Software Security (SSI)

9. Security Requirements Engineering and Threat Modeling – Part 1

Prof. Dr. Marc Rennhard
Institut für angewandte Informationstechnologie InIT
ZHAW School of Engineering
rema@zhaw.ch

Content

- Security requirements engineering / threat modeling overview – why they are fundamental activities
- The basic process of security requirements engineering / threat modeling based on the STRIDE approach
- Attack trees as another method to think about threats against a system
- The importance of knowing your enemy
- Documenting security requirements
- Further security requirements engineering / threat modeling methods
  - Abuse cases, attack patterns

Goals

- You understand the importance of security requirements engineering and threat modeling during early phases of the secure software development process
- You know and understand the security requirements engineering / threat modeling process and can apply it to software systems or applications in development yourself
- You know and can apply two fundamental methods to think about threats / attacks on a system: STRIDE and attack trees
- You understand the importance of knowing your enemy to base your security requirements engineering / threat modeling process on realistic assumptions
- You know how to document security requirements

Software Security (SSI)

Introduction

The Need for Security Requirements Engineering (1)

- Security Requirements Engineering means determining security requirements early in the development lifecycle
- Just like "normal" requirements engineering, it's a fundamental and important activity
  - Missed security requirements are often difficult and expensive to "fix" later
- In practice, security requirements engineering is often neglected today
  - The focus of requirements engineering is mainly on functional aspects
- If security requirements are identified, they are often very general and taken from standard lists, e.g.
  - Use passwords, use encrypted communication channels, use firewalls etc.
  - This is usually not enough to specify the "right level of security" for a particular system

The Need for Security Requirements Engineering (2)

- If security requirements are not properly defined, the following problems arise:
  - There is no basis for integrating appropriate security controls into the system architecture and design
  - There is no basis for implementing appropriate security controls
  - There is no basis to perform focused security tests, which should be driven by security requirements
- → Without adequate security requirements, it's therefore very unlikely the resulting system is going to be secure
- Proper security requirements engineering has the goal to prevent all this by providing foundation for all subsequent security activities

Threat Modeling (1)

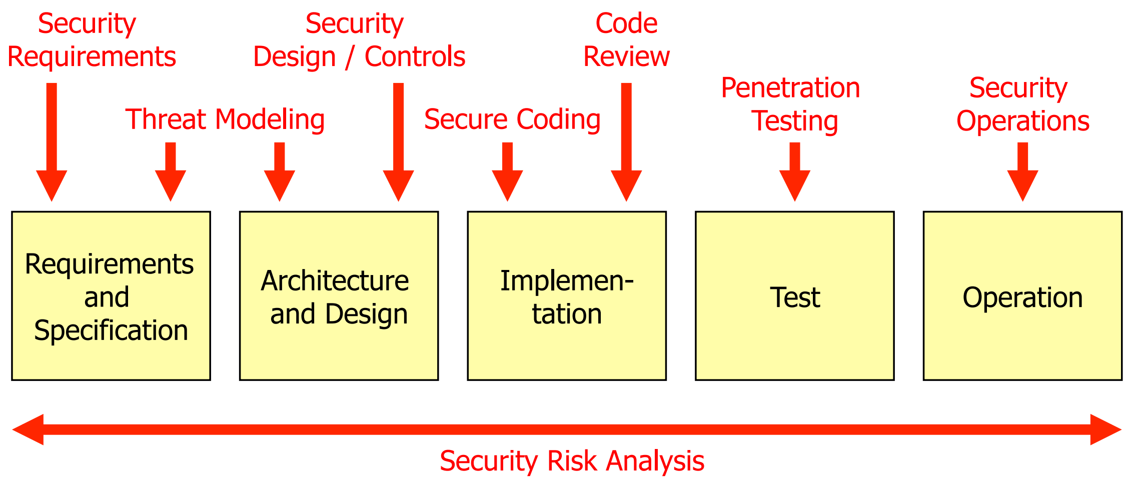
- Threat modeling is closely associated with security requirements engineering
  - Security requirements engineering without threat modeling is hardly going to produce good results
  - In fact, security requirements engineering mainly consists of threat modeling
- The goal of threat modeling is to find out whether the specified security requirements or security controls are appropriate
- Applied to a secure development process, threat modeling consist of the following fundamental steps:
  - Identify possible threats against the system (its assets)
  - Based on these threats, identify vulnerabilities
    - Taking into account already defined security requirements or security controls
  - The identified vulnerabilities provide the basis for additional security requirements

Threat Modeling (2)

- Besides as an activity during a secure development process, threat modeling can also be used as an activity on its own
  - E.g. to perform an analysis of a completed system (design) as an external security expert
- But the result will be typically the same: A list of identified system vulnerabilities
  - Usually rated with respect to their risk / criticality (see chapter on security risk analysis)

Security Requirements Engineering and Threat Modeling in the SDL (1)

- The focus of security requirements engineering and threat modeling is during the early phases during software development
  - This confirms the importance of these activities as they are responsible to provide the foundations for a secure system, influencing all subsequent security activities



Security Requirements Engineering and Threat Modeling in the SDL (2)

- With an iterative development process, security requirements engineering and threat modeling should be part of several iterations
  - During each iteration, the focus should lie on new threats introduced by new functionality
  - As a result, the list of security requirements continuously grows with each iteration

- Already specified security requirements are often elaborated further during later iterations, e.g.:
  - During an early iteration, it is specified that sensitive data must be protected on communication links
  - During later iterations, e.g. when a diagram with system components and interactions is available, this may be refined by specifying what data must be protected on which links

Functional Security Features – and Beyond (1)

