Explain different activities, tasks, and responsibilities within a security test process

STE-3.1.2 (K2) Understand the key elements and characteristics of an effective security test environment

3.2 Designing security tests

STE-3.2.1 (K2) Give examples for security tests on component test level based on a given code base

STE-3.2.2 (K2) Give examples for security tests on component integration level based on given design specification

STE-3.2.3 (K3) Implement an end-to-end security test which validates one or more security requirements related to one or more business process

3.1. The Security Test Process

Like software testing in general, security testing is also a lifecycle activity. The security test process is dedicated to the security scope and must be aligned with the development process so that appropriate test activities are performed when needed.

Each organization's security risks and needs are unique due to the nature of the organization, the technical environments, the Software Development Lifecycle (SDLC) and the business risks. Therefore, the security test process must be defined and implemented in the context of these factors.

3.1.1. ISTQB Security Test Process

Table 3.1 shows how to take into account and handle security test activities within the ISTQB Fundamental Test Process.

Table 3.1 – ISTQB Security Test Process

ISTQB Security Test Process Activity	Security Test Tasks	Responsibilities
Security Test Planning: The goal is to define an appropriate scope of security testing that corresponds to the security risks.	• Take requirements related to security into account • Define security test objectives • Define the scope of security testing • Identify security test resources • Define test estimates and schedules for security testing • Define security test metrics, entry and exit criteria	A Security Test Analyst is responsible for this task. The Security Test Engineer contributes to the planning by giving estimations of test workload and necessary hardware and software resources

Security Test Analysis:
The goal is to gain understanding of all security test basis items and determine “what to test”.
	• Review items that serve as the test basis of security tests, such as security risk assessments, requirements related to security, security-based architecture and security policies
	• Define security test conditions (“what to test”) based on:
	  • Security objectives
	  • Security risks
	  • Security standards and known vulnerabilities
	  • Defences implemented to secure the system and its data
	  • Scope of security testing
		A Security Test Analyst defines the security testing scope (“what to test”)

Security Test Design: The goal is to identify high level test cases, i.e., “how to test”	• Design security test cases and test suites • Prioritize test cases and test suites • Identify necessary test data either for vulnerability assessment or penetration test • Design security test environment (infrastructure and tools) • Set traceability between test basis and testcases	The Security Test Engineer designs and prioritizes security test cases A Security Test Analyst reviews the Security Test Engineer’s work products

ISTQB Security Test Process Activity	Security Test Tasks	Responsibilities
Security Test Implementation:	• Create security test cases, test scenarios, test scripts or other test specifications • Set up a test environment to perform security test	Security Test Engineer implements the security test cases
Security Test Execution:	• Perform functional suitability security tests • Perform penetration tests • Determine specific security vulnerabilities • Report with detailed information the interim Security Test results to management	The Security Test Engineer executes the security tests, produces detailed test results and communicates identified vulnerabilities as soon as possible
Security Test Monitoring and Control:	• Monitor security test progress and test results • Take corrective actions as needed in response to information gathered	The Security Test Analyst is responsible for this task.
Security Test Completion:	• Ensure all planned security tests have been performed • Analyse security test results to evaluate residual risks • Analyse security testing results to improve system and application development in terms of security • Report (at executive level) the final security test results to management and other authorized parties • Determine if security testing deliverables (reports) have been delivered • Archive test results, test data, and other sensitive information in secure locations	The Security Test Analyst collects all information produced during security test execution and produces a high-level report (executive report)

Where exploratory testing has been conducted, the security test design, security test implementation and security test execution are based on results from previous tests using standard techniques for exploring

such as sniffers, scanners, brute force attacks, and bots. The design, implementation and execution are continuously achieved.

3.1.2. The Security Test Environment

While many forms of test can utilize a test environment located on the same server(s) and network(s) with other systems, security testing has specific risks, even if it is virtualized or container-based. For example, performing destructive tests, contamination of the SUT and corruption or divulgation of data require a segregated approach to building a test environment for security testing. Moreover, in most business domains, regulations require that different environments be used for development, testing and live use. For example, PCI DSS Requirement 6.4.2 states that separation of duties between development, test and live environments is required. Similarly, PCI DSS Requirement 6.4.3 states that production data (live PANs) shall not be used for test or development [PCI DSS chapter 6].

The security test environment must contain all needed functions with which to conduct the tests. These include test management tools, security test tools, test automation tools, and tools for managing tests results and test reports. These are needed to enable discovery of as many vulnerabilities as possible within the allocated time, and with as few false positives and false negatives as possible.

It could therefore be necessary to identify, specify and setup a whole “effective" security test environment to protect other environments such as development, other test environments (e.g., for component test, component integration test, system test and acceptance test), and production. This effectiveness must cover either the fault tolerance regarding destructive security tests or provide protection against malicious systems under test and the productiveness of security tests.

The Security Test Engineer must analyze and estimate the required architecture, the APIs and the behavior of the SUT in order to appreciate the impact of security testing and define the most effective test environment.

The main characteristics of a security test environment include:

1. Isolated at the right level (if necessary):
   Depending on the risks, the SUT is isolated either via filtered communications, or the SUT and all other dependant systems are isolated from other environments (e.g., a merchant website needs a separate payment management service).
2. Target environment representative:
   To obtain the correct behaviour of the SUT, the total environment must reflect the target (production) environment in terms of exact version and configuration.
3. Productive:
   Contains all tools needed to plan, prepare, execute and report security tests, either in a manual or (where possible) automated manner. Security test execution needs specific test tools, as described in chapter 9.
4. Recoverable:
   To repeat tests as needed and to recover from corruption should it occur.

3.2. Designing Security Tests

There are several ways to start with Security Test design (noting that security test case design is described in chapter 2.2). The following approaches are possible:

- Based on risk analysis
- Based on an available threat model
- Based on an ad-hoc origin categorization of security risks (see [ISTQB_ATTA_SYL])
- Based on security requirements, functions and mechanisms
- Based on experience
- Based on reference test guides, such as [OWASP Test Guide]

Threat modeling is a repeated activity in which each security test level must be adjusted regarding the test results of the latest threat modeling results.

Depending on the type of project, it is important to ensure there is a security test planned in every applicable SDLC phase.

3.2.1. Security Test Design at Component Test Level

Test basis for security test design at component test level

Examples of work products that can be used to design security tests include:

- Risk analysis
- Requirements of security functions and mechanisms
- Detailed design of security functions and mechanisms (e.g., APIs, algorithms)
- Data models
- Compilation or building rules
- Compiler information

Test objects for security test design at component test level

Typical test objects for security component test include:

- Components
- Dependencies (for example to third party libraries)
- Source code
- Database modules

Typical defects and failures

Examples of typical defects and failures that can be found at component level include:

- Incorrect code and logic
- Incorrect behavior
- Input filtering weaknesses
- Data flow problems
- Call flow problems
- Unreachable (dead) code
- Deliberately inserted malevolent code (software “bombs”)

Types of security tests at component test level

Static and dynamic tests can be applied at component level.

Depending on the security testing objectives, test basis, test objects and test types, different design approaches and techniques can be used at component test level based on the given code:

- Verifying that implementation of security functions and mechanisms behaves as expected by security requirements

  The design of security tests is based on detailed requirements (detailed specifications and detailed design of the SUT). Well-known test techniques based on specifications should be used, like boundary value, equivalence partitioning, etc. [ISTQB FL]. The Security Test Engineer must link its security test cases to the detailed specifications.

- Building confidence in the quality of security code (secured coding)

  Security test cases must be focused on the application of secure coding rules. The Security Test Engineer must also verify that the development team does not use dangerous code instructions and avoids weaknesses in languages and compilers. Usually, development teams or organizations define their own secure coding best practices based on well-known references, which may be internal of the organization, or external like the OWASP foundation. The Security Test Engineer can design test cases based on these rules that can be considered as non-functional requirements (maintainability and other non-functional quality requirements). These security test cases can be processed automatically using static analysis tools.

  Tests for any component should include assessment of possible violations of the following checklist of best practices: [CERT1]

  - Validate inputs
  - Heed compiler warnings
  - Architect and design for security policies
  - “Keep it simple” principle
  - Default denial, which defines an “allow” list
  - Adherence to the principle of least privilege

- Sanitize data sent to other systems
- Practice defense in depth
- Use effective quality assurance techniques
- Adopt a secure coding standard

Tests performed against such best-practice checklists should include assessments of possible violations of these practices based on a well-documented risk analysis incorporating realistic threat modelling.

- Finding vulnerabilities in the components

After verifying the correct implementation of security functions and mechanisms and that secure coding best practices have been followed, the Security Test Engineer should design security tests with the objective to find vulnerabilities in the developed components, e.g., fuzz testing the API of a component.

The Security Test Engineer can use Static Application Security Test (SAST) or Dynamic Application Security Test (DAST) tools to help finding vulnerabilities.

- Mitigating security risks

All the security tests described above help mitigate the security risks of the developed application or system.

Analysis of security test design at component test level

One key measure of adequacy of security test design involves evaluating coverage. Various coverage measures come from the tests performed.

Coverage may be measured as any of the following:

- Percentage of total number of security requirements tested
- Percentage of specified use/abuse security cases tested
- Percentage of critical security functions, scenarios, or mission threads tested
- Percentage of source code coverage (e.g., to identify dead code or backdoors)
- Percentage of data equivalence partitions coverage (e.g., to detect bad exception catches)
- Number of security findings
- Efficiency of security tools used (e.g., false positives, false negatives).

3.2.2. Security Test Design at Component Integration Level

According to ISTQB Foundation Syllabus [ISTQB FL], there are two different levels of integration: component integration test and system integration test. Components and/or subsystems to be integrated can come from a variety of different sources, such as another team in the same company, a subcontractor, a commercial off-the-shelf (COTS) product, a service already available in the cloud or an open-source service. During these integration activities to ultimately build the full target system, the possibilities for security breaches are not simply the summation of the vulnerabilities in each of the

components considered separately. Instead, new attack vectors become possible due to interactions between components within the larger system and because of organizational elements.

However, some interactions between components might mitigate or block possible sequences leading to security breaches.

Component integration test can demonstrate the complexity of a system design and the stability of its behavior. The component integration test approach (e.g., top-down or bottom-up) can affect the timing of revealing security concerns or the need for additional security-specific tests.

As with component tests, component integration tests should be designed on the basis of well-documented risk analysis incorporating realistic threat modelling. As separate components are integrated together, note that “scaffolding” or “mocking” in the form of stubs and drivers may be necessary to test incomplete paths through a system during integration. As more implemented components are added to the system this scaffolding/mocking is incrementally removed, allowing for fuller assessment of functional suitability as well as opening up new paths to vulnerabilities that might be exploited.

According to the level of trust in the components / subsystems to be integrated, the security test design at component integration test level should include:

- Security tests of the secure global architecture based on a technical architecture document
- Security tests of configured integrated flows (e.g., authorized or not, level of confidentiality, integrity and availability)
- Security tests of integrated APIs (e.g., to detect security issues at APIs levels due to lack of controls and lack of knowledge of these APIs)
- Security tests regarding the security configuration of integration components (e.g., filtering access of a component by another since unsigned components should have limited access)
- Verification that integrated components which are external, open-source or commercial are free of vulnerabilities

At component integration level, coverage may be measured as any of the following:

- Percentage of used/tested APIs
- Percentage of tested interactions between components / subsystems based on technical architecture document
- Numbers of security findings
- Number of security findings that should have been found at previous test level
- Efficiency of security tools used (e.g., false positives, false negatives)

3.2.3. System Testing and Acceptance Testing

Security System Test

This is the test level during which the implementation of security requirements is tested to ensure that they function as expected. System security testing activities include performing security tests in some

approximation of the final target environment, necessitating that a transition takes place away from the development environment in which the preceding implementation and integration activities have occurred.

The Role of Security Testing in System Testing

System Security testing is the first opportunity for exercising the end-to-end functionality of the fully integrated components. Although usually done in a development environment, it should reveal emergent properties of the system that would not have been observed before integration was completed. Security requirements are typically considered in conjunction with one of the more functional requirements.

The objective of Security Test in system test is to test:

- all the security requirements implemented the security functions in a test environment representing the operational one
- that the operational configuration is secured

Security Acceptance Testing

This is the final level of testing during which users, or their representatives build confidence that the system is able to deliver the necessary capabilities in the target environment in a secure manner. The security acceptance test objectives include security testing against the security-related acceptance criteria established for the system. Typically, the security-related acceptance criteria focus on functional security controls and processes. The security acceptance test activities may include:

- Installing the system into a pre-production environment
- Performing security tests based on acceptance criteria
- Determining acceptance based on security test results

It should be noted that both system test and acceptance test are essentially black-box tests without regard for the internal structure or behavior of components within the overall system.

The Role of Security Testing in Acceptance Testing

Acceptance testing is distinguished from system testing in that it is performed in a realistic operational environment. It finally places the system in the setting where external threat agents would be seeking to find weaknesses on a day-to-day basis. These tests allow for reasonable evaluation of performance efficiency and other behaviors based on interactions through external interfaces.

Acceptance testing should ideally validate that the initial project goals have been delivered and that documented security acceptance criteria are met. This is accomplished by designing and performing tests to validate security processes / scenarios such as rights control, authorizations management and firewalls filtering.

The best time to define and document acceptance criteria is before system development or purchase. In the context of security testing, the acceptance criteria may be global in nature. For example, there could be acceptance criteria that specify what is acceptable in terms of overall system security. This would

include criteria that are applied to all system functions, such as user authentication, user rights, encryption levels and audit trails.

