Universität Bremen

Deutsches Forschungszentrum für Künstliche Intelligenz
German Research Center for Artificial Intelligence

Systems of High Safety and Security

Lecture 1 from 15.10.25: Einführung

Winter term 2025/26

Christoph Lüth

Organisatorisches

Generelles

- Einführungsvorlesung zum Masterprofil S & Q
- 6 ETCS-Punkte
- Vorlesung und Übung:
  - Mi 10 – 12 Uhr (MZH 1450)
  - Mi 12 – 14 Uhr (MZH 1450)
- Material (Folien, Artikel, Übungsblätter) sind auf der Webseite:

  `https://user.informatik.uni-bremen.de/~clueth/lehre/ssq.ws25/`

- Veranstalter:
- Christoph Lüth `clueth@uni-bremen.de`
- Dieter Hutter (Prüfung) `hutter@uni-bremen.de`

Vorlesung

- Foliensätze als **Kernmaterial**
  - Sind auf Englisch (Notationen!)
- Zusatzmaterial:
  - Vorlesungsnotizen
  - Ausgewählte Fachartikel
- Bücher nur für einzelne Teile der Vorlesung verfügbar:
  - Nancy Leveson: Engineering a Safer World
  - Glynn Winskel: The Formal Semantics of Programming Languages
  - Michael Huth, Mark Ryan: Logic in Computer Science
  - ... weitere im Laufe der Vorlesung

Übungen

- Übungsblätter:
  - "Leichtgewichtige" Übungsblätter, die in der Übung bearbeitet und schnell korrigiert werden können.
  - Übungsblätter vertiefen Vorlesungsstoff.
  - Bewertung gibt schnell Feedback.
- Übungsbetrieb:
  - Übungsgruppen: bis zu **fünf** (idealerweise drei) Studierende
  - Bearbeitung: während der Übung
  - Abgabe: bis zur Vorlesung

Ablauf des Übungsbetriebs

- Abgabe und Korrektur des Übungsbetriebs erfolgt über **gitlab** .
  - Dazu legt pro Gruppe ein Repository an.
  - Ladet mich (clueth) als Developer ein.
- Für jedes Übungsblatt:
  - Ihr ladet das Übungsblatt herunter (uebung-XX.md) und bearbeitet es elektronisch.
  - Die Lösung wird als Markdown in euer Repo abgelegt (dabei Namen uebung-XX.md nicht verändern; Zusatzmaterial als uebung-XX-. . . wenn nötig), und **vor dem Abgabezeitpunkt** hochgeladen (push).
  - Nach dem Abgabezeitpunkt laden wir die Abgaben herunter (pull), korrigieren direkt im Markdown, fügen die Bewertung hinzu, und laden die Korrektur wieder hoch (push).
  - Die Datei 00-BEWERTUNG.md enthält die fortlaufenden Bewertungen für die Gruppe.

Prüfungsleistung

- Bewertung der Übungen:
    - A (sehr gut (1.0) – nichts zu meckern, nur wenige Fehler)
    - B (gut (2.0) – kleine Fehler, im großen und ganzen gut)
    - C (befriedigend (3.0) – größere Fehler oder Mängel)
    - Nicht bearbeitet (oder zu viele Fehler)
- Prüfungsleistung:
    - Teilnahme am Übungsbetrieb
    - Eine **Lösung vorstellen** (pro Gruppe)
    - Mündliche Prüfung am Ende des Semesters
        - Einzelprüfung, ca. 20- 30 Minuten

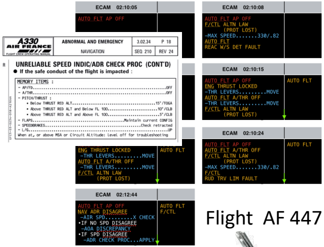
Ziel der Vorlesung

- Methoden und Techniken zur Entwicklung sicherheitskritischer Systeme
- Schwerpunkt: formale Methoden
- Überblick über verschiedene Mechanismen
  - Vertiefung nach Wahl in verschiedenen Veranstaltungen
- Verschiedene Dimensionen
  - Hardware vs. Software
  - Security vs. Safety

> ***Formal Methods*** *refers to mathematically rigorous techniques and tools for the specification, design and verification of software and hardware systems.*
>
> — NASA, `https://shemesh.larc.nasa.gov/fm/fm-what.html`

Overview

Why bother with Safety and Security?