- When starting to think about security requirements in a project, some "obvious" basic security requirements will be defined right away
  - So threat modeling is not necessary to define every single security requirement

- Examples of "obvious" security requirements of an e-shop:
  - Sensitive information such as payment details must be transmitted via a cryptographically secured communication channel
  - Only sales personnel is allowed to view and modify the orders of all customers
  - Customers can only see their own orders

Functional Security Features – and Beyond (2)

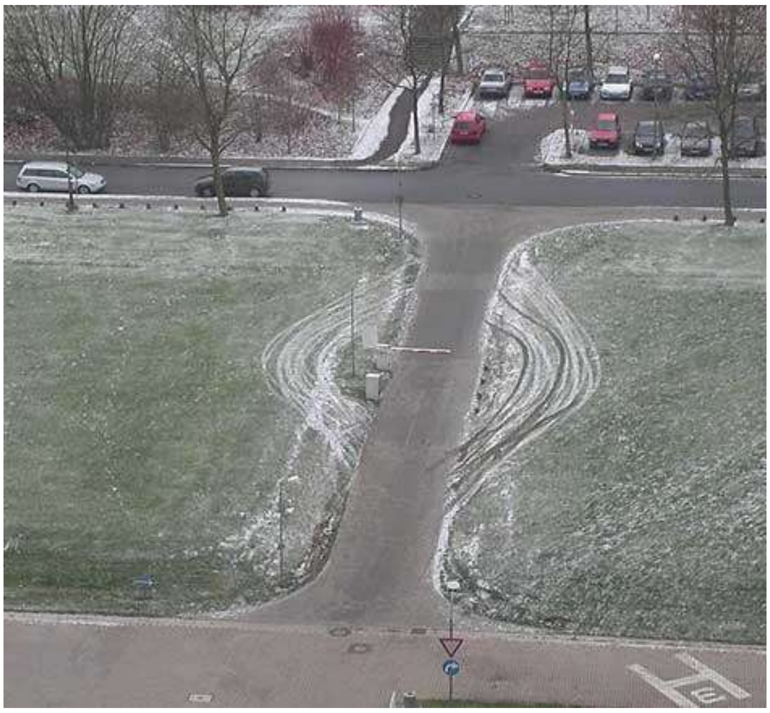
- However, these "obvious" security requirements are often mainly driven by the functional aspects of the system to be developed
  - "We transfer credit card numbers, so we must encrypt communications"
  - "There's a special area for sales personnel, so we need access control to make sure other users cannot access this area"
  - "A customer can see his own orders, so we need again access control"

- If we want the software to be really secure and robust, such a functional view is not enough
  - Typically, attackers do directly attack security functions, but they look for "places" where security was forgotten
  - → Attackers look for ways to circumvent the security measures

Functional Security Features – and Beyond (3)

- So to access credit card information, the attacker most likely won't try to break TLS, but could attempt the following:
  - He'll ask himself where this data may be accessible in non-encrypted form?
  - E.g. in the database (where it might be accessible using SQL injection or by compromising the database server)
- And to access the data that is protected via access control mechanisms, the attacker most likely won't attempt to directly break the access control mechanism itself, but may do the following:
  - He'll likely check whether access control was forgotten in certain parts of the application (e.g. via forced browsing)
  - Or he may try to access the data via other means, e.g.:
    - Via injected JavaScripts which reads the data in the user's browser
    - Again via SQL injection to directly read the data from the database
    - By getting the credentials of a user that has the necessary access rights via various means (guessing, social engineering, via XSS / SQL injection...)

About Circumventing Security…



Functional Security Features – and Beyond (4)

- The most important goal of threat modeling is to uncover these "not so obvious" threats
- This also requires you to start thinking like an attacker, i.e. to "put on the black hat"

- During threat modeling, ask yourself: If I were attacking the system...
  - What would I want? (steal money, get administrator access, take the system offline, deface the website...)
  - How could I accomplish this? (flood the target, elevate privileges, guess password, perform SQL injection...)
    - Be creative and consider a wide range of attacks!
- → This will help you to look at software (and security) from an entirely different side
  - It takes your focus away from existing (functional) security measures and helps you to consider a wide range of possibilities to achieve an attack goal

"What", not "How"

- Security Requirements should describe "what" has to be done, not "how" is has to be done
  - How a requirement is going to implemented (technical details) will be determined when defining the system architecture and design
- A reasonable security requirement:
  - "The web application must employ an authorization mechanism, authorization must be checked on every single request"
  - The choice of the mechanism is not determined by the requirement
- But security requirements should also be precise and not leave too much room for "security interpretation"
  - "Passwords must have at least the following complexity: ≥ 10 characters, at least one digit and at least one special character" is better than
  - "The application must use strong passwords"

Security Requirements Engineering – The Process

Security Requirements Engineering – The Process (1)

- Security Requirements Engineering is a young discipline and far from being a "scientific method"
- Several method have been proposed, but fundamentally they are similar to each other
  - There's also not a "currently best method" or a dominating "industry standard" one should follow
- We do not follow one specific proposed method here, but use a combination of proposed approaches
  - It is mainly influenced by the OWASP threat risk modeling process and Microsoft's threat modeling process

Security Requirements Engineering – The Process (2)

The security requirements engineering process consists of 6 steps:

1. Identify the business and security goals of the system
2. Collect information about the system so you get a good understanding about its purpose and functions
3. Decompose the system to understand its internal workings and as a basis for the following steps
4. Identify threats that are relevant for the system
5. Identify vulnerabilities in the system, given the threats
6. Mitigate the threats where necessary by proposing adequate security requirements