Analysis of Security Test design at the Acceptance Level

At acceptance level, coverage may be measured as the following:

- Percentage of tested security processes / scenarios
- Number of security findings that should have been found at previous test level with their severity
- Efficiency of security tools used (e.g., false positives, false negatives).
- Percentage of tested security requirements
- Percentage of tested operational secure configuration items

4. Standards and Best Practices - 195 minutes (K3)

Test Keywords

best practices, Common Attack Pattern Enumeration and Classification (CAPEC), Common Vulnerabilities and Exposures (CVE), Common Vulnerability Scoring System (CVSS), CWE (Common Weakness Enumeration), CWSS (Common Weakness Scoring System), standards, stride

Learning Objectives for Chapter 4:

4.1 Introduction to standards and best practices

STE-4.1.1 (K3) Explain different sources of test standards and best practices and their applicability

4.2 Apply important standards and best practices for security testing

STE-4.2.1 (K3) Apply the concept of OWASP, CVE and CVSS and how to leverage it for security testing

4.3 Feil! Fant ikke referansekilden.

STE-4.3.1 (K2) Explain Pros and Cons of test oracles used for security testing

STE-4.3.2 (K3) Understand Pros and Cons of using security best practices and standards

4.1. Introduction to Standards and Best Practices

Standards and best practices of various types provide visibility into professional consensus and regulatory obligations. A consensus-based standard represents the considered opinion of a knowledgeable body of experts.

Even if often used as synonyms, there are big differences between standards and best practices, which are explained in the following subsections. The differences have a significant impact on the selection process and possible use cases for utilizing them.

4.1.1. Standards

Standards are defined as “a document, established by a consensus of subject matter experts and approved by a recognized body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons.” ([ISO_Web_21], and Appendix D).

There are several levels of a “recognized body”, which allows for a distinction between different types of standards. One of the highest level of recognition of standards is represented worldwide by the International Standard Organization (ISO). Usually, each country that is part of the World Trade Organization (WTO), has its own local representation. Standards have the highest level of recognition for a Security Test Engineer because of their high level of maturity. However, this maturity has the

disadvantage of taking a lot of time to complete, and often results in standards with a very reactive character.

Recognized bodies may create their own standards. These can be categorized as industry standards, de facto standards and manufacturer specific standards:

- Industry standards:
  These have established over years of application in many contexts and have demonstrated some added values by solving a particular problem. The Internet Engineering Task Force (IETF) is an important player in creating standards at this level. They make standards based on the combined engineering judgement of their participants and their real-world experience in implementing and deploying their specification [IETF23].
- De facto standards:
  These often have their roots in industry standards. Since their coverage and acceptance is high, they even fulfill many of the criteria to be considered at the highest level of standards. A good example is the TCP protocol, that was established as an industry standard, but is today considered to be a de facto standard [IETF23].
- Manufacturer-specific standards:
  Some clients/companies have learned that there is added value in following the proprietary specifications of a specific manufacturer.

In real-life this clear classification might have many fuzzy overlaps and it is not always simple to do a clear classification of a given standard.

Best Practices

Best practices and their recognized body are less formally organized. Regarding Gartner's Glossary [Gart21], best practices stand for a "group of tasks that optimizes the efficiency (cost and risk) or effectiveness (service level) of the business discipline or process to which it contributes. It must be implementable, replicable, transferable and adaptable across industries." On this level, every group of experts, even if they are all working within the same context, can create their own set of best practices.

4.2. Apply important Standards and Best Practices for Security Testing

Several standards and best practices exist for the discipline of IT security testing. Due to the high level of requirements to be fulfilled in order to be considered a standard, their creation and maintenance is much slower than for best practices. This allows for deep recognition within in industry and includes many feedback loops for improvement. However, this impedes the quick adjustment to new trends and risks. In comparison, best practices have a high overall performance efficiency, but it is more difficult for them to become well known, to achieve a high level of coverage, and to be empowered by practical evidence.

4.2.1. Industry Standards for Security Testing

The most established standard in IT-Security is the series of ISO 27000. The [ISO 27001] standard is internationally accepted and entitled "Information technology — Security techniques — Information

security management systems — Overview and vocabulary". The focus of this standard is on information security management, i.e., to identify risks, to evaluate them and to manage them through information security controls. All these activities are combined in an information security management system (ISMS) which is the overall core of the ISO 27000 standard. The standard is broad in scope and focuses on the general way in which an organization should assess their risks, contrast them with their specific needs and deal with the most relevant risks. The core standard can be applied to all organizations.

The 27000 series consists of more than 40 individual standards, which can be classified into the following:

- Main standard: General overview and introduction to an ISMS (starting from 27000 to 27005)
- Topic specific standards to cover specific topics like service management ISO 27013 and public cloud provider ISO 27017 (see for example [ITGOV23a])
- Domain specific standards to focus specific domains like telecommunication providers ISO 27011 and financial industry ISO 27015 (see for example [ITGOV23a])

The most commonly used standards that apply to the context of security testing and cover the relevant test objects and test conditions which the Security Test Engineer should consider, are the following:

- ISO 27000: This part explains the overall structure of the ISO 27000 series and gives an introduction to an ISMS and the role security testing can play.
- ISO 27001: This is the most used standard, as it lists a comprehensive set of recommendations and security controls to structure and build an individual ISMS. Its focus is to establish a comprehensive view on the relevant assets within an organization, their exposed risks and possible mitigations. [ISO 27001]
- ISO 27001, Appendix A:
  The most important part of ISO 27001 for a Security Test Engineer is presented in this appendix. It lists security controls for different aspects such as access control, disaster recovery and network security. Each of these controls, if applied in a specific context, are important inputs for a Security Test Engineer, as it's their task to measure the effectiveness of a security control. [Cald11]
- ISO 27002: This standard takes the generic security controls from ISO 27001 and gives some more guidance on how to apply them in practice and how to specify them in more detail for a specific context. [Cald11]
- ISO 27003: This standard supports an organization to create a plan to establish an ISMS based on ISO 27001.

De facto Standards for Security Test

There are many de facto standards which can be leveraged by a Security Test Engineer. One of the most important series of de facto standards stems from the MITRE corporation, even though its main business is not to generate standards. MITRE is a private, not-for-profit company which provides engineering and technical guidance for the federal US government. The most important sponsors of MITRE are the

Department of Defense, the Federal Aviation Administration and the Department of Homeland Security [MITRE21].

For the area of Security Testing, MITRE hosts and maintains the following well-known standards that are valuable added value for the Security Test Engineer:

Common Attack Pattern Enumeration and Classification (CAPEC™)

CAPEC™ provides a publicly available catalogue of common attack patterns. The idea is to get a better understanding of how adversaries exploit weaknesses in applications and other cyber-enabled capabilities. Attack patterns are based on software design patterns for attackers. Two typical entry attack patterns are SQL injection (CAPEC-66) and relative path traversal (CAPEC-139) [CAPEC21].

CAPEC provides different views on its data sets. The most relevant ones are:

- Domain of attack, such as “Software”, “Social Engineering” and “Physical Security”. On the highest level CAPEC lists 9 domains of attack.
- Mechanisms of attack, such as “inject unexpected items” and “manipulate system resources”. On the highest level CAPEC lists 6 mechanisms of attack.

Each test object a Security Test Engineer tests should be locatable within this catalogue. Often CAPEC is the starting point to get an initial overview of possible attacks that might be relevant for a given system.

The following MITRE standards are used for further refinement for effective security testing:

Common Weakness Enumeration (CWE)

CWE is a list of software/hardware weaknesses. Usually, each Common Attack pattern has one or more weaknesses usable for leveraging a CAPAC attack pattern [CWE21]. CWE uses the concept of views, the most commonly used of which are:

- Software-Development, such as “API”, “Bad Coding Practices” and “Permission Issues”. On the highest level, CWE lists 40 software development assets.
- Hardware Design, such as “Memory and storage issues”, “Core and compute issues” and “Peripherals, On-Chip fabric, and Interface I/O Problems”. On the highest level CWE lists 12 hardware design assets.

Each common weakness is an effective starting point for a Security Test Engineer to test whether the underlying attack pattern can be exploited.

Open Web Application Security Project (OWASP)

It is important to realize that CWE and OWASP [OWASP21] strongly overlap and that they both list common weaknesses. OWASP is well known for publishing its OWASP Top-10 ranking.

Common Weakness Scoring System (CWSS)

The more common a weakness becomes, the more important it gets to have a prioritization scheme in place. CWSS provides a mechanism for prioritizing software weaknesses in a consistent, flexible, open manner [CWSS21]. The prioritization is calculated by three sets of metrics:

- Base Finding Metric Group:
  The inherent risk of the weakness, confidence in the accuracy of the finding, and strength of controls is calculated. A typical metric is “technical impact”, that ranges from complete control over a system to no technical impact.
- Attack Surface Metric Group:
  This calculates the barriers that an attacker must overcome in order to exploit the weakness. A typical metric is “required privilege”, that ranges from no privileges required to administrator privileges
- Environmental Metric Group:
  This calculates the characteristics of the weaknesses that are specific to a particular environment or operational context. A typical metric is “Business impact”, that ranges from “the business could fail” to “no impact”.

By using specific, predefined weights, all of these metrics can be aggregated into one overall CWSS value for one specific weakness. CWSS can handle unknown metrics by default values or by defining/focusing on an individual metric subset. In addition, many metrics of the Base Finding Metric Group can automatically be calculated by a static analysis tool.

Common Vulnerability Scoring System (CVSS)

A very similar prioritization mechanism to CWSS is CVSS [CVSS21], which follows a very similar approach, but assumes an existing, deployed vulnerability (see CVE below).

Common Vulnerabilities and Exposures (CVE)

CVE is a database of publicly disclosed information about security issues [CVE21]. A CVE number uniquely identifies a particular vulnerability from the list. CVE helps because it provides a standardized identifier for a given vulnerability or exposure within a specific system. If a system is affected by a specific CVE, this vulnerability is a specific instance of a common weakness (CWE) that can be used to do a specific attack (CAPEC). New entries within the CVE repository usually originate from the daily work of Security Test Engineers. If they identify a new vulnerability unknown to CVE, they can publish it at CVE to engage the security community to identify counter measures.

Best Practices for Security Test

Best Practices only need to achieve very low formal criteria to be considered as Best Practices. Many best practices may fail after some time if they don’t help, some will fade away because of missing publication/marketing, but a few might improve their maturity on their way to being considered for a standard.

One typical mature best practice that is still used today is the Stride methodology which was invented by Microsoft [Micro09]. Stride allows for systematic threat modeling from an attacker perspective. The term itself is an acronym for six threat categories, which classifies potential threats: **s**poofing, **t**ampering, **r**epudiation, **i**nformation disclosure, **d**enial of service and **e**levation of privilege.

- Spoofing identity, i.e., to claim within a system to be a person or system you are not
- Tampering with data, i.e., the malicious modification of data
- Repudiation, i.e., threats that take aim at auditing and tracing, ensuring that bad behaviours cannot be proven
- Information Disclosure, i.e., the exposure of information to individuals who are not supposed to have access to it
- Denial of Service, i.e., to deny service to valid users
- Elevation of Privilege, i.e., an unprivileged user gains privileged access.

Generally, Stride is used to support developers to consider threats during the design activity and to close identified gaps. The Security Test Engineer can use the same approach to focus on testing.

4.3. Leveraging Standards and Best Practices

There are many use cases possible for leveraging standards and best practices. In general, these use cases can be divided into mandatory applications of them and voluntary applications of them.

4.3.1. Mandatory Application

In this type of use cases, standards and best practices are mandatory for another party:

- Security requirements for contracts:
  Best practices are an effective way to specify security requirements for software development, especially those that are delegated to a third party. Instead of listing all specific requirements, only the fulfillment of a specific standard is required, which implies fulfilling all security advice and requirements contained.
- Security requirements as regulation:
  Even regulative institutions (e.g., in the banking domain) often use standards and best practices requirements, which are easy to manage.

4.3.2. Voluntary Application

In this type of use case, the application of specific standards and best practices is an explicit decision by the management to generate the following added value:

- Establishing a high level of security by reusing established security knowledge stored in existing standards and best practices
- Well-known evidence to demonstrate awareness for security
- General marketing purpose and creation of unique selling points in a competitive business area.

4.3.3. Test Oracles Extracted from Standards and Best Practices

A general use case for leveraging standards and best practices that is independent from being mandatory or voluntary is the notion of using powerful test oracles. At application level the test oracle is usually the security requirement section in the specification. On lower levels, e.g., included libraries, underlying operating system, network traffic, standards and best practices can quickly be utilized. Especially the more volatile type of best practices might list many known vulnerabilities for a given system and determine expected results to be used as evidence of being secure or insecure. This is a powerful tool for Security Test Engineers, as they only have to define corresponding low-level test cases, execute them, and then compare the computed results with the ones listed in the best practice.

4.3.4. Pros and Cons of Leveraging Standards and Best Practices

Leveraging standards and best practices for Security Test has many advantages, but there might also be some negative aspects to be considered carefully for a specific context. In general, the following advantages apply to leveraging standards and best practices:

- Consistent terminology:
  In IT there are many marketing-driven terms, synonyms and phrases without a clear definition and without a clear distinction between them. Standards and sometimes even Best Practices can support the clarification of terminology.
- Reusing expert knowledge:
  Defining standards and best practices can be a time-consuming task which is usually done by security experts. Their knowledge can be captured and re-used in standards and best practices.
- Benchmark and completeness double-check:
  If an enterprise uses its own specific Security Test framework, existing standards and best practices can be used as a benchmark and used to check for the completeness of their solutions.
- Improved commitment between supplier and client.
  The more established and recognized a standard or best practice is, the more efficiently it can be used as the basis for commitment between consumer (what they want to have) and supplier (what they have to do).
- Easy communication about the achieved level of security:
  If a company uses its own set of Security Tests without any external reference, it might be difficult to demonstrate their effectiveness. Using standards and best practices helps achieve an overall positive attitude and simplifies communication dramatically.

However, some negative aspects are possible when using standards and best practices for Security Testing:

- Wrong selection:
  There are many available standards and best practices, each having their own focus and necessary preconditions to be applicable. Leveraging the wrong source not only reduces the

impact of achieving better security, but might even decrease the resources available to be spent on security.

- Best practices within a wrong specific context:
  Whereas most standards have achieved high quality due to their long creation processes and long feedback cycles, best practices may come and go on a short-term basis. Especially when initially proposed, their correctness and added value is not always clear and might not have a strong link to the specific context. The use of a new, proprietary best practice which has not yet shown any evidence of creating any added value might even decrease the level of security.
- Missing customization:
  Frequently, standards and best practices define certain parameters that have to be fulfilled to be applicable in a specific context. If this is omitted or not done properly their application might yield limited added value.
- Commodity considerations:
  The more established and popular a standard or best practice becomes, the less it can be used to create uniqueness compared to other competitive products (if required).
- Operational Blindness:
  Flaws or the rise of new threads could lead to lower attention if standards or best practices are not adopted timely.