A330 AIR FRANCE FLIGHT CREW OPERATING MANUAL	ABNORMAL AND EMERGENCY NAVIGATION	3.02.34 P 18 SEQ 210 REV 24

R **UNRELIABLE SPEED INDIC/ADR CHECK PROC (CONT'D)**

- **If the safe conduct of the flight is impacted :**

```
MEMORY ITEMS :
- AP/FD.................................................................OFF
- A/THR.................................................................OFF
- PITCH/THRUST :
   • Below THRUST RED ALT...........................................15°/TOGA
   • Above THRUST RED ALT and Below FL 100..........................10°/CLB
   • Above THRUST RED ALT and Above FL 100...........................5°/CLB
- FLAPS.................................................Maintain current CONFIG
- SPEEDBRAKES...............................................Check retracted
- L/G....................................................................UP
When at, or above MSA or Circuit Altitude: level off for troubleshooting
```

```
ECAM   02:10:05
AUTO FLT AP OFF
```

```
ECAM   02:10:08
AUTO FLT AP OFF
F/CTL ALTN LAW
      (PROT LOST)
-MAX SPEED.......330/.82
AUTO FLT
REAC W/S DET FAULT
```

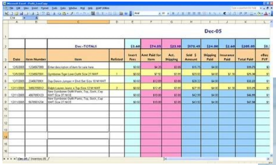
```
ENG THRUST LOCKED                AUTO FLT
 -THR LEVERS.........MOVE
AUTO FLT A/THR OFF
 -THR LEVERS.........MOVE
F/CTL ALTN LAW
      (PROT LOST)
```

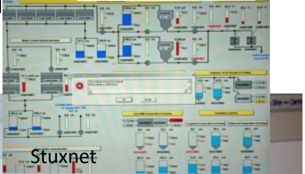
```
ECAM   02:10:15
AUTO FLT AP OFF                  AUTO FLT
ENG THRUST LOCKED
-THR LEVERS.........MOVE
AUTO FLT A/THR OFF
-THR LEVERS.........MOVE
F/CTL ALTN LAW
      (PROT LOST)
```

```
ECAM   02:10:24
AUTO FLT AP OFF                  AUTO FLT
AUTO FLT A/THR OFF
F/CTL ALTN LAW
      (PROT LOST)
-MAX SPEED.......330/.82
F/CTL
RUD TRV LIM FAULT
```

```
ECAM   02:12:44
AUTO FLT AP OFF                  AUTO FLT
NAV ADR DISAGREE                 F/CTL
 -AIR SPD.........X CHECK
•IF NO SPD DISAGREE
 -AOA DISCREPANCY
•IF SPD DISAGREE
  -ADR CHECK PROC...APPLY
```

Flight AF 447





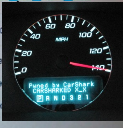
Friday October 7,2011
By Daily Express Reporter

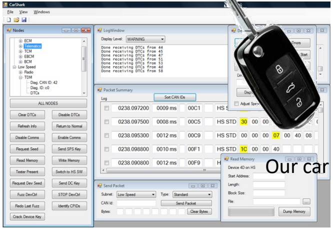
AN accounting error yesterday forced outsourcing specialist Mouchel into a major profits warning and sparked the resignation of its chief executive.

The connection has timed

The server at www.cia.gov is taking too

- The site could be temporarily unavailable moments.
- If you are unable to load any pages, che connection.
- If your computer or network is protecte permitted to access the web.





Display Level: WARNING

```
Done receiving DTCs from 44
Done receiving DTCs from 45
Done receiving DTCs from 47
Done receiving DTCs from 51
Done receiving DTCs from 53
Done receiving DTCs from 4d
Done receiving DTCs from 58
```

Log

```
□ 0238.097200  0009 ms  00C1  HS S
□ 0238.097500  0008 ms  00C5  HS STD  30  00  00
□ 0238.095300  0012 ms  00C9  HS STD  00  00  00  07  00  40  08
□ 0238.098800  0010 ms  00F1  HS STD  1C  00  00  40
□ 0238.090800  0012 ms  00F9  H
```

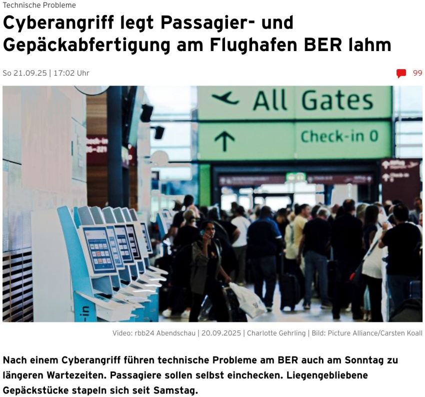
Subnet: Low Speed
Type: Standard
CAN Id:
Bytes:

Device 4D on HS
Start Address:
Length:
Block Size:
File:

Our car

Cyberattacks on European Airports

- Cause: Ransomware attack on an external service provider.