Threat Modeling activities

Step 1: Identify Business and Security Goals

- The first step when performing security requirements engineering is identifying the business goal and the security goals
  - This helps to understand the overall goals and purpose of the system and provides the basis for all subsequent steps
- Try to express the business goal in one or at most a few sentences
  - This forces you to really think about the main business goal
- Driven by the business goal, identify a few security goals
  - The security goals should be important to achieve the business goal, but they may also be required due to general policies or regulations
  - Again, focus on the most important, overall security goals and don't go too much into the details
  - Something between 3 and 6 security goals is usually reasonable
- Business and security goals are usually defined by performing interviews with the stakeholder
  - E.g. the external client or internal project sponsor

The University Library Application (1)

- As an example to illustrate the entire process, we use a fictional web application, the "University Library Application"
- Current state of the project:
  - Several functional requirements and even some security requirements have already been defined
  - Designing the system has started
  - The team is suddenly unsure whether security is considered adequately, which is where you are hired as a security expert
- As a security expert, you understand the importance of security requirements engineering, so this is where you start
  - As some security requirements have already been defined, this is used as the basis for your analysis

The University Library Application (2)

- According to the process, the first step is identifying the business and security goals
- Carrying out interviews with the stakeholder results in the following:

Business Goal:
The system allows its users efficient online access to the university library

Security Goals:
- The integrity of the system and its data shall be maintained
- The confidentiality of personal user data and credentials shall be guaranteed
- Any system activity is logged and can be linked to a user

Step 2: Collect Information (1)

- The second step is getting a good understanding about the system
- This includes the following:
  - What functions does the system provide in detail?
  - Who uses the system (users, administrators, other systems...)?
  - What data does the system process?
  - What are the most important assets?
    - Should be driven by the business and security goals
    - E.g. data that are directly necessary to achieve the business goal are more valuable than others
  - How does the system work (components, technologies, interactions...)?
  - What are the external dependencies that must be considered?
    - This is important as they may have security implications that are not directly under control of the developing team
  - What is the service level the system must comply to (e.g. 24/7)?
  - What security requirements or controls have already been defined
  - ...

Step 2: Collect Information (2)

- This can be achieved by:
  - Analyzing available artifacts
    - Specifications, security requirements, design & architecture documents etc. → any documentation available (as pure text, UML diagrams or whatever)
  - Carrying out interviews with involved people (typically engineers)
- The more information that is available, the more thorough the subsequent steps can be performed
  - In early phases, there often exists only a general description and some functional requirements
    - Only basic security requirements can be derived (with limited time effort)
  - As the system architecture and design advances, more information will be available allowing for a more detailed analysis
    - Which likely will produce further and more specific security requirements
- Security requirements engineering is therefore usually applied repeatedly while the overall system design is developed
  - Which fits well with an iterative software development process

The University Library Application (3)

Collecting information on our example application reveals the following:

- General information of the application:
  - The university library application is a web application to provide librarians and library users (students and staff) with online services
    - As this is the first version, the functionality will be limited
  - There will be three types of main users of the application:
    - Students, Staff, Librarians
  - Offered functionality:
    - Students and staff will be able to log in and search for and reserve books
    - Staff members can additionally request new books
    - Librarians will be able to log in, search for books, maintain the list of available books, view book reservations, and add and delete users
  - Users have individual login credentials, librarians share one account
  - High availability is not needed, downtimes during the weekend or even partial downtimes during workdays are not critical

The University Library Application (4)

Some security requirements have also been defined and documented:

- Users and librarians can access the web application server only via cryptographically protected channels (HTTPS / TCP port 443)
- When TLS is used, servers are authenticated using Extended Validation (EV) certificates
- Direct access to the web and database servers for configuration and log monitoring is only allowed to administrators and only via SSH
- Administrators must have at least security clearance "medium" (employed ≥ 5 years, regular background checks)
- All performed actions are logged locally on the web application server
- All queries are logged on the database server
- The SSH deamons log successful logins and login failures

The University Library Application (5)

There are also some external dependencies for the application:

- The university library application runs on standard university servers for web applications
  - Linux, Java, Tomcat
  - Hardened according to the university's server hardening standards, which are considered adequate for typical university services
    - Includes latest operating system and software security patches
- The database server will be MySQL on a Linux server, also hardened according to university standards
- The server components are physically located in the same network as servers of other applications with similar security requirements, access to the network is protected by packet filtering firewalls

The University Library Application (6)

We also determine the assets ("the crown jewels") of the application, which helps to identify the most important system components:

- Both server-side systems (integrity of systems and data)
  - Otherwise, efficient system usage is not possible
- Personal user data (account details, reservations)
- User and librarian credentials (username & password)
  - To keep personal user data confidential and to prevent system abuse
- Administrator credentials, which would provide attackers with powerful access to the system
- The logs, as they allow identify problems quickly and resume normal operation

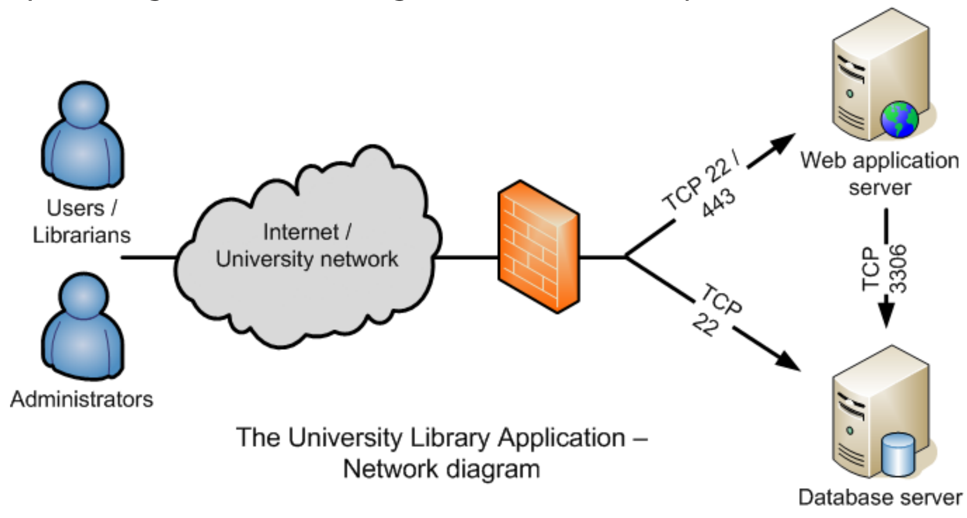
Don't just pick the assets at random, but pick the ones that are important with respect to defined business and security goals!