5. Adjusting To the Organizational Context - 195 minutes (K4)

Test Keywords

privilege escalation, security policy, security service, social engineering

Information Security Keywords

regulation, rootkit

Learning Objectives for Chapter 5:

5.1 The Impact of Organizational Structures in the Context of Security Test

STE-5.1.1 **(**K3) Analyze a given organizational context and determine which specific aspects to consider for security testing

5.2 The Impact of regulations on security policies and how to test them

STE-5.2.1 (K3) Analyze the impact of regulations on security policies and how to test them

5.3 Analyze an Attack Scenario

STE-5.3.1 (K4) Analyze an attack scenario (attack performed and discovered) and identify possible sources and motivation of the attack

5.1. The Impact of Organizational Structures in the Context of Security Testing

Information security is not only achieved by securing the infrastructure and relying on technologically implemented measures. In addition, the people and processes of a company must be considered as well. People often become a victim of social engineering attacks and important processes (such as a defined emergency response) can be either missing or can be improper in their implementation. A Security Test Engineer therefore needs also to cover these aspects during a security test, because they both affect the information security of a company. People have a defined role. Depending on their role, they are involved in different processes. Roles and processes are usually strongly dependent on the organizational structure.

One such organizational structure can be broadly classified into the following three types:

- Functional structure: organized by common functions, such as production, marketing, human resources, IT and accounting
- Divisional structure: Organized as a collection of functions which produce a product
- Matrix structure: employees are grouped by both function and product simultaneously

The way in which these organizational structure impact information flow and the implementation of administrative decisions is considered below:

- In a functionally structured organization, information needs to be exchanged between the different departments across the company and administrative decisions are implemented directly in a top-down approach from the management to the whole company
- Divisionally structured organizations add an administrative layer at the top of each division, and therefore decisions can affect only a single division. In addition, the information flow between divisions is slightly reduced, even though the divisions often contain similar departments, such as development
- Matrix structures try to unite both aspects. They are functionally separated, but also adopt a product-based focus without adding the separate administrative layer found in divisional structures. However, there is a higher risk of conflicts since decisions can be made from both a product perspective and also from a purely administrative perspective.

Bringing this to the context of Security Testing, a tester should be aware of the organizational structure for the following reasons:

1. The test results of a security test will be influenced by the department that has ordered and planned the test.
2. Depending on the overall structure of the company, a tester can take advantage of weaknesses in the information flow.

The first of these two reasons result from the fact that IT and Security departments are usually authorized to implement and assure security, but other departments may also have awareness of that. For example, knowing that an employee of the Penetration Test Team is visiting another department will increase the chance that people in that department actually keep to the security policies, at least for the time of their stay.

The second of the above two reasons results from the likelihood that for each organizational structure, particular weaknesses might exist. In a functional structure, a security tester could take advantage of this as follows:

- Employees from different departments might not know people from other departments, particularly those responsible for IT Administration
- Security awareness and the acceptance of certain security measures might be significantly lower in departments where only non-technical staff are working
- Information about an incident might reside within a single department for a period of time, resulting, in the worst case, in delays to the reaction time

In divisionally structured organizations, similar potential weakness can be considered, although these may be transferred to divisions:

- Employees from different departments might not know people from other departments. Depending on how the IT infrastructure of the company is maintained, they might not know who is responsible for IT Administration
- Information about an incident might reside within a single department for a period of time, resulting, in the worst case, in delays to the reaction time
- Depending on the size of a single division, teams might also be subdivided by functionality into smaller departments inside the division, making the second bullet regarding security awareness and the acceptance of certain security measures also valid for divisional structures.

Also, it needs to be noted that even though companies with a divisional structure distribute similar functionalities over different divisions, some services like IT Administration often reside in a central department.

Finally, for matrix organizations, a person might take advantage of possible conflicts between administrative and product management. However, this is not always the case and, as already mentioned for divisional structured organizations, some services might be centralized.

Some considerations

The above information only takes a very high-level perspective of the organizational structures and their potential security weaknesses. In practice, many companies do not have purely functional, divisional or matrix structure. In particular the security management function is often handled by a central department which dictates security measures, such as a company-wide security policy.

A security policy can be defined as “A high-level document describing the principles, approach and major objectives of the organization regarding security.” [ISTQB Glossary], whereas a security service according to NIST is defined as “a capability that supports one, or many, of the security goals. Examples of security services are key management, access control, and authentication.” [NIST02].

Studying the company’s security policies can reveal potential attack vectors by making known the constraints placed on the behavior of its members as well as the constraints imposed on adversaries by security mechanisms. Company security policies may not be publicly available. Some company policies may only be accessible to employees or even just certain members of the staff.

An important aspect to consider in the organizational context is the way in which the company outsources parts of their production or services. The relevant partner(s) should also be considered as potential targets for a security test. This depends on the nature and content of the contract between the two organizations that define the legal obligations. External partners are often given (limited) virtual private network (VPN) Access, work on the same code repository or have an access token for a local office. Even though they often have only restricted accounts, it might be the first step towards a successful attack.

Another focus regarding partners in the context of security testing is the analysis of the supply-chain, as attacks in this area can have serious consequences (e.g., [WIRED21]).

The general aspects covered in this section could hold for almost any company, but neglect specific industrial issues, such as the type of product or service that a company offers, as well as the industrial sector the company operates in. Offering a web service for music might have different security requirements compared with a medical device used in a hospital. Precisely for that reason, regulations exist for certain sectors which prescribe requirements for processes, safety, security measures, or other domain-specific aspects. (See section 5.2 for further information). This might affect companies developing their own products far more than companies who, for example, sell Commercial Of The Shelf (COTS) products.

In conclusion, this section describes the following security testing aspects which should be considered when choosing test techniques:

- The organizational structure of the company (functional, divisional, matrix)
- The security policies of the company
- Outsourcing, business partners and the supply-chain of the company
- The business model of the company (service-driven, own products or COTS products)
- Regulatory domains which impact the company

5.2. The Impact of regulations on security policies and how to test them

Security regulations drive the content of security policies which drives the information security control framework for security testing. The Security Test Analyst develops this control framework. With knowledge of the framework, a Security Test Engineer then develops and uses test cases to test the controls.

5.2.1. The impact of regulations on security regulations

Due to the strong interconnectivity of most industrial sectors, cyber security attacks can have a deep impact not only on a single company but also in worst case on the overall infrastructure of a whole country. As a reaction to this, governments have defined regulations in order to force critical companies to adapt their security level to at least a minimum level. Non-compliant companies may be fined or ultimately temporarily shut down until the required security measures are implemented. Companies that are affected by regulations therefore have an incentive to improve their security measures and security policies at least to the required security level. NIST defines laws and regulations in the context of computer security as “federal government-wide and organization-specific laws, regulations, policies, guidelines, standards, and procedures mandating requirements for the management and protection of information technology resources.” Although this might be true in some cases, general regulations can be defined on a global, union or national level, such as:

- Global regulations defined by e.g., by organizations like WTO
- Union specific regulations such as the GDPR and Network and Information Systems (NIS) Regulations defined by the European Union (EU)
- National regulations such as the Cyber Security Sharing Act in the United States of America (USA)

In addition to this, further regulations may apply to specific industrial sectors, such as:

- Health Insurance Portability and Accountability Act [HIPAA]
- UNECE WP.29 for automotive sector [UNECE20]
- (DVO) (EU) 2019/1583 for aviation security [BSI21]
- Payment Card Industry Data Security Standard (PCI-DSS) [PCI22]

The formulation of regulations is done by specific institutions such as the Cybersecurity and Infrastructure Security Agency (CISA) in USA, or the Federal Office for Information Security (BSI) in Germany. In the EU, the European Network and Information Security Agency (ENISA) defined the NIS directive, which was set into policy in 2016. The aim of this was to increase and standardize the cybersecurity level across all member states. In addition to this, the same institutions often publish recommendations (for example [TR02021]), best practices or at least references to other publications.

This is important, because regulations in general can be very unspecific about which actual technology to use in practice. Due to technology changing over time, this would require that an ongoing adaptation of the defined laws would be needed. However, there is a common understanding about “state-of-the-art” technology which is published, for example, by institutions such as TeleTrust [TELETRUST] or NIST and is adapted over time.

Regulations are often unspecific because they aim to cover a broad scope of industrial sectors. Keeping to a fixed set of IT security technologies could cause problems, as some technologies might become non-applicable for certain companies.

While the use of current technology is one part of regulations, the following three cornerstones also need to be considered in general:

- Resources (e.g., hardware, software, state-of-the-art technology)
- Personnel
- Information Security Processes

Regarding personnel, there are four main aspects to consider:

- Personnel must have the awareness about the importance of information security and must understand that they are equally responsible for ensuring security
- They must have the required knowledge to implement and to apply defined security measures (noting that the type and specificity might vary according to different roles). Skills and knowledge are needed about the actual defined security policies and procedures.
- They must accept and apply the defined Information security processes (see below)

- Some personnel require special clearances

Information Security Processes include aspects such as:

- Defining responsibilities. In the context of regulations, this does not only affect roles and responsibilities inside a company, but also the institutions which are responsible for monitoring compliance and reporting incidents, such as the national Cyber Emergency Response. Often a person is nominated as the Single Point of Contact (SPOC) within companies. They have to define when and to whom they need to make reports
- How to deal with new or leaving employees, personnel who change departments, or external employees
- In the event of a security alert, who needs to be informed, who will be responsible for taking decisions and when does the company have to report the incident to a (federal) institution
- How to deal with business partners and suppliers
- Regular reviews and re-evaluations of currently defined processes and measures
- Auditing procedures, including preparations and corrections after an audit has taken place.

The aspects described above are an integral part of a working information security management system (ISMS). Some regulations aim to establish and preserve an essential ISMS (see chapter 8).

How to test security policies

Security testers have a high level of responsibility in testing security policies for companies affected by regulations. The main reasons for this are:

1. From a company's perspective, it is important to be compliant. Otherwise, the company may have to pay penalties or risk their business being temporarily shutdown.
2. Since incidents for regulated industry sectors can have far more serious consequences than for other sectors, testing must be done very thoroughly to ensure a high level of security.

The next step is to evaluate best practices and state-of-the-art technologies, since regulations may only refer to them. Security testers need to validate that the given security measures for a SUT are still sufficient. For example, they need not only to check if data is encrypted, but also which algorithm was used, since this might already be insecure.

For testing purposes, the results of previously conducted audits can be considered as part of the test basis. However, findings from a previous audit which have now been implemented need to be confirmation tested. The tester cannot simply assume that the implementation has been correctly performed. Furthermore, as regulations and key objectives of a security policy include personnel and processes, test activities must also include these aspects.

Testing of personnel aspects can be conducted by applying tests such as faking a social engineering attack or trying to bypass (physical) access control. These kinds of tests are dependent on the organizational department that requested the security test.

Finally, the security testing of processes is not limited to backup and restore, but also involves aspects such as emergency response and reporting. These tests can be very elaborate and expensive, as many people might be involved during the test.

5.3. Analyzing an Attack Scenario

5.3.1. Common Attack Scenarios

Security incidents vary widely in terms of the attack techniques and tools applied, the type of attacker and the motivation for performing an attack. As a result, it is difficult to give a generic description of an attack. However, certain steps are common for almost every attack. These steps can be defined as:

1. Information gathering
2. Exploitation/gaining access
3. Persisting/maintaining access
4. Clearing tracks

By way of comparison, security incident handling is defined according to NIST [NIST03] by the following steps:

1. Preparation
2. Detection and Analysis
3. Containment, Eradication and Recovery
4. Post-Incident Activity

While both enumerations describe a common sequence of attack and response, factors such as motivation, resources, the skills of an attacker and the approach used have a strong impact on both the success of an attack and the consequences for the attacked party.

Classification of attackers and their motivation

The word “hacker” is used in this section as a synonym for an attacker. However, the term hacker refers in general to a highly technical-skilled person.

Attackers can be divided into different types, depending on their technical skills and the resources are available to them:

Type of attacker	Description
Script Kiddies	These are people with a low level of technical knowledge, who use existing tools and scripts without fully understanding them and who have very limited resources.
Scammers	These people use simple techniques such as Phishing but usually target many people, which increase their chances

Type of attacker	Description
Private hackers	These people might have a solid technical background and are interested in IT security or are very curious
Professional hackers	These people have a very high technical background and are able to perform highly sophisticated attacks in order to earn a living with hacking
Governments	These organizations pay complete teams for spying, hacking or sabotage and have considerably more resources available to them than single persons or small groups.

While this is a coarse-grained categorization depending on skill and resources, another important aspect is the motivation of an attacker. Script Kiddies might just want to play around with something they've just found online or impress their friends, whereas professional hackers earn their money with hacking and therefore also want to have a good reputation. There are the following top-level categories of motivation:

- Personal motivations (fame, vengeance, jealousy, curiosity)
- Political motivations ("hacktivism", war, espionage)
- Professional motivations (e.g., money, reputation, industrial espionage).

Depending on the level of motivation, an attack can be performed against a single entity or several entities. For example, ransomware is a malware which usually encrypts data and blocks the use of the infected system until the victim pays a certain amount of money. Since infecting more systems will increase the chance for an attacker to earn money, ransomware usually is written to infect as many systems as possible.

In contrast to this, computer worms such as Stuxnet [WIKI02], were mainly developed for the special case of infecting Supervisory Control and Data Acquisition (SCADA) systems. These have been used for sabotaging the nuclear programs of entire countries.

