Future-Proof Software-Systems

(Zukunftsfähige Software-Systeme)

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TU Dresden WS 2015/2016

Part 4B: Architecting for Resilience

V0.5 / 17.01.2016

Content

Part 4A:

1. Managed Evolution (Repetition)
2. Resilience
3. Architecting for Resilience
4. Resilience Architecture Principles
   - *Universal* Resilience Architecture Principles

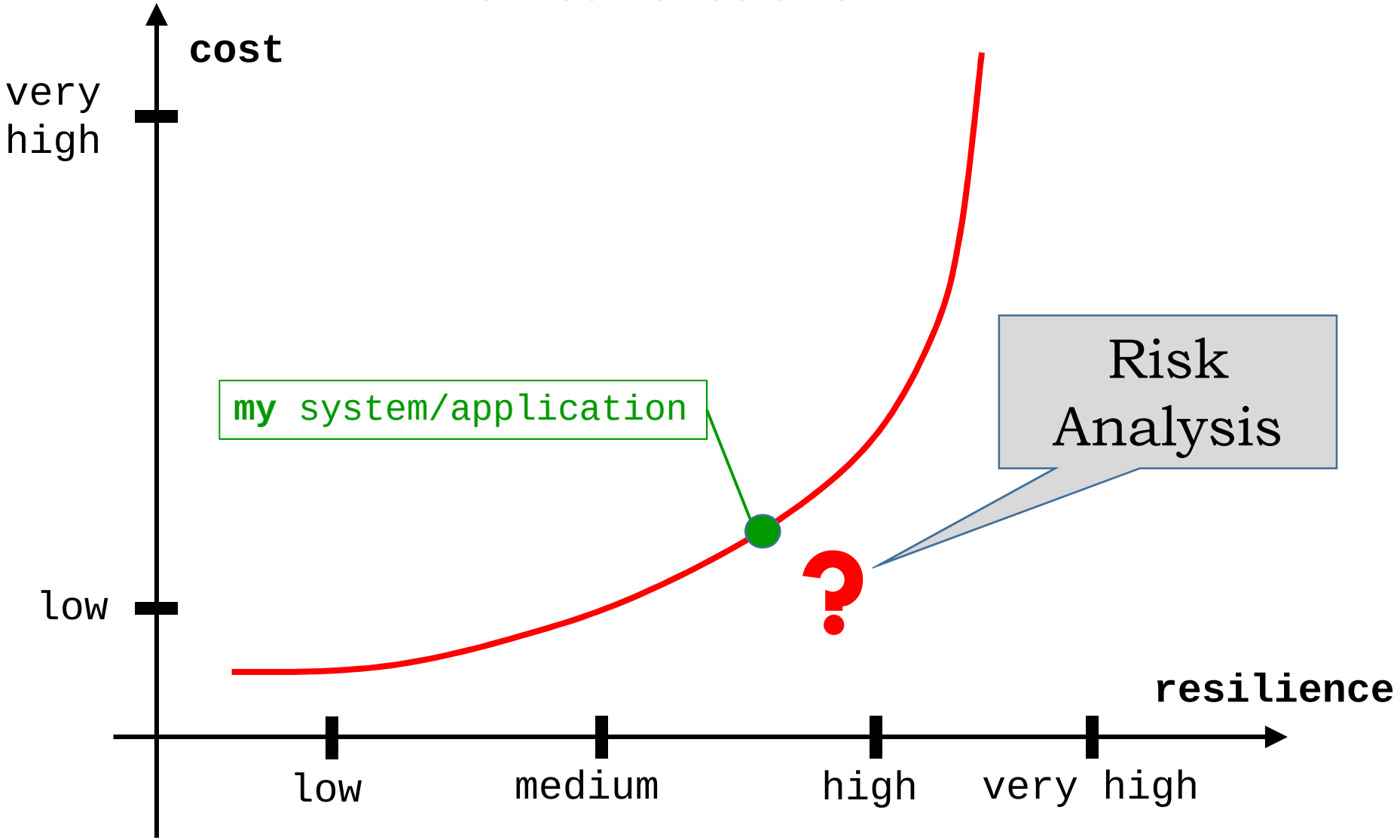
Part 4B:

- *Specific* Resilience Architecture Principles
- Autonomic Computing

Future-Proof Software-Systems:

Risk Analysis

The «resilience dilemma»



http://www.aeroartinc.com

Resilience properties of the SW-system

- **Safety**
- **Security**
- **Integrity**
- **Availability**
- **Confidentiality**
- **Certifiability**
- **Reliability**
- **Diagnosability**
- **Standards adherence**
- **Accountability**
- **Traceability**
- **Non-Repudiation**
- **Fault-Tolerance**
- **Business Continuity**
- **Recoverability**
- **Graceful Degradation**
- **Auditability**
- **Real-TimeCapability**
- **Fail-Save Behaviour**
- **Survivability**
- **Performance**

etc.

Resilience Profile

Quality Property	*Type*
Business Value	Primary Characteristic
Agility	Primary Characteristic
Availability	√
Security	√
Safety	√
Privacy/Confidentiality	√
Performance	
Usability	
Robustness	√
Operating Cost	
Reusability	
Compliance to laws and regulations	√
Adherence to industry-standards	
Memory Size	
Power consumption	
Testability	
etc.	
	√ = Resilience

identical for all systems

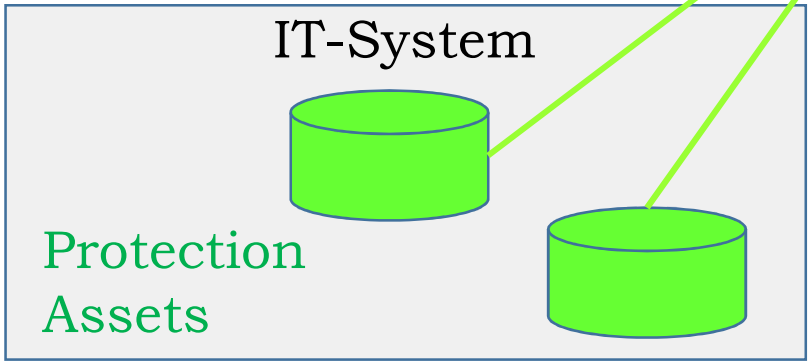
Resilience set: dependent on application area

Additional quality properties: dependent on application area

How do I find out which specific resilience *principles* and *patterns* are important for my application?

http://managementresearchdevelopment.com

⇒ by executing a *risk analysis*

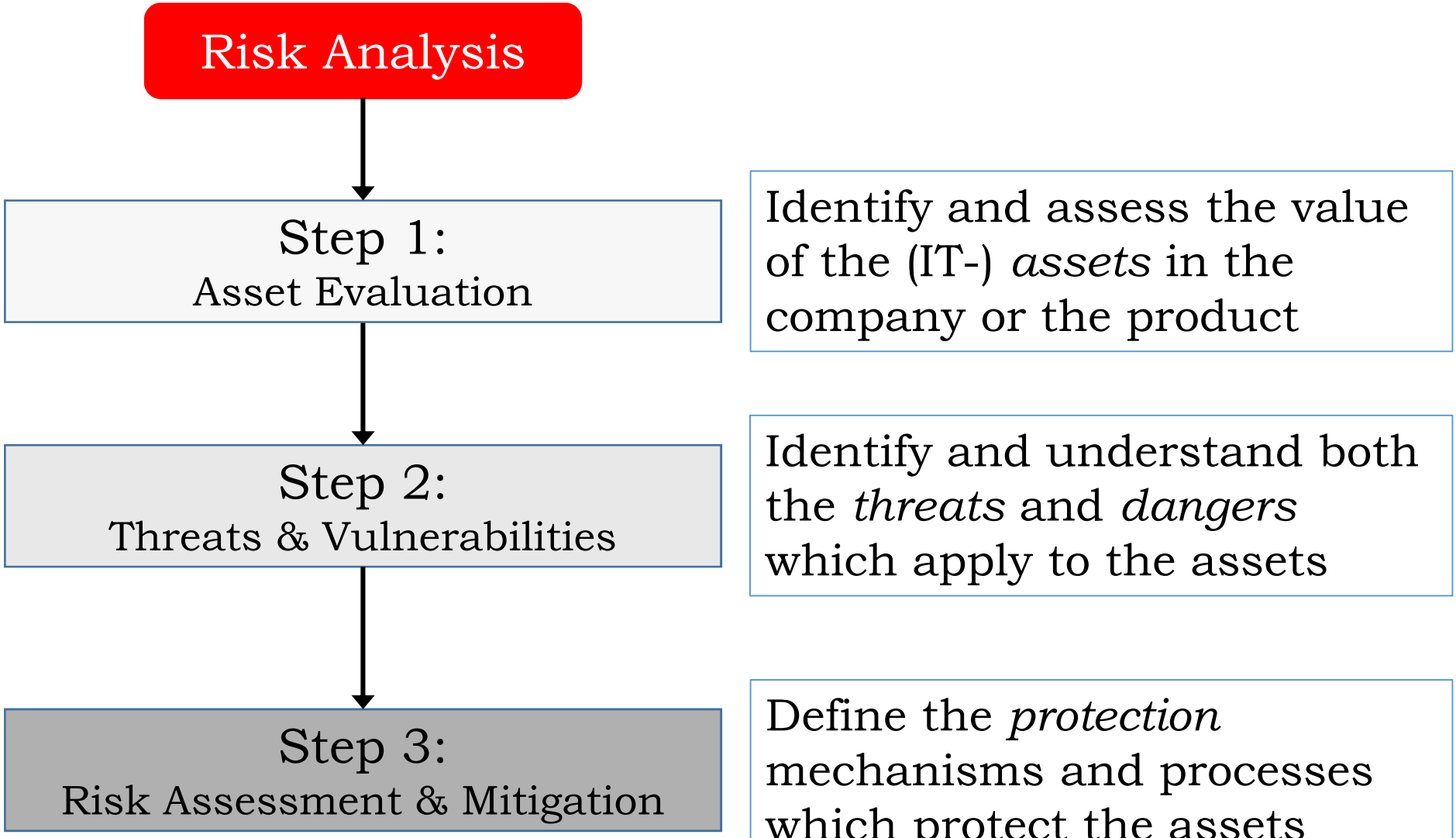


Risk Analysis

Step 1:
Asset Evaluation

Step 2:
Threats & Vulnerabilities

Step 3:
Risk Assessment & Mitigation


Risk Analysis
Step 1:
Asset Evaluation
Identify and assess the value of the (IT-) *assets* in the company or the product
Step 2:
Threats & Vulnerabilities
Identify and understand both the *threats* and *dangers* which apply to the assets
Step 3:
Risk Assessment & Mitigation
Define the *protection* mechanisms and processes which protect the assets