Step 3: Decompose the System

- The next step is to decompose the system into its component
- There are multiple ways to do so, e.g. by drawing a network diagram or a data flow diagram
- It's important to include all relevant information
  - System components such as servers
  - Different users
  - Interactions between users and system components and between system components
  - Interactions with external systems or applications
- Choose a reasonable level of detail that allows to perform a sound and efficient threat modeling process
  - Often, it's not necessary to include very many details as this will only make threat modeling much more complex without producing significantly better results

Network Diagram (1)

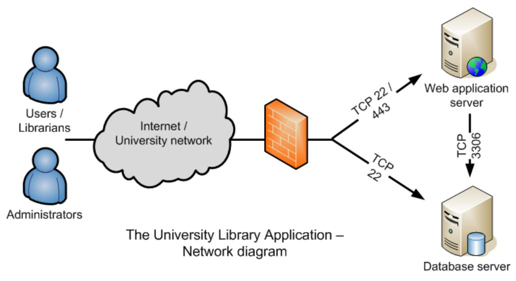
- A network diagram typically includes the most important users, system components, communication relationships, and protocols / ports
  - Suited as a first overview, also to make sure all involved persons have the same and correct understanding of the system
  - If threat modeling is done by an external team, this can be verified by showing the network diagram it to the development team



The University Library Application – Network diagram

Network Diagram (2)

- This network diagram can already be used to think about threats and security requirements:
  - The web application server is the entry point into the application, so it must authenticate users before allowing access to restricted information
  - Credentials are sent across the network, which could be sniffed by attackers, so this must be protected (as is already the case with HTTPS/SSH)
  - All servers in the network can access the database server, so it must authenticate the web application server before granting access



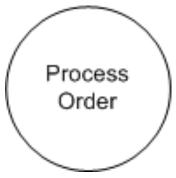
- But in general, network diagrams only serve as a first overview how system components interact

- To really perform threat modeling, one uses more detailed diagrams, e.g. data flow diagrams

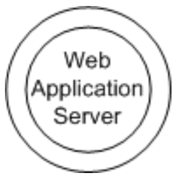
Data Flow Diagrams (1)

- Data Flow Diagrams (DFD) are well suited to decompose a system at various levels of details
  - The system components are depicted with different elements

- Process: represents a task within the system; a task usually receives and processes data and forwards data to other components
  - E.g. the authentication process in an application or the method that processes orders made by customers

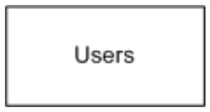


- Multiple Process: used to represent a collection of processes
  - Examples: an entire mail server or a web application server

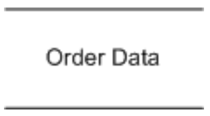


Data Flow Diagrams (2)

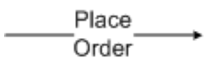
- External Entity: used to represent any entity outside the system that interacts with the system
  - E.g. users, administrators, but also external components used by / interacting with the system (e.g. a 3rd party web service)



- Data Store: used to represent locations where data is stored
  - Examples: database files, configuration files, log files

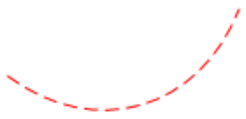


- Data Flow: represents interactions within the system; the arrow indicates the direction of the data flow
  - Examples: data sent over a network or data exchanged within components of a mail server



Data Flow Diagrams (3)

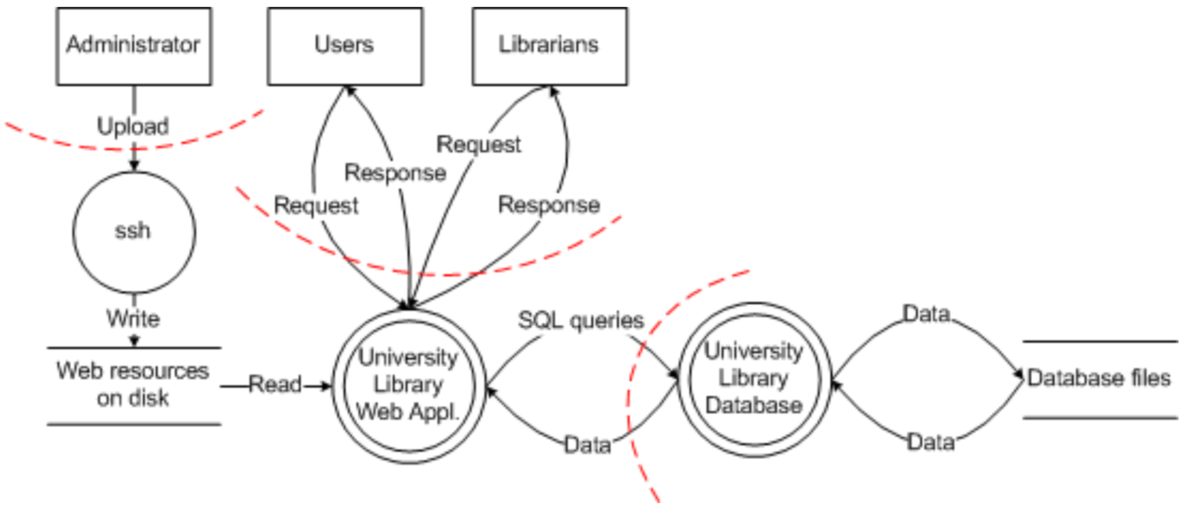
- Privilege Boundary (or Trust Boundary): used to mark the change of privilege / trust levels as the data flows through the system