5.3.2. Common Approach of a Hacker

Information gathering

In general, the first phase of an attack is information gathering, also known as reconnaissance. An attacker seeks information about the target and tries to find security weakness in the following areas:

- IT infrastructure (e.g., a known software vulnerability)
- Physical infrastructure and the related access control mechanisms (e.g., breaking into an office, which might have a poor alarm system and allows access to sensitive information)
- Employees, who may have a poor awareness of security
- Processes inside a company, which might be exploitable

Information gathering can be either active or passive. Passive information gathering can be done by searching the web using specialized search queries, such as Google, which can reveal a surprisingly large amount of information. This practice has become known as “Google hacking” or “Google dorking” [WIKI01]. Additionally, social media platforms are an important source of information about employees, especially concerning their telephone numbers, email addresses and other personal information which can be used for social engineering. Using the details of a person allows attackers to personalize their attacks, such as with spear phishing, or sending personalized mails with malicious attachments. These may use, for example, a person’s correct name, address, or birthday to create emails with content that sound very familiar or intimate to a victim, thereby increasing the probability that the victim opens the malicious attachment or clicks on a link and visits a malicious website.

Active information gathering includes the use of tools and techniques which interact with the target but increases the risk of becoming recognized as an attacker. It can be performed in different ways:

- Trying to contact company personnel either via email or telephone (Vishing)
- Searching a victim's garbage for useful information, such as addresses and telephone numbers [SENG22] This is known as “Dumpster Diving”
- Port Scans
- Operating System Fingerprinting
- DNS Enumeration (see below)
- Vulnerability Scanning
- Collecting useful information that is publicly available (Open-Source Intelligence – OSINT).

Techniques such as DNS Enumeration might remain undetected, whereas other techniques such as port scanning or vulnerability scanning can often be easily identified by analyzing the log files of servers or firewalls. Network intrusion detection systems (NIDS), which are usually implemented as a security measure in the network infrastructure, analyze incoming traffic for suspicious patterns and raise an alert if they recognize possible malicious traffic. In particular vulnerability scanners have an easily detectable network fingerprint. Although using scanners can reveal useful information to the attacker very quickly, their use also increases the risk of being detected.

The duration of the information gathering phase can vary considerably and will depend on the motivation of the attacker. A script kiddie can become bored after a few minutes or hours because they just want to play around with a tool they found on the internet, whereas politically motivated attackers might gather information over months before they actually launch an attack. Active information gathering methods will always leave traces but sometimes will only be detected through forensic investigations after an attack has been performed successfully.

Apart from motivation, the type of attack also influences the information gathering phase. An attacker who wants to perform a DoS attack which only affects availability might not need to intrude into a private network and therefore can ignore certain information. However, more information always increases the chances for a successful attack.

Identifying a vulnerable system can be done by enumerating all available services and their versions and afterwards doing a lookup on publicly available exploit databases.

It should be noted that legal public services can automate active constant scanning on the entire internet, updating their databases constantly. Services like these allow searching for unsecured devices which use default passwords and vulnerable services. The services can be used by companies as well as private persons, making it easier for anyone to find vulnerable systems. They allow searching for specific IP addresses, domains, and web server versions, making this another useful tool for information gathering.

However, information gathering can also be done offline, for example by performing dumpster diving, observation, and claiming to be a customer or infiltrating a company as an employee. This greatly increases the chance of being detected and is therefore avoided in most cases. Only if an attacker has a very high motivation or where learning about a target may have already failed might it be considered as an approach for information gathering.

Finally, information gathering is a recurring task performed during an attack, because once an attacker has gained access to infrastructure which is not publicly available, they need to keep learning about it.

Exploitation/Gaining Access

Once attackers have gained a reasonable knowledge about their target, they will transition to the actual attack. “Reasonable knowledge” in this context means that they have actually found at least one way which will have a high probability of success. A successful attack can be caused by:

- Known software vulnerabilities in unpatched software
- Misconfiguration (e.g., missing or wrong configuration)
- Zero-Day Exploits
- Weak Passwords
- Social Engineering

If a software exploit succeeds, the attacker will usually not have an administrator account. This might represent an obstacle to them as they would want to alter the system for their purposes (e.g., by stopping or modifying anti-virus software). Therefore, the acquisition of higher privilege levels is often required after the initial access. Privilege escalation can succeed for the same reasons as the initial exploit, such as a software vulnerability or misconfiguration. Misconfiguration is a serious threat to privilege escalation. On UNIX systems, for example, many programs allow access to a root shell and, if they permit the use of SUDO, (an acronym for "super user do"), they may use this to execute programs as a super user or another user [GTFO22].

While these are attacks that can be executed remotely, it is also possible for an attacker to gain direct access from a company's internal network. An attacker could be an employee who wants to harm the company because of a personal issue. In addition, an attacker could gain physical access to an office because of insufficient access control and from there might be able to connect to the internal network.

Social engineering is a threat which can lead to the attacker obtaining direct access. It is defined according to NIST as “the act of deceiving an individual into revealing sensitive information, obtaining unauthorized access, or committing fraud by associating with the individual to gain confidence and trust.” [NIST05].

Persisting/Maintaining Access

Gaining unauthorized access to a system often uses exploits that may be difficult to apply, have a high probability of failure or can only be applied at certain times. Therefore, attackers need to maintain access to the compromised system until they have achieved their goals. Again, this depends on the hacker’s motivation as some may only be interested in a successful exploit, but do not want to go further.

Persisting access is usually achieved via rootkit, which are specifically created for this purpose. Rootkits try to maintain access, even if a system is rebooted. Since anti-malware software tries to detect malicious software, rootkits are constructed to hide themselves and additional malware such as key loggers and network sniffers on the system. They can also enable the automated remote control of compromised systems, allowing attackers to create botnets for performing DDoS attacks against other systems, or misusing them as spam server.

Clearing tracks

As hacking can have serious legal consequences, hackers want to stay anonymous or at least do not want to be identified in person. As a result, they have a high motivation to remove all traces of their preceding activities after they have achieved their goal. This includes removing all programs and files the attacker has copied to the compromised system(s), clearing, or removing log files, command histories and perhaps destroying the hardware they used for the attack.

Although these are tasks which an attacker performs on completion of an attack, hackers will also use techniques such as proxy chaining, VPN or already compromised jump servers during their remote access to obscure their traces.

An attacker must be aware that each activity they perform against a system can be potentially logged, and in most cases, they will be unable to delete all their traces completely.

In context of security and penetration testing, it can also be necessary to act in a similar way, since the SUT might be an Intrusion Detection System (IDS) or an emergency response process.

5.3.3. Incident response and post incident analysis

The previous sections described an attack scenario from an attacker's perspective. On the other hand, companies invest in security measures to detect and resolve security incidents, which is a task known as incident response. Note that incident response and the previously described attack phases usually take place at the same time. In many cases, an attacker has already been detected in an earlier phase (e.g., persisting phase), and not just after they have already tried to clear their tracks.

Preparation

While preparation is part of incident management, it is not part of incident response but builds the foundation for a working incident response procedure that will take place in case of a security incident.

Incident response aims to achieve the following:

- Identify an incident and analyze the situation
- Containment, e.g., isolate compromised systems, shutting down services
- Eradication e.g., remove compromised user accounts, remove malware, patch a system
- Recovery e.g., bringing services online again, restoring data etc.

After an incident has been resolved, there should be a review in order to identify weaknesses in the infrastructure as well as in the incident response processes.

Detection and analysis

The detection of an incident can be either intended or unintended by the attacker. In the case of a website defacement for example, it is the attackers' intention that the attack will be recognized. In other cases, they might leave a message to a system administrator.

Different tools can be used to help in detecting suspicious activities. These include network/host intrusion detections systems (NIDS/HIDS), malware scanners and log analyzers. In the best case, an attack can be identified before the attacker has succeeded. This can be the case if an attacker is too conspicuous during scanning, or if their first attempts at an exploit fail. Also, many failed login attempts or login attempts from users that do not exist or usually do not login remotely can be an indication of a potential attack. If this can be detected outside of the company's network, there is a good chance to defeat the attack.

If suspicious activities are detected inside the company's network, it must be analyzed which systems are already compromised and how the attacker gained access. This can be done by the IT department, but more commonly a forensics team starts to analyze the incident. The response to an incident is time-critical and actions must take place as early as possible to avoid further harm.

Containment, Eradication and Recovery

If there is a clear picture about which systems are compromised, the next step is to contain these systems to prevent an attacker from compromising further systems. This can be achieved, for example, by shutting down services temporarily, by moving them to another network or locking user accounts.

An important aspect to consider during this phase is that some actions might delete forensic evidence, which could be useful for post-incident analysis. For example, shutting down a system will delete the main memory, which might contain useful data such as the initial exploit that was used. Again, it is vital to react quickly, as an attacker might compromise further systems. The actions performed have to be decided based on the risk level.

Containment and analysis of the situation will alternate at a certain point, as it must be re-evaluated if all systems have been identified correctly and the attacker is not able to gain further access. If there is sufficient certainty that all affected systems have been identified and contained, eradication can take

place. An important aspect during this phase is providing evidence for further analysis. Eradication can include the deletion of a whole system and recreating it later from a backup for example. It is also possible to remove only partial components of the system and replace them during the recovery phase with a new component. In both cases, it must be assured that the used backup or component does not contain traces from the previously resolved incident.

Post-Incident Activity

After resolving an incident, several steps must be taken to evaluate and improve the current security strategy. This includes:

- Forensic investigations, which in the best case can identify the attacker
- Closing security vulnerabilities that might have been revealed through the attack
- Re-evaluating the current infrastructure
- Increasing the security awareness of employees
- Re-evaluating and perhaps adapting security policies
- Refining incident response processes
- Making announcements to clients or customers, especially if the company has reporting obligations. This includes reporting to the corresponding institution or the government.

6. Adjusting to Software Development Lifecycle Models - 165 minutes (K4)

Test Keywords

Software Development Lifecycle (SDLC)

Learning Objectives for Chapter 6:

6.1 The Effects from Different Software Development Lifecycle Models

STE-6.1.1 (K2) Summarize why security testing activities should cover the software development lifecycle

STE-6.1.2 (K4) Analyze how security testing activities are impacted by different system development models

6.2 Security Test during maintenance

STE-6.2.1 (K3) Define and perform security regression tests and confirmation tests based on a system's change

STE-6.2.2 (K2) Analyze security testing results to determine the nature of a security vulnerability and its potential technical impact

6.1. The Effects from Different Software Development Models on Security Testing

The application or system lifecycle can be described as a model with different SDLC life cycle processes. The most-used SDLC life cycle phases are: planning, analysis, design, development, test, implementation, maintenance and termination.

The activities and planned tasks for each of these phases may differ according to the application, system, project or organization. These are defined in the SDLC model which may then be executed using a sequential or an Agile software development approach.

Using a sequential development approach, it is easier to recognize the different SDLC phases more clearly. With the Agile approach it may not be so clear when and which activity or task from which lifecycle process is to be performed. The activities and tasks may be frequently repeated, adding value to the application or system with each single iteration.

In the ISTQB Certified Tester Foundation Level [ISTQB FL] syllabus, several development models are mentioned, including the waterfall model and Agile Development Lifecycle (i.e., RUP, Scrum, Kanban and Spiral). It is mentioned that testing should be adapted to these models to be most effective. As may be expected, approaches to security testing also need to be adapted to different SDLC models. This syllabus discusses DevOps in addition to the above-described models.

The Security Test Engineer should have knowledge about the most important characteristics of these SDLC models and how they may impact their ability to perform security testing. In line with normal software testing, security testing must be adapted to the actual context, which includes the development model in use.

When comparing these categories, differences can be observed regarding the following attributes. A change in any of these attributes will also have an impact on how security testing is executed:

Attribute	Description
Development duration	The time needed from a requirement formulation until deployment • The duration will also affect the allowed time to execute security testing during the development lifecycles • The less time the more challenging choices need to be taken and priorities set
Deployment size	Larger batches of functionality or a single feature per deployment • Often in direct relation with the development duration • The smaller the size of a deployment, the more specific one can (and must) focus on security Testing • With larger deployments, the attack surface may be substantially increased in one go. At the same time the need for regression testing increases in incremental models
Allowed testing time	The amount of time resources reserved to perform the test • In most cases, functional testing may be planned but non-functional testing (incl. security testing) is often not planned in project lifecycles • If time allows, it can create opportunities for more extensive non-functional testing including security testing
Team independency	The level of security decisions which can be taken by the team • It may allow the team to assign or hire autonomous security testing competence if needed
Team cross-functionality	The availability of all needed skills (for the development) in the team.

Attribute	Description
	• The team may have different and complementary security testing competence available
Automation level	How much of the development process is automated. • Much of the security testing may be executed automatically using SAST- and DAST-related activities
Management principles	line organization, project, or product oriented. The principles on how the team is managed may influence how Security Test is organized. Use of enabling teams, continuous focus on security or just during the project phase or only during maintenance.
Test environment	A separate and dedicated test environment can be established for destructive security testing.

6.1.1. Sequential Development Models

The complete SDLC is often specified by all life cycle processes needed to develop, maintain and support the system from its early initiation until its retirement / disposal. A much-used standard describing all these processes, and their relationships is [ISO 15288]

The system development model describes the implementation of (parts of) the SDLC needed to develop and implement a system. This implementation does not necessarily include all SDLC processes and should be adjusted to the organization (see chapter 5) and the project context.

Information security and security verification should be an integrated aspect covered in all software development lifecycle processes used in the organization. Only then can a truly holistic approach be achieved. This will also support or guarantee that the required activities during the development processes can be conducted in a consistent way.

In [NIST 800-160] the security challenge is describing system security as a design problem. It notes that "a combination of hardware, software, communications, physical, personnel and administrative-procedural safeguards is required for comprehensive security. In particular, software safeguards alone are not sufficient."

This NIST standard presents considerations and approaches covering all software development lifecycle processes on how to address security information activities.

The sequential Waterfall model or its implementation the V-model is still a much-used model. The V-model extends the Waterfall model by referring to generic testing activities for each of its phases with the goal of moving testing "to the left" (i.e., earlier). These models are more established in organizations with distinct separation between the different teams and development phases. In general, we may expect the Security Test Engineer to have time to plan, prepare and execute the security testing when using this development model. Phases in the model are scheduled in sequence but may overlap with each other.

