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of Applied Sciences

School of
Engineering

IAMP Institute of Applied
Mathematics and Physics

Use of STPA in digital instrumentation and control systems of nuclear power plants

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Agenda

- Project background and objectives
- System under consideration
- Analysis approach
  - Process towards the hierarchical control structure
  - STPA step 1 and 2
  - Blended approach
- Conclusion and outlook

Project Background

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- Replacement of existing instrumentation and control system (I&C system)
- Simultaneous transition from analog to digital system

How can STPA be efficiently applied to an I&C system as it is used in nuclear power plants?

Project Objectives

- Develop process to «transform» an I&C system specification into a hierarchical control structure
- Investigate potential of STPA (with respect to nuclear power plant I&C systems) by performing a case study
- Investigate potential to integrate existing analyses (FTA, ETA, FMEA, ...) into STPA (blended approach)

→ Detailed documentation

→ Case study

→ Knowledge transfer

System Under Consideration - Selection of the Case Study

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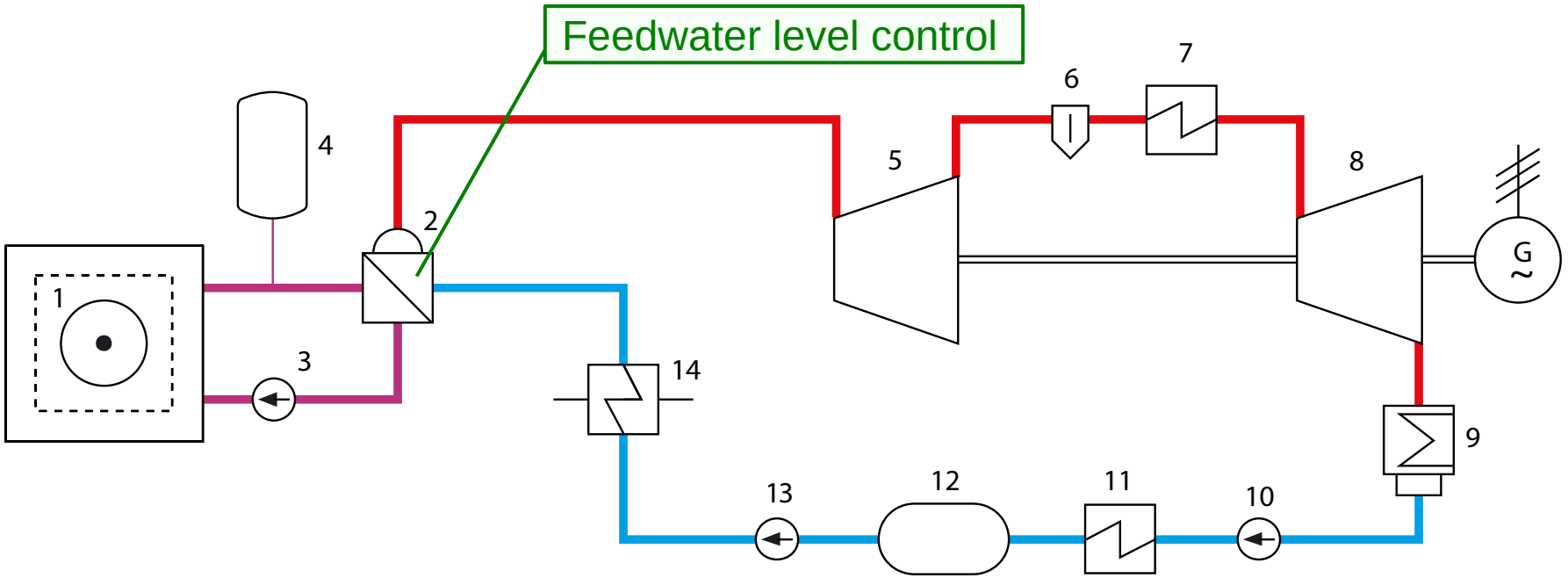

1 Reactor
2 Steam generator
3 Reactor coolant pump
4 Pressuriser
5 High-presure turbine
6 Water separator
7 Superheater
8 Low-pressure turbine
9 Condenser
10 Condensate pump
11 Low-pressure preheater
12 Feedwater tank
13 Feedwater pump
14 High-pressure preheater

