Information & Communication Security (SS 15)

Security Engineering

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Agenda

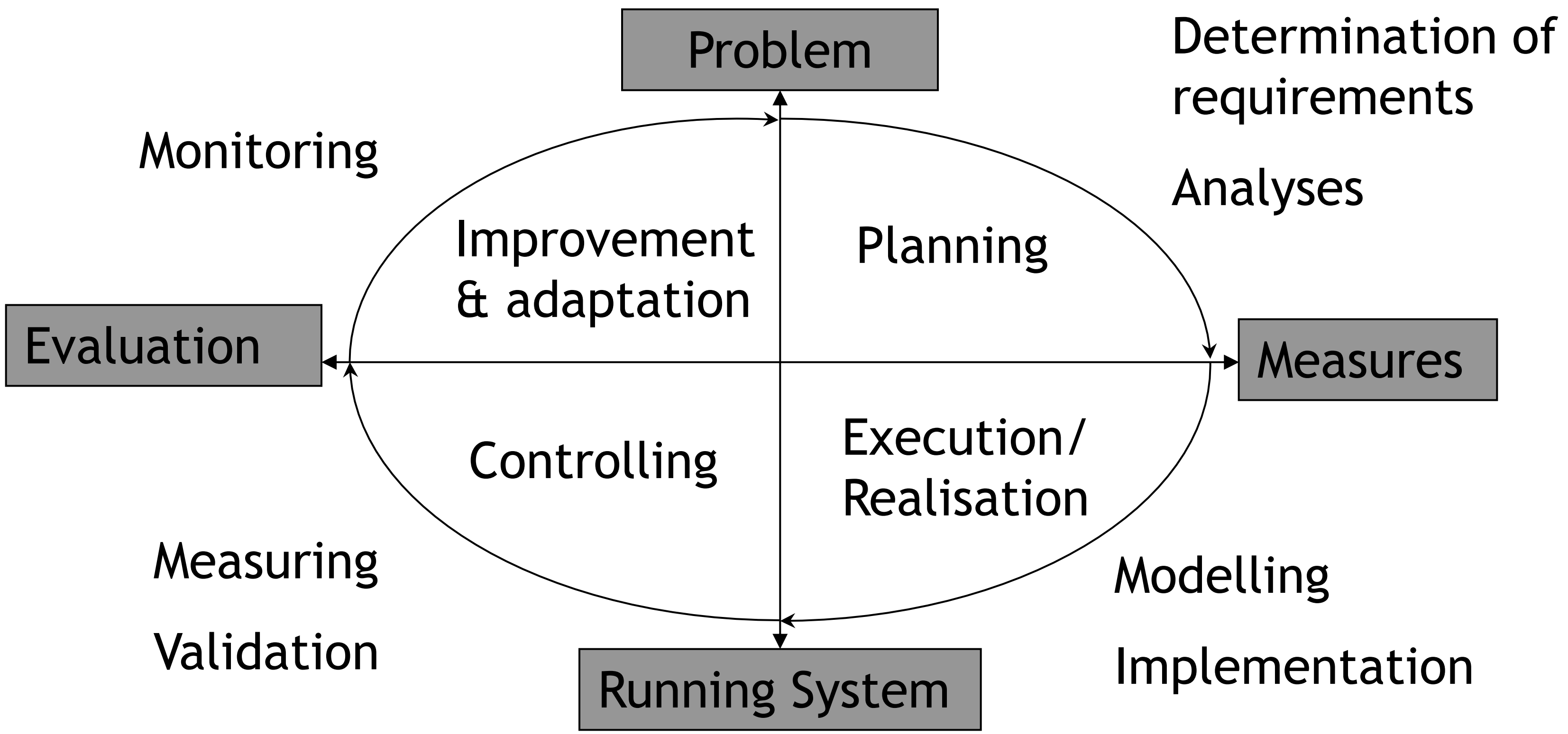
- **Introduction**
- Secure System Development Process
- Analysis
- Modelling
- Design
- Validation and Evaluation
- Security Monitoring
- Security Engineering with UML