In these models, the Security Test Engineer should be aware of the following:

- Security requirements and risks are defined early in a project and should be documented in software requirement specifications.
- Security requirements may change over the course of the project as new threats are discovered, but these may not be reflected in updated software requirements. Security testing may therefore appear to be very specific and complete but may not actually be complete or current due to late project risks.
- Security testing can be performed at any time or development phase, but it is common for them to be performed late in the project.
- It may be difficult to address the results of security testing and remediations at the end of a sequential lifecycle project as deadlines will mostly be set at an early stage in the project.

6.1.2. Agile Development Lifecycle Models

Agile development lifecycle models promote the completion of work to be done by self-organizing and cross-functional teams in (very) short iterations. Enabler teams which deliver specific services to the project may be available to these Agile development teams to assist with specific domain competencies, such as security testing.

Generic to Agile software development is that increments (of system and software) are delivered in a series of iterations. Each of these iterations may take from days to some weeks. Agile software development models tend to be used mainly in the system/application development phase, although some models, such as Kanban, can also be applied during the operation phase.

The Scrum framework in various implementations is most used in Agile software development. All analysis, design, coding, and testing is to be done during this iteration, including the security testing.

Product backlogs act, at least partly, as a requirement specification. Both security requirements and other non-functional requirements are expected to be part of the product backlog. Epics are split into several user stories and tasks which are selected by the team(s) to be developed or delivered in one of the sprints.

Developed functionality may be changed or even deleted in future sprints. The “growing” functionality and future changes or even deletions make an unstable test basis to work with. In a way an Agile Development Lifecycle can be seen as a mix of development (new functionality) and maintenance (platform and existing functionality) during the project phase. Repeating the automatic security test is therefore essential.

Several approaches can be adopted to performing the security testing activities. Examples are:

- Do some security testing and then shift the focus to functional, technical, or platform-related test objects in each different sprint
- Do some security testing in most sprints and perform a complete security test in a dedicated sprint
- Perform all security tests in one (late) sprint (which resembles the Waterfall approach).

The Agile development team may involve an Enabler team or hire resources to perform the security testing as these competencies often do not reside in the team.

As the solution changes with each sprint regression testing must be performed. Security is not tested or patched into an already-built application. Rather, it is achieved through security-oriented design ("security by design") and verification throughout the process of construction. In common with software testing in general, security testing must also occur within the development lifecycle.

[Synopsys] has described how security testing can be applied in an Agile development lifecycle by applying the following four principles defined in the Agile Manifesto:

- Developers and testers over security specialists
- Securing as you work over securing after you're done
- Implementing features securely over adding security features
- Mitigating risks over fixing defects.

Developers and testers over security specialists

Experienced security specialists are valuable resources. Agile teams rarely have the luxury of having their own dedicated security specialists. This means that most of the time, software development teams should be responsible for their own security, and they can't wait for an external security review before the code moves to the next development phase. Security must be integrated into code development and testing. Teams must own security the same way they own user experience, reliability, performance efficiency, and other non-functional requirements.

Securing as you work over securing after you're done

Applying secure methodologies and practices when creating, releasing, and maintaining functional software is a must. At the same time, security activities should not force developers to stop what they're doing, go to another tool for remediation, and then come back to what they were doing. The alternative is to integrate security feedback and information into the developer's tools. Security tasks are presented (e.g., on whiteboards) and priorities set to make them visible alongside other tasks.

Implementing features securely over adding security features

The focus should always be on delivering the software's business mission, but the integration of security should always be a consideration. This means that architects, developers, testers and other stakeholders must consider security aspects and work together to define and build more secure systems. Secure systems should be designed and built from the beginning.

Mitigating risks over fixing defects

Risks should be considered which are specific to the business, users, data, and software. Risk management considers the right way to deal with a risk. This may be achieved by taking a high-level view of what could go wrong instead of distilling "security" down to a long list of individual defects that need to be resolved. Although threat modeling is more difficult than simply localizing and fixing defects, it is an effective approach to detecting problems early in the SDLC. It is definitely cheaper when problems can be resolved before releasing software.

6.1.3. The DevOps Approach

Most Agile software lifecycles cover the delivery of the system or software to the operation department. DevOps as a development model goes further by specifically including deployment in the production environment as well as tasks concerned with operation, maintenance and monitoring. The main objective with DevOps is to deliver (small) changes quickly. In addition, team culture has a much larger impact on the success of the team. DevOps teams are generally more autonomous and more product oriented.

DevSecOps spans the entire software development lifecycle, including development, security, and operations. During development, security focuses on identifying and preventing vulnerabilities, while in operations, monitoring and defending against attacks are the main objectives.

In general DevOps iterations can be as short as an hour and deliveries are typically single development feature/tasks or small branches. The DevOps team aims to get testing results available almost immediately after making a change at each step in the development process. This puts high pressure on the testing and methodologies in use, which in turn has a major effect on the possibilities to perform security testing.

To achieve short DevOps development iterations many of the repetitious and resource-intensive tasks are automated. This is mostly done in the form of a “pipeline” consisting of a number of “pipeline phases”, each of which can hold one or more “jobs” relating to performing specific tasks in the build and deployment process. One pipeline phase may be called “system testing” and may have a job which executes automated regression test. This pipeline is then run for each feature to be delivered.

DevOps comes in different flavors. The two most-used approaches are:

- Using only a main or master branch. Changes are developed and tested in a short-lasting feature branch or "trunk” and directly deployed into production after approval. This is also known as “trunk-based” development.
- Using a separate development branch allowing changes to be delivered into a test environment continuously and deployed together in a small batch after a short period. This is also known as “feature-based” development.

Security testing activities take time. A common question to be answered involves deciding whether to execute security tests for each pipeline or whether to schedule execution during the night after running some pipelines.

DevSecOps is a concept which indicates the importance given to security testing in DevOps. It is often considered as several security testing “jobs” executed automatically in the pipeline and includes both static analysis (“shift left” approach) and a focus on security-related monitoring and prevention, such as training and secure coding.

Emphasis is placed on security as a team responsibility with security being considered as part of all development activities during all phases for everyone in the team.

Common challenges in implementing security testing using the DevOps model are:

- Security testing is still considered as a specialized task to be done by specific resources. This inhibits the much-needed integration of security testing within the DevOps team.

- Security may become over-prioritized, resulting in other quality characteristics, such as performance efficiency and usability, becoming neglected. Security is important but needs to be implemented in a balanced approach.
- Security may lead to the inhibition of developer creativity, team autonomy and the possibility to experiment. These attributes are considered to be essential for a successful DevOps implementation.

The Phoenix Project [TechTarget] describes the following practices needed for a successful implementation of DevOps. These should also be applied to security testing:

- Create and maintain a “flow” of tasks
  Security testing is often considered as a large or single task (e.g., application test, network scan, architecture review). When applying a DevOps model, it is necessary to plan, prepare and execute security testing in smaller tasks. These should progress (“flow”) in the same way as other development tasks by applying concepts such as making tasks visible, limiting work in progress, assigning individual tasks to individual people, and automating where possible.
- Ensure instant feedback
  Test results should be available as quickly as possible. They must be understandable and resolvable. The ability to do this is supported by the above-mentioned “flow” and by using smaller tasks. This also helps to reduce technical debt.
- Encourage a DevOps security culture
  The team must be open and transparent regarding security issues. They must be motivated to report security-related issues and consider security as a team responsibility.

Conceptionally, DevOps allows for failing, learning and improving. When introducing DevOps, it is considered better to get started with some small improvements and get the “flow” running.

To be efficient, the Security Test Engineer should integrate all necessary security-related tasks in the DevOps (CI/CD) pipeline described above. This means not only focusing on the security testing, but also formulating and improving epics, user stories and tasks during the planning phase. In fact, each of the DevOps phases should include security related tasks and automate them where possible.

6.2. Security Testing During Operations and Maintenance

6.2.1. Security Regression Testing and Confirmation Testing

Security testing continues after the system is put into production. Changes may occur to the technical environment, external and internal (domain) systems and SUT integrations. The changes may be due to regular security updates or other changes in middleware, firmware and hardware. In addition, the SUT will be subject to planned and unplanned changes which might open up new vulnerabilities and possible exploits.

All these changes require at least periodic security regression testing. Depending on the size of the changes, a new security test may be needed.

Regression testing is intended to confirm that all previously acceptable behaviors of the system remain intact after modifications have been made, and that these modifications did not result in other negative behavior.

Security tests might involve checking that the system continues to successfully resist attempts to defeat established security controls. Enhancements to usability or performance efficiency are especially prone to negatively impacting security controls.

Security regression testing should focus on confirming satisfaction of all security requirements, as well as testing for new vulnerabilities that might have been introduced during maintenance activities.

Regression testing is often applied with a collection of test cases that are based on test individual functions. However, for security testing, it is often insufficient to detect regression defects with a security impact. End-to-end regression testing scenarios are more robust and provide a higher level of confidence that complete transactions can be performed in a secure way. For this type of regression test, a set of security test scenarios should be defined and tested each time a change is made to the system. Regression defects can appear from changes in all system-relevant parameters. Some of the regression defects may have a security impact.

After a system has been placed into service, additional development effort may be required to correct defects in the released version (corrective maintenance), to adjust to other changes in the operating environment (adaptive maintenance), or to extend or enhance features (perfective maintenance).

The security test perspective for system maintenance focuses on testing changes made to correct defects and core functionality. The purpose of this is:

- to ensure that no new vulnerabilities have been introduced in the SUT
- to verify that existing security defenses are still effective following a change

Security testing should also be performed to ensure that new vulnerabilities have not been introduced during changes. Part of the maintenance process is to keep firewalls and other security technology current. Continuous system monitoring can detect suspicious activity that may need to be addressed immediately.

7. Security Testing as Part of an Information Security Management System - 105 minutes (K3)

Test Keywords

Information Security Management System (ISMS)

Learning Objectives for Chapter 7:

7.1 Acceptance Criteria for Security Testing

STE-7.1.1 (K2) Understand acceptance criteria of security testing and how they influence selecting security testing approaches and test techniques

7.2 Input for an Information Security Management System (ISMS)

STE-7.2.1 (K2) Understand the role of security testing for an effective information security management system

7.3 Improving an ISMS by Adjusted Security Testing

STE-7.3.1 (K3) Evaluate ISMS maturity by bringing in different test approaches, new test objects or improved coverage

STE-7.3.2 (K2) Understand measurability within an ISMS

7.1. Acceptance Criteria for Security Testing

Security testing can be applied as a one-off ad-hoc activity for a system before go-live or as continuous, systematic process in development. Both types will generate test results, but their ability to provide evidence of significant security risks varies heavily. The same applies to different security test techniques. For example, white-box security testing will generate other test results and might identify other vulnerabilities than those generated by using black-box security testing.

Just as with software engineering in general, requirements for security tests are rarely clearly defined, complete, accurate or consistent. Commencing security testing based on such poorly defined requirements might generate some test results, but their value depends a lot on requirements value which is not predefined in advance. Any actions based on such requirements is likely to be risky for the following reasons:

- Questionable test method:
  All security testing uses a specific or a combination of different test methods leveraging a test technique, each of which has strengths and weaknesses. The “best” test technique or the “best” does not exist per se, but some preferences exist for achieving a given goal. Without them all methods and techniques might match expectations, but without any guarantee.

- Questionable coverage:
  Most test techniques do not have a predefined definition of “complete”, but need well defined target metrics that have to be met so that the test can be considered as done. The type of metrics and their thresholds depend very much on the goals of the security test. Without them, the Security Test Engineer may achieve a level of coverage that might or might not fit to the goals.

To avoid these pitfalls, it is essential to define acceptance criteria in advance of any security testing. These must be fulfilled before using the test results as a basis for identifying any deviations or action items. For more details refer to acceptance criteria [ISTQB Glossary].

The word “accepted” is key. ([WaCh90]) states that this means “that interim and final software products are examined to determine whether they meet specific criteria. If they do, then they have passed acceptance”. Naturally, security requirements should have their own acceptance criteria (cf. ([WaCh90]), which support the acceptance decision to reject, partially acceptance, or accept.

Security testing can be well-suited to control the security acceptance criteria defined for a SUT. The test results, which are usually aggregated in a test report, should contain all necessary information for enabling an acceptance decision. To support this decision-making, the security selected test approach should be based on the specific acceptance criteria. Usually this is done in the following steps:

- Read the security acceptance criteria carefully (valid for all types of acceptance criteria)
- List possible security testing techniques (cf. chapter 2) that can be used to support the acceptance decision. Keep in mind that some security test techniques might cover zero, one or several acceptance criteria
- Create a specific suite of security tests for these specific acceptance criteria. The guiding principles for this are:
  - Possibility of application:
    Is a specific test technique possible for the SUT? (e.g., are there corresponding tools available?)
  - Optimization of cost, time and quality:
    The challenge is to define a specific suite of tests and tools that generates significant test results, that can be applied within a given timeframe, and which is cost efficient.

After selecting the best security test methods and tools, the security test has to be applied, and the test results analyzed and reported in the test report. The test report itself should reflect the acceptance criteria and form the basis for the security acceptance decision.

7.2. Input for an Information Security Management System (ISMS)

Testing itself does not improve quality. Testing gives maximum transparency about the specific level achieved for a specific quality characteristic, such as security. The test report in itself does not improve the security level at all. If test report findings are analyzed and most of them are resolved, a confirmation test might be appropriate to demonstrate an increase in security. In addition to these system-specific risk

mitigation actions, some of the findings might motivate a specific security policy to avoid such vulnerabilities in the future. On the other hand, some of these findings might have their roots in a lack of security awareness or using immature/non-systematic techniques.

To leverage security testing to the highest level of efficiency and effectiveness, it must be integrated into an overall security process. It must try to minimize risk and ensure business continuity by pro-actively limiting the impact of a security breach. This is precisely the goal of an ISMS. [ITGov23b] defines an ISMS as follows:

- An ISMS takes a systematic approach to securing the confidentiality, integrity and availability (CIA) of corporate information assets.
- An ISO 27001 ISMS consists of policies, procedures and other controls involving people, processes and technology.
- An ISMS is an efficient way to keep information assets secure, based on regular risk assessments and technology- and vendor-neutral approaches."

An ISMS takes a holistic view on security and "ensures the effective interaction of the three key attributes of information security:

- Process
- Technology
- Behavior [Cald11]

It is clear that the security testing of applications and systems is directly related to "technology". However, each vulnerability identified by security testing might have its root in process or/and behavior, and might be mitigated in the future by changing processes or/and behavior.

