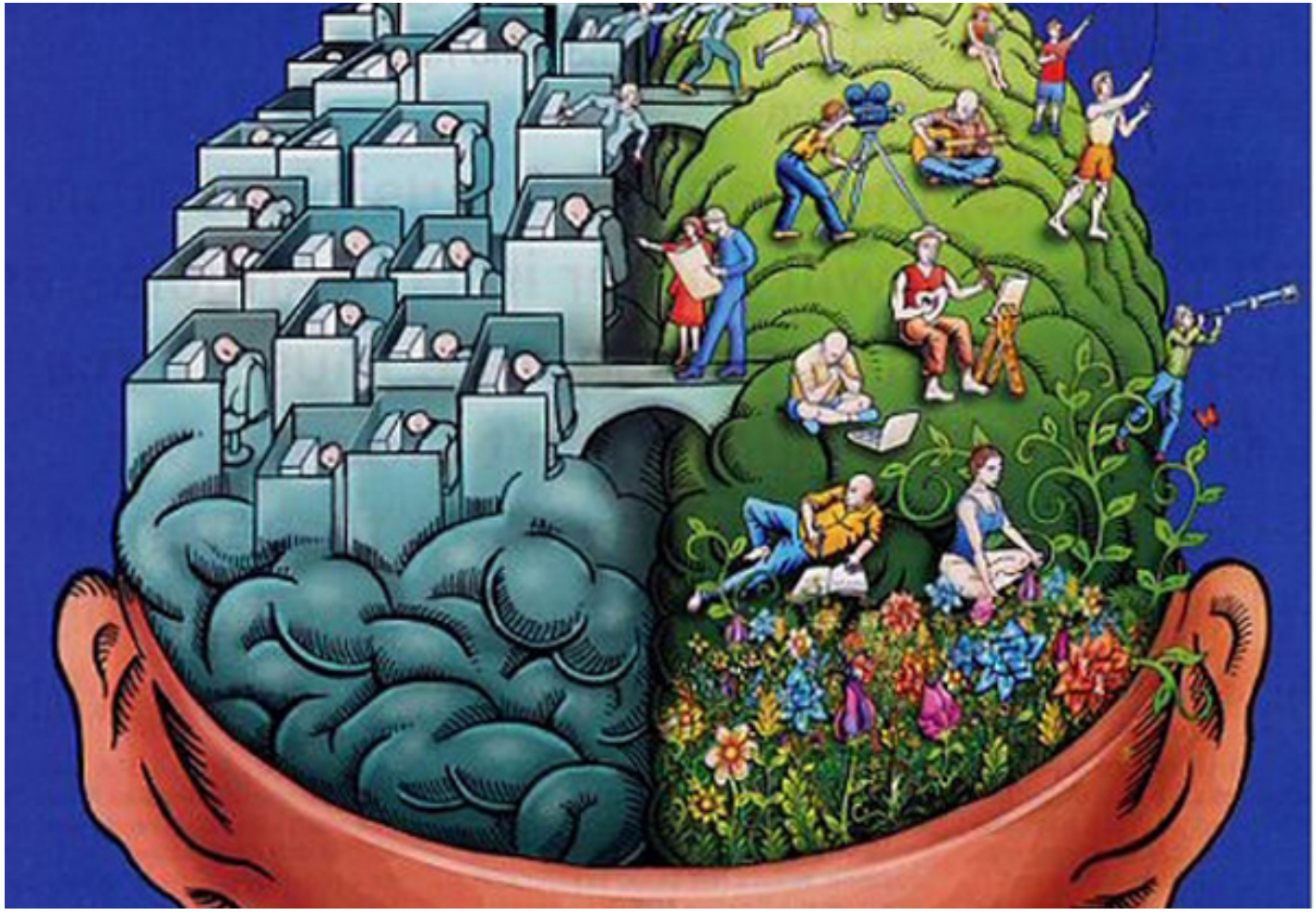
Introduction and Motivation

Software Security

Steffen Helke
Chair of Software Engineering

15th October 2018

Brandenburgische
Technische Universität
Cottbus - Senftenberg



Out of the crooked timber of humanity, no straight thing was ever made.

Note: Ross Anderson's book *Security Engineering* opens with this quotation written by a German philosopher. Original source: Immanuel Kant's Essay, *Idea for a General History with a Cosmopolitan Purpose*, 1784.

The Importance of Security

➜ Almost every day, we see reports in the news about hacker attacks

THE VERGE TECH SCIENCE CULTURE CARS REVIEWS MORE

TECH CYBERSECURITY

UK hospitals hit with massive ransomware attack

52

Sixteen hospitals shut down as a result of the attack

by Russell Brandom | @russellbrandom | May 12, 2017, 11:36am EDT

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Peter O'Conner / Flickr

A massive ransomware attack has shut down work at 16 hospitals across the United Kingdom. According to *The Guardian*, the attack began at roughly 12:30PM local time, freezing systems and encrypting files. When employees tried to access the computers, they were presented with a demand for $300 in bitcoin, a classic ransomware tactic.

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HACKER ATTACK

Germans Don't WannaCry

The global ransomware virus WannaCry that made headlines over the weekend left Germany relatively unscathed. Do Germans know something the rest of the world does not?

Handelsblatt Staff *May 15, 2017 2:45 pm*

Viral, but attenuated. Source: DPA

The global computer virus WannaCrypt - nicknamed WannaCry - shut down more than 230,000 computers in 150 countries over the weekend. But in Germany, at least so far, it has been a nuisance rather than a catastrophe. At train stations, some arrival and departure screens have malfunctioned, a few ticket machines stopped working, and so forth. Deutsche Bahn, Germany's state-owned railway operator, said that actual traffic was not affected. No sweat.