Introduction

- Security Engineering – a disciplined approach to build secure systems

- General methodical approach from Software Engineering

Iterative Engineering Process



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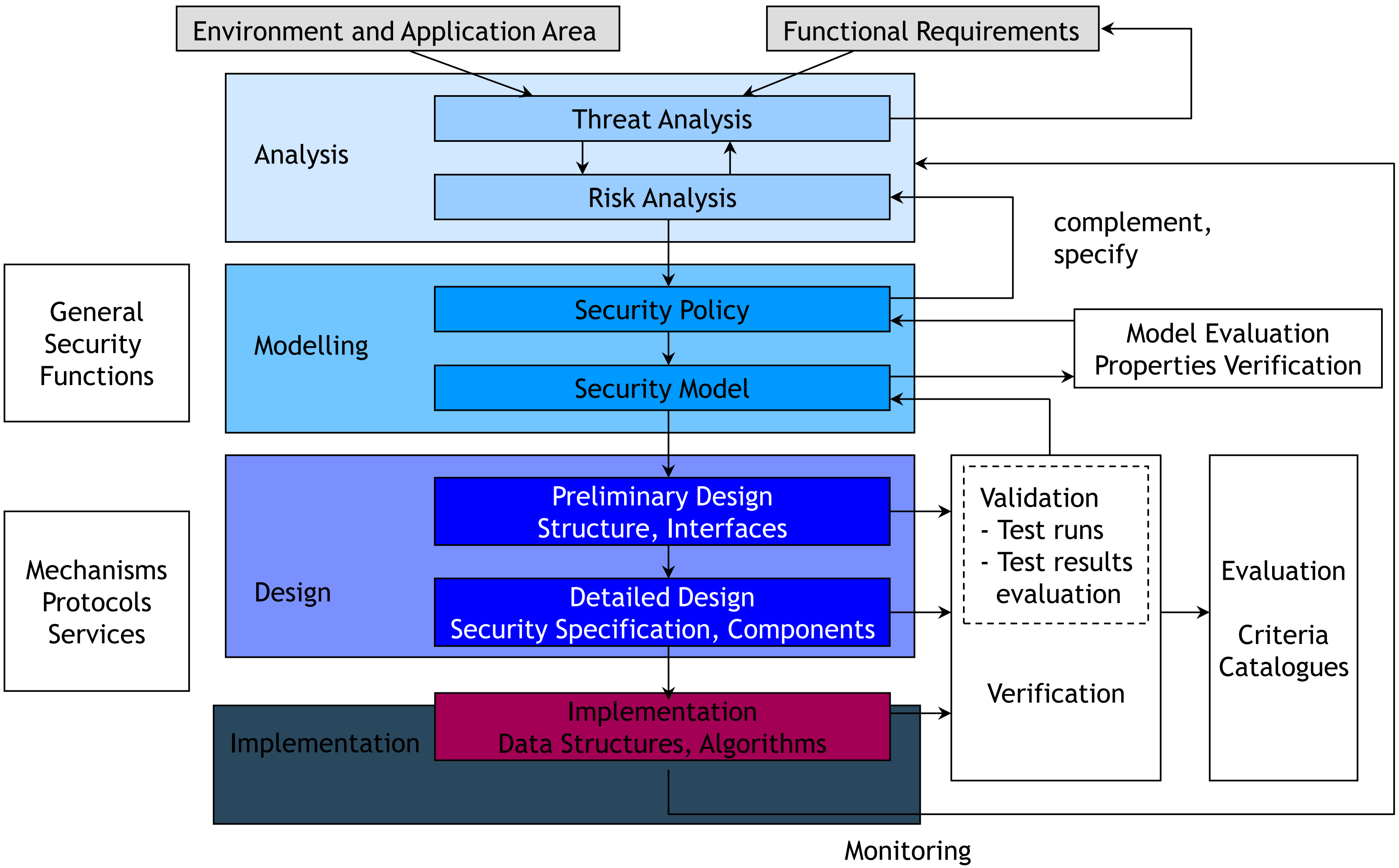
Secure System Development Phases

- Planning phase
  - Structural analysis
  - Determination of requirements, especially for protection
  - Threat analysis
  - Risk analysis
- Realisation phase
  - Security policy
  - Strategy model
  - Implementation
- Controlling
- Improvement and adaptation

Secure System Development Process



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- Secure System Development Process
- **Analysis**
  - **Structural Analysis**
  - Determination of protection needs
  - Threat Analysis
  - Risk Analysis
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Structural Analysis

- System Requirements
  - System Functions
  - System Components
  - System Purposes

=> Requirements specification

=> Net topology

- Connection of the Local Area Network to the outside world: ISDN, DSL, Satellite
- External connections (e.g. a mother company and a subsidiary company): Broadband LAN, leased lines

=> Properties of each component

- Unique ID
- Operating System
- IP Address
- Purpose

Example: Mobile OS

Requirements specification

- Functional requirements

  [FR25] The OS should provide usual environment to users and developers

  [FR26] The OS should provide a trusted way of user authentication

  [FR27] User should be able to refine access permissions concerning their objects without disturbing the security of the whole system

  [FR28]Users should be able use the OS without experience in security

  . . .

- Performance requirements
- Quality requirements

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Determination of Protection Needs

- Possible damage
  - Difficult to define in general
    - ➢ Assess based on scenarios

- Semi-quantitative categories for Protection Needs
  - Low to medium: Damage is manageable.
  - High: Damage could be considerable.
  - Very high: Damage may reach an existential dimension.

Damage Scenarios

- Violation of laws, rules, or agreements
  (e.g. the constitution, (German) BGB, etc.)
- Curtailing the right of informational self-determination
  (e.g. unwarranted transfer of personal data)
- Curtailing of personal integrity
  (e.g. medical systems (or databases))
- Curtailing task completion
  (e.g. defective production because of wrong control data)
- Negative consequences for the reputation
  (e.g. website deformation => prestige loss)
- Negative financial consequences
  (e.g. unwarranted research findings transfer)

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Threat Analysis

- The examination of threat sources against system vulnerabilities to determine the threats for a particular system in a particular operational environment
- Available approaches
  - Threat matrix
  - Attack tree