There are at least the following reasons for an organization to implement an ISMS which are directly supported by security testing [Cald11]:

- Strategic, to better manage information security within the context of overall business risks
- Customer confidence, to demonstrate that an organization complies with information security management best practices
- Regulatory, to meet various regulatory requirements
- Internal effectiveness, to tactically manage information more effectively within an organization.

Security testing plays an important role in establishing an ISMS. Since it relates to testing, it demonstrates the status quo of a system. This can be understood as follows:

- as evidence for a goal, which was planned to be reached
- as evidence for a starting point, which motivates further security actions.

A well-known feedback loop for modeling the goal and starting point is the "Plan-Do-Check-Act" cycle (PDCA). ISO 27001 "adopts the PDCA process model, which is applied to structure all information security management system processes" [Cald11]. Both aspects, goal and starting point, are visible within this model:

- Goal:
  After the “Plan” and “Do” steps, the “Check” step establishes whether the planned goal has been reached
- Starting point:
  The result of the “Check” step, which is supported by security testing activities, is analyzed within the “Act” step to improve the overall process. Its deviations are the basis for the next PDCA cycle.

Security testing provides the most added value within an organization if its settings consider both aspects (i.e., goal and starting point)

To measure achievement of “Plan” and “Do” step in terms of improved security, a security test approach must be precisely adjusted, so that the security test exactly matches the planned goal. It is good practice to define acceptance criteria for security tests for the “Check” step in advance when defining the security plan.

To leverage security testing as starting point for the next PDCA cycle, the test technique, the applied tools, the executed test suites and all test results, (positive ones as well as negative ones), have to be reported within the test report.

It may be possible to leverage the same security test approach not only for setting a new starting point, but also for measuring the effectiveness of the next PDCA iteration. Security testing in that sense has to be applied in a very systematic approach. All relevant parameters must be stored to allow for a repeatable, objective security test.

7.3. Improving an ISMS by Adjusted Security Testing

The effectiveness of a defined ISMS in providing increased security is highly dependent on the proactive actions introduced by an ISMS. This means that an ISMS should derive security controls based on the current security status, and the analysis of an assessment or a current business situation (e.g., an incident).

In addition to any direct risk mitigation action that is undertaken to correct issues identified within the status quo, the ISMS tries to derive controls that prevent such issues from occurring in future development. The more iterations a specific ISMS has experienced PDCA iterations, the better the set of deviated security controls and the better the security level of all developed applications.

7.3.1. Improving Holistic View of an ISMS

To improve an ISMS by increasing its holistic view, security testing has to take on a new responsibility in addition to setting the baseline for “Check” step within the PDCA cycle (see above). If the goal is to mature the ISMS itself, the Security Test Engineer must bring in completely new aspects that were not yet planned as part of the PDCA cycle. These new tests might generate additional insights into the SUT, which can then be used to further improve ISMS maturity by deriving additional security controls.

Typical dimensions that a Security Test Engineer can use for enhancing ISMS scope are:

- Additional test objects:
  Each system that must reach a specific level of security has to be considered within its typical environment when it is in production. The system might be located behind a firewall, it might be connected with a central database, it might have an API-interface to external applications/systems, it may be controlled by a daily backup process, and it might have a connection to the privileged accounts management system. The more systems that are connected to the SUT, the broader the attack surface. Each system can be attacked, and if it is broken there is a high probability that the overall network of systems fails as well.

  An ISMS should cover as many aspects as possible to manage information security as holistically as possible: Each aspect should reflect possible attack vectors. dTo do that, it is essential for a Security Test Engineer to focus on as many test objects as possible, because any one of them might be a risky component in an overall network. If one of the tests identifies additional weaknesses for a component that is not yet part of the overall ISMS, it can improve its maturity based on this new information. It is not the Security Test Engineer's task to define countermeasures (e.g., security policies or process adjustments), but their task does include being open-minded regarding additional SUT components being useful for maturing the ISMS.

- Additional test approaches:
  Another possibility for a Security Test Engineer to bring in additional insights into a system is to use different types of testing. Even if the "check" action as part of the PDCA cycle focuses on a dynamic black-box test of the SUT, it might be beneficial to execute a static white-box test as well. This could potentially show additional vulnerabilities that were not identified so far and that could also be used by hackers. These new insights should be leveraged as input to an ISMS to further improve its maturity.

- Improved coverage:
  Even when remaining with the existing test object and test approach, the Security Test Engineer can generate valuable insights for maturing the ISMS. Simply by adding some more test cases could generate completely new insights. This easily can be done by using structured fuzz test tools or Rainbow Tables.

  Another way to improve the coverage might be to enhance the number of test cases executed per unit of time unit (e.g. by automating some use cases) or increase the number of test cycles performed to enforce unusual behavior that can be used for attacks. If these improved coverage measures identify additional vulnerabilities, it will help improve the ISMS maturity.

7.3.2. Improving Measurability Within an ISMS

The Security Test Engineer can improve ISMS maturity by introducing a metrics-based feedback loop. These metrics are usually named “Key Performance Indicators” (KPI) and support continuous improvement using PDCA cycles. The fundamental idea of the underlying PDCA cycle is to check the effectiveness of preceding “Plan” and “Do” actions. The more objective this check act can be done, the more objective the feedback loop becomes. The policies deriving from ISMS include coverage metrics for test techniques and behavior. If a policy from an organization’s overall policy portfolio includes the direct use of a test technique, then security testing can directly check whether that particular policy was successful.

However, even if a policy only indirectly touches the processes used, the Security Test Engineer can still support the measurement of its effectiveness. For example, it might be difficult to directly measure the effectiveness of some training given regarding secure coding conventions. One way could be to conduct examinations at the end of each training. Another way would be to setup a security test that precisely checks for the occurrences of security anti-patterns which had been covered in the training. The more frequently these anti-patterns still exist after the training, the less value the training added in terms of security.

The same could also be said when evaluating the effectiveness of unwanted behavior. For example, the security test might define a phishing simulation which counts the number of unwanted clicks made within an email. When considering phishing, higher click rates are generally seen as being bad because it means users failed to notice the email was a phish, while low click rates are often seen as good. However, to measure the effectiveness of an awareness initiative, this security test has to be repeated to enable a “before / after” change to be measured. [StGrTh20]

Security testing can improve ISMS maturity because feedback loops are based on the hard facts generated by security testing. Improvements take place more quickly and more are more reliable than those based on subjective or emotional feelings.

8. Reporting Test Results - 135 minutes (K3)

Test Keywords

risk mitigation, ethical hackers, test report, risk appetite

Learning Objectives for Chapter 8:

8.1 Security Test Reporting

STE-8.1.1 (K2) Understand the criticality of security testing results and how this affects their handling and communication

8.2 Identifying and Analyzing Vulnerabilities

STE-8.2.1 (K3) Evaluate the results from a given security test to identify security vulnerabilities

8.3 Close Vulnerabilities

STE-8.3.1 (K3) Evaluate different techniques for closing identified vulnerabilities

8.1. Security Test Reporting

Each test, including a security test, ends in a test report [ISTQB Glossary]. Without test reporting, a test lacks the evidence that can be used to determine actions or decisions based on the test result.

The following standard information will be especially important when reporting a failed security test case (for all standard information being part of a test report cf. [CTFL]):

- Used test environment: This usually includes specific IP-addresses, applied IP white-listings, used accounts/passwords, etc.
- Preconditions of the executed tests. This includes all preparation activities to be applied before the prepared test suite can be executed. This might include activities such as log-in-details, specific configuration file settings or specific perimeter configurations.
- Used test data
- Procedure of test execution
- Expected and observed behavior

A failed security test means a specific test has detected the violation of at least one security aspect from the CIA-Triad (cf. Chapter 1). A good test report includes sufficient level of detail to enable the test to be repeated. Tools used to execute the tests might be named in the report and screenshots might be included in to underpin a test result with evidence.

In general, security test reports shall be handled with high level of confidentiality. If this type of information is leaked outside the company, it could dramatically reduce the producers' reputation. Even worse, the information could be used to attack any systems which include this product.

The more failed tests a security test report contains, the more critical and sensitive the report and its communication is. In general, every security test report must be communicated with care within the company. This includes internal communications within the company producing the SUT, as attackers might come from inside a company (cf. [SwissCybInst20]). On the other hand, security test reports might be important for many people within an organization. This paradox directly influences the security tester's reporting activities and is usually resolved by creating different versions of the same report, each of which contains different levels of detail. Each version of the report should follow the "need-to-know"-concept. This particularly applies to those whose task it is to mitigate identified risks and therefore receive a complete test report or fragments of it based on the "need-to-know" concept.

The sensitivity of a security test report may be modified according to vulnerabilities identified. This is essential when ethical hackers identify a vulnerability in an available SUT and wish to inform only the producer to give them the opportunity to mitigate this risk before the test report is made publicly available. This responsible disclosure is one of the ethical characteristics of an ethical hacker, especially for white-hat hackers [Huneidy21]. Grey-hat hackers often use test report publication to increase pressure on the company to work on patches [Huneidy21].

8.2. Identifying and Analyzing Vulnerabilities

It is important to note that the absence of a failed test suite does not mean that the system is without errors. Even passed test suites do not necessarily mean that the examined attack vector cannot be exploited. It simply states that with the test suites used it was not possible to exploit an analyzed attack vector.

If a security test fails, a potential vulnerability is identified. Usually, the test report gives all evidence needed to enable repetition of the failed test case. A security test report might demonstrate many vulnerabilities. The following steps must be performed before any remedial action is taken:

- Vulnerability-demarcation:
  Usually a failed test represents a single failed test case and represents one vulnerability. However, several other test cases might exist which show the same vulnerability. For example, if an empty input parameter can be used to take over control of an application, maybe the same behavior can be achieved when using a 100MB file as input parameter. During the vulnerability-demarcation phase, different but similar tests are executed to demarcate the identified vulnerability. This is important for the subsequent risk assessment and has to be supported by the Security Test Engineer.

- Adjusting probability (as part of risk):
  This step is performed to double-check the probability of being able to identify a vulnerability in production. Usually, a security test is not done on a production system. Even if the test environment is similar, it will never be completely identical. In particular, some security controls might be explicitly disabled to allow a security test to be performed. If a SUT demonstrates a vulnerability, it might be obfuscated by other parameters put in place for production. If this is the case, the vulnerability still exists, but cannot be directly exploited due to other parameters. This

adjustment might change the risk exposure suggested by the security test and might therefore change the overall necessity to plan risk mitigation actions. The Security Test Engineer is tasked with considering this risk-adjustment and taking corresponding actions.

- Adjusting impact (as part of risk):
  This step is performed to double-check the possible impact arising from the exposure to a vulnerability. Usually, the Security Test Engineer's focus is on technical aspects, which makes the calculation of business impact difficult to estimate. Especially if the Security Test Engineer reuses impact assessments for identified vulnerabilities from an outside source (see CVSS, chapter 4), they can be imprecise for a specific context. If a vulnerability is identified, the business stakeholders refine the possible impact. The vulnerability may be estimated to have no impact from a business perspective (e.g., if the impacted system component is only seldom used), or it might be considered to have a high level of business criticality. This adjustment might change the risk exposure suggested by the Security Test Engineer and warrant an update to planned risk mitigation actions.

If all three of the above steps are applied, a clear view can be obtained of the identified vulnerability and its identified risk. The adjustment of risk probability and impact must consider some important parameters:

- Close communication with business stakeholders, as they are the final resort when discussing possible impact.
- Close communication with operation team (ops-team), as they are the final resort when considering production parameters and how they differ from those used in the security testing.
- Even if the existence of the vulnerability in the SUT is clear, stakeholders may try to actively influence the risk adjustment step.

If the remaining risk exposure is considered to be too high to go live or to stay live, a risk mitigation plan should be created. Management is responsible for deciding about the urgency of such risk mitigation plans. The decision can be between the following levels of urgency:

- Stop operation immediately or stop further go live-activities.
  If risk exposure is considered to be too high and cannot be accepted, it can only be avoided by not running the application or system. The level of risk (high, medium, low) that influences this decision depends on the risk appetite, which is defined as "*the amount of risk that an organization is willing to accept to achieve its objectives*" [CARM22]
- Continue running the system running with intensive monitoring:
  If the system is too critical or the risk is not too critical the application or SUT might continue running, but is intensively monitored
- Add risk mitigation actions to the normal release plan:
  If the risk can be handled or the system has many strict release constraints, the risk mitigation actions are analyzed and performed but not directly applied to the tested system. Instead, the

patched components are added to the normal release cycle to ensure that the next planned release contains the required security patch.

The Security Test Engineer must ensure that confirmation tests and regression tests are performed for each risk mitigation action The confirmation test should not only consider the evidence provided in the test report, but should also use of the lessons learned from the vulnerability demarcation step.

8.3. Close Identified Vulnerabilities

If an identified vulnerability is known in terms of vulnerability demarcation, and if it is decided to mitigate the risk, at least two high-level alternatives are available for mitigating the identified vulnerabilities:

- Hide the vulnerability by reducing expected risk
- Avoid the vulnerability by patching affected system.

Both alternatives can be combined. Hiding the vulnerability may provide a short-term solution and the real patching task can be done afterwards.

8.3.1. Hide Vulnerability

The idea of hiding vulnerabilities is similar to the approach tester applies, when they differentiate between a defect that does not cause a failure, and a defect that causes a failure, (i.e., that can possibly impact a customer).

Even if the risk adjustment steps have shown that the identified vulnerability is caused by a failure, (i.e., it exposes a high risk), the system itself might be changed in a way such that the defect does not reveal itself to the customer, even if the defect remains unchanged. In terms of risk mitigation, this type of action targets the reduction of impact. The defect still exists in the system, but it cannot be exploited anymore. Typical approaches for hiding vulnerabilities in this way are:

- Traffic blocking:
  Modern firewalls allow for very sophisticated analyses and blocking mechanisms. If the traffic needed to exploit the vulnerability is well understood, many firewalls can be configured to block such traffic patterns. By doing so the vulnerability remains unchanged, but it can no longer be exploited.
- Virtual patching:
  Virtual patching does not necessarily block traffic, but it converts it in a way that the vulnerability cannot be exploited. [OWASP11] defines this as “a security policy enforcement layer which prevents the exploitation of a known vulnerability. The virtual patch works since the security enforcement layer analyzes transactions and intercepts attacks in transit, so malicious traffic never reaches the web application. The resulting impact of a virtual patch is that, while the actual source code of the application itself has not been modified, the exploitation attempt does not succeed.”