  - Example 1: Data flow between external users and a web application
    - Depending on their rights, the users are typically only allowed to use a subset of all functions offered by the web application
    - This is a change of privilege levels because data from (typically) low-privileged external users are processed by the high-privileged web application
  - Example 2: Data flow between web application server and database server
    - The web application is likely not allowed to use all functions (CRUD) available on the database server
  - In general, privilege boundaries usually imply that some sort of access control must be performed:
    - E.g. to guarantee low-privileged users can only access the allowed functions
  - When identifying threats and vulnerabilities (steps 4 & 5), it's usually a good idea to analyze DFD elements "close to privilege boundaries" with extra care

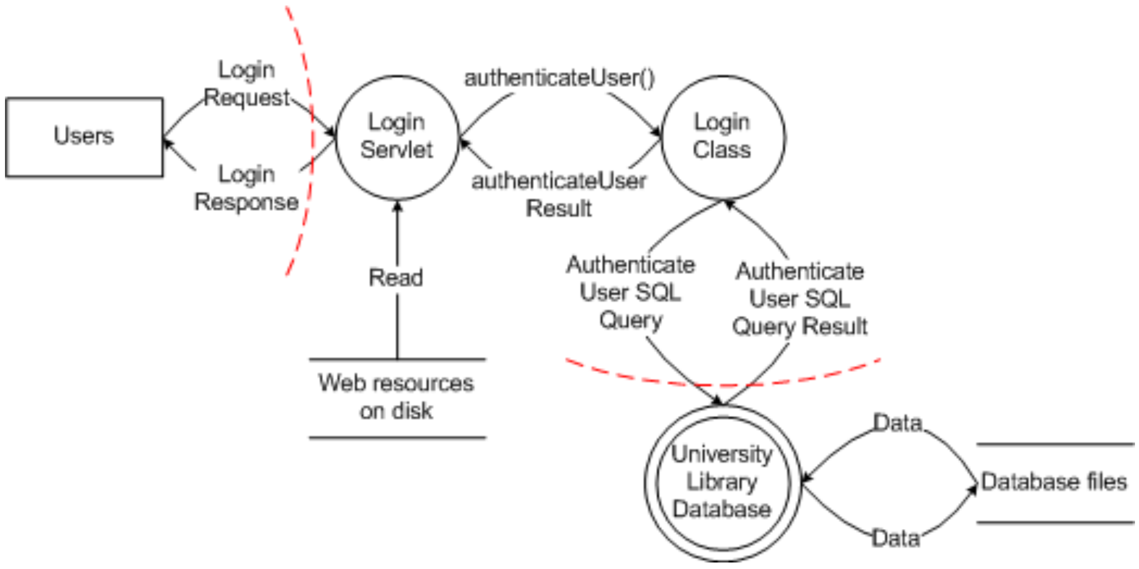
A First, High-Level DFD

- It usually makes sense to begin with a high-level DFD
  - High-level means that larger system components such as the web application are depicted as multiple process and not split further



Drilling Down

- One can also drill down deeper
  - In this DFD, the focus is on the login process of users and the web application component is split into a login servlet and a login class



Step 4: Identify Threats

- The next step is to identify threats that are relevant for the system under analysis
- A good way to do this is by using the Microsoft STRIDE approach
- STRIDE basically is a checklist of six attack / threat categories:
  - Spoofing
  - Tampering
  - Repudiation
  - Information disclosure
  - Denial of service
  - Elevation of privilege

STRIDE (1)

- Spoofing
  - Spoofing means an attacker pretends to be somebody or something else (e.g. another user or another server)
  - Examples: Accessing a system with another user's identity, e-mail spoofing, e-banking server spoofing to collect credentials during a phishing attack...
- Tampering
  - Attacker modifies data or code in a malicious way (at rest or in transit)
  - Examples: Modifying a file with insufficient access protection (e.g. world-writeable), modifying data sent across unprotected network links (e.g. replies from a DNS server)...
- Repudiation
  - Attacker can deny having performed an action because there's no evidence to link the action to the attacker
  - Examples: Manipulating log files after a successful attack to remove traces…

STRIDE (2)

- Information disclosure
  - Attacker gets access to information he's not authorized to read
  - Examples: Reading files with plaintext passwords, reading credit card data sent across unprotected network links, reading data from the database using SQL injection…
- Denial of service
  - Attacker denies access to legitimate users
  - Examples: Crashing an application or a system (triggering an exception, causing a buffer overflow), flooding a system with large amounts of network traffic...
- Elevation of privilege
  - Attacker gets more privileges than he is entitled to
  - Examples: Exploiting a vulnerable program that runs with administrator rights, circumventing poor access control mechanism…

Applying STRIDE to Data Flow Diagrams

- The STRIDE categories are mapped to the DFD elements according to the following table:

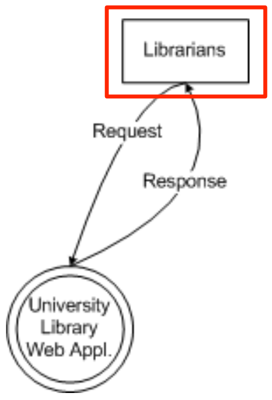
DFD Element Type	**S**	**T**	**R**	**I**	**D**	**E**
External Entity	X		X			
Data Flow		X		X	X	
Data Store		X	X*	X	X	
(Multiple) Process	X	X	X	X	X	X

  - Privilege boundaries are not considered as they primarily serve to identify interesting areas in a DFD
- Examples:
  - Spoofing threats affect external entities or processes
    - But one cannot directly spoof a data flow as it always originates from a spoofed external entity or a process
  - Tampering threats affect data flows/stores (manipulating the data) and processes (manipulating them so they behave differently)

Step 5: Identify Vulnerabilities

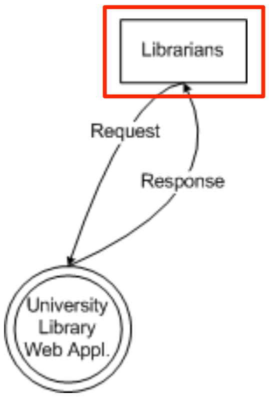
- Identifying vulnerabilities can be done as follows:
  - Go through all DFD elements...
  - ... and think about how the relevant STRIDE threat categories may be used to attack the system
- For each relevant combination, do the following:
  - Identify possible threat / attack scenarios
  - Check if countermeasures are in place that protect from the threat
  - If no sufficient countermeasures are in place, a vulnerability has been identified
- In the following, we consider some examples using the high-level DFD
  - This DFD is well suited to perform threat modeling of the overall system

External Entity Example (SR): Librarians (1)



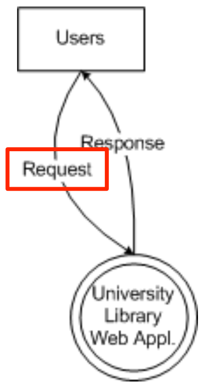
- Spoofing Threat
  - There’s a spoofing threat if the attacker manages to learn the librarians’ password (by guessing, stealing...)
- Countermeasures
  - Password-based authentication is used to prevent non-authorized access, which is basically good
- Rating
  - The requirements do not specify a minimal password strength, weak password will likely be selected
  - In addition, using a shared account among librarians increases the probability that passwords will be written down next to the librarians’ computers
  - Overall, this is not considered sufficient to adequately protect from the threat → We identify this as a vulnerability (V1)

External Entity Example (SR): Librarians (2)



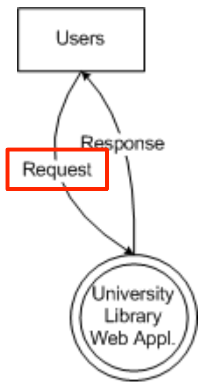
- Repudiation Threat
  - There's a repudiation threat if librarians can perform malicious actions and can deny having done this
- Countermeasures
  - Librarians use a special account, which allows assigning actions to librarians
- Rating
  - But as the librarians share an account, the logged actions cannot be unambiguously assigned to individual librarians
  - → We identify this as a vulnerability (V2)

Data Flow Example (TID): Request (from Users) (1)



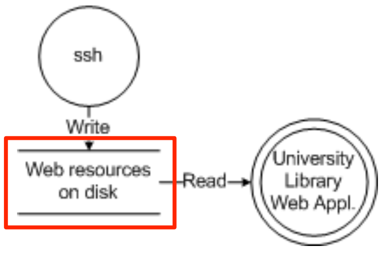
- Information Disclosure Threat
  - There's an information disclosure threat if an attacker can read the password being transmitted
- Countermeasures
  - Usage of TLS with server-side certificates prevents this
- Rating
  - → We do not identify a vulnerability
- Tampering Threat
  - There's a tampering threat if an attacker manages to modify the data without being detected (although it's unclear what his gain would be)
- Countermeasures
  - Usage of TLS allows to detect any tampering
- Rating
  - → We do not identify a vulnerability

Data Flow Example (TID): Request (from Users) (2)



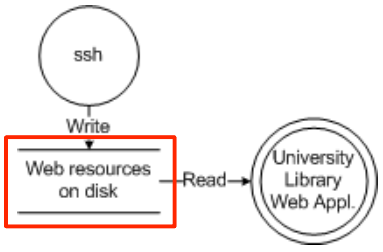
- Denial of Service Threat
  - There's a denial of service threat if an attacker manages to prevent data from legitimate users from reaching the web application (e.g. by exhausting a communication link or network device by flooding)
- Countermeasures
  - There are no specific countermeasures to prevent this
- Rating
  - As this is not a high-availability system, this is acceptable → We do not identify a vulnerability

Data Store Example (TR*ID): Web Resources on Disk (1)



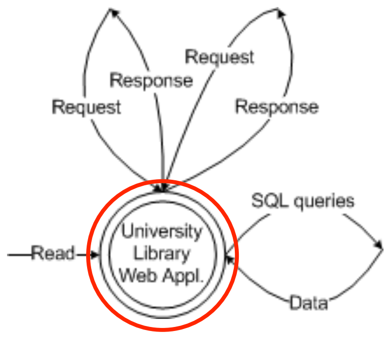
- Tampering Threat
  - There's a tampering threat if an attacker manages to modify the web resources, e.g. to deface the website or to modify the code so that credentials are sent to the attacker
- Countermeasures
  - The university's server hardening standards that are considered adequate for typical university services
  - Only trusted administrators can log in and upload web resources
- Rating
  - → We do not identify a vulnerability