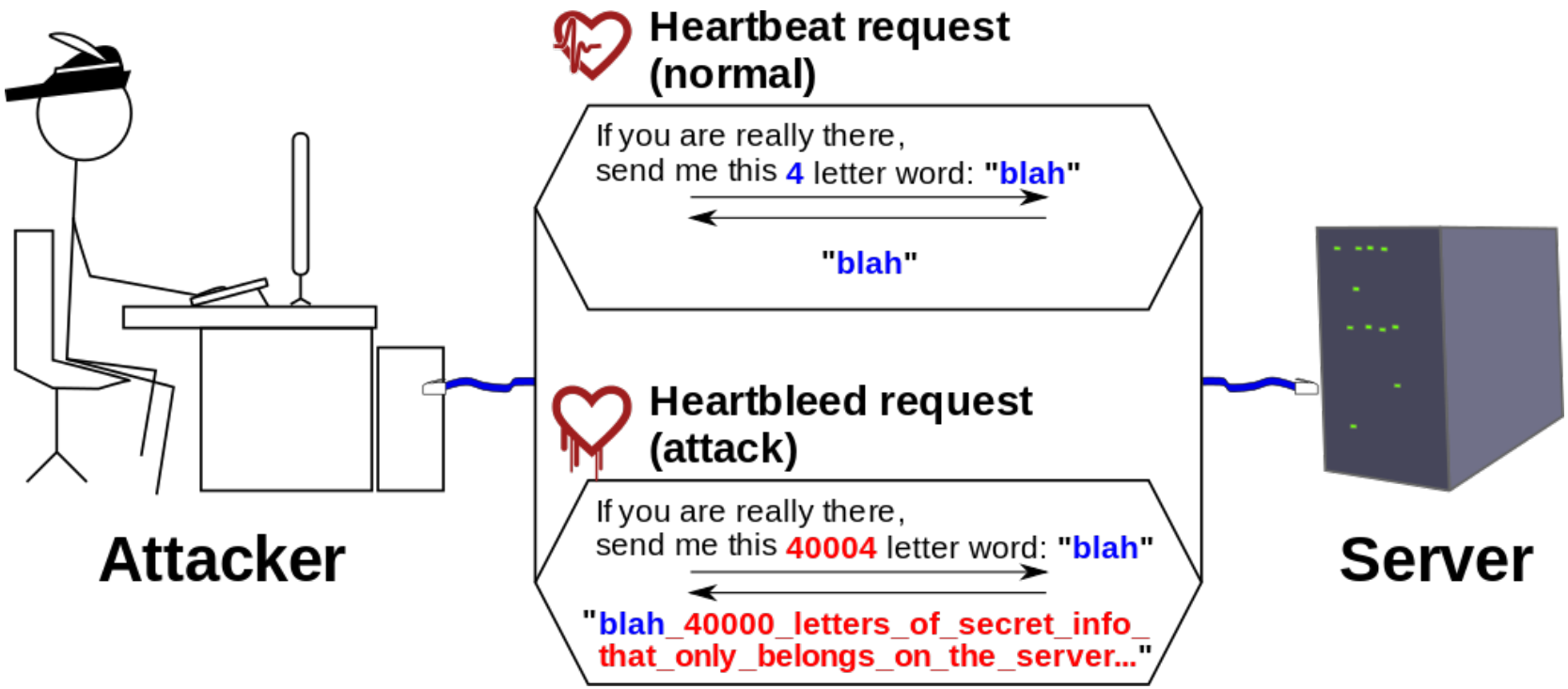
WannaCry Ransomware

Don't pay, it's better to submit a complaint to the police.

Heartbleed Bug

Exploit: OpenSSL Implementation of 2012

- Heartbeat functionality for encryption protocols, e.g. SSL/TLS
- Poor input validation allows an unautorized information flow

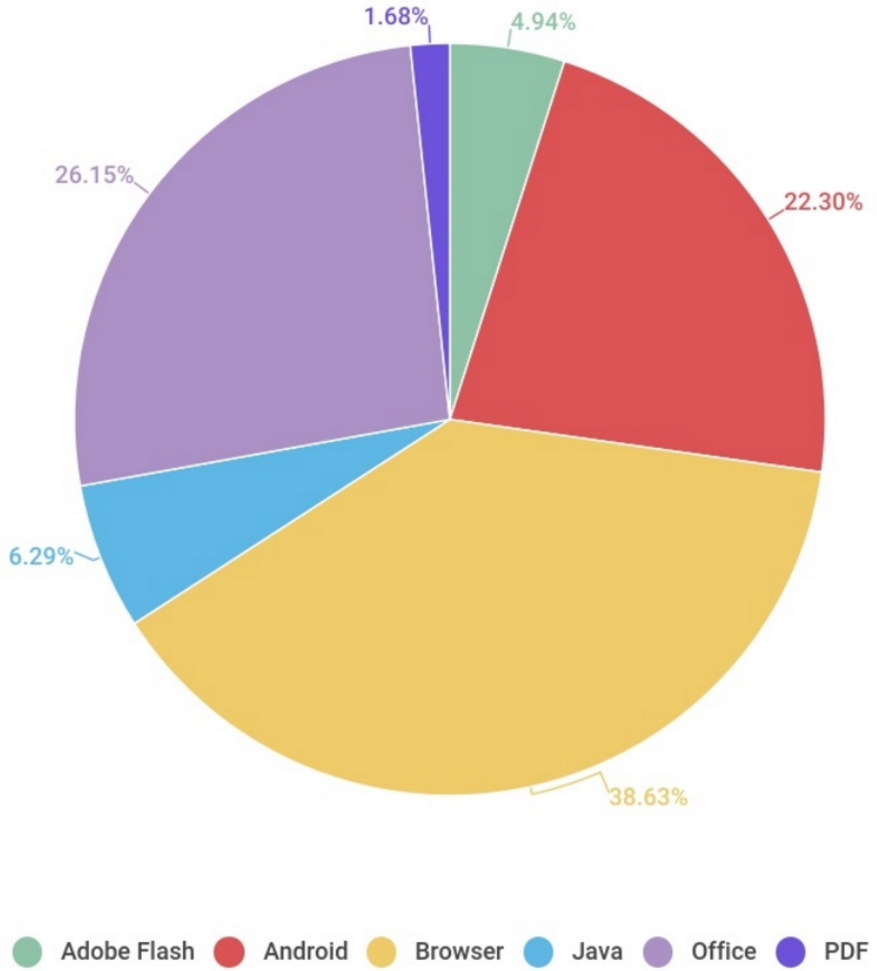


Gives the attacker the possibility to access confidential data

Source: http://de.wikipedia.org/wiki/Heartbleed [Accessed May 2018]

Vulnerable apps exploited by cybercriminals

➜ current statistic, the second quarter of 2017 (Q2 2017)

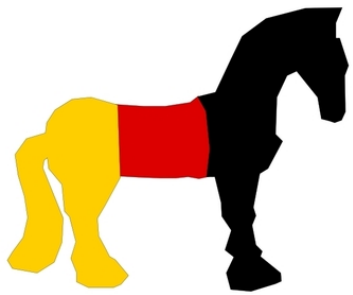


Source: Kaspersky Lab, https://securelist.com/it-threat-evolution-q2-2017-statistics/79432/[Accessed September 2017]

Objectives of today's lecture

- ➜ Understanding the *rules and conditions* of this course
- ➜ Getting familiar with the *content overview* and some *basic terms*
- ➜ Being able to name important *standard literature*

- ➜ Understanding the weaknesses of the *trojan horse of the german government*



- ➜ Being able to judge the *personal suitability* for this course

Who is giving this lecture?