http://seattlewebdesign

Example: System = Financial Institution

Protection Assets

- …
- Customer Data
- …

Threats & Dangers

- …
- Unauthorized Access
- …

Protection Means

- Authentication
- Authorization
- Access Control
- …

https://roadloans.com/

Example: System = Passenger Car

Protection Assets

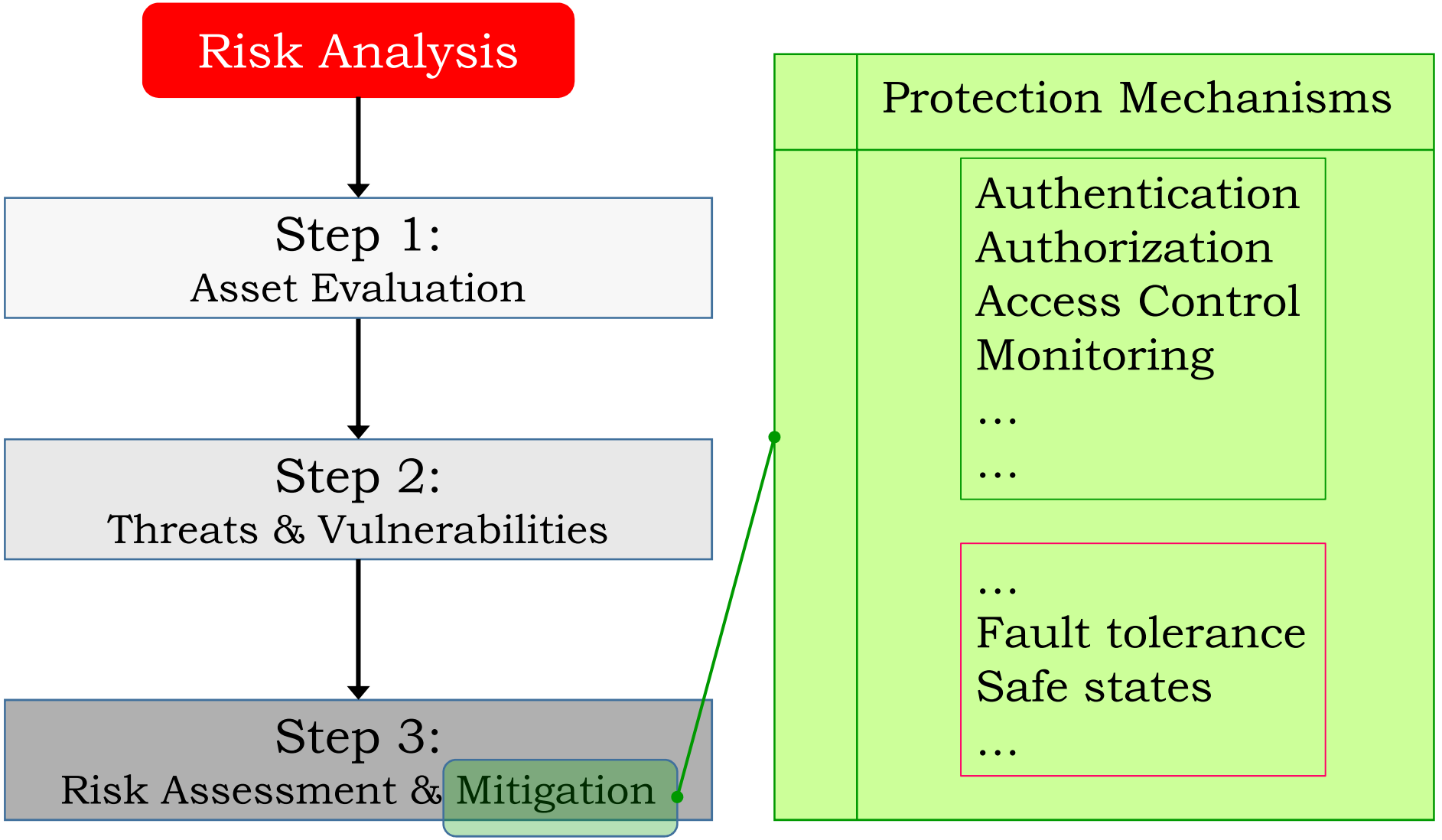
- …
- Life & Health of Passengers
- …

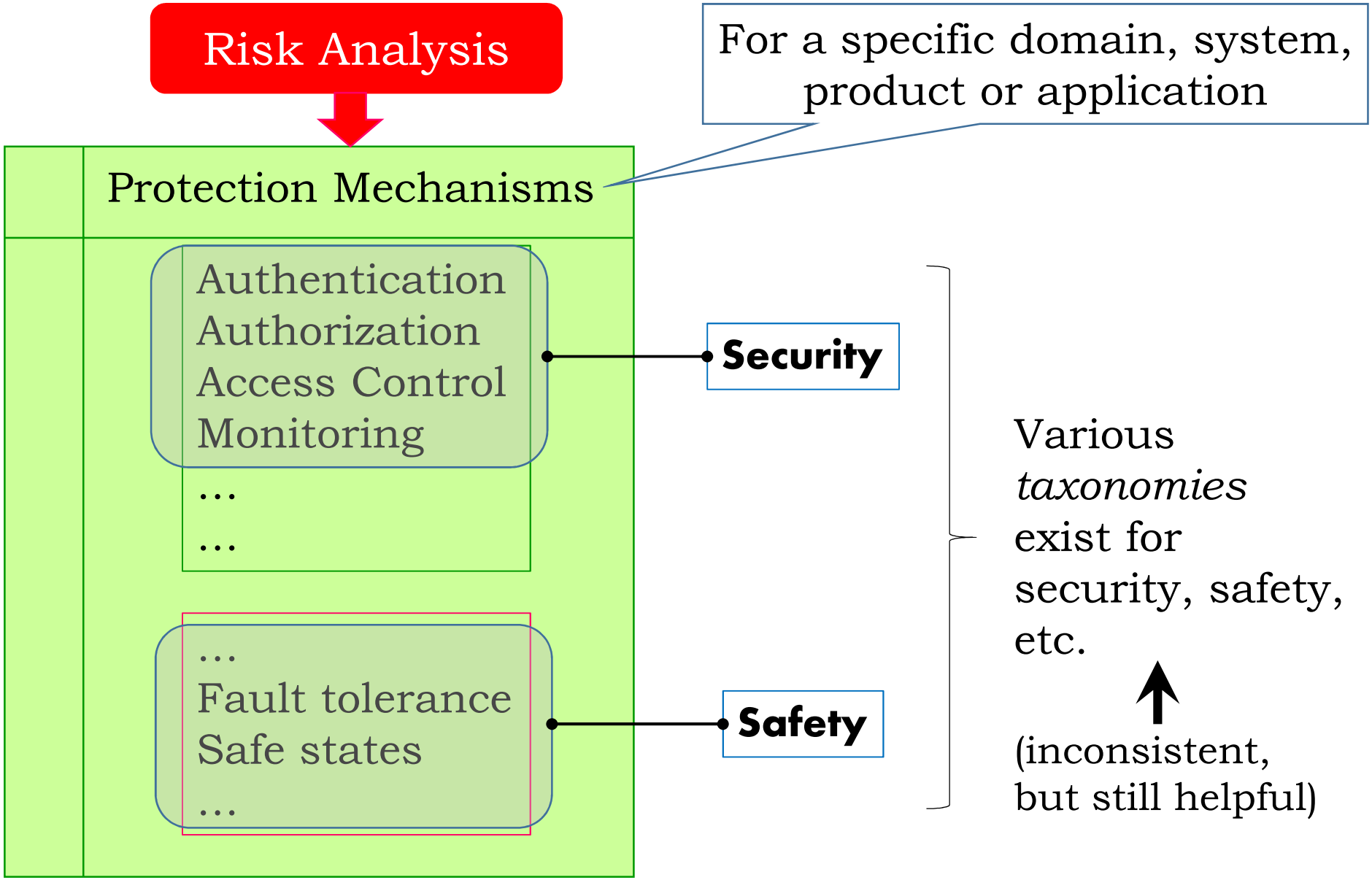
Threats & Dangers

- …
- Electronic System Failure
- …

Protection Means

- …
- Fault tolerance
- Safe states
- …


Risk Analysis
Step 1:
Asset Evaluation
Step 2:
Threats & Vulnerabilities
Step 3:
Risk Assessment & Mitigation
Protection Mechanisms
Authentication
Authorization
Access Control
Monitoring
…
…
…
Fault tolerance
Safe states
…


Risk Analysis
For a specific domain, system, product or application
Protection Mechanisms
Authentication
Authorization
Access Control
Monitoring
...
...
Security
...
Fault tolerance
Safe states
...
Safety
Various *taxonomies* exist for security, safety, etc.
(inconsistent, but still helpful)

Risk Analysis

Protection Mechanisms

Authentication
Authorization
Access Control
Monitoring
…
…

Security

…
Fault tolerance
Safe states
…

Safety

Applicable Resilience *Principles* and *Patterns*

Summary

1. Specify your system
2. Resilience Analysis
3. Applicable Principles and Patterns

http://seattlewebdesign

https://roadloans.com/

Decide on general (overarching) principles

Risk Analysis

Protection Mechanisms

Resilience Principles and Patterns

… others

https://www.npmjs.com

Summary

Applicable Resilience Principles and Patterns

Resilience Engineer:
- Security Engineer
- Safety Engineer
- Certification Engineer
- …

Important and interesting role

Summary

3. Applicable Principles and Patterns

Resilience Principles and Patterns

→ **Specific** (Property-dependent) Resilience Architecture Principles & Patterns







Future-Proof Software-Systems:

Specific (Property-dependent) Resilience Architecture Principles & Patterns

General Resilience Architecture Principles

Resilience

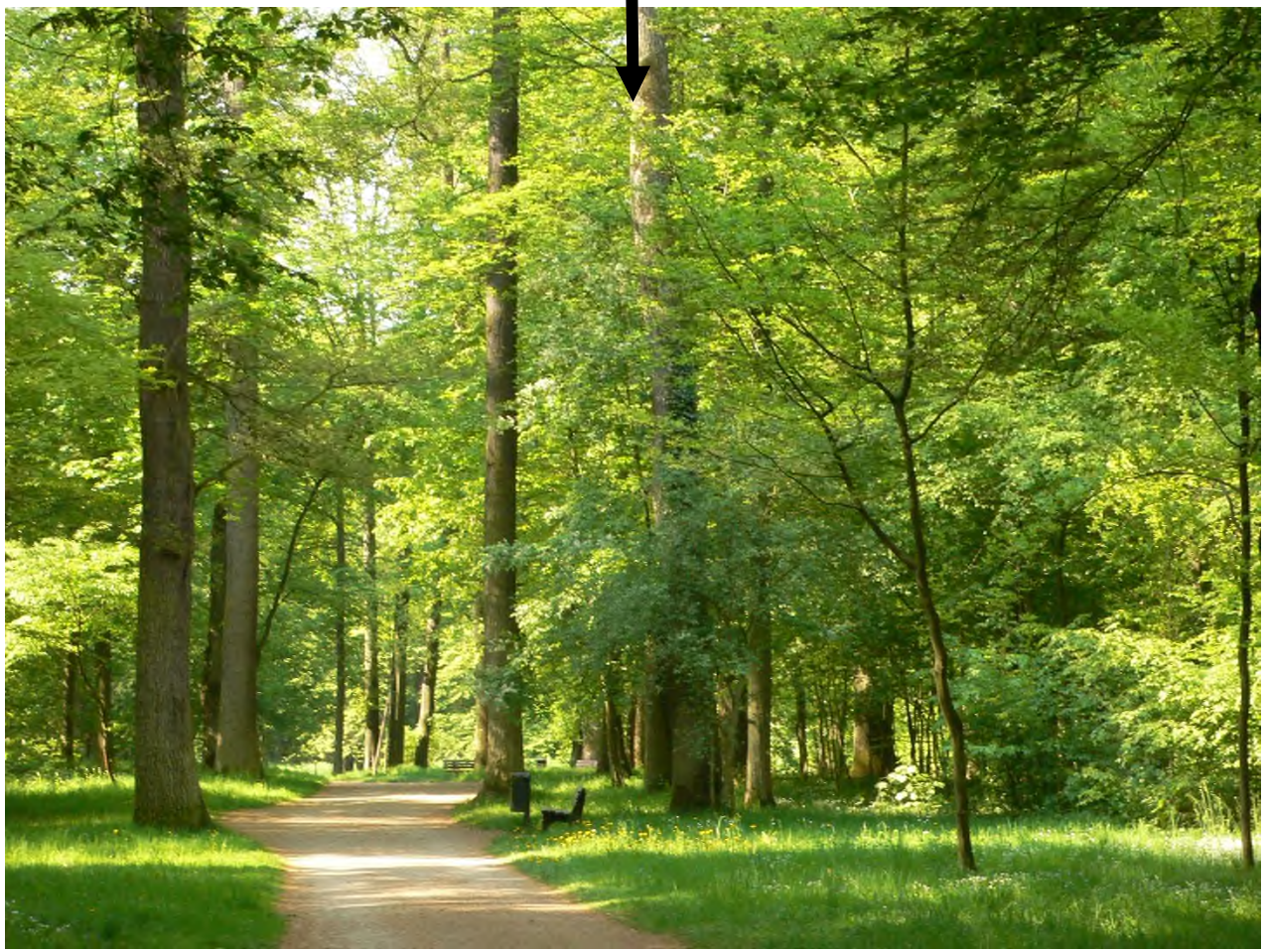
http://en.wikipedia.org/wiki/Czechoslovak_border_fortifications

- R1: Fault Containment Regions
- R2: Single Points of Failure
- R3: Multiple Lines of Defense
- R4: Fail-Safe States
- R5: Graceful Degradation
- R6: Dependable Foundation

√

Specific (Property-dependent) Resilience Architecture Principles

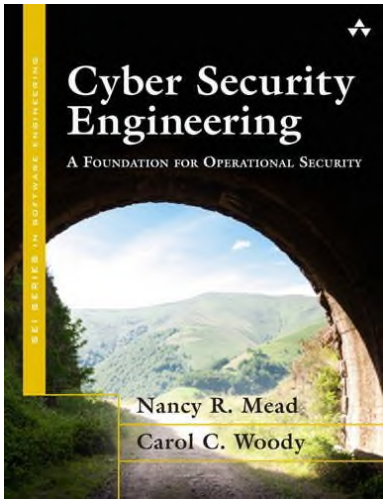
Specific IT Resilience Architecture Principles & Patterns