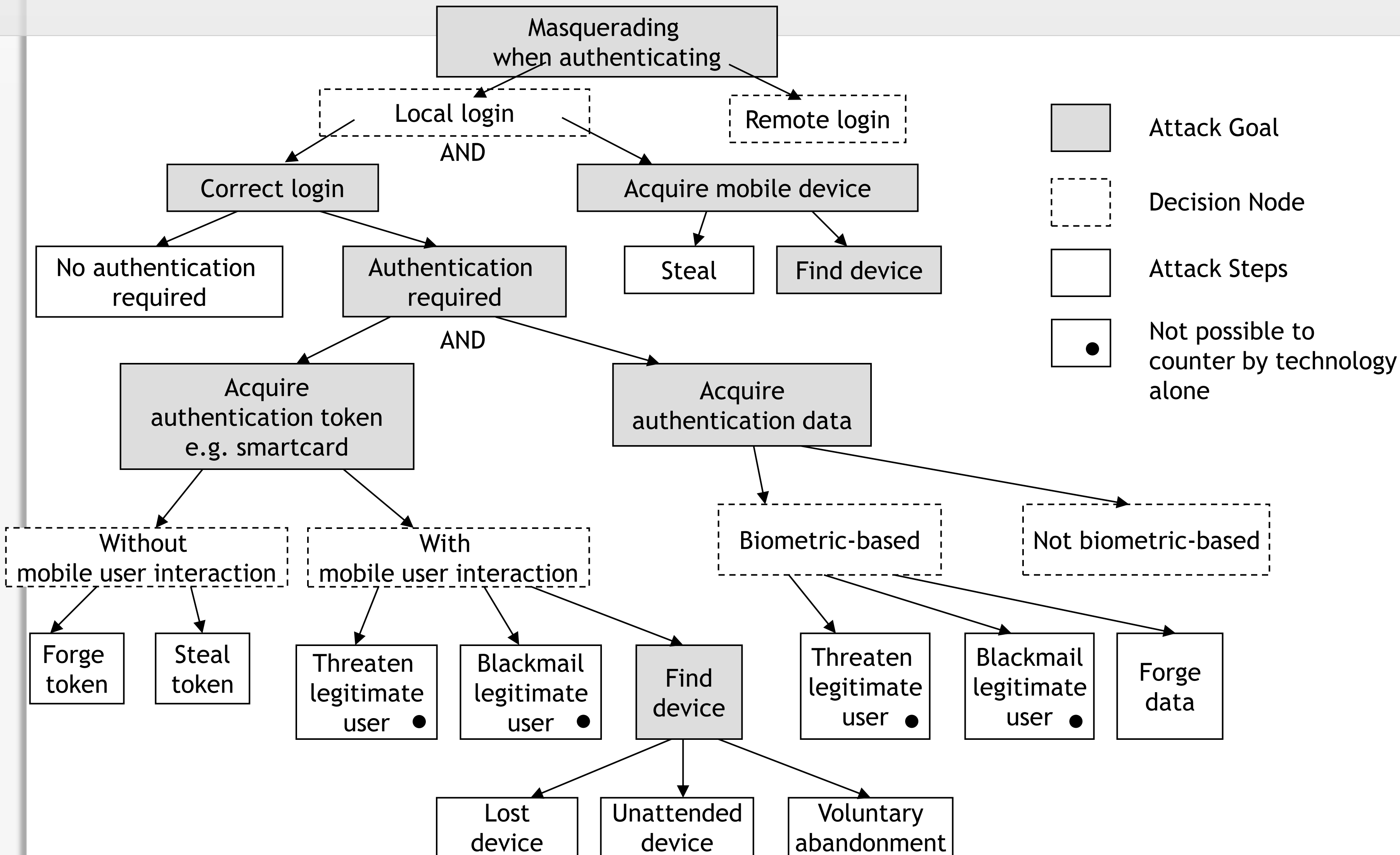
Attack Tree

- System threats can be presented as an **attack tree**:
  - **Tree root**: symbolizes the attack goal
  - **Next level(s)**: contain(s) provisional goals (as nodes) required to reach the final attack goal
  - **Nodes**
    - **“Or” nodes** (standard): represent alternatives
    - **“And” nodes:** have to occur in common
  - **Leaves**: contain options to attack the goal

Possible Attack Goals

- Intruding into a system by using the identity of an authorized user
- Disabling required functions (e.g. for protection)
- Reading (and writing) of sensitive data
- Unauthorized changing and receiving of sensible information exchanged via (electronic) communication ways

Example: Attack Tree for the Mobile OS



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Risk Analysis

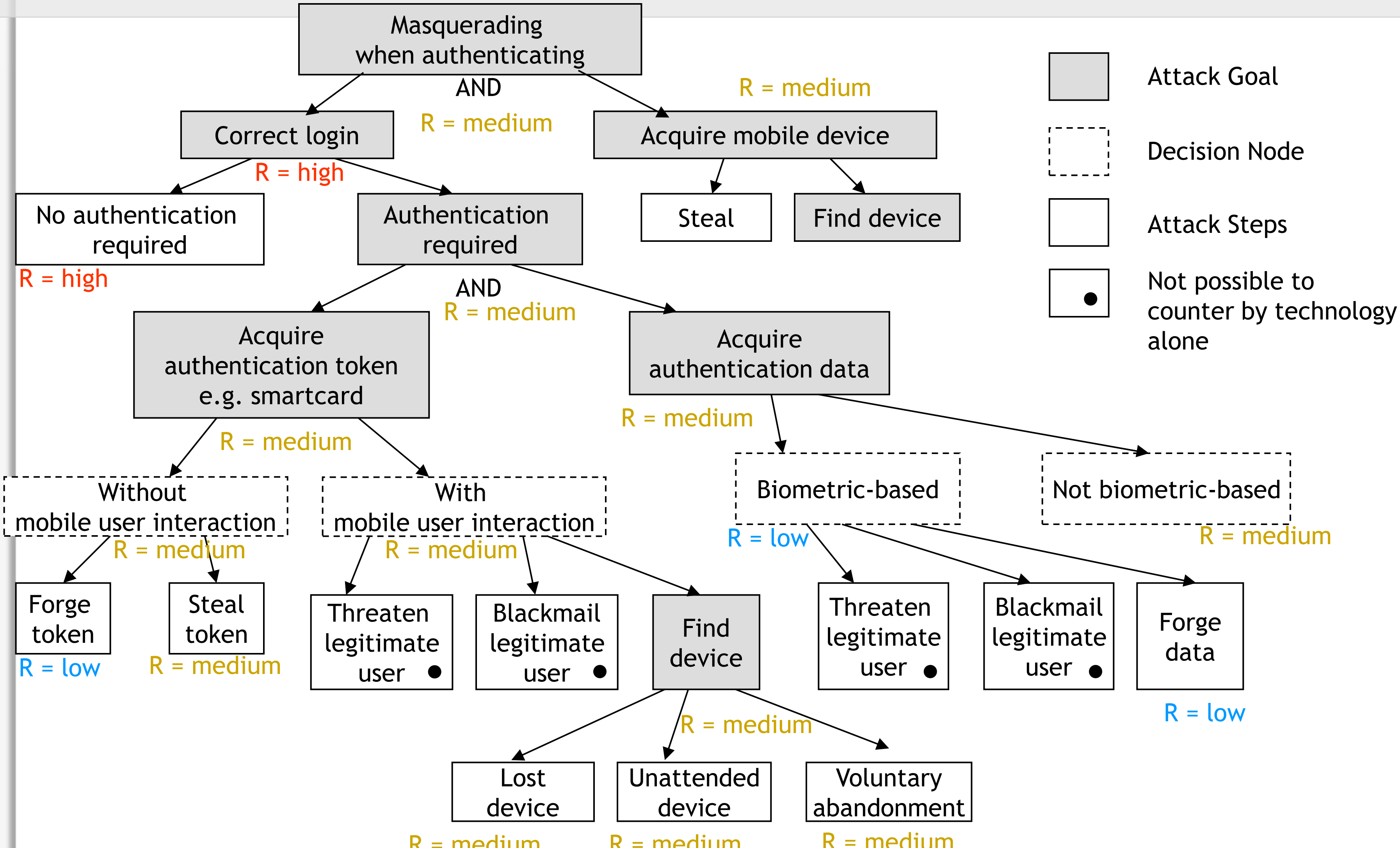
- Threat rating
- Items to be considered
  - Who is the **attacker** (e.g. spy, hacker, co-worker, ...) ?
  - Attacker's **knowledge** (newbie or IT Professional)
  - Estimation of possible **damage** (low to high)
  - Attacker's **final goal** (information, money, ...)
  - **Reasons** for attacking (experiment, revenge, gains, ...)
  - Attacker's **budget** (low to high)