- **Contact Person**
  Steffen Helke, Assistant Professor, Software Engineering
  Development of Safe and Secure Software Systems
- **Email Address**
  steffen.helke@b-tu.de
- **Consultation Hour**
  Wednesday, 1pm-2pm
- **Room**
  VG1c 2.13
- **Secretary's Office**
  VG1c 2.20

Attributes of this course

- ➜ Master module *Software Security*
- ➜ Study program Cyber Security M.Sc.: compulsory elective module (complex "Cyber Security Methods")
- ➜ also suitable for the following study programmes: Computer Science M.Sc., Information and Media Technology M.Sc., eBusiness M.Sc. and Applied Mathematics M.Sc.

Forms of Teaching and Proportion

- ➜ Lecture (2 Hours per Week) + Exercise (2 Hours per Week)
- ➜ Lectures and exercises will be mixed as desired

Preconditions

- ➜ Basic knowledge in software engineering and
- ➜ mathematics, e.g. logic, algebra and number theory

Prerequisite and Module Examination

Exercises

➜ Successful passing of two exercise sheets

Presentation

➜ Successful presentation on one technical topic, four students per one event

Final Module Examination

➜ Written examination, 90 min *or*

➜ Oral examination, 30-45 min (with small number of participants)

Where do I register and find more information?

Website

- ➜ https://www.b-tu.de/elearning/btu/course/view.php?id=3649
- ➜ Collection of slides, exercise sheets, etc.
- ➜ Regular visit to this Moodle course website is strongly recommended

Overview of Contents

Part I: Security Engineering

1. **Foundations and Motivation**
   - Examples of vulnerabilities in software, e.g. buffer overflows
   - Basic terms, definitions, protection goals
   - Malware categorisation, virus vs. worm, trojan horse, etc.
   - Anonymity, remailer and anonymous web browsing, e.g. TOR

2. **Security Analysis**
   - Process models for security engineering
   - Misuse cases, attack trees, multilateral security
   - Conflicting protection goals and compromises

3. **Security Design**
   - Security models (MLS and BIBA)
   - Security Patterns
   - Information flow control using JiF

Part II: Encryption Techniques

4. Foundations

- History of cryptology, monoalphabetic and polyalphabetic cipher, one-time pad, Enigma
- Prime numbers, prime factorisation, number theory, Chinese remainder theorem (CRA)

5. Asymmetric Encryption

- Encryption and digital signatures using RSA
- Pseudo-one-time pad using s^2-mod-n generator
- GMR - strong cryptographic signature system

6. Symmetric Encryption

- Functional principle of DES, Triple-DES and AES
- Cryptographic systems in operation: block cipher vs. stream cipher, ECB, CBC, CFB, OFB, CTR

Part III: Security Protocol Engineering

7. Foundations

- Needham-Schroeder protocol, typical attacks, man-in-the-middle attack and replay attack
- Kerberos protocol, differences between v4 and v5, time stamps and nonces to prevent replay attacks

8. Verification

- Analysis using Burrows-Abadi-Needham logic (BAN logic)
- Specifying protocols using CSP and verifying using FDR
- Verifying using Proverif based on the Dolev-Yao attacker model

9. Summary and Outlook

- Repetition of important content and preparation for the exam
- Research topics for master theses

What shall you read for this course?

Script

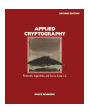
- Andreas Pfitzmann: *Security in IT-Networks*

  ➜ only the first *three* chapters are relevant!

Books

R. Anderson: *Security Engineering*,
Wiley, 2001.

C. Eckert: *IT-Sicherheit* (in German),
Oldenburg-Verlag, 2014 (9. Auflage).

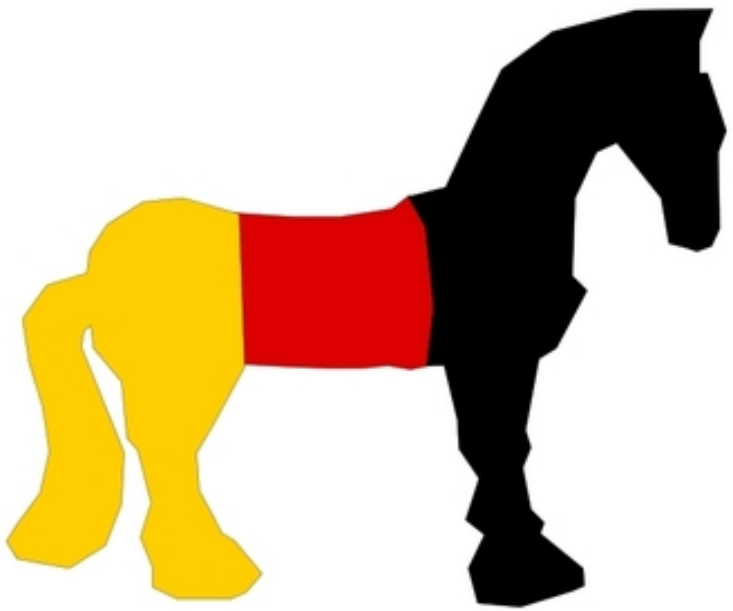


B. Schneier: *Applied Cryptography*,
Wiley, 1996.

Collection of Articles

- adressing special topics, e.g. for presentations, available on our Moodle website

Example: Trojan Horse of the German Government

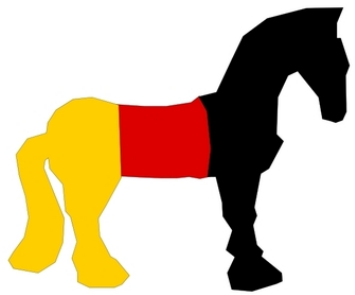


Bundestrojaner

Background to the Trojan Horse of the German Government

General remarks

- Increasing communication via VoIP or Skype
- Usually this communication will be encrypted
- Hence, source tracking is necessary for the purposes of spying



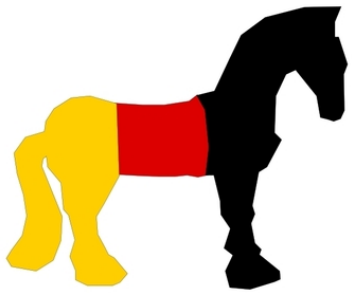
Constraints (German Laws)

- Source tracking using trojan horses in general is not allowed
- The observation is only permitted in certain situations, e.g. if the life of a person is in danger

Design of the Bundestrojaner, Version 2010

Features (some critical)

- Creating screenshots
- Observation of VoIP or Skype
- Reloading of any software modules
- Transporting observed data via a server from the USA to Germany



Weaknesses

- Weak authentication mechanism
- Encryption using AES is good, however the encryption was combined with a weak block cipher (ECB)
- ECB – Electronical Code Book

Basic Terms

What is the Difference between Safety and Security?