http://www.outdoor-magazin.com

… a very large and rich field of engineering

Security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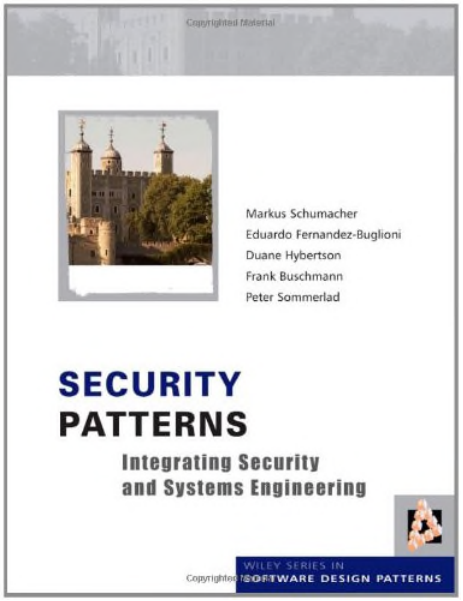
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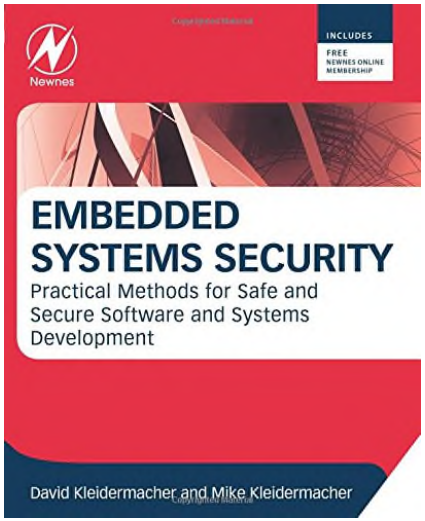
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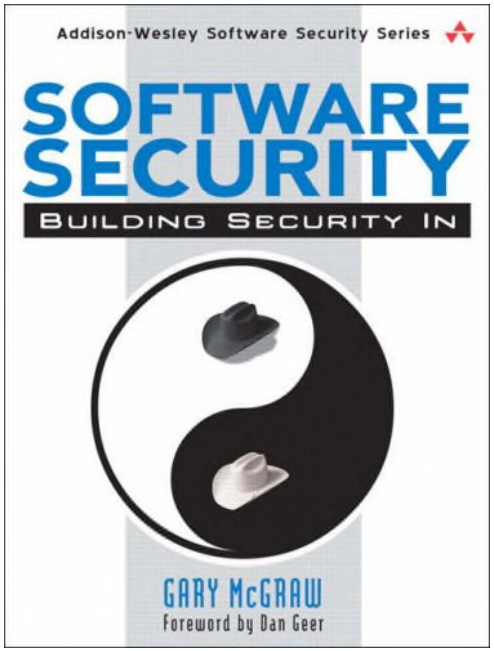
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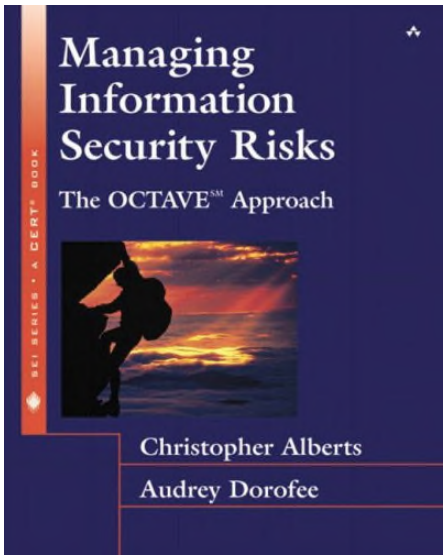
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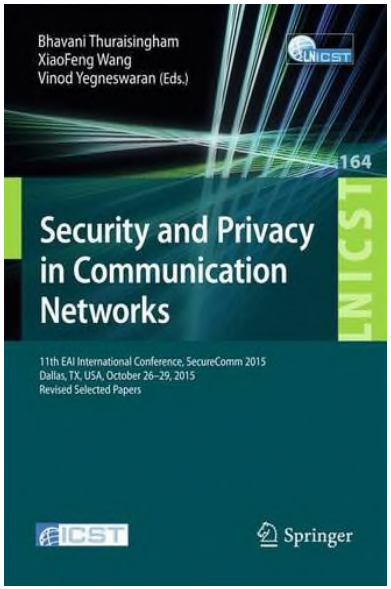
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XiaoFeng Wang
Vinod Yegneswaran (Eds.)
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11th EAI International Conference, SecureComm 2015
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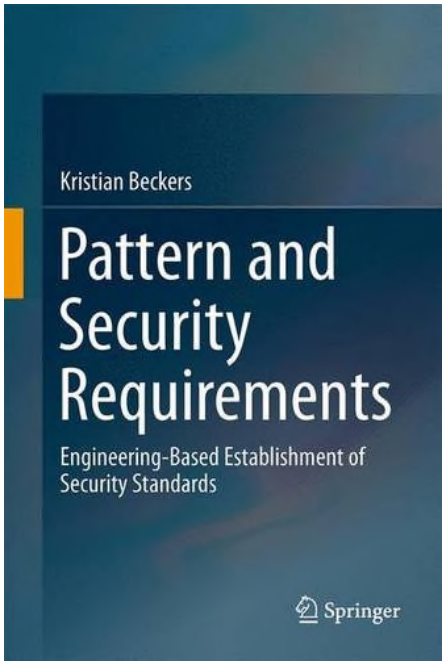
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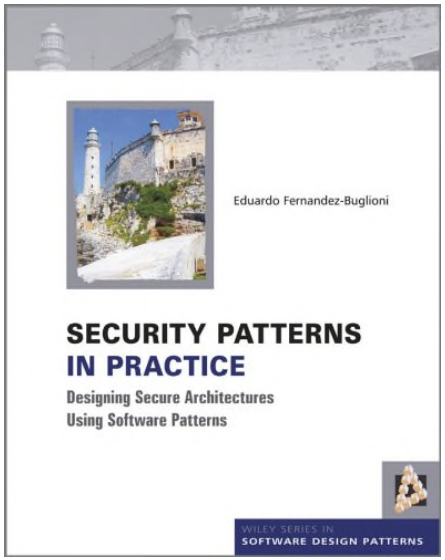
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Safety


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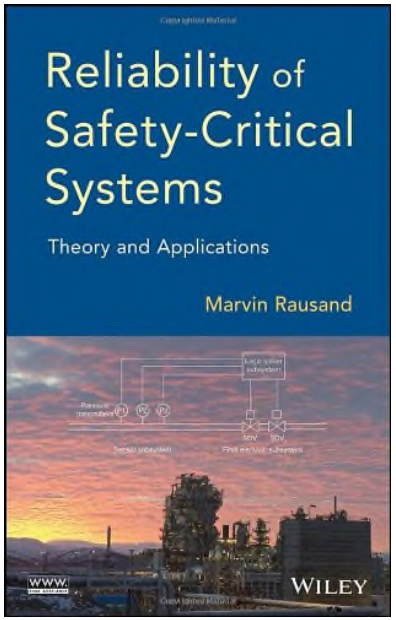
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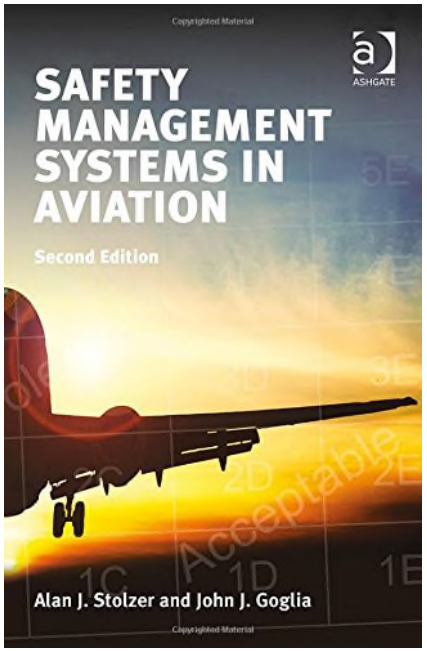
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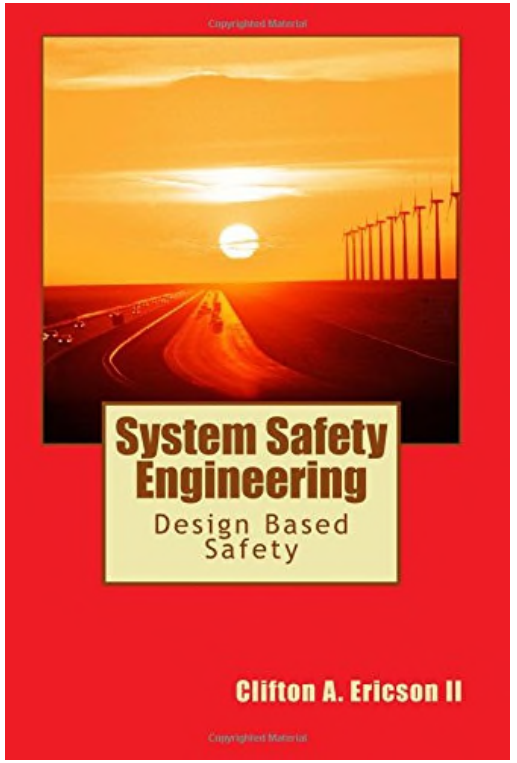
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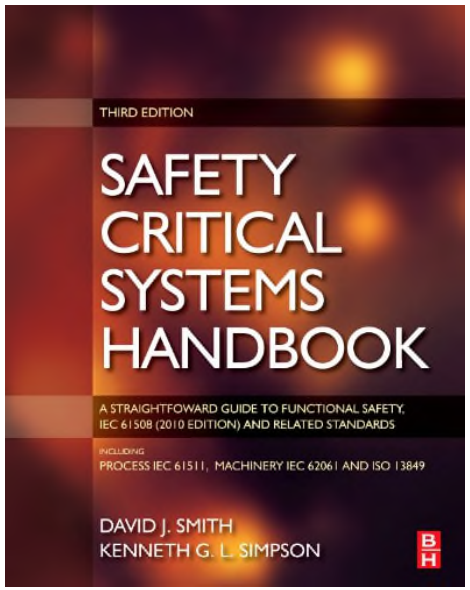
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DAVID J. SMITH
KENNETH G. L. SIMPSON
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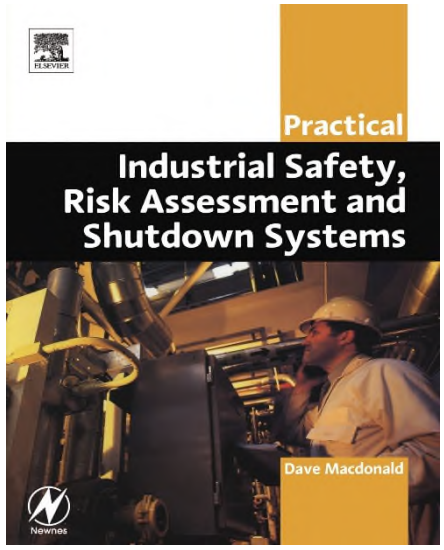
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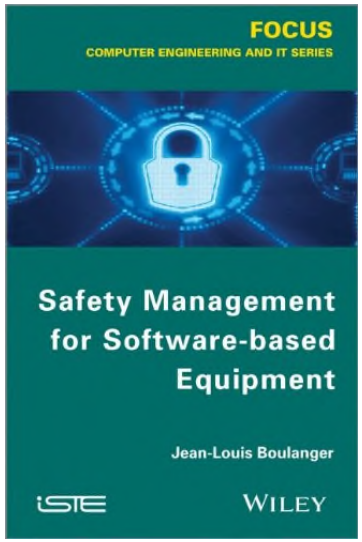
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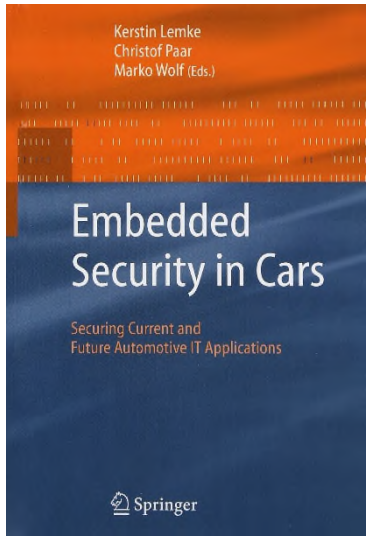
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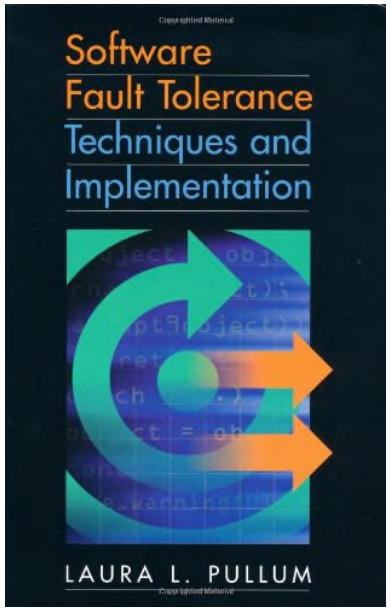
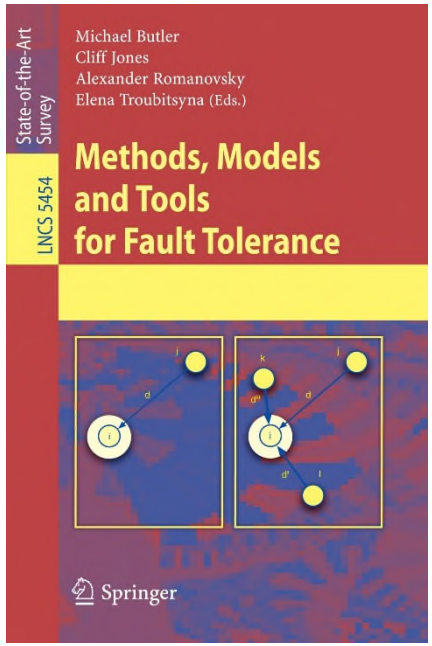
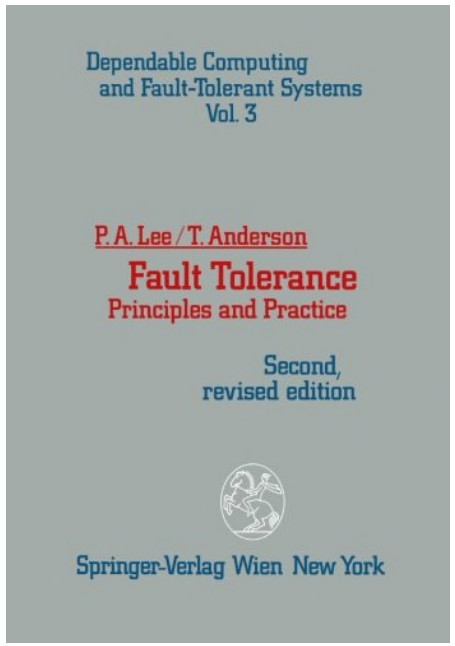
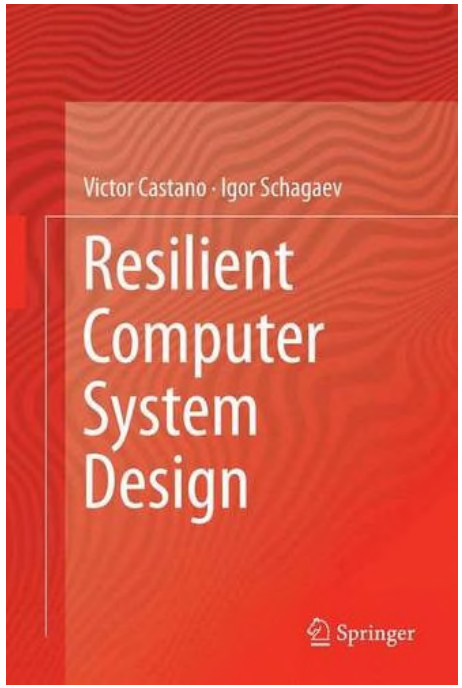
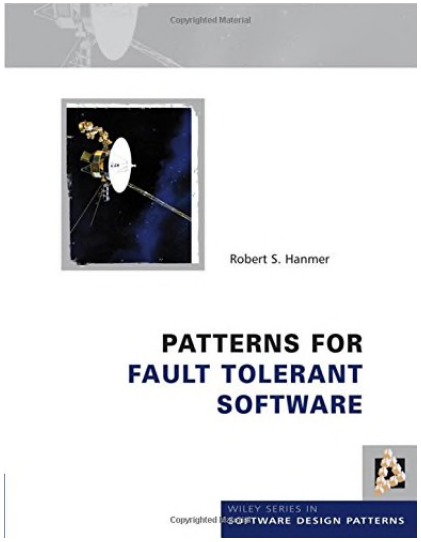