Risk Analysis Approaches

- **Quantitative Approach**
  - Attempts to assign real and meaningful numbers to all elements of the risk analysis process
  - Each element within the analysis is quantified and entered into equations to determine total and residual risks.
  - Purely quantitative risk analysis is not possible, because
    - the method is attempting to quantify qualitative items
    - there are always uncertainties in quantitative values

- **Qualitative Approach**
  - Walks through different scenarios of risk possibilities
  - Ranks the seriousness of the threats and the validity of the different possible countermeasures

Example: Risk Analysis on the basis of an Attack Tree



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- **Modelling**
  - **Security Policies**
  - Abstract Security Models
  - Basic Security Functions
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Modelling Security Policies ?

- In a formally ideal world a complete workable security policy can be modelled formally …
- … but only in a formally ideal world.
- Therefore models model what can be modelled:
  - Abstract Security Requirements
  - Relations between
    - A concrete (but maybe incomplete) set of security policy elements and
    - Basic Security Functions

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Abstract Security Models

- Model formal aspects of a security policy
- Goal is to prove
  - Consistency of a system
  - Completeness of a system
- Typical examples are Access Control Models

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Basic Security Functions

- Identification and Authentication
- Administration of Rights
- Verification of Rights
- Conservation of Evidence
- Availability of the services

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Identification and Authentication

- Both subjects (the entities who access) and objects (the entities which are accessed) have to be identified clearly.
- Subjects needs to prove their identity.
- Clarify if the subject has to authenticate for each action or only once (until session is closed), e.g.
  - Logon only once to an operating system
  - Authentication against a web-server only once
  - Authentication to an Anti-Theft-Device every time the engine is started
- Procedure in case of failure of identification or authentication:
  - Log files including ID, IP, time, date, ...
  - Disable the subject's account
  - Reset the password

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Administration of Rights

- Defining access rights
- Access rights required for each object: to be defined in the security model
- Determination of who might change these rights:
  - Only the administrator
  - Users with super user rights
- Defining availability of rights
  - Always available
  - Only available for certain tasks

Verification of Rights

- Frequency of verification
  - Once per session
  - Every time an object is accessed
  - Often due to the costs: once per session
- Exceptions
  - System components found to be fully trustable:
    - Once per session
    - Never
  - Example: Kernel tasks

Conservation of Evidence

The following facts of an attack have to be recorded:

- Every information concerning the attacker
  - User name
  - From outside/inside
  - IP address
  - ...
- Objects and operations which have been affected:
  - Unique ID
  - IP address
  - User account
  - ...
- Time and date of the attack
- Possibilities which could allow the subject to change the recorded data
- Events leading to the recording of the attack
  - Wrong password
  - Non existing ID

Availability of Services

or *how to avoid denial-of-service attacks*

Two properties have to be defined:

- Warranty
  - For every function of every component
  - The priority of the components
- Boundary conditions to be able to miss a component

Example:

- The function to verify an authentication should always be available.

Example Mobile OS

Security Policy Elements vs. Basic Security Functions

Security Policy Elements

- A security token is required for user authentication.
- All incorrect authentication cases are recorded and notified.

Basic Security Functions

Authentication

Conservation of Evidence

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  - **Security Architecture**
  - General Design Principles
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Security Architecture

- Description of the architecture in a **coarse grained way**
  - Components which are to be protected
  - Components which are protecting
- Description of the architecture in a **fine grained way** – a closer frame for the implementation
  - Required coding tools
  - Used algorithms
  - Employed data structures

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General Design Principles (1)

- **Economy of Mechanism:** The protection mechanism should have a simple design without overhead.
- **Fail-safe Defaults:** The protection mechanism should deny access by default, and grant access only when explicit permission exists.
- **Complete Mediation:** The protection mechanism should check every access to every object.
- **Open Design:**
  - The strength of protection mechanisms should not depend on attackers being ignorant of their design.
  - It may however be based on the attacker's ignorance of specific information such as passwords or cipher keys.