Functional Reliability (Safety)

- Idea: Protecting the environment from the system
- Functions should be implemented correctly according to the specification

Information Security (Security)

- Idea: Protecting the system from its environment
- Only authorised modification or retrieval of information is allowed

Different Types of IT Systems

Closed Systems

(of the same kind; alike.)

- Homogeneous hardware, similar operating systems
- Technology often only from one supplier
- Limited number of participants
- Same location
- Central administration

Open Systems

(diverse in character or content.)

- Heterogeneous hardware and operating systems
- Networked and physically distributed systems
- Decentralized administration

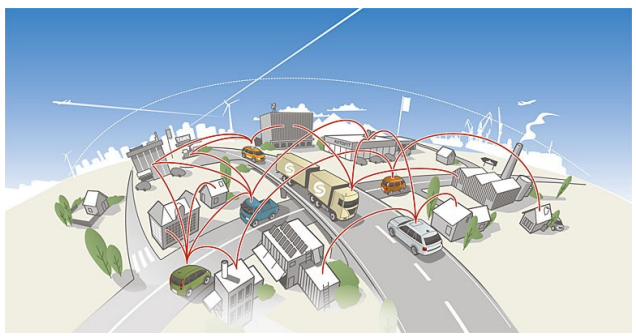
Socio-technological Systems

- Understanding IT systems as a part of society
- Compliance with legal requirements
- Taking into account user acceptance of security concepts

Open Computer Networks in our Everyday Life

- ➜ Main communication medium of industrialized countries
- ➜ Almost all computers are integrated into networks

- ➜ Formerly closed systems are now also integrated into networks, e.g. embedded systems
- ➜ Useful for software updates, maintenance and error analysis during operation



What are the Consequences?

All people in this world increasingly depend on the correct functioning of software systems that surround them personally, socially, economically and politically.

- **What are the challenges?**
  We need to develop *dependable* software systems
- **How this can be implemented?**
  We need to establish high quality standards for such software systems

Dependability defined by Jean Claude Laprie

What does dependability means?

Quelle

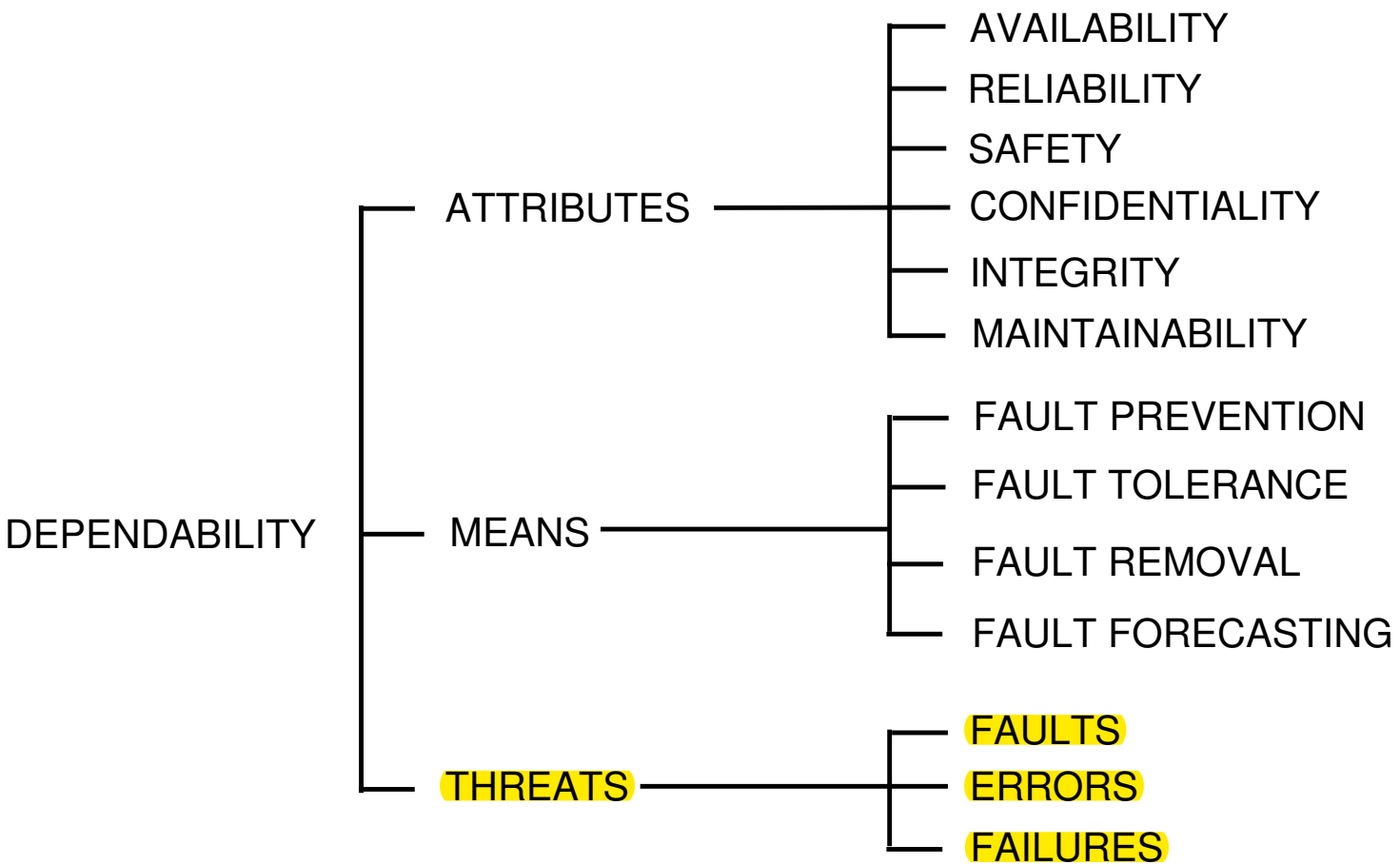
- Jean Claude Laprie (ed.): *Dependability: Basic Concepts and Terminology*. Springer, 1992.