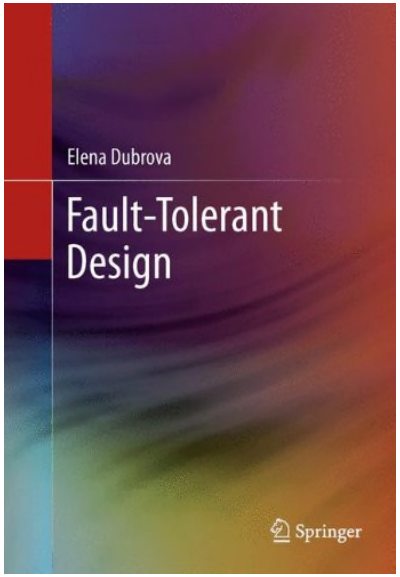


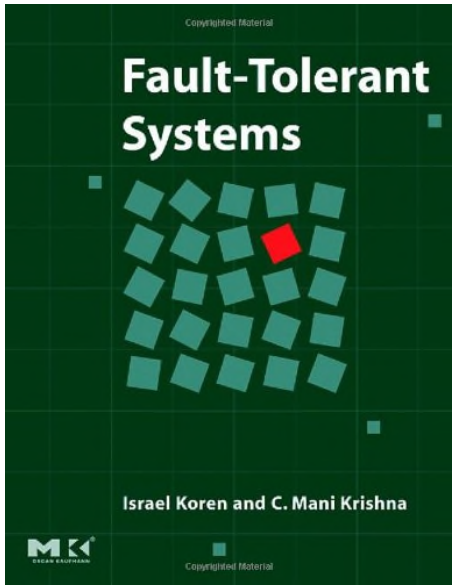




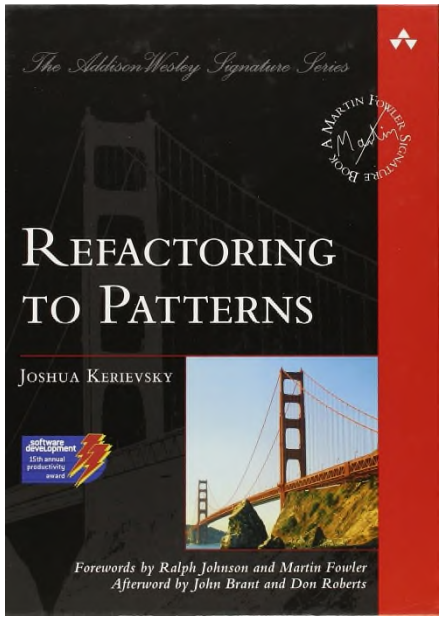
Fault-Tolerance







Patterns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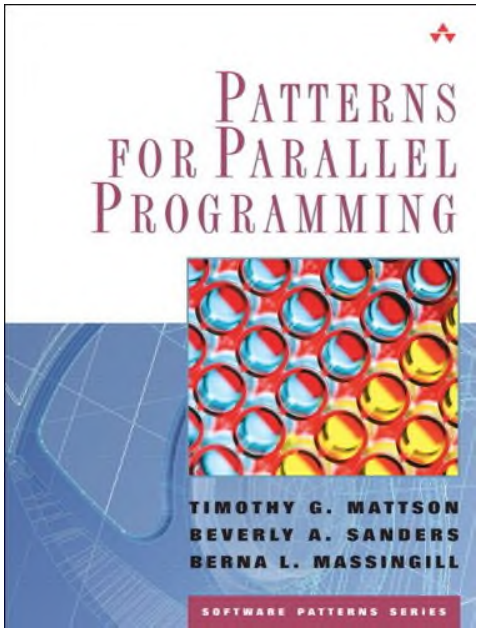
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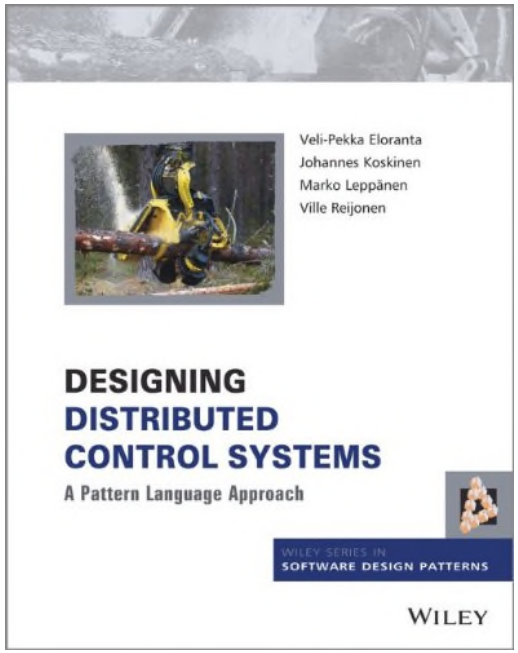
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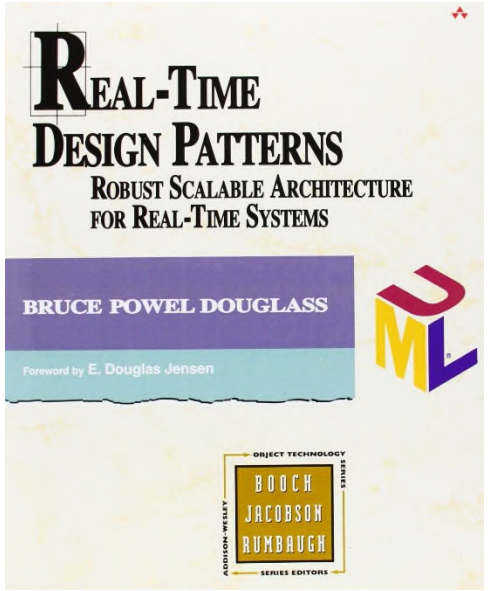
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Addison-Wesley
Series Editors

What can we learn in this lecture?

https://www.npmjs.com

We cannot become full **Resilience Engineers** in this lecture

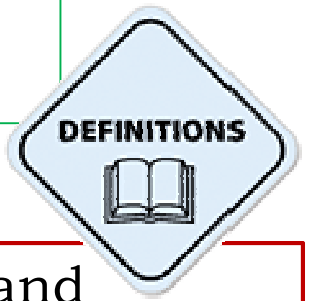
… but we can learn:

- The *methodology*
- Some important *principles & patterns*

Choice for this lecture

We will focus on Principles & Patterns for:

- Security
- Safety
- Integrity



Information **security** protects the confidentiality, integrity and availability of computer system data and functionality from unauthorized and malicious accesses

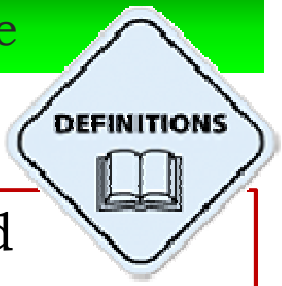
Safety is the state of being protected against failure, damage, error, accidents, harm, or any other event that could be considered non-desirable in order to achieve an acceptable level of risk

Integrity assures that functions or data are executed as implemented and have not been altered, modified, deleted or replaced

Future-Proof Software-Systems:

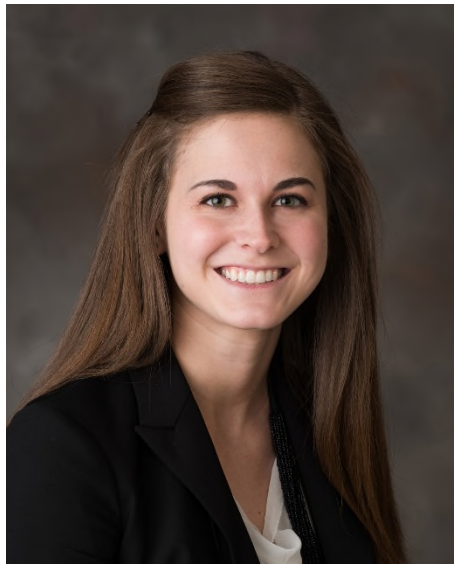
Specific (Property-dependent) Resilience Architecture Principles for:

Security



Information *security* protects the confidentiality, integrity and availability of computer system data and functionality from unauthorized and malicious accesses

Authentication



http://engineering.unl.edu

?

Electronic channel

http://www.rand.org

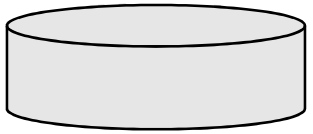
Real world

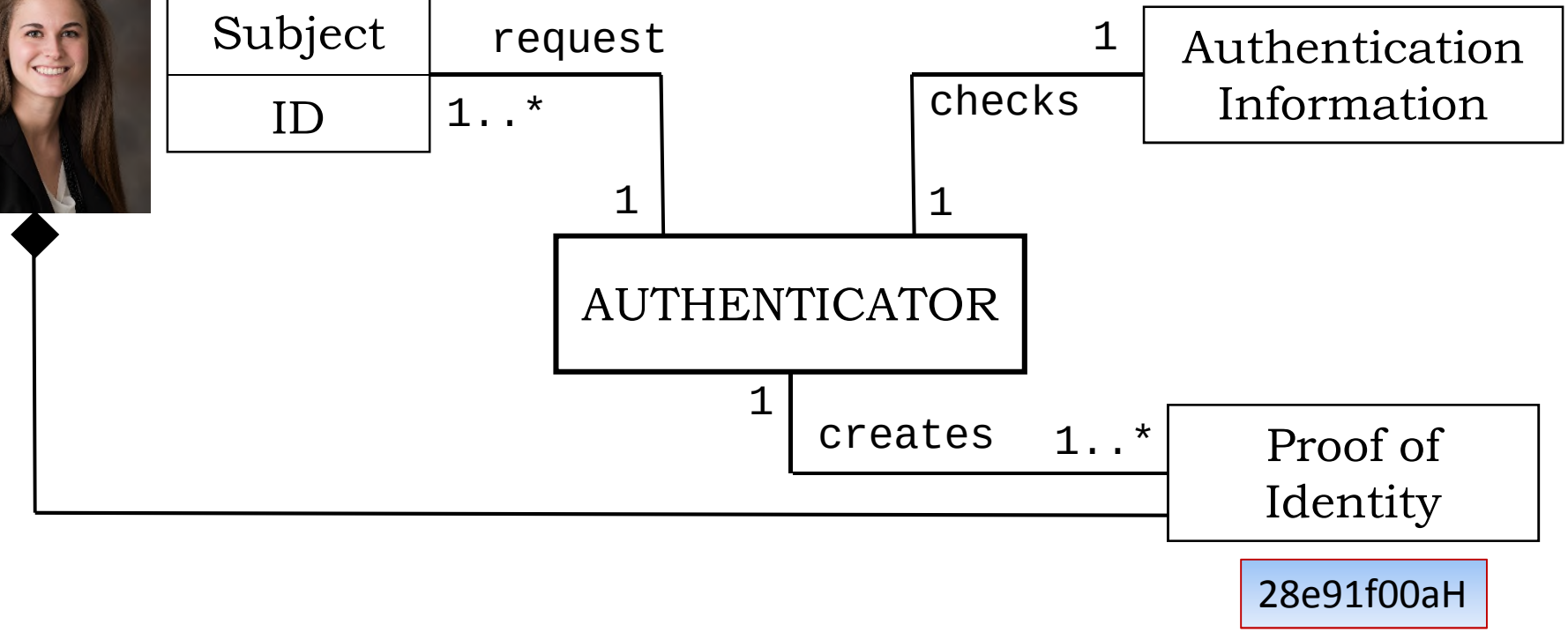
Computer representation

Authentication

Authenticator Pattern

[Schuhmacher, ISBN 978-0-470-85884-4]