Exemplary illustration

System Under Consideration – Information Sources Used

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Information sources used:

- Facility documentation
- System specifications (level 3 & 4 documents)
- Manuals
- Expert knowledge

Case Study - System Architecture

A generic way to represent a control function:

Source: IEC 61508 «Functional safety of electrical/electronic/programmable electronic safety-related

Case Study - System Architecture

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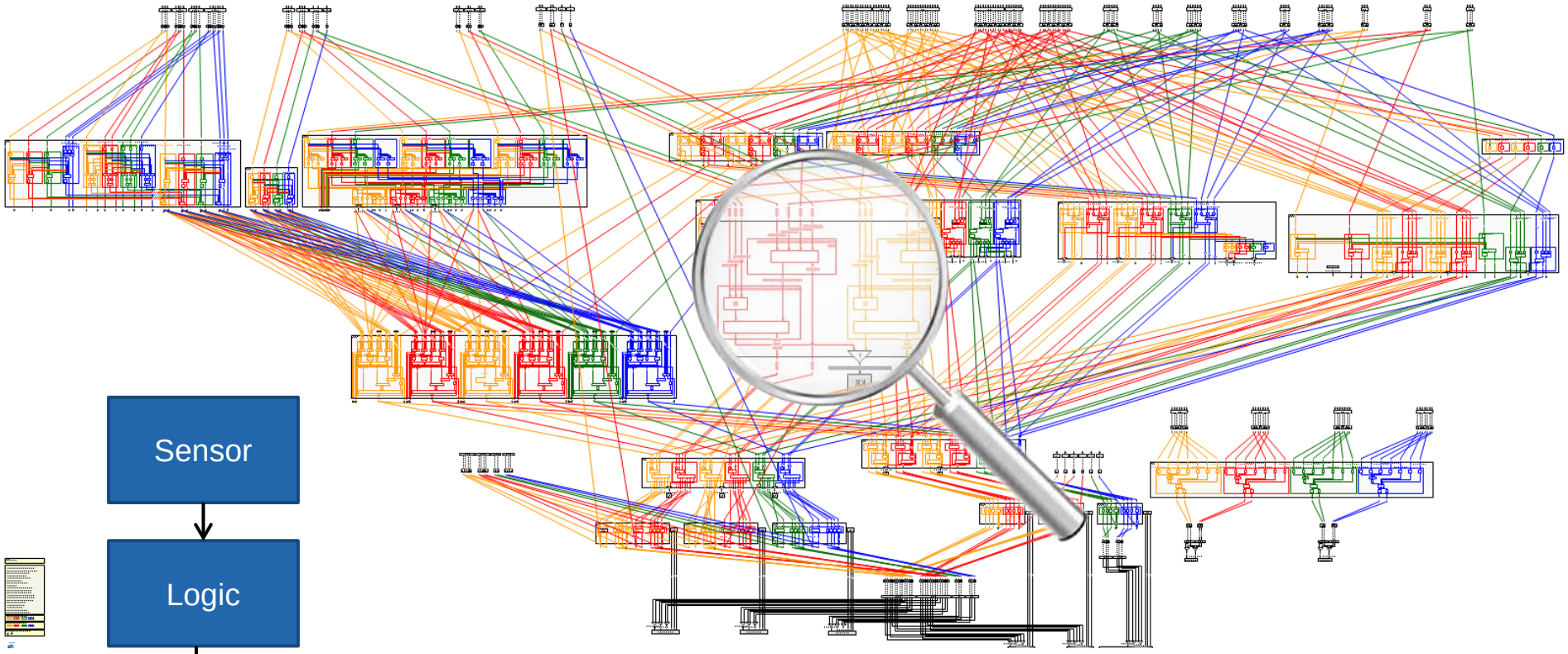

Not what you want to start with!