➜ Objective of this document is to give an informal and precise definition of dependable systems

Background

- Results of an exhaustive discussion on the characteristics of fault-tolerant systems
- Translations in many different languages
- Common reference for quality standards to clarify terms

Dependability defined by Laprie



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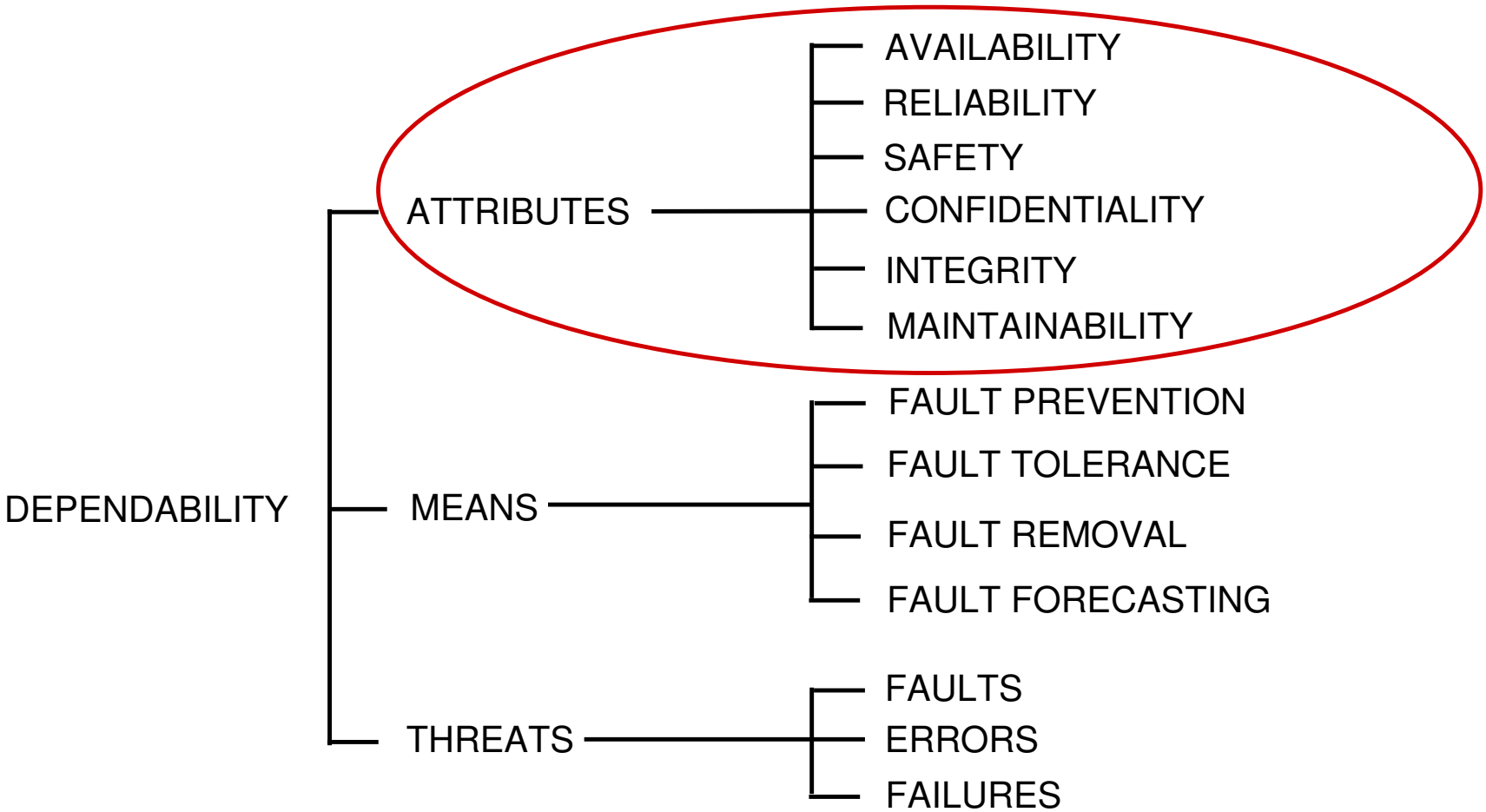

Attributes of Dependable Systems

Attribute = A C I M R S

- **Availability**
  readiness for correct service at a certain point in time
- **Reliability**
  continuity of correct service over a certain time interval
- **Safety**
  absence of catastrophic consequences on the environment
- **Confidentiality**
  absence of unauthorized disclosure of information
- **Integrity**
  absence of unauthorized system modifications
- **Maintainability**
  ability to undergo modifications and repairs

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  ability to undergo modifications and repairs

Three important protection goals (CIA)

Question : What is important the protection goals for security?
Answer: CIA.

Note: This does not refer to the Central Intelligence Agency ;-)
It's just a kind of mnemonic

1. **Confidentiality**
   absence of unauthorized disclosure of information
2. **Integrity**
   absence of unauthorized modifications of information
3. **Availability**
   readiness for correct service at a certain point in time

Reliability vs. Availability

Question: What is the difference between Reliability and Availability?
Answer: Continuity and readiness in certain time interval and time respectively

➜ **Availability**
readiness for correct service at a certain point in time

➜ **Reliability**
continuity of correct service over a certain time interval

➜ **Safety**
absence of catastrophic consequences on the environment

➜ **Confidentiality**
absence of unauthorized disclosure of information

➜ **Integrity**
absence of unauthorized system modifications

➜ **Maintainability**
ability to undergo modifications and repairs

Reliability vs. Availability

Reliability

- Measure for continuity of correct service
- Estimated value for the time period until the system next fails
- e.g. *Mean Time between Failures* (MTBF)

Availability

- Measure for correct service at a certain point in time
- Definition is additionally influenced by *Mean Time to Repair* (MTTR)
- e.g., it could be calculated by $\frac{MTBF}{MTBF+MTTR}$

⇒ Reduced downtime (MTTR) increases availability, but not system reliability!

Reliability		Repairing capability		Availability
constant	$\wedge$	decreasing	$\Rightarrow$	decreasing
constant	$\wedge$	increasing	$\Rightarrow$	increasing
increasing	$\wedge$	constant	$\Rightarrow$	increasing
decreasing	$\wedge$	constant	$\Rightarrow$	decreasing

[and symbol]