Authentication

Authenticator Pattern

[Schuhmacher, ISBN 978-0-470-85884-4]

User Name
Password

Subject

ID

request

1..*

1

checks

1

Authentication Information

AUTHENTICATOR

1

creates

1..*

Proof of Identity

28e91f00aH

Authorization

Authorization:
Allow or deny access
to a computer resource

http://stonehousesigns.com

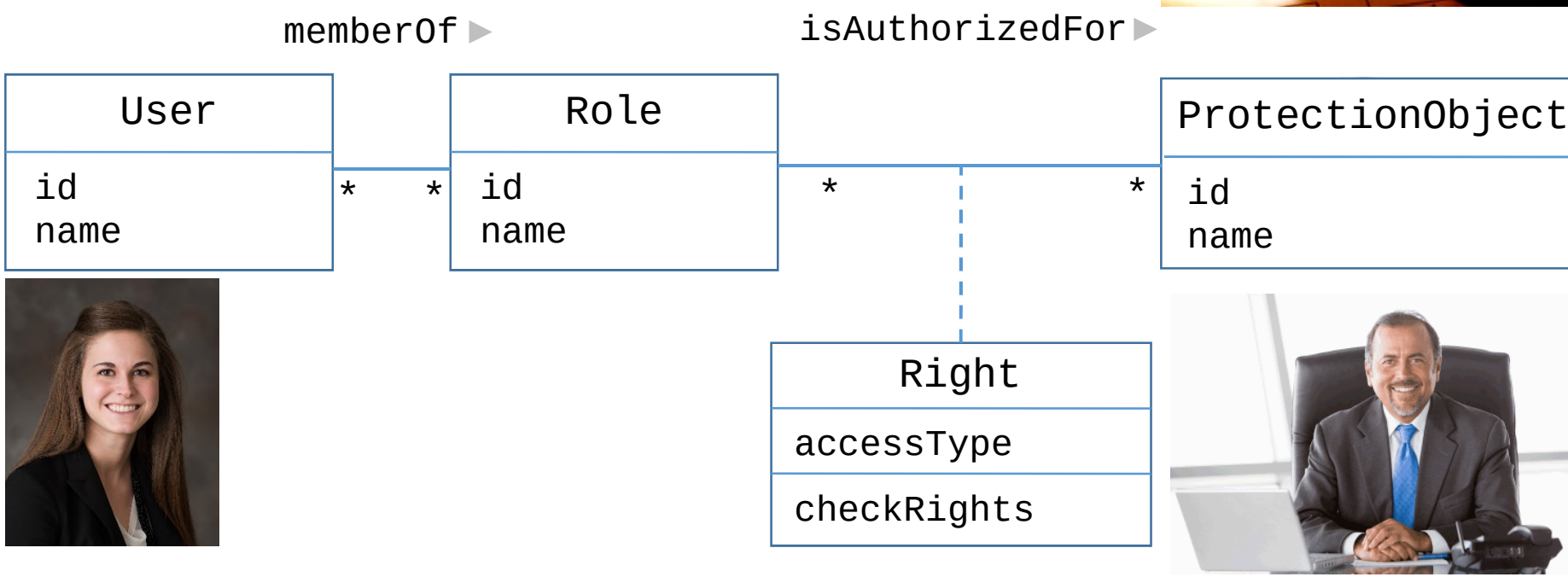
RBAC Pattern
[Fernandez, ISBN 978-1-119-99894-5]

Full Access with Errors Pattern
[Schuhmacher, ISBN 978-0-470-85884-4]

Authorization

RBAC Pattern

[Fernandez, ISBN 978-1-119-99894-5]



The `User` and `Role` classes describe registered users and their predefined roles. Users are assigned to roles, roles are given rights according to their functions

Authorization

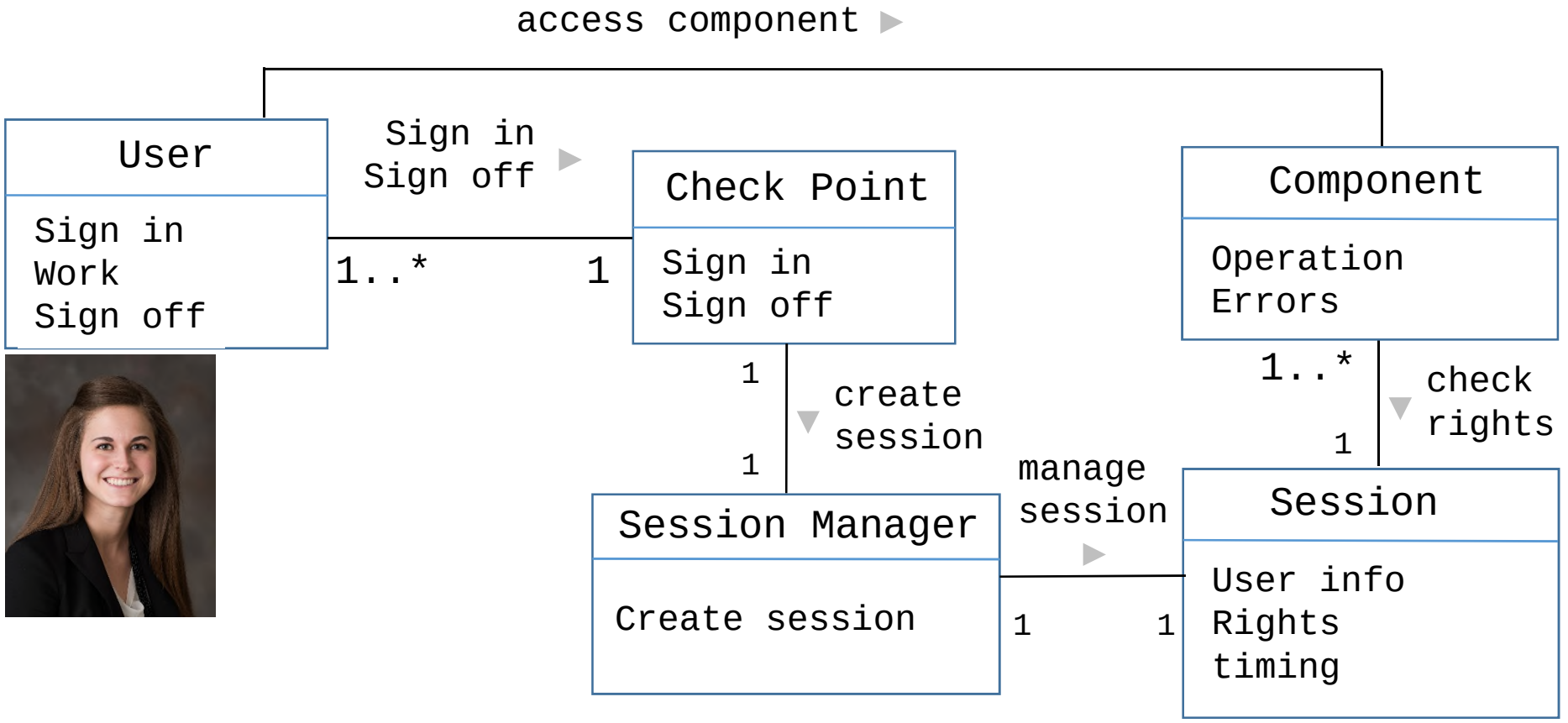
Full Access with Errors Pattern

[Schuhmacher, ISBN 978-0-470-85884-4]

Access Control

Security Session Pattern

[Schuhmacher, ISBN 978-0-470-85884-4]

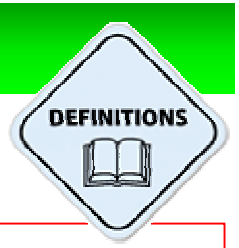


Future-Proof Software-Systems:

Specific (Property-dependent) Resilience Architecture Principles for:

Safety

Safety



Safety is the state of being protected against *failure*, damage, error, accidents, harm, or any other event that could be considered non-desirable in order to achieve an acceptable level of risk

Protection Assets

- …
- Life & Health of Passengers
- …

Threats & Dangers

- …
- Electronic System Failure
- …

Protection Means

- …
- Fault tolerance ❶
- Safe states ❷
- …

Safety

Architectural Patterns
[Hanmer, ISBN 978-0-470-31979-6]

Detection Patterns
[Hanmer, ISBN 978-0-470-31979-6]

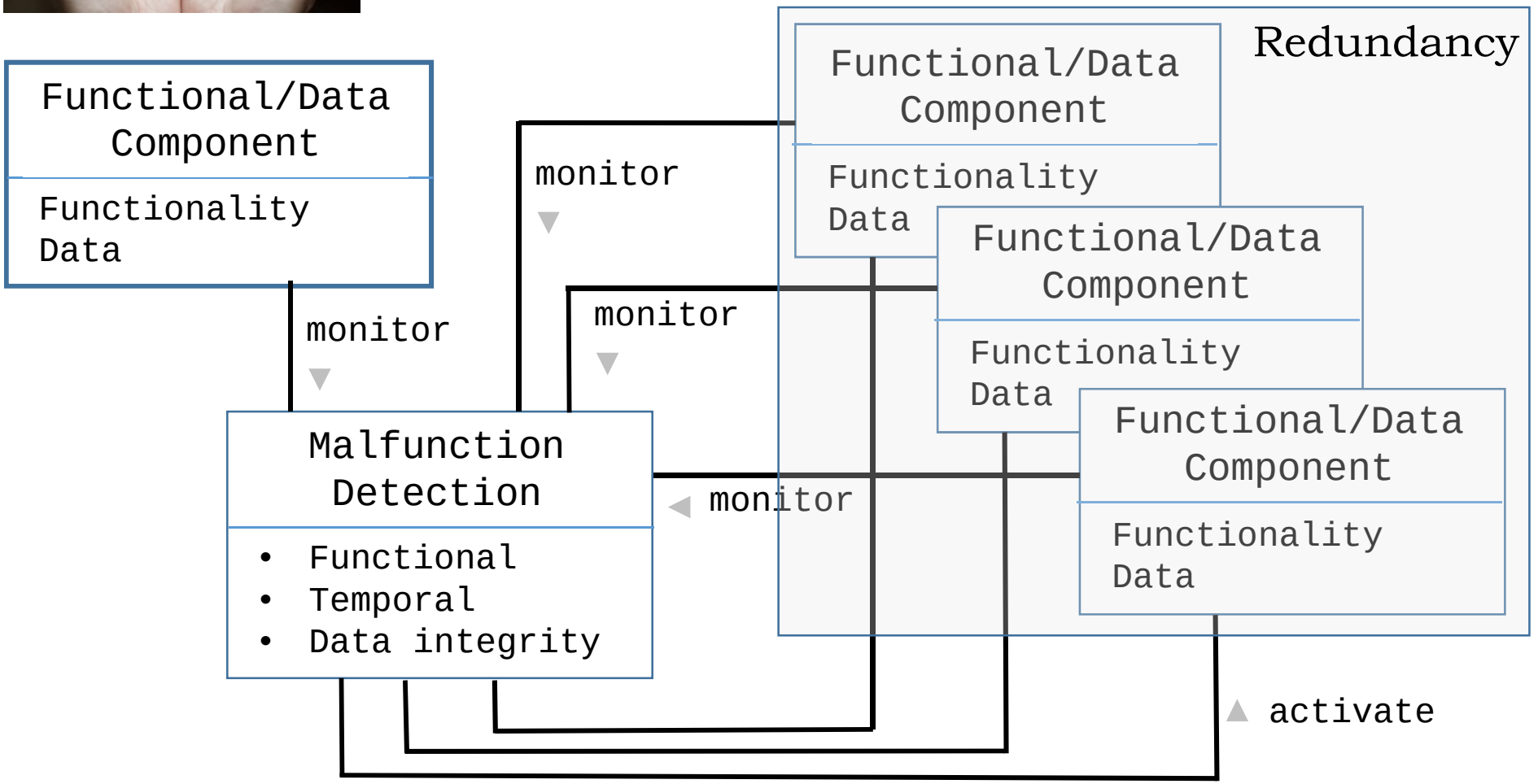
Error Recovery Patterns
[Hanmer, ISBN 978-0-470-31979-6]

Error Mitigation Patterns
[Hanmer, ISBN 978-0-470-31979-6]

Fault Treatment Patterns
[Hanmer, ISBN 978-0-470-31979-6]