Data Store Example (TR*ID): Web Resources on Disk (2)



- Information Disclosure Threat
  - There's an information disclosure threat if an attacker manages to read the web resource (e.g. to get valuable information from them)
  - This could help the attacker to identify vulnerabilities in the web application code (e.g. servlets)
- Countermeasures / Rating
  - → For the same reasons as with tampering, we do not identify a vulnerability
- Denial of Service Threat
  - There's a denial of service threat if an attacker can exhaust storage
- Countermeasures
  - None
- Rating
  - → We do not identify a vulnerability, as the application does not continuously write this data store (unlike, e.g., a log file)

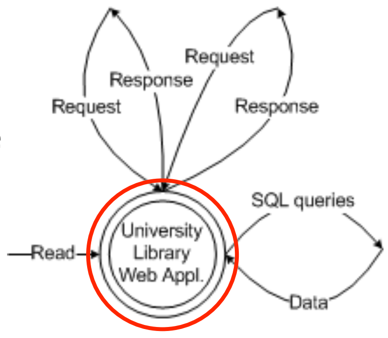
Process Example: University Library Web Appl. (STRIDE) (1)



- Spoofing Threat
  - There's a spoofing threat if the attacker operates his own version of the library web application to collect credentials
- Countermeasures
  - An EV certificate is used to authenticate the web application, which is considered sufficient to protect from the threat
- Rating
  - → We do not identify a vulnerability

Process Example: University Library Web Appl. (STRIDE) (2)

- Tampering Threat
  - There's a tampering threat if an attacker manages to modify the running web application or the Java/Tomcat software to collect credentials
- Countermeasures
  - The university's server hardening standards are considered adequate to protect from external attackers that attempt to get access and modify the code
  - Using Java makes it unlikely to inject code by exploiting, e.g., a buffer-overflow vulnerability
- Rating
  - → We do not identify a vulnerability

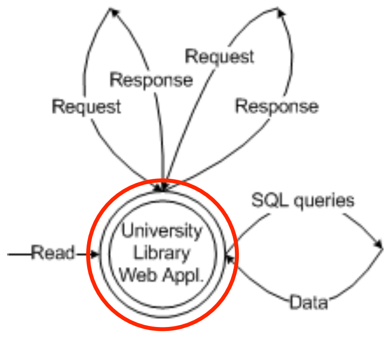


Data Store Tampering vs. Web Appl. Code Tampering

- You may have noticed that the attack goal "collecting user credentials by modifying the web application" has already occurred twice
- This is reasonable as we have identified two ways to achieve this goal:
  - Data store: By modifying the web resources on the disk (servlets, JSPs...)
  - Process: By modifying the running web application by injecting code or by modifying the underlying Java/Tomcat software
  - In both cases, one analyses whether appropriate countermeasures are in place or whether there are vulnerabilities
- In fact it is important to identify all ways to achieve an attack goal as the attacker just needs one vulnerability to be successful
  - Therefore, apply an attack goal in the context of all relevant DFD elements

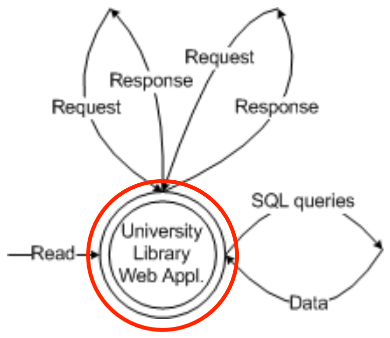
Process Example: University Library Web Appl. (STRIDE) (3)

- Repudiation Threat
  - There's a repudiation threat if the web application – after being compromised and modified to stop logging – performs non-legitimate transactions
- Countermeasures
  - Logging on the web application server will no longer work, but all queries are also logged on the database (which runs on a separate host)
  - So the attacker would need to compromise two systems to completely remove any traces
- Rating
  - → We do not identify a vulnerability



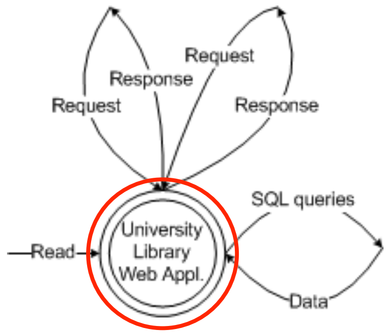
Process Example: University Library Web Appl. (STRIDE) (4)

- Information Disclosure Threat
  - There's an information disclosure threat if the web application allows accessing data via SQL injection
- Countermeasures
  - The security requirements do not make any statements to prevent this
- Rating
  - → We identify this as a vulnerability (V3)



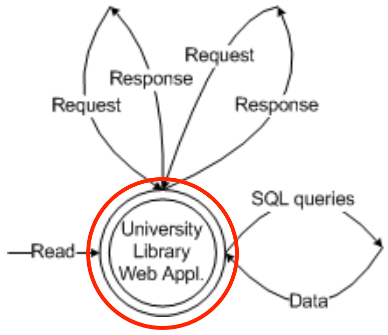
Process Example: University Library Web Appl. (STRIDE) (5)

- Denial of Service Threat
  - There's a denial of service threat if an attacker manages to prevent the web application from offering its services
- Countermeasures
  - The university's server hardening standards are considered adequate to prevent from some DoS threats (e.g. crashing the system/service by sending a malformed packet)
- Rating
  - Because of the hardening standards and as this is not a high-availability system, this is acceptable → We do not identify a vulnerability



Process Example: University Library Web Appl. (STRIDE) (6)

- Elevation of Privilege Threat
  - There are elevation of privilege threats if an attacker manages to circumvent access control checks to get access as a (e.g.) librarian
- Countermeasures
  - The security requirements do not state anything about whether access control must be performed
- Rating
  - → We identify this as a vulnerability (V4)