Example 1

- System *A* fails *once a year*
- System *B* fails *once a month*

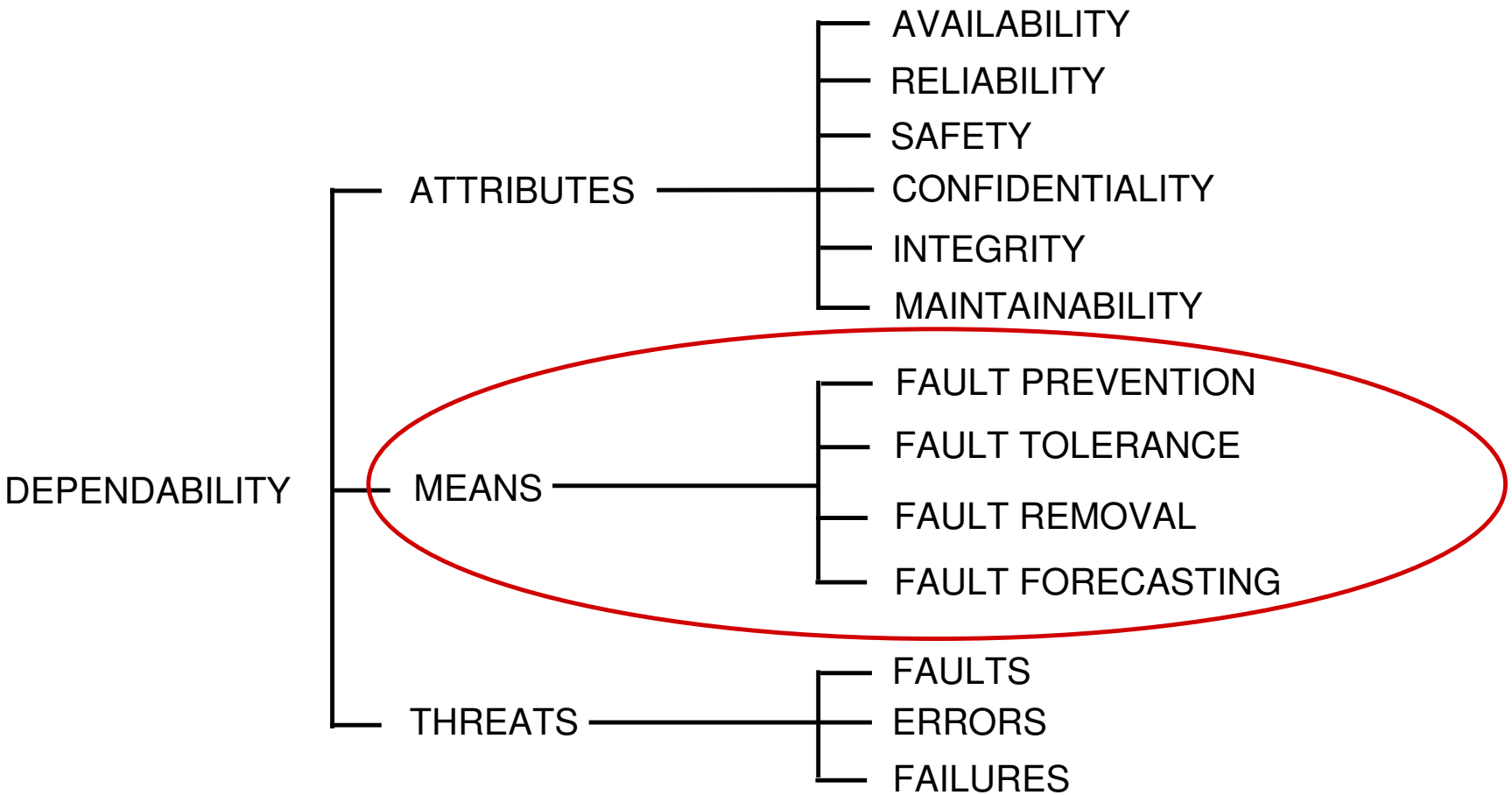
➜ *A* is more reliable than *B*

Example 2 (as an extension of Example 1)

- Restarting System *A* takes *3 days*
- Restarting System *B* takes *10 minutes*