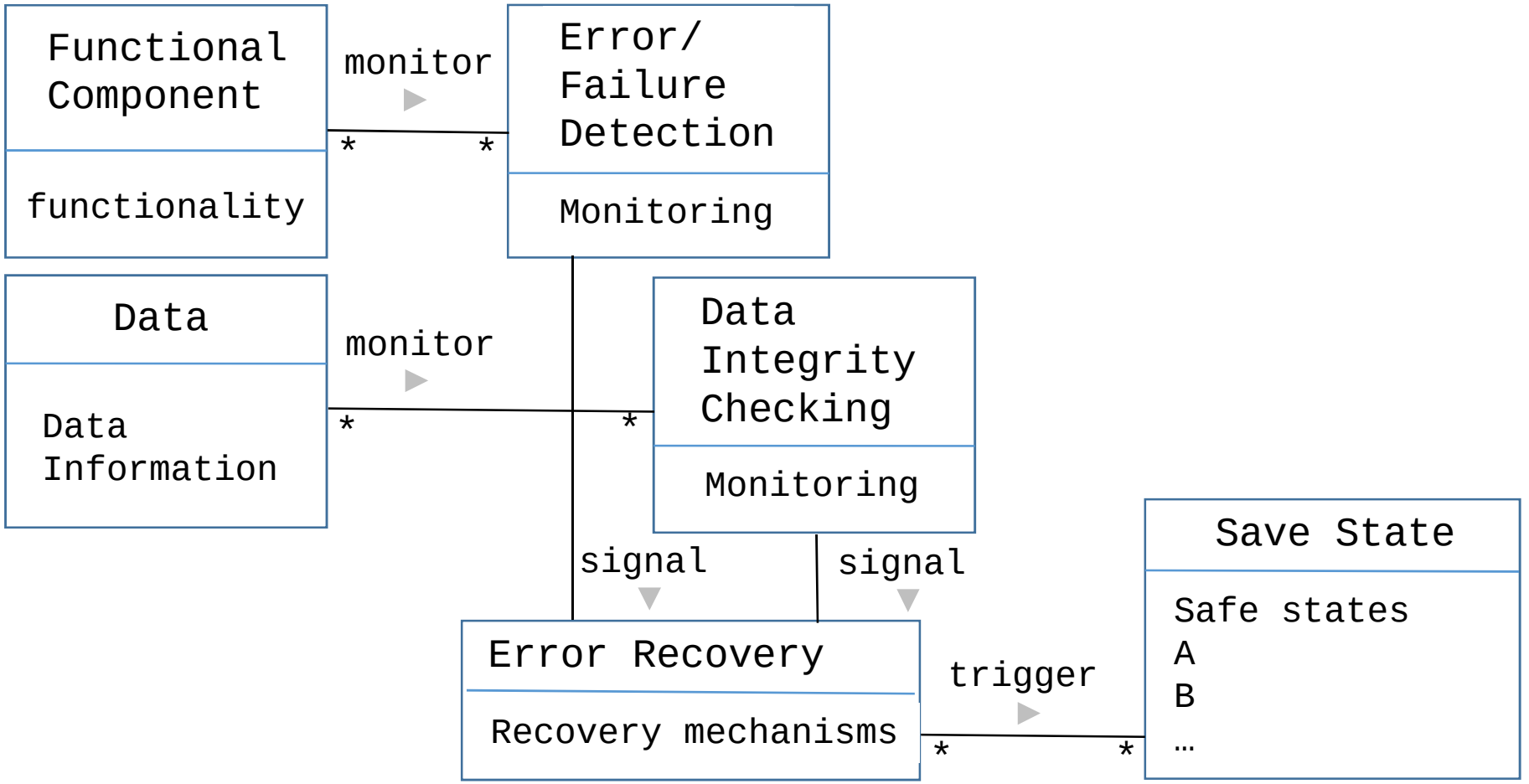
Safety

Fault Tolerance



Safety

Fail Safe State Pattern



Future-Proof Software-Systems:

Specific (Property-dependent) Resilience Architecture Principles for:

Integrity

http://www.phdconstruction.com/

Enterprise Record Archive

Each enterprise is obliged by law to generate records and to keep them available *unaltered* for 10 years (CH)

Protection Assets

- Electronic Records (Archive)

Threats & Dangers

- Record modification

Protection Means

- Integrity protection

http://www.nelbaliproperty.com

Data Integrity

How can you assure and prove that a *digital document* has not been altered?

Digital Data Integrity Protection Technolog
Hashing & Digital Signatures

Hashing & *Digital Signatures* are a secure technique to preserve the integrity of a digital document over long periods of time

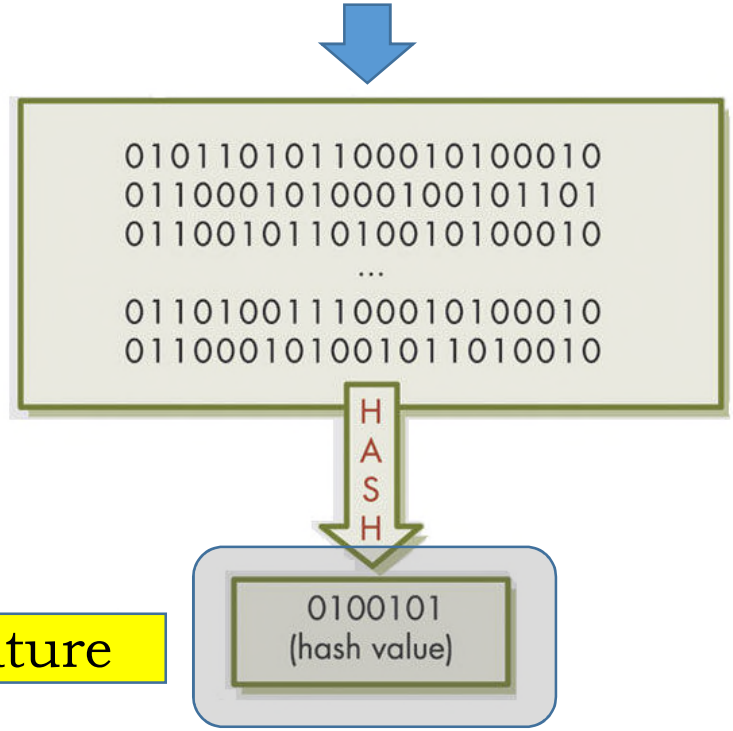
https://www.tsl.texas.gov/

Data Integrity

http://www.nelbaliproperty.com

Hashing & Digital Signatures

http://de.dreamstime.com

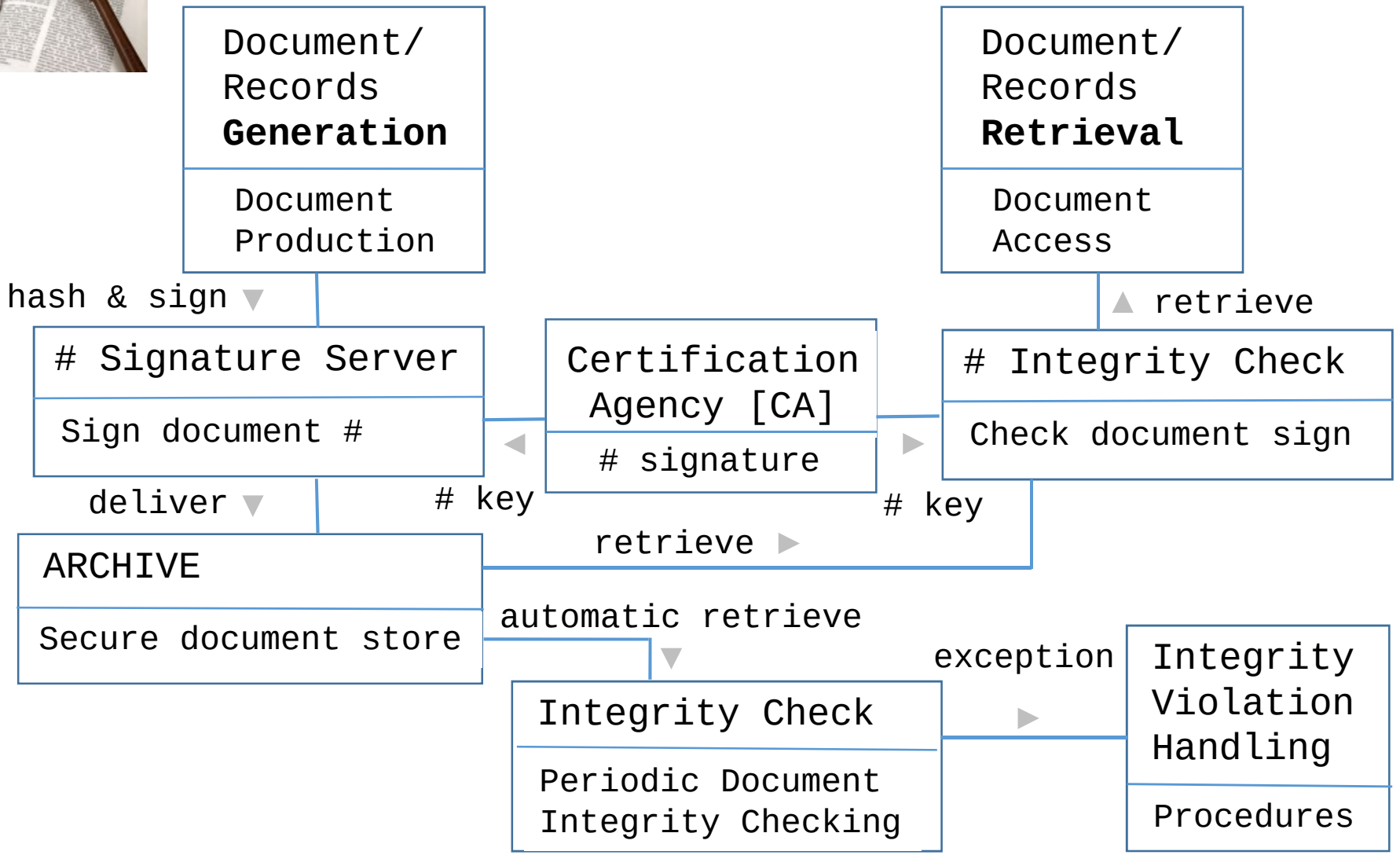


http://www.3gforensics.co.uk

Document ID
Time Stamp
Hash Value

Digital Signature

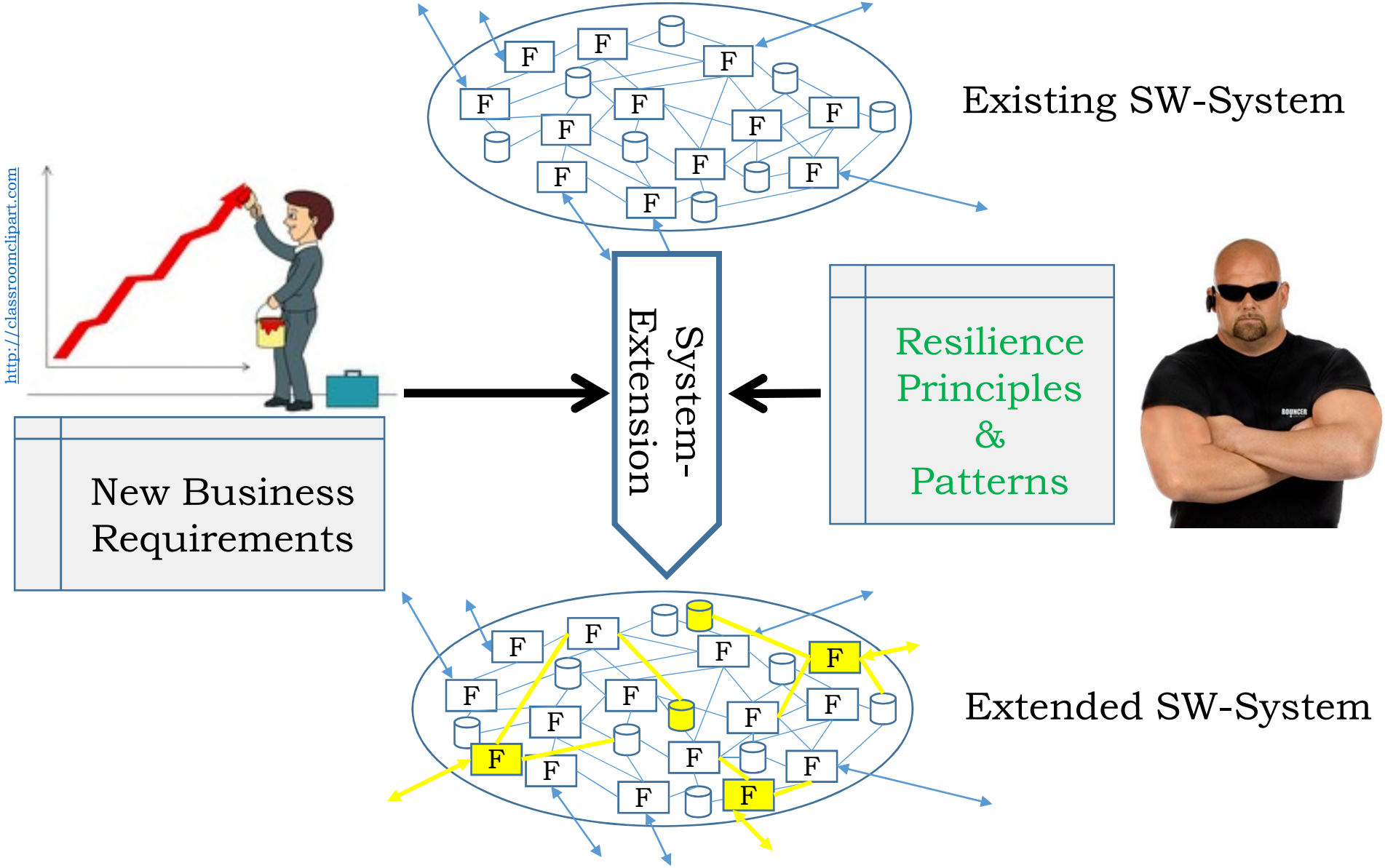
Data Integrity Assurance Pattern



Future-Proof Software-Systems:

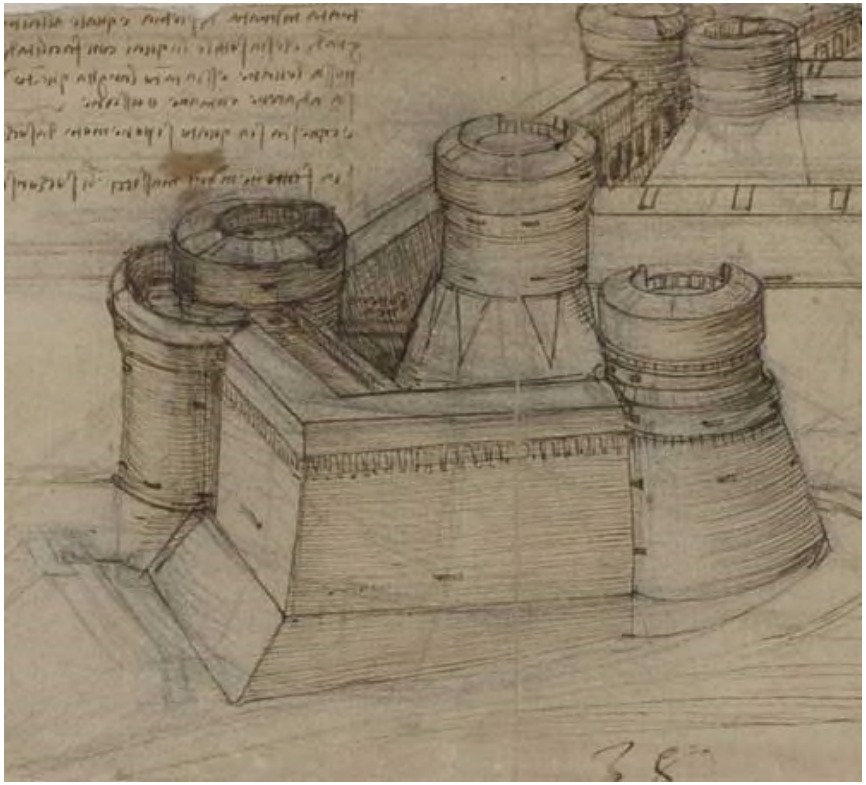
Principle-Based Resilience Engineering [Key Points]

Future-Proof Software-Systems: Resilience Engineering



Resilient Architecture

Resilience Architecture *Principles & Patterns*



http://www.marinabaysands.com

Strong, resilient architecture

The Principles & Patterns Challenge

Principles & Patterns =

Very valuable software/system *architecture knowledge* in proven & easily accessible form

https://pmtgurumantra.wordpress.com

… However,

Principles & Patterns are *not* directly applicable
(⇒ they represent generic solutions)

Principles & Patterns in the literature are often *inconsistent*:

- Different terminology
- Different representations
- Duplicated functionality
- Functional overlaps
- … even some contradictions

https://pmtgurumantra.wordpress.com

Example

Subject
ID

User
id name

Authenticator Pattern
[Schuhmacher, ISBN 978-0-470-85884-4]

RBAC Pattern
[Fernandez, ISBN 978-1-119-99894-5]

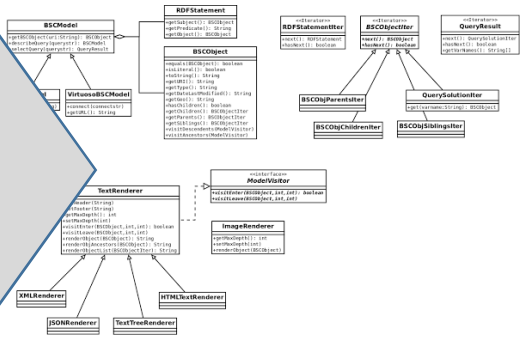
https://cms.sachsen.schule

Principles & Patterns are *not* directly applicable:

⇒ Need for adaptation & integration into *your* system!

Learn & understand

Apply & enforce

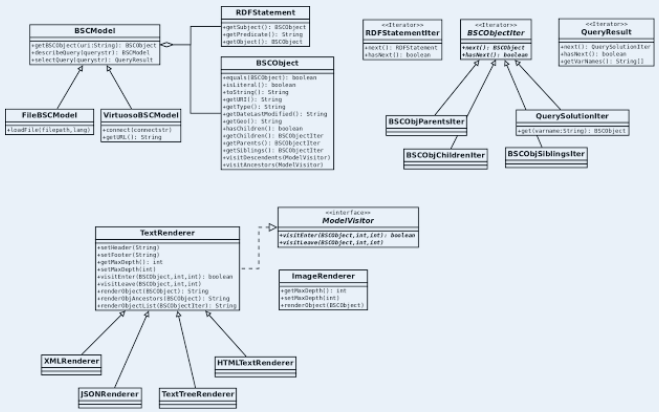


Future-Proof Software-Systems Engineer

Architecture & Resilience *Principles & Patterns*

Future-Proof Software-Systems Engineer

Apply & enforce



Pattern Integration

Future-Proof Software-Systems:

Autonomic Computing

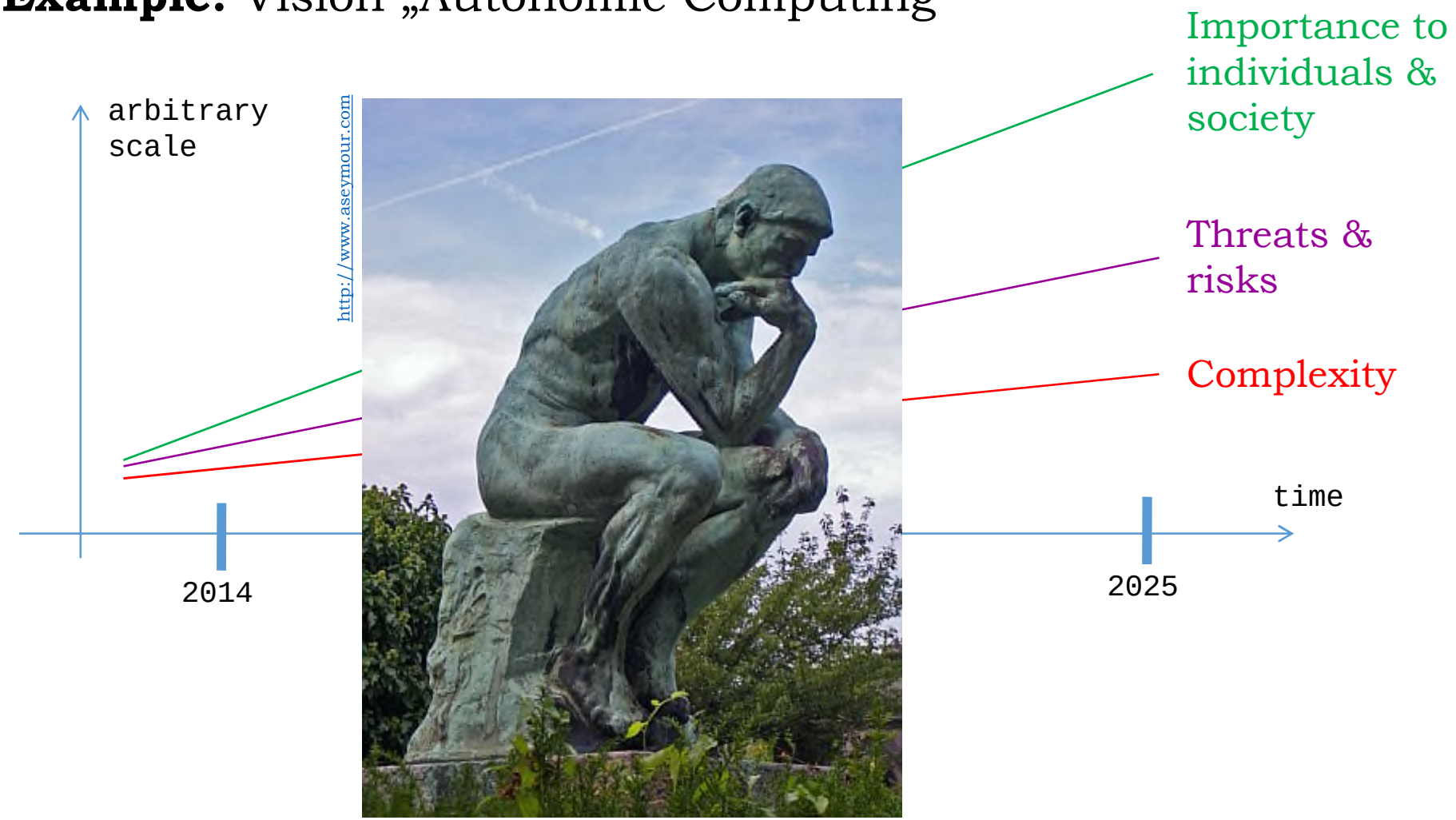
❶ **Specific** Countermeasures (⇔ Risk Analysis) → Resilient Code

❷ **Architectural** Countermeasures (Principles) → Resilient Architecture

❸ **Adaptive Behaviour** («Autonomic Computing») → Resilient System

«Autonomic Computing»

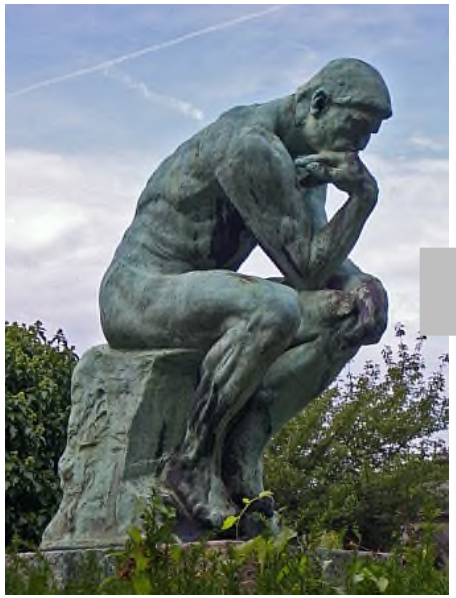
Example: Vision „Autonomic Computing“



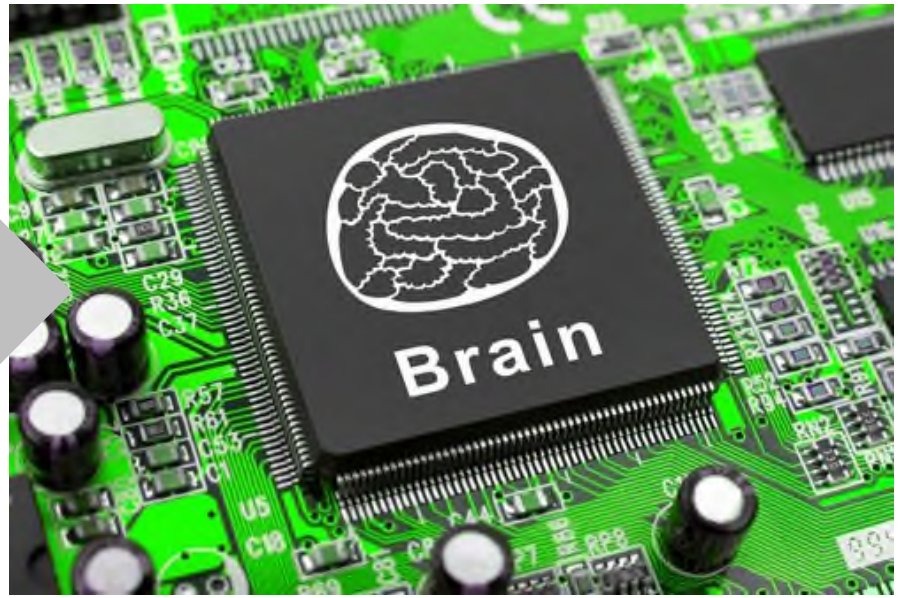
Can we humans successfully cope with these trends ?