General Design Principles (2)

- **Separation of Privilege:** The protection mechanism should decide on access based on more than one piece of information.
- **Least Privilege:** The protection mechanism should force every process to operate with the minimum privileges needed to perform its task.
- **Least Common Mechanism:** The protection mechanism should be shared as little as possible among users.
- **Psychological Acceptability:** The protection mechanism should be easy to use (at least as easy as not using it).

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Validation and Evaluation

Validation

- Internal classification by documentation of test ...
  - Targets
  - Plans
  - Methods

Evaluation

- Often done by a 3rd party
  - Based on a(n) (inter)national criteria catalogue
    - the Common Criteria (IS 15408)
    - the European ITSEC
    - the German IT security criteria
- Assures a certain level of security

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Security Monitoring

- Done during operation
- Allows fast reaction on new incidents, especially if they are not covered by the security system
- Possibly use of tools, e.g. Intrusion Detection Systems

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- **Security Engineering with UML**

UML in Security Engineering (1)

UML is an opportunity for secure systems development that is feasible in an industrial context:

- As UML is the de-facto standard in industrial modelling, a large number of developers is trained in UML.
- Compared to previous notations with a user community of comparable size, UML is relatively precisely defined.
- A number of analysis, testing, simulation, transformation and other tools are developed to assist the every-day work using UML.

UML in Security Engineering (2)

- Use Case Diagrams describe typical interactions between a user and a computer system (or between different components of a computer system).
- Activity Diagrams can be used e.g. to model workflows and to explain use cases in more detail.
- Class Diagrams define a static structure of the system.
- Sequence Diagrams describe interaction between objects via message exchange.
- Deployment Diagrams describe the underlying physical layer.