Step 6: Mitigating the Threats

- The last step of threat modeling is to define new security requirements that eliminate or reduce the identified vulnerabilities
- A nice property about STRIDE is that each threat directly maps to a security properties

STRIDE Threat	Security Property
Spoofing	Authentication
Tampering	Integrity
Repudiation	Non-repudiation
Information disclosure	Confidentiality
Denial of service	Availability
Elevation of privilege	Authorization

- Mitigating the threats therefore means proposing appropriate security requirements that can provide the desired security property

Mitigating the Identified Threats (1)

- Vulnerability V1: spoofing librarians because
  - A shared account is used
  - Password strength is not enforced by the system
- According to the table of security properties, this affects authentication and corresponding security requirements should be defined
- In this case, this could result in the following:
  - Use individual accounts for librarians with dedicated passwords
  - Enforce a minimal password quality (length, character mix, compare with dictionary...)
  - Optional: integrate into university-wide identity management system (if such a system is available)
- The same proposal also mitigates the reputation threat (V2) by librarians

Mitigating the Identified Threats (2)

- Vulnerability V3: Information disclosure of the web application because the security requirements do not make any statements with respect to preventing SQL injection attacks
- According to the table of security properties, this affects confidentiality and corresponding security requirements should be defined
  - Confidentiality is not just about encrypting data, it's about providing information only to legitimate users and systems
- In this case, proposed security requirements could include:
  - Accessing the database is only allowed via prepared statements
  - All data received from users should be considered non-trusted and should first be validated before processed further
  - Use a technical database user with minimal privileges

Mitigating the Identified Threats (3)

- Vulnerability V4: Elevation of privilege when using the web application because the security requirements do not make any statements with respect to access control
- According to the table of security properties, this concerns authorization and corresponding security requirements should be defined
- In this case, defined security requirements could include:
  - The web application must employ an authorization mechanism
  - Authorization must be checked on every single request (complete mediation)

Security Requirements Engineering / Threat Modeling – Remarks (1)

- As said before, this is not a scientific method but rather a creative process
  - As a result, this is best be done in a team, where different views and knowledge areas of the participants can be considered
- As long as a system is developed further, security requirements engineering / threat modeling never really stops
  - It's an iterative process – and therefore fits well with iterative software development in general
  - When the system is extended, new security requirements may have to be defined
- Even without any system extension, it may be necessary to adapt security requirements, e.g. when new types of attack surface
  - In these cases, a new type of attack can be the trigger for a new iteration

Security Requirements Engineering / Threat Modeling – Remarks (2)

- What's the appropriate level of detail to use for the DFD?
  - A high-level DFD as we used it here is usually well suited to analyze a system with "typical security requirements"
  - In some cases, a more detailed view is appropriate
    - To analyze very security-critical processes, it may be reasonable to identify all involved components in detail
    - E.g. the entire payment process in an e-banking system
- "Tricks" to simplify a complex DFD
  - Combine elements with the same privilege level
    - Consequently, we did not split the web application multiple process into smaller processes in the University library application example as all these processes have the same privilege level
  - Two data flows between the same two elements that use the same protocols can also often be combined into one bi-directional data flow
    - In our example this could have been done with the request / response data flows between users and the web application

Security Requirements Engineering / Threat Modeling – Remarks (3)

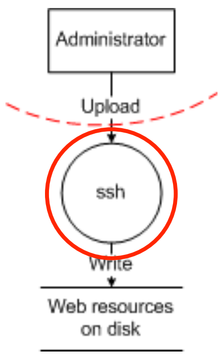
- Often, threats are not independent: a successful attack means other attacks can be carried out
  - If the attacker manages to spoof the administrator, he likely gets access to the system, where he can view and tamper data, delete data and stop processes (DoS), remove log data to cover his traces (repudiation) etc.
  - Don't think to far, simply consider each threat against each element on its own (otherwise, it gets quickly very complicated)
  - As positive side effect, this "forces" you to think about defense in depth
    - Because for each threat and each component (DFD element), you have to ask yourself what you can do HERE to protect from this threat
- Don't make security assumptions!
  - You analyze what you see and not what "you would like to see"
  - If it's not in the documentation and if no one has told you about a security requirements or control in an interview, assume it's not there
  - It's good to be on the conservative side, if someone tells you afterwards that "this requirement has been defined or this control is in place", no great harm was done

Security Requirements Engineering / Threat Modeling – Remarks (4)

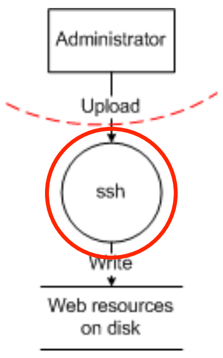
- Don't forget insiders
  - Often, security analyses focus on external attackers, but in reality, internal attacks are more likely
    - This includes malicious insiders (disgruntled employees)...
    - ...but also "accidents by insiders" (e.g. an administrator who connects an infected laptop to the network in the server room)
- Document your findings and refine / extend them during each iteration
  - No really good tools available, a spreadsheet is a good start
  - Microsoft has made available the SDL Threat Modeling Tool, which allows drawing DFDs and applying STRIDE to the elements
- Even the best security requirements engineering / threat modeling process can never prove a system is secure
  - But you can significantly increase the likelihood that the system does not contain major security design flaws

Exercise (1)

Consider the ssh process, identify one threat for each STRIDE category and determine whether appropriate countermeasures are in place. If a vulnerability is identified, propose new appropriate security requirements.



Exercise (2)


Administrator
Upload
ssh
Write
Web resources on disk