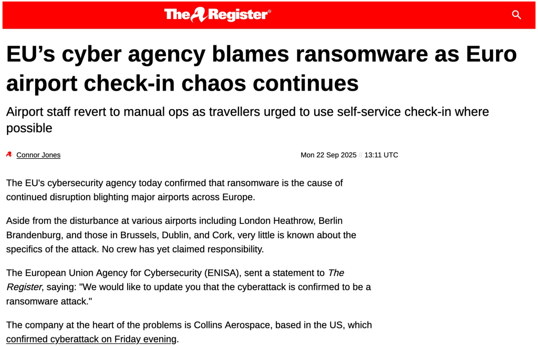
Technische Probleme

Cyberangriff legt Passagier- und Gepäckabfertigung am Flughafen BER lahm

So 21.09.25 | 17:02 Uhr 99

Video: rbb24 Abendschau | 20.09.2025 | Charlotte Gehrling | Bild: Picture Alliance/Carsten Koall

Nach einem Cyberangriff führen technische Probleme am BER auch am Sonntag zu längeren Wartezeiten. Passagiere sollen selbst einchecken. Liegengebliebene Gepäckstücke stapeln sich seit Samstag.



The Register®

EU's cyber agency blames ransomware as Euro airport check-in chaos continues

Airport staff revert to manual ops as travellers urged to use self-service check-in where possible

Connor Jones Mon 22 Sep 2025 // 13:11 UTC

The EU's cybersecurity agency today confirmed that ransomware is the cause of continued disruption blighting major airports across Europe.

Aside from the disturbance at various airports including London Heathrow, Berlin Brandenburg, and those in Brussels, Dublin, and Cork, very little is known about the specifics of the attack. No crew has yet claimed responsibility.

The European Union Agency for Cybersecurity (ENISA), sent a statement to *The Register*, saying: "We would like to update you that the cyberattack is confirmed to be a ransomware attack."

The company at the heart of the problems is Collins Aerospace, based in the US, which confirmed cyberattack on Friday evening.

The Register (above).

rbb24 (left).

Ariane 5

- Ariane 5 exploded on its virgin flight (Ariane Flight 501) on 4.6.1996.
- How could that happen?

What Went Wrong With Ariane Flight 501?

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9. This assumption was not documented because it was satisfied tacitly with Ariane-4.
10. Positioning system was redundant, but both systems failed (systematic error).
11. Transmission of data to ground control was even unnecessary!

What is Safety and Security?

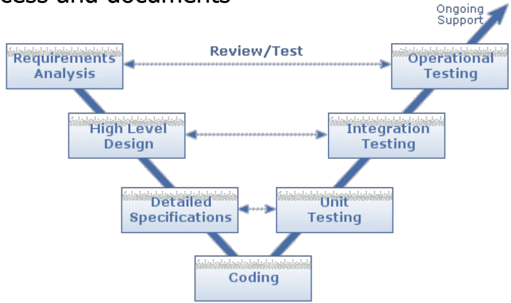
- **Safety** is ensured if product achieves acceptable levels of risk or harm to people, business, software, property or the environment in a specified context of use.
- Threats from “inside”
  - Avoid malfunction of a system – this concerns both hardware and software
  - E.g. planes, cars, railways
- Threats from “outside”
  - Protect product against force majeure (“acts of god”, “höhere Gewalt”)
  - E.g. Lightening, storm, floods, earthquake, fatigue of material, loss of power

What is Safety and Security?

- **Security** is ensured if product is protected against potential attacks from people, environment etc.
- Protection against threats from "outside"
  - Analyze and counteract the abilities of an attacker (also called malicious agent).
- Protection against threats from "inside"
  - Monitor activities of own personnel, to prevent
    - selling of sensitive company data
    - insertion of Trojans during HW/SW design
    - involuntary misuse
- In this context: "cybersecurity" (not physical security)

Software Development Models

- Definition of software development process and documents
- Examples:
  - Waterfall Model
  - **V-Model**
  - Model-Driven Architectures
  - Agile Development



- Motivation:
  - A well-defined development process is more likely to result in a high-quality product than a chaotic process
  - "Process quality ensures product quality"

Verification and Validation (V&V)

- **Verification**: have we built the system right?
  - i.e. correct with respect to a reference artefact
    - specification document
    - reference system
    - model

Deutsch: Korrektheit

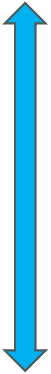
- **Validation**: have we built the right system?
  - i.e. effective (or adequate) for its intended operation?