Security Requirements Capture

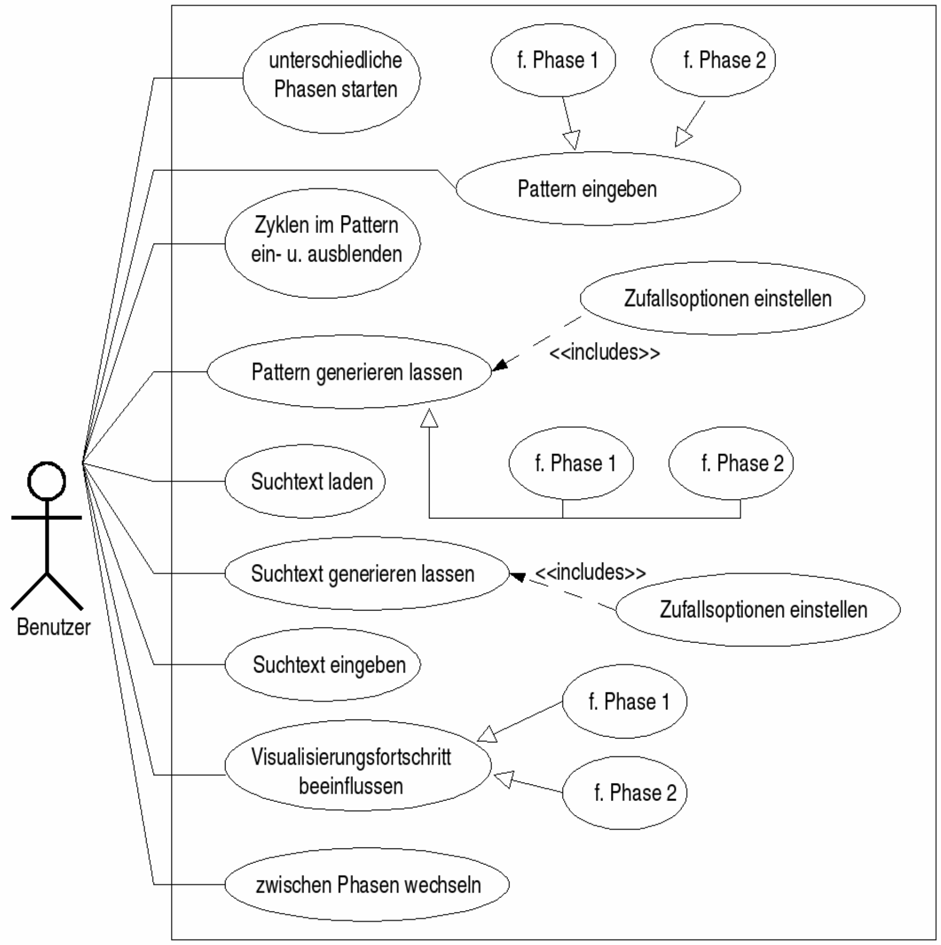
Secure Business Processes

Structural Data Security

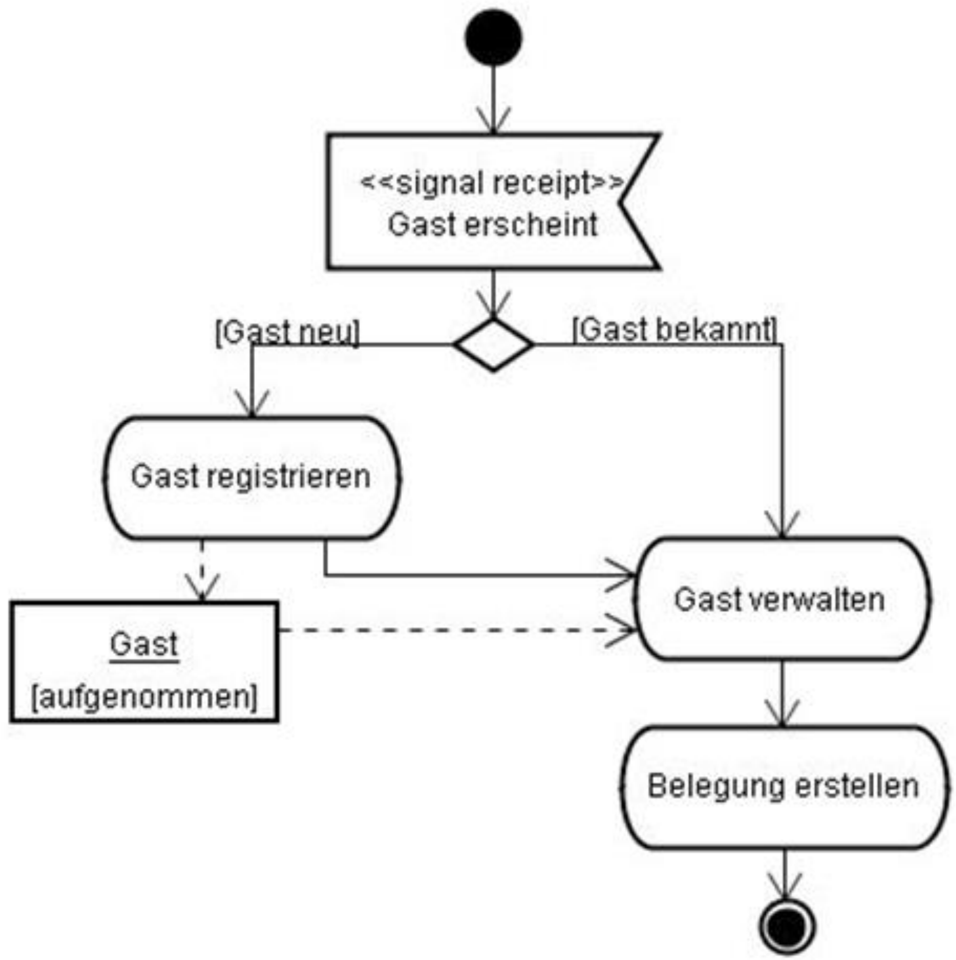
Security-Critical Interaction

Physical Security

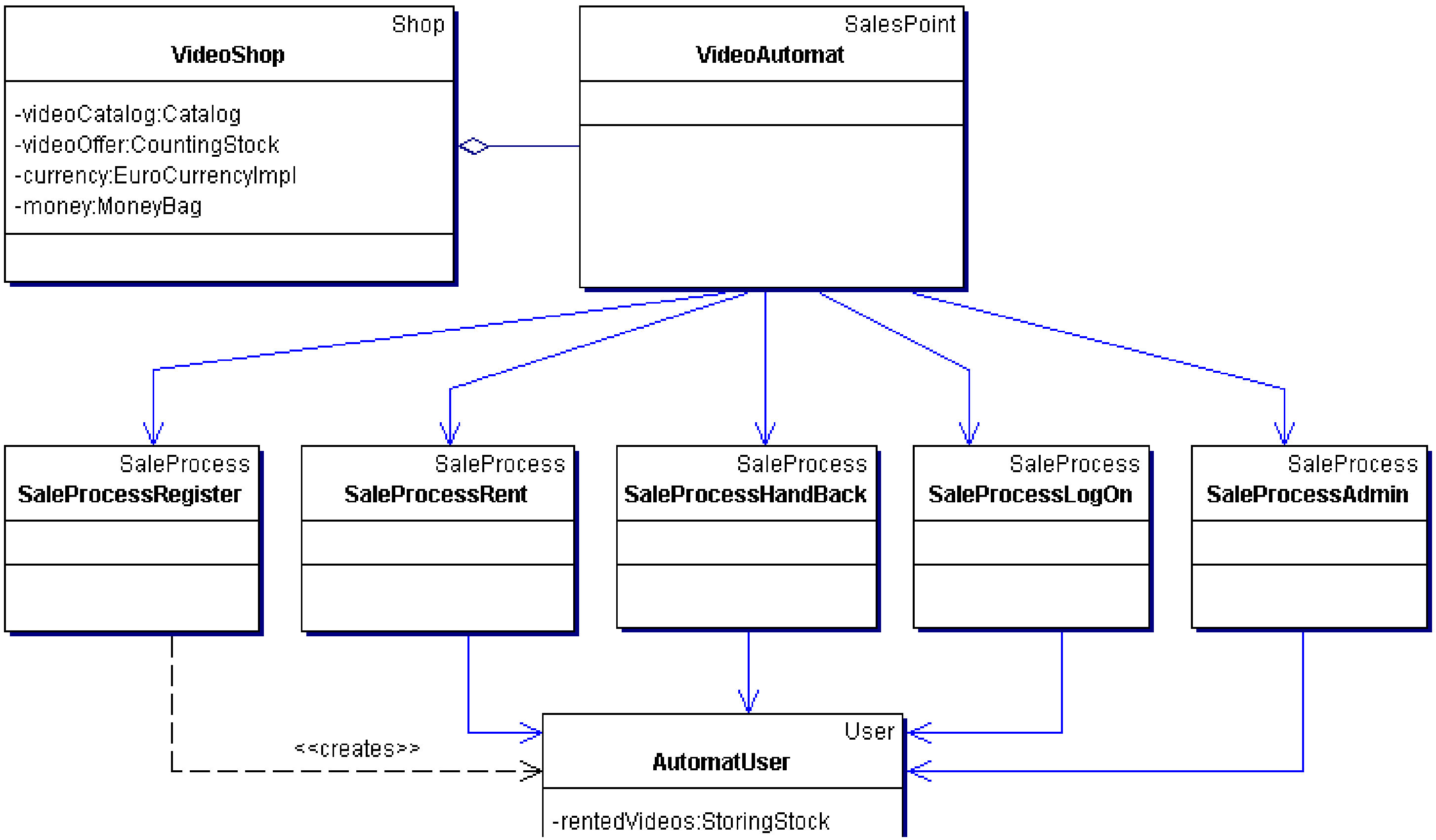
Use Case Diagram



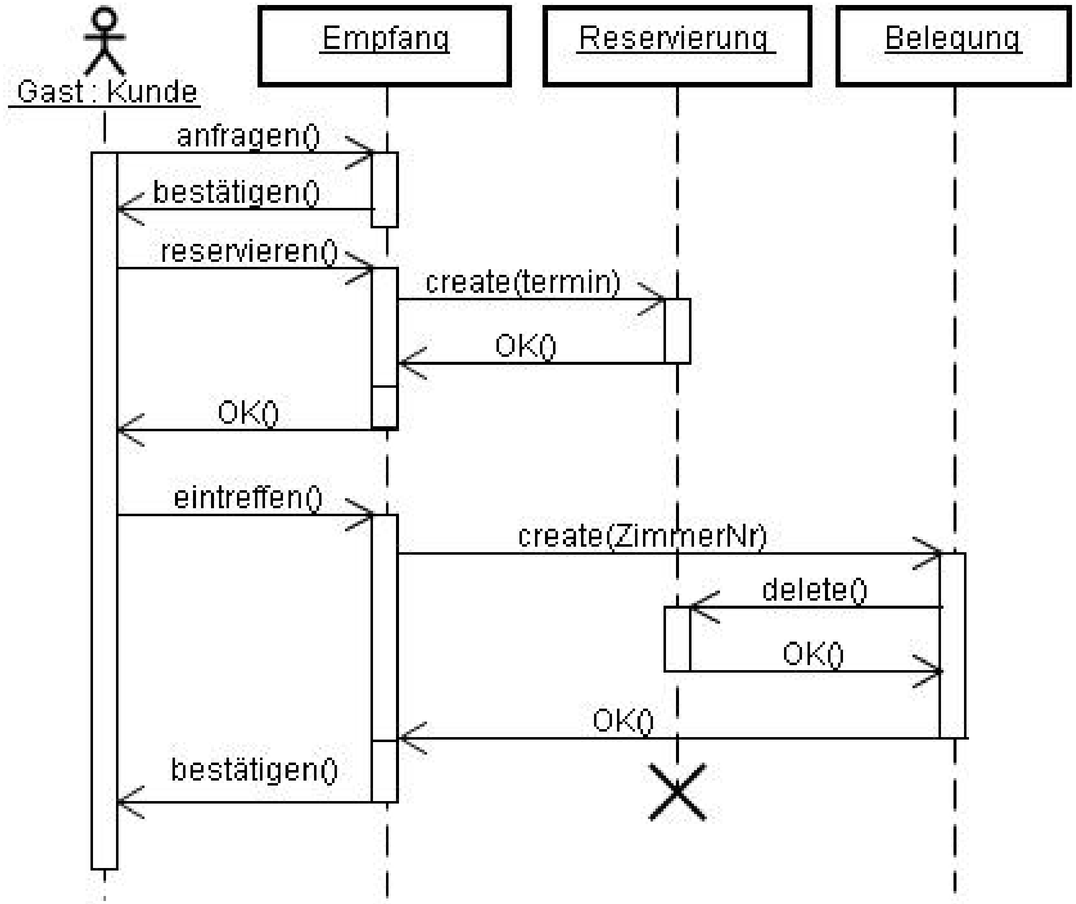