Example: Vision „Autonomic Computing“

http://www.aseymour.com



Probably NOT



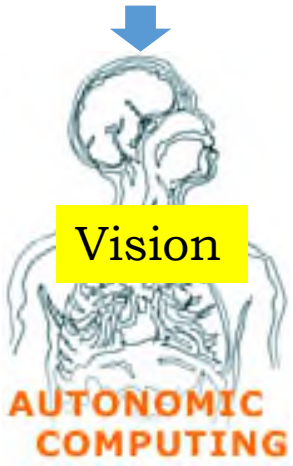
http://mcvcbca.blogspot.ch/2012

Can we humans successfully cope with the trends of:

- increasing complexity
  - raising importance
- accelerating threats & risks

?

… we will need the support of intelligent machines



Paul Horn, **IBM**, 2001

Autonomic Computing (IBM Concept 2001)

https://www.illustrationsource.com

Basic idea: Enable the computer for self-defense

< 2010 ⟶ > 2010

Disruptive Incidents
1. Xxx
2. Yyy
3. Zzz

System

Safety Case

predict

Complexity

t

Tractability

t

Incident

Resilient System

adjust

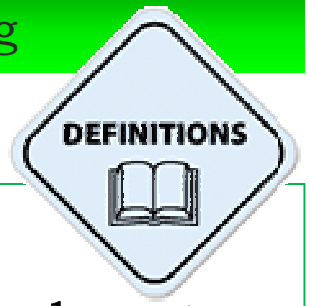
https://www.illustrationsource.com

Autonomic Computing Vision

Autonomic Computing has four areas of concern:

1. Self-Configuration
2. Self-Healing (error correction, fault recovery)
3. Self-Optimization (automatic resource control for optimal functioning)
4. **Self-Protection** (identification and protection from attacks in a proactive manner)

… often called the self-X properties



Autonomic =
Computer systems and networks that configure themselves to changing conditions and are self-healing in the event of failure and self-defending in the event of attacks. "Autonomic" means "automatic responses" to unpredictable events.

Autonomic computing is an approach to address the complexity and evolution problems in software systems.

A software system that operates *on its own* or with a minimum of human interference according to a set of rules is called autonomic.

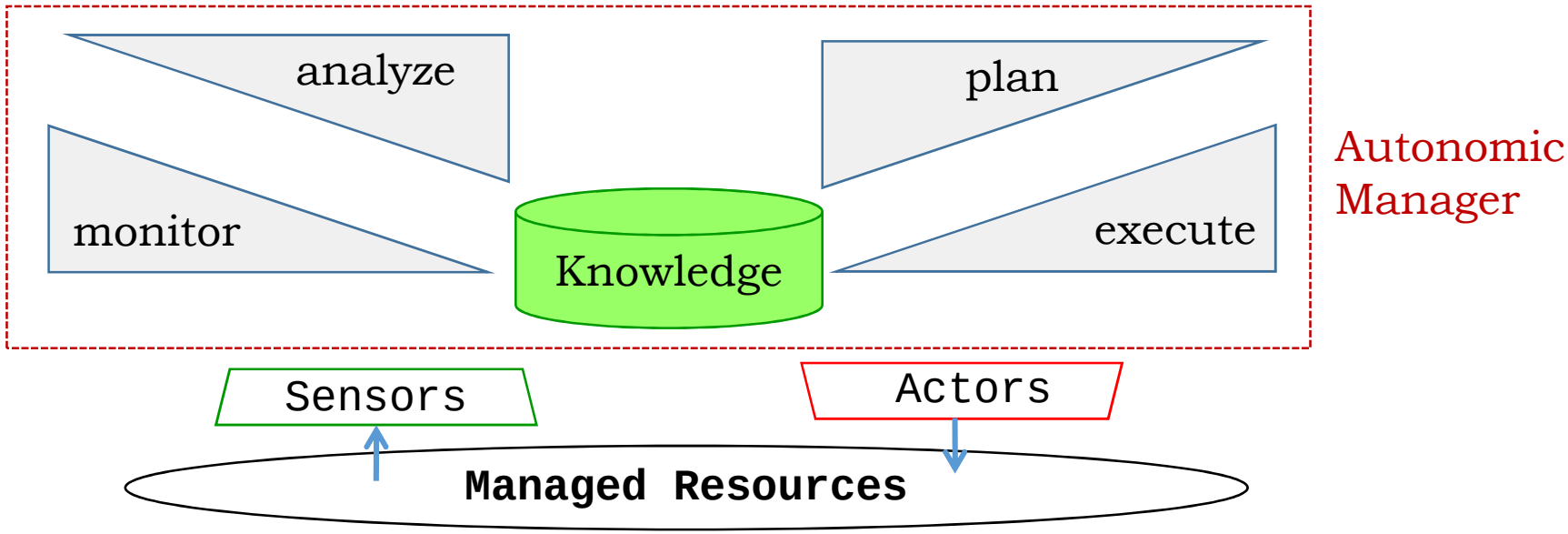
Modern, active research area

Example: Vision „Autonomic Computing“

„Horn envisioned autonomic computers that could sense, analyze and respond to situations automatically“

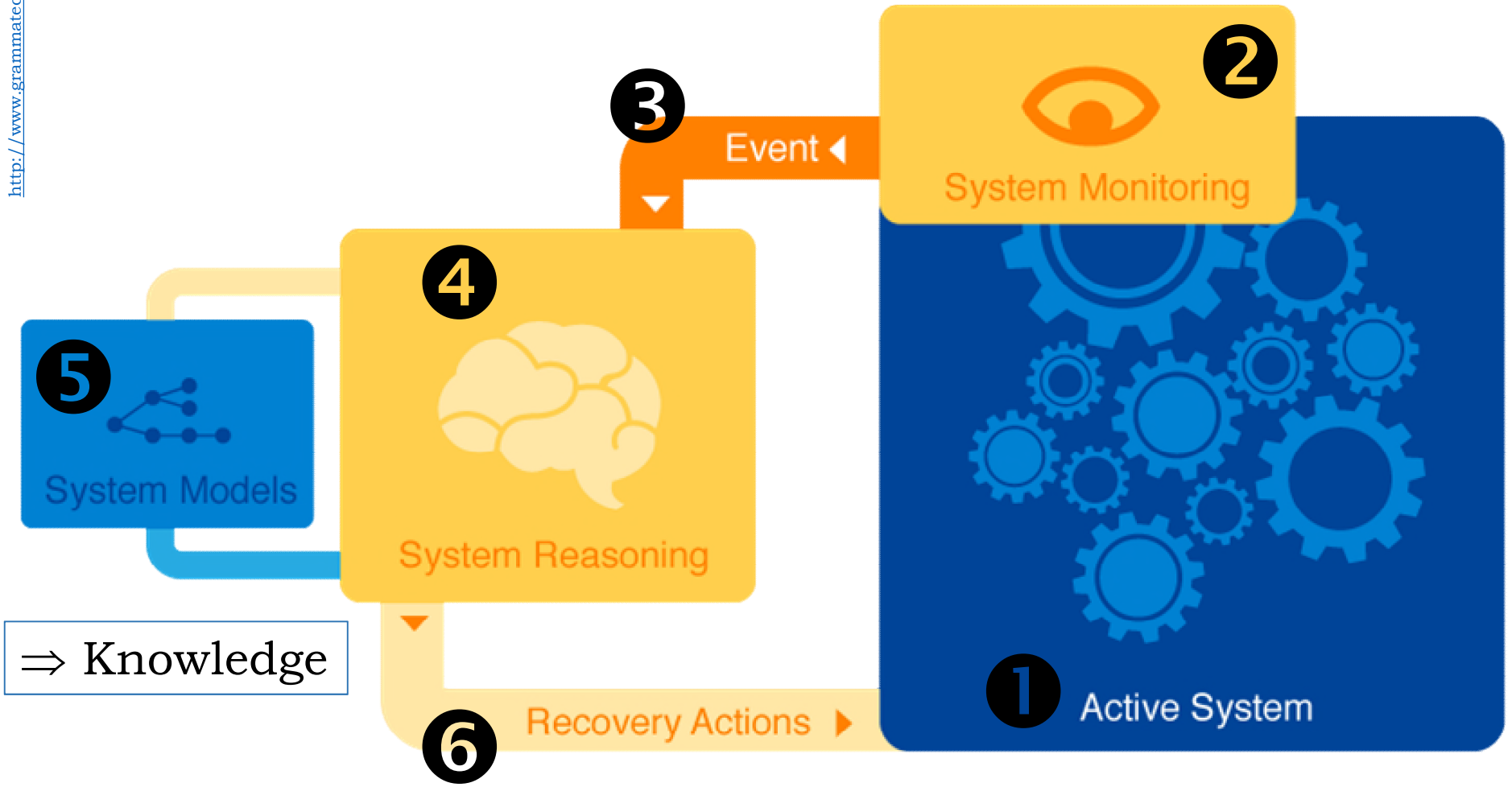
Self-protecting **Self-optimizing**

Self-healing **Self-configuring**



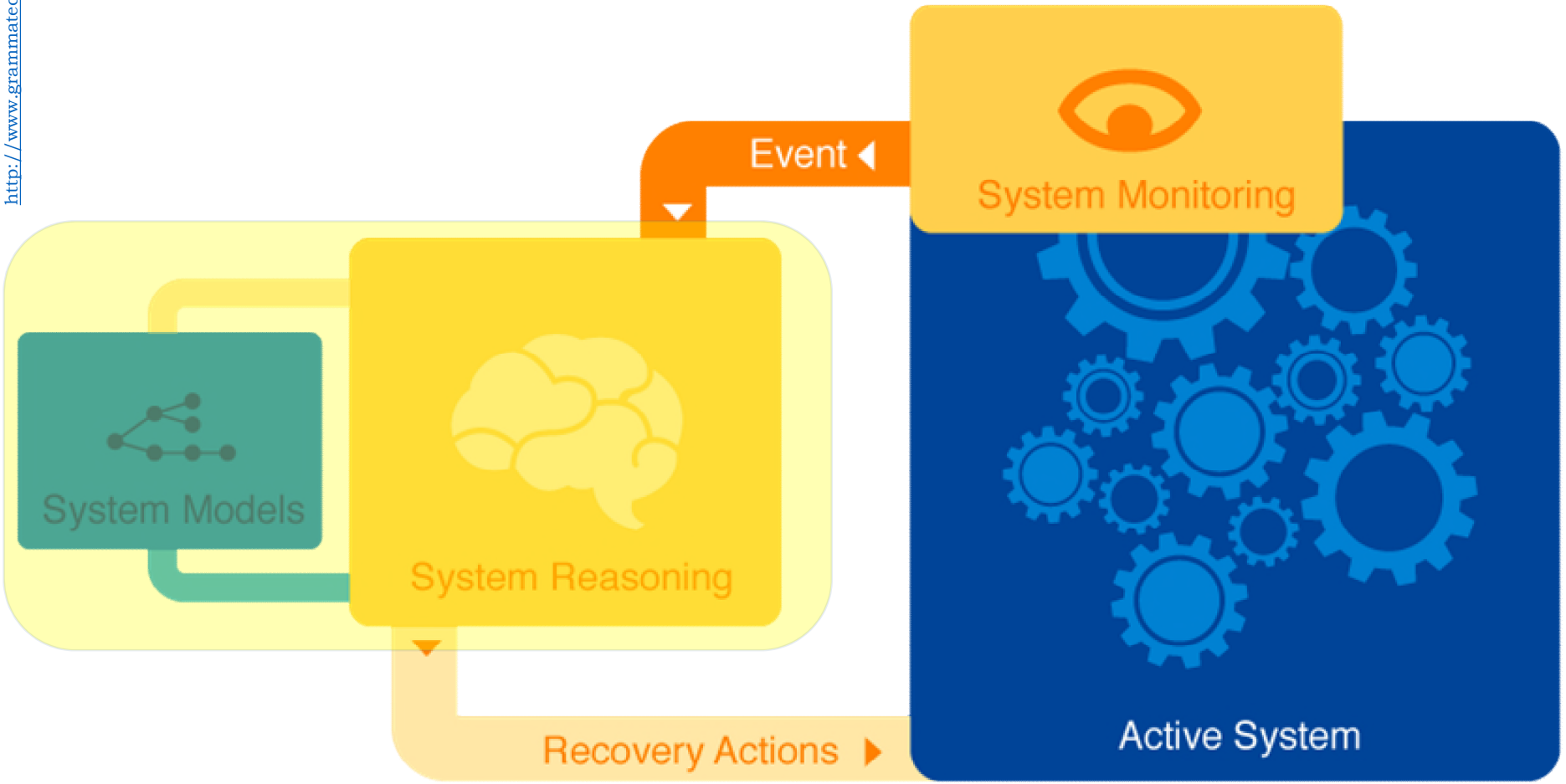
Autonomic Computing Schema:

http://www.grammatech.com



http://www.grammatech.com

Autonomic Computing Schema:



Artificial Intelligence

Example: Autonomic Computing for Traffic Control

http://iict.bas.bg/acomin/events/3-4-October-2013/KStoilova_ppt.pdf

Large area traffic control

http://www.autoevolution.com

- The autonomy is achieved by applying *multilevel optimization* for the control process
- Thus, an increase of the transport parameters, defined as solutions of the optimization problem, is achieved.

Applications:

Rules, optimization and artificial intelligence (cognition) instead of fixed algorithms

References:

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Future-Proof Software-Systems: Content

This is the end of Parts 1-4:

You know now the *foundations* and *principles* of future-proof software-systems

Part 5:

Describes the „future-proof software-systems engineer“ and his working context