➜ The availability of *B* is better than that of *A*

Means to achieve Dependability



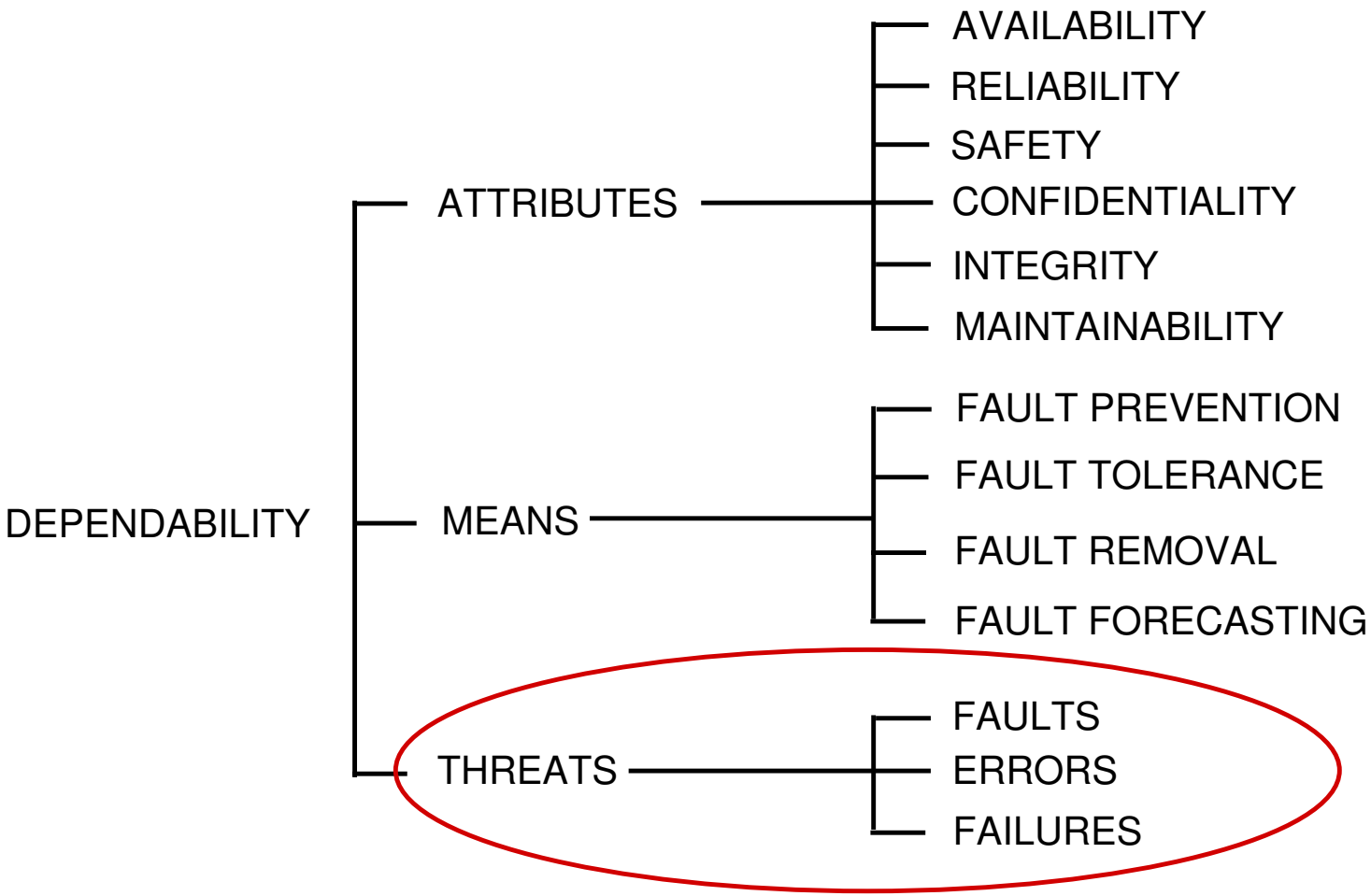
Means to achieve Dependability

~~(an action or system by which a result is achieved; a method.)~~

Question : What is means of the dependability? Answer: Fault F, T, P, R

- **Fault Prevention**
  - ➜ to prevent the occurrence or introduction of faults
- **Fault Removal**
  - ➜ to reduce the number and severity of faults
    (the fact or condition of being severe.)
- **Fault Tolerance**
  - ➜ to avoid service failures in the presence of faults
- **Fault Forecasting**
  - ➜ to estimate the present number, the future incidence, and the likely consequences of faults

What are the threats to dependability?



What are the threats to dependability?

- **Faults**

  faults may exist, e.g. inside of code,

  ➜ but do not necessarily have to be activated

- **Errors**

  transition from correct system state to an *error state*

  ➜ the cause of an error is usually a fault

  ➜ errors are observable by reading error states,
  however the services may not influenced

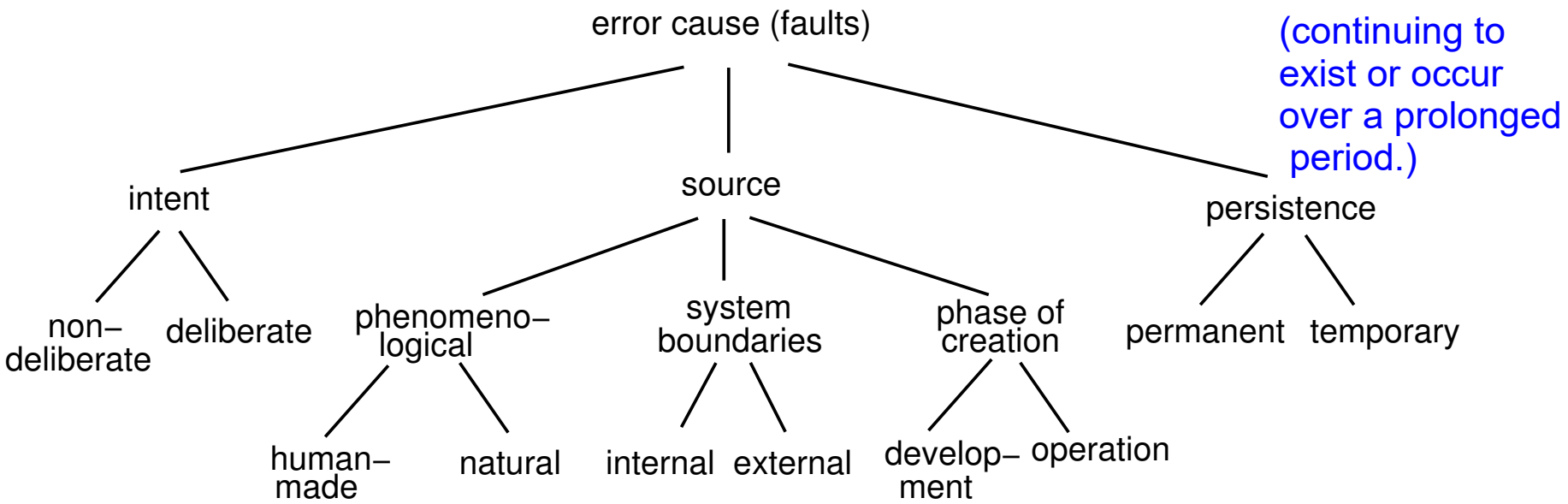
- **Failures**

  transition from correct service to an *incorrect service*

  ➜ the cause of a failure is usually an error

  ➜ failures become observable at the service interface

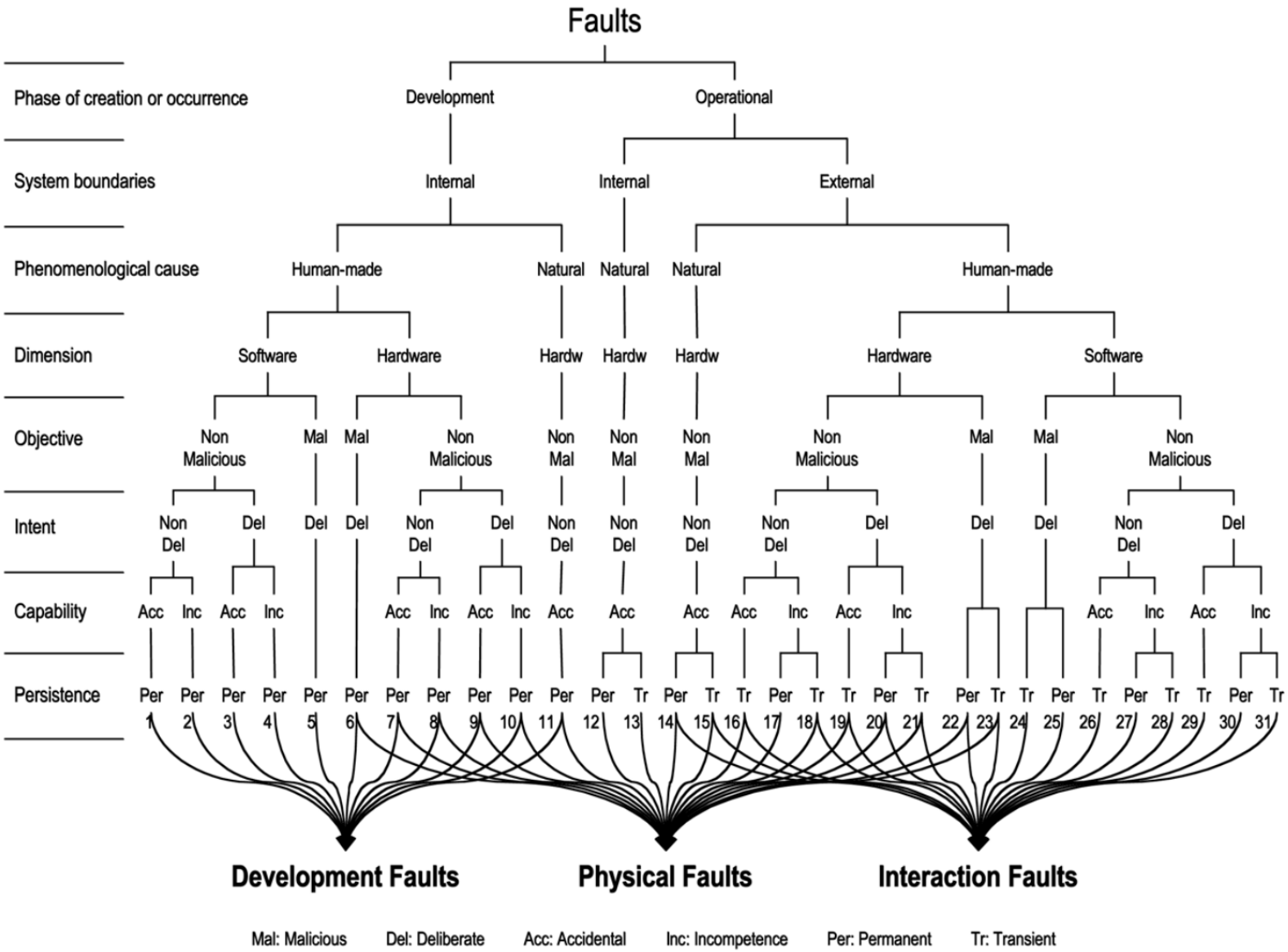
How to classify faults?