Activity Diagram



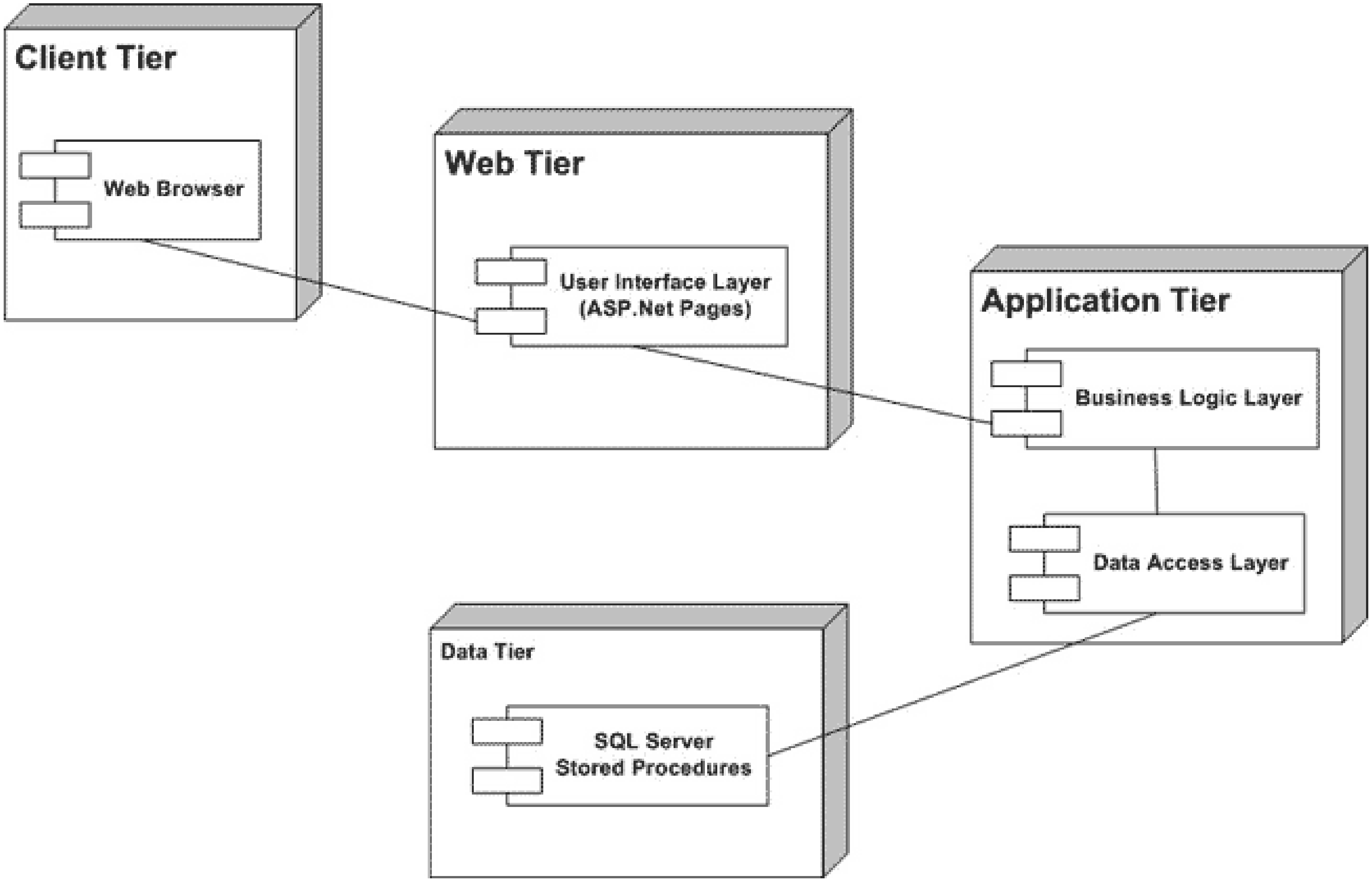
Class diagram



Sequence diagram



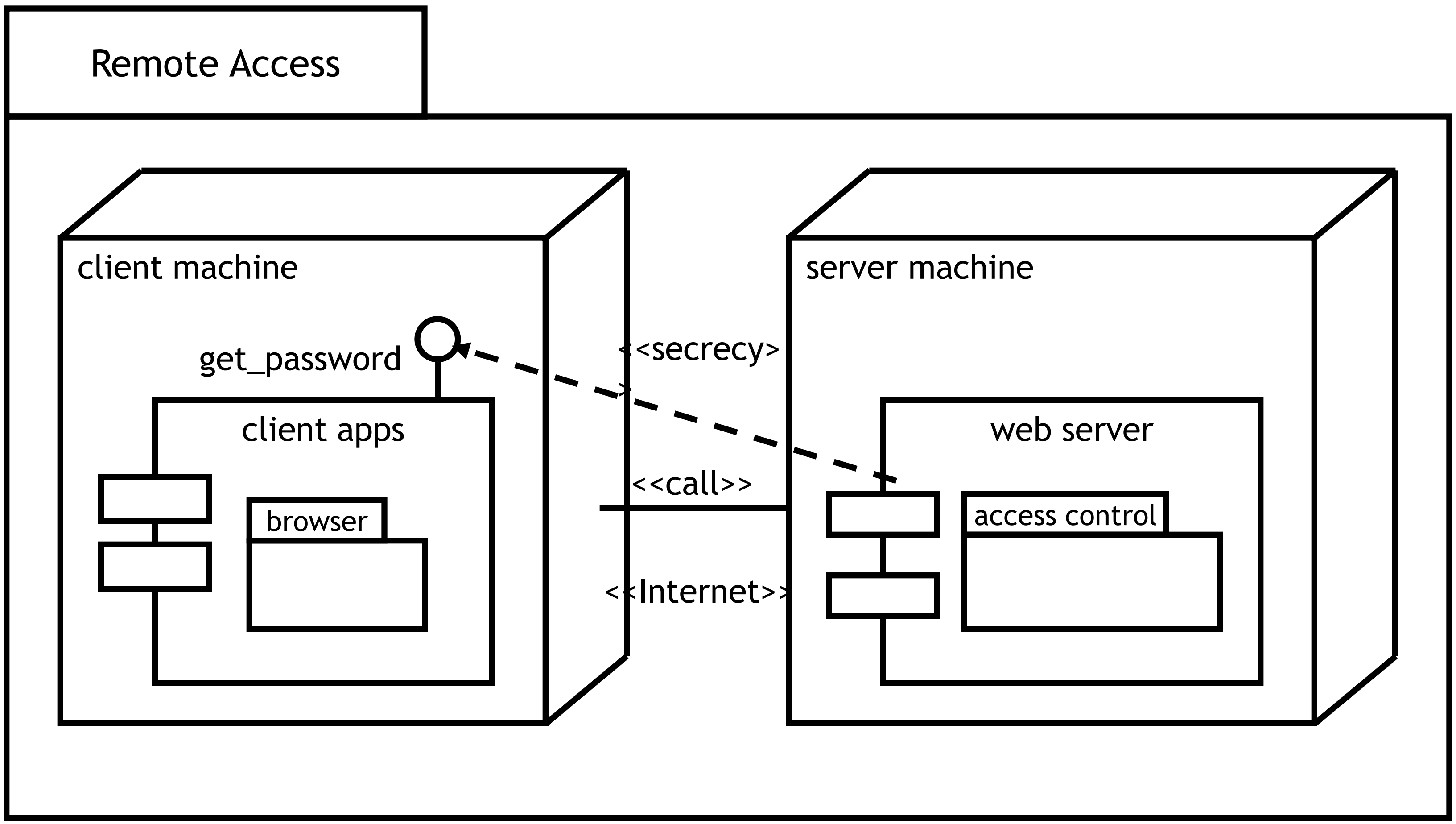
Deployment diagram



UMLsec

- Extension for secure systems development:
  - Evaluate UML specifications for weaknesses in design
  - Encapsulate established rules of prudent secure engineering as checklist
  - Make security considerations available to developers not specialized in secure systems
  - Consider security requirements from early design phases in system context
  - Make certification cost-effective

Example: Deployment Diagram



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