- Switching off or reconfigure specific system features.
  If the vulnerability has a very limited scope within the system, it might be possible to switch off the functionality affected by the identified vulnerability.
- Reduce scope of vulnerabilities.
  It might be possible to accept the risk associated with a vulnerability by reducing its scope. For example, it might be possible to set up IP-filters so that only well-known machines with dedicated IP addresses can connect the vulnerable machine. In addition, it may be possible to disable the vulnerable machine from external access and to allow only internal access.

The Security Test Engineer is responsible, when confirmation testing, for applying all hidden vulnerability approaches to ensure that the specific vulnerability cannot be exploited anymore.

8.3.2. Avoid Vulnerability

Generally, avoiding the vulnerability is a very time consuming and expensive action. The following steps have to be performed to avoid the vulnerability:

Step	Description
Locate the vulnerability	• As the risk mitigation action has to be taken at the level used to implement the functionality (e.g., code, models, configurations) it might take time to identify the affected component and within that component the affected area based on an identified vulnerability at system level
Understand the vulnerability	• Before making a repair, a full understanding of the vulnerability has to be obtained by analysis of the vulnerability in the affected area (e.g., code snippet)
Identify the risk mitigation action	• An approach for risk mitigating has to be developed. • The mitigation action might consist of a completely new algorithm, a new component, a small configuration change or only some minor code adjustments (e.g., including a specific exception behavior).
Execute the risk mitigation action	• The identified risk mitigation action is applied.
Confirmation test (retest)	• Retest the system to test if the vulnerability has been deleted.

Step	Description
Regression test	• Testing is a fundamental part of avoiding vulnerabilities and should not only focus on the changed code. It is essential that the complete regression test suite has been executed to make sure that the system is still running correctly, and the mitigation action has had no unwanted side effects.
Deploy	• Deploy patched system. • After the system is deployed there is usually some close monitoring for a period to be sure that the system is running well.

9. Security Test Tools - 90 minutes (K3)

Test Keywords

Dynamic Application Security Testing (DAST), Interactive Application Security Testing (IAST), Static Application Security Testing (SAST), vulnerability scanning

Software Security Specific Keywords

Open-Source Software (OSS), Software Composition Analysis (SCA)

Learning Objectives for Chapter 9:

9.1 Categorization of Security Test Tools

STE-9.1.1 (K3) Analyze different use cases and apply categorizations for security testing tools

9.2 Selecting Security Testing Tools

STE-9.2.1 (K2) Understand the usage and concepts of dynamic security testing tools

STE-9.2.2 (K2) Understand the usage and concepts of static security testing tools

9.1. Categorization of Security Test Tools

There are several possibilities to categorize security test tools. A selection of these categorizations includes:

- The activity in the security test process where the tool can be used
- Open-source versus closed-source
- Static versus dynamic test tools
- Platform / infrastructure versus application
- Security test execution versus security test management
- Black-box test versus white-box test versus grey-box test

Each of these categorizations has its advantages and disadvantages when the Security Test Engineer is selecting the most appropriate security test tool. This syllabus presents three principal categorizations:

- Black-box test versus white-box test
- Static security test versus dynamic security test
- Open source versus closed source

It is expected that the Security Test Engineer builds their own library of tools for their domain and contexts. Nevertheless, they may still adopt the suggested categorizations.

9.1.1. White-box Security Test Tools

If the Security Test Engineer has code-level access, white-box test tools provide them with knowledge relating to the code, configuration information, libraries used, applications, system and platform, architecture, and login details. In addition to having access to such internal details, one important pre-requisite is for the Security Test Engineer to have permission to perform the analysis, since they will be trying to identify and assess the vulnerabilities of the system and integrated systems.

9.1.2. Black-box Security Test Tools

A prerequisite for performing black-box testing is access to a running application or system in a production-similar environment. This is necessary to be able to execute the test within black-box security test tools, which consider the software under test as black box and do not need any internal knowledge. Black-box-security tools place their focus on identifying internal vulnerabilities when running the application / system.

9.1.3. Grey-box Security Test Tools

Performing grey-box security testing gives the Security Test Engineer some limited information about the application / system internals and access to a running version. Grey-box security test tools can be seen as a mixture of white-box security test tools and black-box security test tools: They need some internal information as well as a running system. The focus is to identify vulnerabilities by running the application / system and executing tests which consider internal details.

9.1.4. Static Security Test Tools

An important dimension for security test tool categorization is based on the difference between static and dynamic security testing. Definitions, differences, and descriptions of static and dynamic security test are discussed in chapter 2.1.2.

Within this category, the tools can be considered according to their use. These include network testing, operating system testing, database testing and application testing.

Static security testing has much in common with white-box security testing. The main difference is that static security test tools don’t need the application or system to be running. The tool accesses the code, libraries or configuration files in scope and analyzes these with regard to the tool’s internal repository of known syntax, semantic or code standard vulnerabilities for the particular language in use.

There are various ways to perform security tests with tools. For static security test tools these include, but are not limited to, SAST and SCA. These are explained in more detail below.

Static Application Security Testing (SAST)
SAST is a typical static security testing activity mostly included in a Dev(Sec)Ops pipeline as discussed in chapter 6.1 and [NIST DevSecOps]. Within these pipelines it runs automatically whenever some code

lines have changed and are checked in. Using SAST that way gives very immediate feedback. SAST is primarily focused on the application and in most cases does not cover any platform or infrastructure components. In addition, these tools give good code coverage metrics.

There is a strong dependency between static security testing and the tool attribute “open-source software”, as open-source tools by definition deliver the source-code. That means that static application security testing can be executed for all open-source systems. This is not the case for closed-source applications. There might be possible to have some static testing (e.g. identifying some reused libraries), however sometimes this type of analysis is made impossible due to obfuscation or by special license agreements prohibiting static analyses.

Software Composition Analysis (SCA)
SCA has many touch points with security. SCA tools analyze vulnerabilities in the code, including the dependencies and the open-source components used by the application. These components are well known and may have several vulnerabilities. SCA tools can suggest security vulnerability remediations based on the identified components. When doing this, almost all SCA tools use the Common Vulnerabilities and Exposures [CVE21] database of publicly disclosed source of information about known security vulnerabilities. (See chapter 4.2.2)

9.1.5. Dynamic Security Test Tools

Dynamic security testing tools interact with the SUT while it is running. Both black-box security testing and grey-box security testing are closely linked with dynamic security testing. The tools may be considered in the categorizations DAST and IAST.

Dynamic Application Security Test (DAST)
As with SAST, DAST is commonly used in a Dev(Sec)Ops context [NIST DevSecOps]. The testing activity is executed automatically in the pipeline using a configurable black-box security testing tool. This analyses the application or simulates an attacker while the software is running, looking for vulnerabilities such as input validation, fuzz test, authentication and authorization, configuration and deployment, session management, error handling, and cryptography.

The DAST scan simulates different real-time attacks on the SUT in an automated fashion to identify any vulnerabilities in the application. Because of the nature of dynamic test, test techniques are used and these only work on running services. As a result, these are more time and performance consuming compared to static testing. Even though DAST focuses on the application, the identified vulnerabilities often relate to the infrastructure components which are necessary to run the application.

In general, dynamic DAST does not reliably cover all OWASP Top 10 [OWASP Top 10] or SANS CWE Top 25 issues [CWE21]. Many tools can cover specific aspects of each of the vulnerability classes, but a false sense of security can emerge from using these tools.

Interactive Application Security Test (IAST)

IAST is a hybrid test approach which leverages both static and dynamic security testing. The tools are used to determine if known vulnerabilities in the source code are exploitable during runtime.

An agent is installed in the environment where the application is running which monitors the application and identifies any vulnerabilities in the application while the Security Test Engineer (or dynamic security test tool) is interacting with the SUT.

9.1.6. Considerations for Selecting Tools

The Security Test Engineer must know which tool to select for which context. They should therefore have knowledge on the different categorization schemes and tools belonging to each categorization.

Security Test tool catalogues may help to select the right tool. Some examples can be found on in: [KALI], [OWASP], [SANS] and [NIST]. Note, however, that tools may be categorized differently in some of these catalogues and may be present in one and missing in another's.

The Security Test Engineer does not need to know about and be able to operate all security test tools available. Those Security Test Engineers who have been active for a longer time in one particular domain / context would typically build their own specific libraries.

When selecting a tool or building a tool library, it is recommended to follow this advice:

- Focus first on what needs to be verified
- Do not become dependent on a single supplier for your required test results. Use multiple suppliers for the same tool functionality.
- Periodically scan the market for new emerging tools.

Open-Source vs Closed Source

The difference between open-source and closed source (licensed) test tools can be an important aspect of tool selection.

Anyone can participate in the development of open-source applications or tools. This helps to eliminate security vulnerabilities as quickly as possible, at least if the open-source project has an active development community. In addition, open-source tools can be proofed, (at least theoretically), so that back-doors would be visible in the code and can be excluded.

Open-source software can be customized and used for specific contexts, giving it a clear advantage in addition to being generally free of charge.

The following characteristics might be considered as disadvantages of using open-source in some contexts:

- Missing professional support (especially when no active community supports a specific product). However, some companies specialize in providing support for OSS applications, which is an important aspect for the enterprise environment.
- Licensing issues (e.g., when using GNU's Not Unix (GNU) Public Licenses)
- It is necessity to have necessary development skills available (e.g., to adjust to specific contexts)
- If there is a vulnerability in the open-source system, there is a risk that someone will identify it and will create exploits

- Further development of OSS applications is uncertain, as they are mostly community driven.

In contrast to OSS applications, closed source applications use proprietary code that is not available to the user. This offers the following advantages:

- It is more difficult to locate security vulnerabilities, as the code cannot be analyzed by everybody.
- Tools vendors generally offer support contracts for the enterprise.

The following characteristics might be considered as disadvantages of using close-source in some contexts:

- License fees have to be paid (in most cases)
- There is no guarantee against back-doors
- Any security vulnerabilities could remain unknown for a long time
- Strong vendor lock-in may occur where a customer becomes heavily dependent on a specific vendor's products or services, making it difficult to switch to a different vendor
- In general, there is only limited ability to customize the tool to a specific context (code is fix).

9.2. Applying Security Test Tools

9.2.1. Understand the Usage and Concepts of Static Security Test Tools

The following aspects describe some of the principal characteristics of static security test tools (SAST):

- Usage of SAST is the mor effective the knowledge about the SUT exists.
- SAS can be applied even if the application itself can still be incomplete and contain functional defects
- They are strongly related to white-box tests
- They are well-suited for finding unsecure code or misconfigurations early in the SDLC, since they only require static information like the source code
- They cover the complete source code and configurations and therefore require read access to them
- They read the given object, such as the source code of an uncompiled application, and compare this with pre-defined data sets of best practices and known vulnerable entities, e.g., unsecure commands and chains within the source code
- Automation makes them cost effective
- They often provide false positives since they are not context aware. This means they do not know the use cases, call stack and composition of multiple lines of code. As a result, they might identify vulnerabilities in code that will never be executed in real-life, and therefore do not have any negative impact on security.

Using for example network scanning, a static application security tool would assess the configurations files to find unsecure configurations.

Some commonly used static test tools are listed below. Note that all of these tools are open-source. The list of specific tools might dramatically change over time.

Tool Name	Use
Clair	container vulnerability scanning [CLAIR22]
Dependency Check	Open-source SCA tool being part of OWASP [OWASP24]
GitLab SAST service	A collection of SAST tools for source code scanning [GITLAB22]
SonarQube	Used for source code scanning [SONAR22]
Terrascan	IaC scanning [TERRASCAN22]

9.2.2. Understand the Usage and Concepts of Dynamic Test Tools

Dynamic security test tools are used when the system / application is running. They check results on a running environment.

Continuous application security is important in the context of the continuous integration and delivery approach found in Agile Software Development Lifecycles. Security needs to be continuously and repeatedly verified for each increment. The motivation for using dynamic test tools (DAST) is to have them running on a regular basis and applying automation to ensure that the latest known vulnerabilities are immediately found and reported. Continuous security monitoring and improvement is also called Dev(Sec)Ops, (see chapter 6 and [NIST DevSecOps]).

DAST typically focus on OWASP's top 10 vulnerabilities such as: injections (e.g., SQL injection, XSS, command injection), broken access controls, cross-site-request-forgery (CSRF), race conditions, business logic errors, memory leaks, known vulnerabilities.

It is also important to mention that automatic DAST tools only scan a set of pre-defined vectors. Therefore, other testing and security checks are still mandatory.

Using the example of network scanning, a dynamic test tool first scans the network for open ports, then runs services under those ports.

Some commonly used dynamic test tools are listed below. Note that some of these tools are open-source and some are also proprietary (as indicated). The list of specific tools might dramatically change over time.

Tool Name	Proprietary?	Use
BurpSuite	yes	API Security Test [BURP22]
Ffuf	no	Web fuzzing [FFUF22]

Tool Name	Proprietary?	Use
FuzzDB	no	Library for injection patterns [FUZZDB22]
Kubeaudit	no	Vulnerability scanning in the context of Kubernetes and Docker environments [KUBEAUDIT22]
Metasploit	yes	Pen-test Framework that contains multiple modules for different use cases (vulnerability scanning, obfuscators, exploitation, reverse shells etc.) [METASPLOIT22]
Nessus	yes	Vulnerability & patch management scanning [NESSUS22]
Nmap	no	Network scanning [NMAP22]
OpenVAS	yes	Vulnerability scanning [OPENVAS22]
(OWASP) ZAP	yes	Web application Security Test [ZAP22]. In 2023 ZAP left OWASP and is now named without OWASP prefix
Sqlmap	no	Automated SQL injection tests and detection of further vulnerabilities with focus on databases [SQLMAP22]
SSLScan	no	SSL/TLS vulnerability scanning [SSLSCAN22]
SSLyze	no	SSL/TLS vulnerability scanning [SSLYZE22]
WireShark	No	Network sniffer for later analyses [Bullock2017]

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Appendix A – Learning Objectives/Cognitive Level of Knowledge

The following learning objectives are defined as applying to this syllabus. Each topic in the syllabus will be examined according to the learning objective for it.