Deutsch: Wirksamkeit

V&V Methods

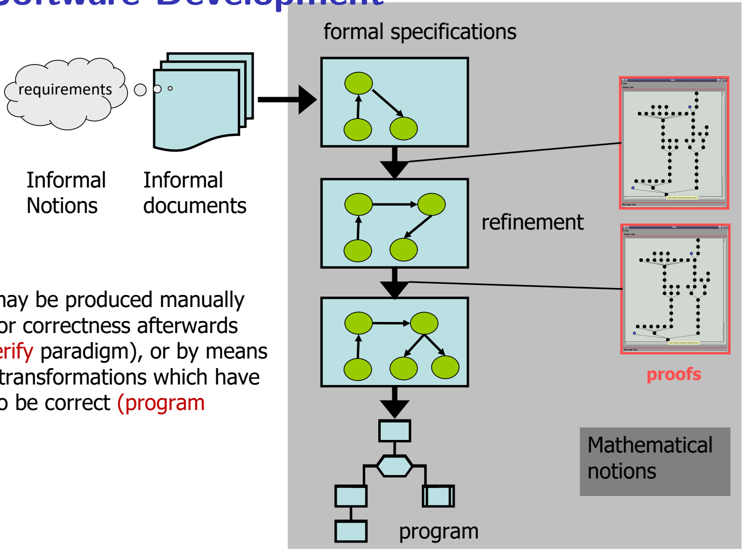
- **Testing**
  - Test case generation, black- vs. white box
  - Hardware-in-the-loop (HiL) testing: integrated HW/SW system is tested
  - Software-in-the-loop (SiL) testing: only software is tested
  - Program runs using symbolic values (symbolic execution, concolic test)
- **Simulation**
  - An executable model is tested with respect to specific properties
  - This is also called Model-in-the-Loop (MiL) testing
- Static/dynamic **program analysis**
  - Dependency graphs, flow analysis
  - Symbolic evaluation, abstract interpretation
- **Model checking**
  - Automatic proof by reduction to finite state problem
- **Formal Verification**
  - Symbolic proof of program properties

Easy to use



Powerful
(Covers all cases)

Formal Software Development



Refinements may be produced manually and checked for correctness afterwards (invent-and-verify paradigm), or by means of automated transformations which have been proven to be correct (program synthesis)

Concepts of Quality

What is Quality?

- Quality is the collection of its characteristic properties.
- Quality model: decomposes the high-level definition by associating attributes (also called characteristics, factors, or **criteria**) to the quality conception.
  - See Wikipedia for a long list of quality attributes.
- Quality **indicators** associate **metric values** with **quality criteria** , expressing “how well” the criteria have been fulfilled by the process or product.
  - The idea is to **measure** quality, with the aim of continuously **improving** it.
  - Leads to **quality management**
    - TQM = total quality management
    - Kaizen = continuous incremental quality improvement
  - . . . but note Goodhart’s law:
    “*When a measure becomes a target, it ceases to be a good measure.*”

Quality Criteria: Different Dimensions of Quality

- For the development of artifacts quality criteria can be measured with respect to the
  - development process (**process quality**), or
  - final product (**product quality**).
- Another dimension for structuring quality conceptions is
  - **Correctness** (*Korrektheit*): the consistency with the product and its associated requirements specifications, and
  - **Effectiveness** (*Wirksamkeit*): the suitability of the product for its intended purpose.
- A third dimension structures quality according to product properties:
  - **Functional properties** : the specified services to be delivered to the users
  - **Structural properties** : architecture, interfaces, deployment, control structures
  - **Non-functional properties** : usability, reliability, availability, security, maintainability, guaranteed worst-case execution time (WCET), costs, absence of run-time errors, . . .

Other Norms and Standards

- ISO 9001 (DIN ISO 9000-4):
  - Standardizes definition and supporting principles necessary for a quality system to ensure products meet requirements
  - ‘Meta-Standard’
- CMM (Capability Maturity Model), Spice (ISO 15504)
  - Standardizes maturity of development process
  - Level 1 (initial): Ad-hoc
  - Level 2 (repeatable): process dependent on individuals
  - Level 3 (defined): process defined & institutionalized
  - Level 4 (managed): measured process
  - Level 5 (optimizing): improvement feed back into process

Summary

- **Safety** vs. **Security**
- **Quality**
  - collection of characteristic properties
  - quality indicators measuring quality criteria
- Relevant **aspects of quality** here
  - Functional **suitability** and **safety** (functional correctness)
  - **Dependability** (availability, reliability, security — non-functional correctness)
- Next week
  - Concepts of safety, legal requirements, certification

Veranstaltungshinweis

Trustworthy Tuesday (E-Mail follows)