Examples

1. Malicious and incorrect function (e.g. Trojan Horse)
   ➜ deliberate, internal, human-made, development, permanent
   (done consciously and intentionally)
2. Incorrect computation caused by electromagnetic radiation
   ➜ non-deliberate, external, natural, temporary, operation

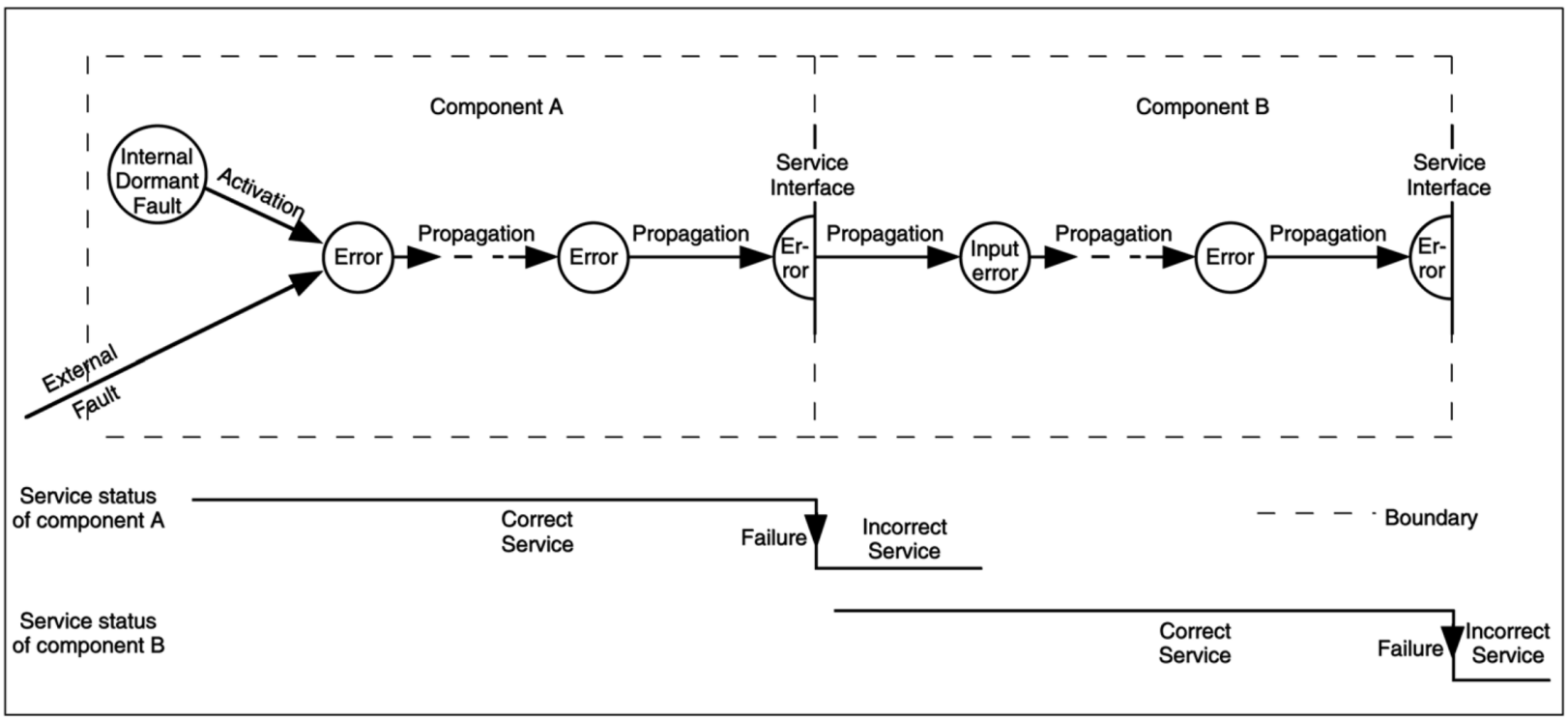
The classes of combined faults



Quelle: Avizienis et. al: *Basic Concepts and Taxonomy of Dependable and Secure Computing*, IEEE Transaction on Dependable and Secure Computing, 2004.

Propagation between system components

- Faults activate errors inside of a component
- Errors are successively transformed into other errors
- Some errors cause failures at the service interface and failures of components can be external faults of other components



Quelle: Avizienis et. al: *Basic Concepts and Taxonomy of Dependable and Secure Computing*, IEEE Transaction on Dependable and Secure Computing, 2004.

What does Security mean?

➜ 4 sub categories defined by Claudia Eckert [Eckert,2014]

Note: Security is a terribly overloaded word, which often means quite incompatible things to different people.

Quotation by Ross Anderson: *Security Engineering*, 2008.

What does Security mean?

1. **Safety**
   - Protecting the environment from the system
   - Functions should be implemented correctly according to the specification
2. **Security**
   - Protecting the system from the environment
   - Only authorised modification or retrieval of information is allowed, focus on *protection of data currently being processed*
3. **Protection**
   - Similar definition to security, but with a focus on protecting archived data (e.g. backups)
4. **Privacy**
   - Ability and/or the right to control the transfer of your personal data