The learning objectives begin with an action verb corresponding to its cognitive level of knowledge as listed below.

Level 1: Remember (K1)

The candidate will remember, recognize and recall a term or concept.

Action verbs: Recall, recognize.

Examples
Recall the concepts of the test pyramid.
Recognize the typical objectives of test.

Level 2: Understand (K2)

The candidate can select the reasons or explanations for statements related to the topic, and can summarize, compare, classify and give examples for the test concept.

Action verbs: Classify, compare, differentiate, distinguish, explain, give examples, interpret, summarize

Examples	Notes
Classify test tools according to their purpose and the test activities they support.	
Compare the different test levels.	Can be used to look for similarities, differences or both.
Differentiate test from debugging.	Looks for differences between concepts.
Distinguish between project and product risks.	Allows two (or more) concepts to be separately classified.
Explain the impact of context on the test process.	
Give examples of why test is necessary.	

Examples	Notes
Infer the root cause of defects from a given profile of failures.	
Summarize the activities of the work product review process.	

Level 3: Apply (K3)

The candidate can carry out a procedure when confronted with a familiar task or select the correct procedure and apply it to a given context.

Action verbs: Apply, implement, prepare, use

Examples	Notes
Apply boundary value analysis to derive test cases from given requirements.	Should refer to a procedure / technique / process etc.
Implement metrics collection methods to support technical and management requirements.	
Prepare installability tests for mobile apps.	
Use traceability to monitor test progress for completeness and consistency with the test objectives, test strategy, and test plan.	Could be used in a LO that wants the candidate to be able to use a technique or procedure. Similar to 'apply'.

Level 4: Analyze (K4)

The candidate can separate information related to a procedure or technique into its constituent parts for better understanding and can distinguish between facts and inferences. A typical application is to analyze a document, software or project situation and propose appropriate actions to solve a problem or task.

Action verbs: Analyze, deconstruct, outline, prioritize, select.

Examples	Notes
Analyze a given project situation to determine which black-box or experience-based test techniques should be applied to achieve specific goals.	Examinable only in combination with a measurable goal of the analysis.

Examples	Notes
	Should be of form 'Analyze xxxx to xxxx' (or similar).
Prioritize test cases in a given test suite for execution based on the related product risks.	
Select the appropriate test levels and test types to verify a given set of requirements.	Needed where the selection requires analysis.

Reference

(For the cognitive levels of learning objectives)

Anderson, L. W. and Krathwohl, D. R. (eds) (2001) A Taxonomy for Learning, Teaching, and

Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Allyn & Baconppendix B – Business Outcomes traceability matrix with Learning Objectives

The table below shows the syllabus Business Outcomes and number of Learning Objectives.

Business Outcomes: Security Test Engineer		Number of LOs
ID	Description	
STE-BO1	Understand the fundamental security paradigms, and their impact on security testing	5
STE-BO2	Use and apply appropriate Security Test techniques and know their strengths and limitations	7
STE-BO3	Contribute to planning, designing, and executing Security Test	6
STE-BO4	Understand how Security Test standards and security best practices can be utilized for Security Test	4
STE-BO5	Adjust and perform Security Test activities accordingly to specific organization context	3
STE-BO6	Adjust and perform Security Test activities accordingly to specific development methods and software development lifecycles	4
STE-BO7	Feed Security Test results into an information security management system (ISMS) for an active security risk management	4
STE-BO8	Collect, evaluate, and aggregate test results, write a detailed test report with all evidence and findings	3
STE-BO9	Based on a needed Security Test approach identify proper requirements for tooling and assist in the selection of Security Test tools	3

The following table shows the traceability between Business Outcomes and Learning Objectives

			Business Outcomes								
LO Number	Learning Objective	K-Level	STE-BO1	STE-BO2	STE-BO3	STE-BO4	STE-BO5	STE-BO6	STE-BO7	STE-BO8	STE-BO9
STE-1.1.1	Explain different security levels of assets and their corresponding protection level	K2	x								
STE-1.1.2	Explain the relationship between information sensitivity and security testing	K2	x								
STE-1.2.1	Describe the role of security testing in the context of security audits	K2	x								
STE-1.3.1	Explain the concept of Zero Trust	K2	x								
STE-1.3.2	Apply Zero Trust concept in Security Testing	K3	x								
STE-1.4.1	Exemplify the concept of Open-Source Software (OSS) reuse in software development and its impacts on security testing	K2	x								
STE-2.1.1	Define the security test techniques according to black-box, grey-box, or white-box security context	K3		x							
STE-2.1.2	Define the security test techniques according to dynamic security testing or static security testing	K3		x							
STE-2.2.1	For a given project, present security test cases, based on a given security test approach, along with identified functional and structural security risks	K3		x							
STE-2.2.2	Describe how to do recertification testing and a reconciliation testing for identities and permissions	K2		x							
STE-2.2.3	Describe how to test Identity and access management control	K2		x							
STE-2.2.4	Describe how to test data protection control	K2		x							
STE-2.2.5	Describe how to test protective technology	K2		x							
STE-3.1.1	Explain different activities, tasks, and responsibilities within a security test process	K2			x						
STE-3.1.2	Understand the key elements and characteristics of an effective security test environment	K2			x						
STE-3.2.1	Demonstrate security design	K2			x						
STE-3.2.2	Design security tests on component level based on given code	K2			x						
STE-3.2.3	Design security tests on component integration level based on given design specification	K2			x						
STE-3.2.4	Demonstrate an end-to-end security test which validates one or more security requirements related to one or more business process	K3			x						
STE-4.1.1	Explain different sources of test standards and best practices and their applicability	K3				x					
STE-4.2.1	Understand the concept of OWASP, CVE and CVSS and how to leverage it for security testing	K3				x					
STE-4.3.1	Explain Pros and Cons of test oracles used for security testing	K2				x					
STE-4.3.2	Understand Pros and Cons of using security best practices and standards	K3				x					
STE-5.1.1	Analyze a given organizational context and determine which specific aspects to consider for security testing.	K3					x				
STE-5.2.1	Analyze the impact of regulations on security policies and how to test them.	K3					x				
STE-5.3.1	Analyze an attack scenario (attack performed and discovered) and identify possible sources and motivation of the attack.	K4					x				

			Business Outcomes								
LO Number	Learning Objective	K-Level	STE-BO1	STE-BO2	STE-BO3	STE-BO4	STE-BO5	STE-BO6	STE-BO7	STE-BO8	STE-BO9
STE-6.1.1	Summarize why security testing activities should cover the software development lifecycle	K2						x			
STE-6.1.2	Analyze how security testing activities are impacted by different system development models	K4						x			
STE-6.2.1	Define and perform security regression tests and confirmation tesst based on a system's change	K3						x			
STE-6.2.2	Analyze security testing results to determine the nature of a security vulnerability and ist potential technical impact	K2						x			
STE-7.1.1	Understand acceptance criteria of security testing and how they influence selecting security testing approaches and techniques	K2							x		
STE-7.2.1	Understand the role of security testing for an effective information security management system	K2							x		
STE-7.3.1	Support ISMS maturity by bringing in different test approaches, new test objects or improved coverage	K3							x		
STE-8.1.1	Understand the criticality of security testing results and how this affects their handling and communication	K2								x	
STE-8.2.1	Apply the results from a given security test to identify security vulnerabilities	K3								x	
STE-8.3.1	Apply different techniques for closing identified vulnerabilities	K4								x	
STE-9.1.1	Analyze different use cases and apply categorizations for security testing tools	K3									x
STE-9.2.1	Understand the usage and concepts of dynamic security testing tools	K2									x
STE-9.2.2	Understand the usage and concepts of static security testing tools	K2									x

Appendix C – Release Notes

ISTQB® Security Test Engineer is a new release. For this reason, there are no detailed release notes per chapter and section.

Appendix D – Security Testing Specific Terms

Term Name	Definition
Asset	An item of value to stakeholders. (NIST glossary)
Blast radius	In cloud computing, the term blast radius is used to designate the impact that a security breach of one single component of an application could have on the overall application. Reducing the blast radius of any component is a good security practice.
Buffer overflow	A condition at an interface under which more input can be placed into a buffer or data holding area than the capacity allocated, overwriting other information.
CIA Triad	The CIA triad represents the three pillars of information security: Confidentiality, integrity and availability (NIST)
Common Attack Pattern Enumeration and Classification (CAPEC)	A catalog of known cyber security attack patterns to be used by cyber security professionals to prevent attacks. (Wikipedia)
CVE (Common Vulnerabilities and Exposures)	A system that provides a reference method for publicly known information-security vulnerabilities and exposures. (Wikipedia)
CVSS (Common Vulnerability Scoring System)	A free and open industry standard for assessing the severity of computer system security vulnerabilities by assigning severity scores to the vulnerabilities. (Wikipedia)
CWE (Common Weakness Enumeration)	A category system for hardware and software weaknesses and vulnerabilities. (Wikipedia)
CWSS (Common Weakness Scoring System)	The Common Weakness Scoring System (CWSS) provides a mechanism for prioritizing software weaknesses in a consistent, flexible, open manner. Very similar to CVSS
Defense in depth	Information security strategy integrating people, technology, and operations capabilities to establish variable barriers across multiple layers and missions of the organization.
Denial-of-service	A security attack that is intended to overload the system with requests such that legitimate requests cannot be serviced
DevSecOps	DevSecOps (Development, Security, and Operations) is a facilitating development of applications since it facilitates agile and secure development, delivery, deployment, and operations through (a) primitives, such as continuous integration, continuous delivery/continuous deployment (CI/CD) pipelines (explained in

Term Name	Definition
	section 3); (b) security testing throughout the life cycle; and (c) continuous monitoring during runtime, all of which are supported by automation tools.
Ethical hacker	Ethical hackers use hacking skills to help companies find ways to strengthen their security; […] goal is to evaluate the existing security system and find ways to strengthen and improve protection. When an ethical hacker finds vulnerabilities in a company's software, the company can then resolve the issues before a malicious hacker can exploit them."
Firewall	A component or set of components that controls incoming and outgoing network traffic based on predetermined security rules.
Grey hat hacker	Grey hat hackers, that are between white-hat and black-hat hackers, often use test report publication to increase pressure on the company to work on patches: "They announce the security flaws to the public in the hopes that the company will be forced to finally improve security.
Honeypot	A system (e.g., a web server) or system resource (e.g., a file on a server) that is designed to be attractive to potential crackers and intruders, like honey is attractive to bears [NIST]
Information Security	The protection of information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide confidentiality, integrity, and availability. [NIST]
Information Security Management System (ISMS)	ISMS [Information security management system] is part of the overall management system, based on a business risk approach, to establish, implement, operate, monitor, review, maintain and improve information security. The management system includes organizational structure, policies, planning activities, responsibilities, practices, procedures, processes and resources.
Information sensitivity	A measure of the importance assigned to information by its owner, for the purpose of denoting its need for protection [NIST].
Intrusion Detection System	A system which monitors activities on the 7 layers of the OSI model from network to application level, to detect violations of the security policy
Open-Source Software	Software that can be accessed, used, modified, and shared by anyone. OSS is often distributed under licenses that comply with the definition of "Open Source" provided by the Open-Source Initiative and/or that meet the definition of "Free Software" provided by the Free Software Foundation.

Term Name	Definition
Perimeter security	Perimeter security consists of integrated components, and systems, both digital, electronic, and mechanical, that protect a system or location, that detect and reject intruders.
Port scanning	Using a program to remotely determine which ports on a system are open (e.g., whether systems allow connections through those ports) [NIST]
Protection level	Protection levels prescribed to meet the security requirements specified for an information system; may include security features, management constraints, personnel security, and security of physical structures, areas, and devices
Risk appetite	The types and amount of risk, on a broad level, [an organization] is willing to accept in its pursuit of value. (NIST Glossary)
Rootkit	A set of tools used by an attacker after gaining root-level access to a host to conceal the attacker's activities on the host and permit the attacker to maintain root-level access to the host through covert means. (NIST)
Security Level	Security levels provide a qualitative approach to addressing security by using terms such as "low", "medium", and "high"
Security Policy	A high-level document describing the principles, approach and major objectives of the organization regarding security.
Security Risk	A quality risk related to security.
Security Service	A capability that supports one, or many, of the security goals. Examples of security services are key management, access control, and authentication (NIST)
Security Testing	A type of testing to determine the security of a component or system.
Sensitivity	A measure of the importance assigned to information by its owner, for the purpose of denoting its need for protection (NIST)
Social Engineering	The act of deceiving an individual into revealing sensitive information, obtaining unauthorized access, or committing fraud by associating with the individual to gain confidence and trust (NIST)
Software Composition Analysis (SCA)	Software composition analysis (SCA) – Used to identify open-source and third-party components in use in an application, their known security vulnerabilities, and typically adversarial license restrictions (NIST)

Term Name	Definition
Stride	Stride allows for a systematic threat modeling. The term itself is an acronym for six threat categories, which classifies potential threats.
Threat	Any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, or the Nation through an information system via unauthorized access, destruction, disclosure, modification of information, and/or denial of service. (NIST Glossary)
Threat modeling	A form of risk assessment that models aspects of the attack and defense sides of a logical entity, such as a piece of data, an application, a host, a system, or an environment. (NIST Glossary)
Vulnerability scanning	A technique used to identify hosts/host attributes and associated vulnerabilities [NIST]
Web Application Firewall	Application that monitors, filters and blocks data packets as they travel to and from a website or web application
Zero-trust	A collection of concepts and ideas designed to minimize uncertainty in enforcing accurate, least privilege per-request access decisions in information systems and services in the face of a network viewed as compromised. (NIST Glossary)

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All terms are defined in the ISTQB® Glossary (http://glossary.istqb.org/).