Problem of Terminology - Functional Entities

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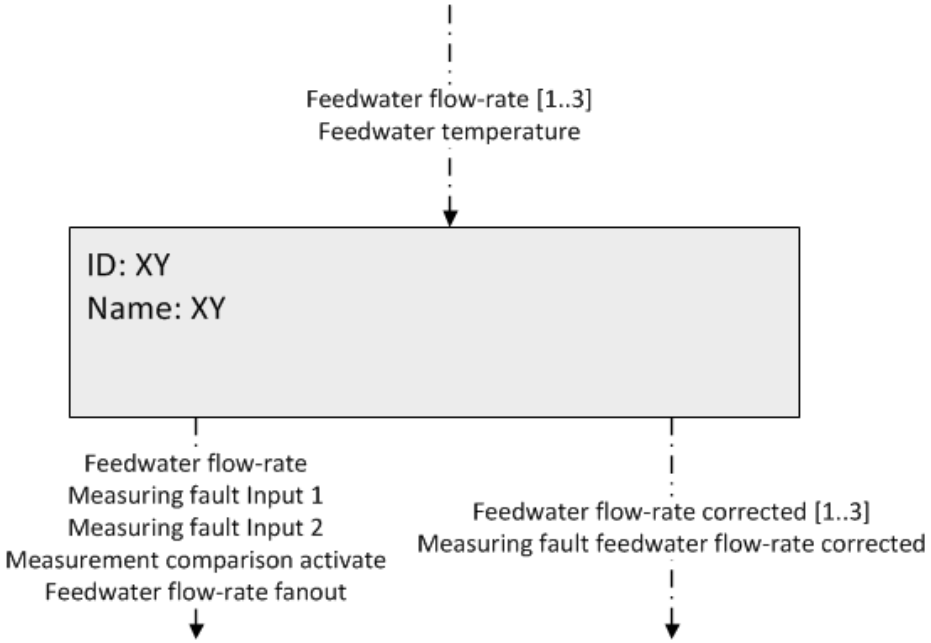

Is this a

- function,
- module,
- sub-system,
- class,
- component, …?

Identification of Controllers - What is a controller in the sense of STPA

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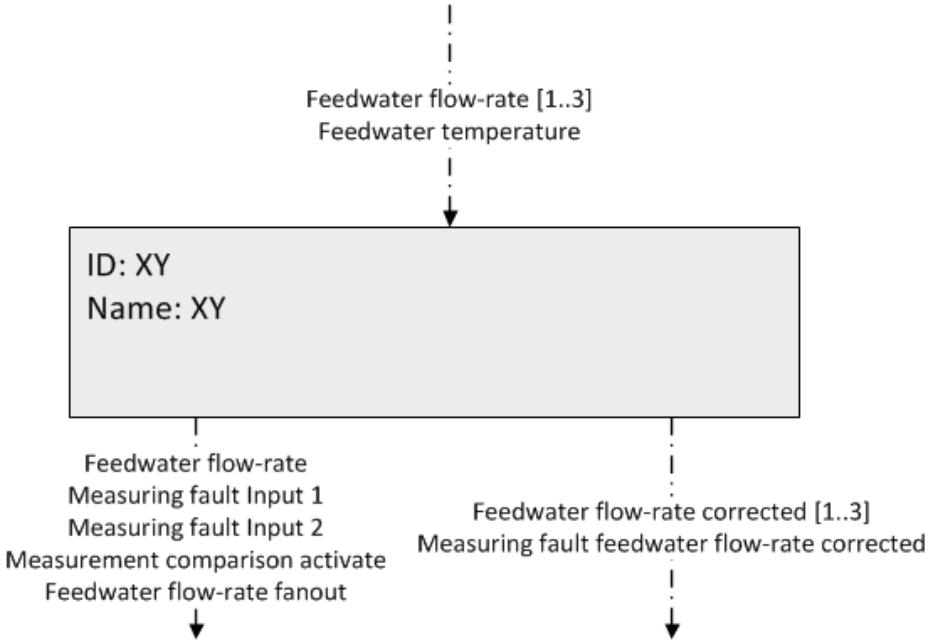

«Controller»?

Does functional entity …

- bear responsibility for a part of the process?
- possess necessary means to interact with process?
- receive necessary feedback for adequate control?

Recombination of Functional Entities - First Step towards the HCS

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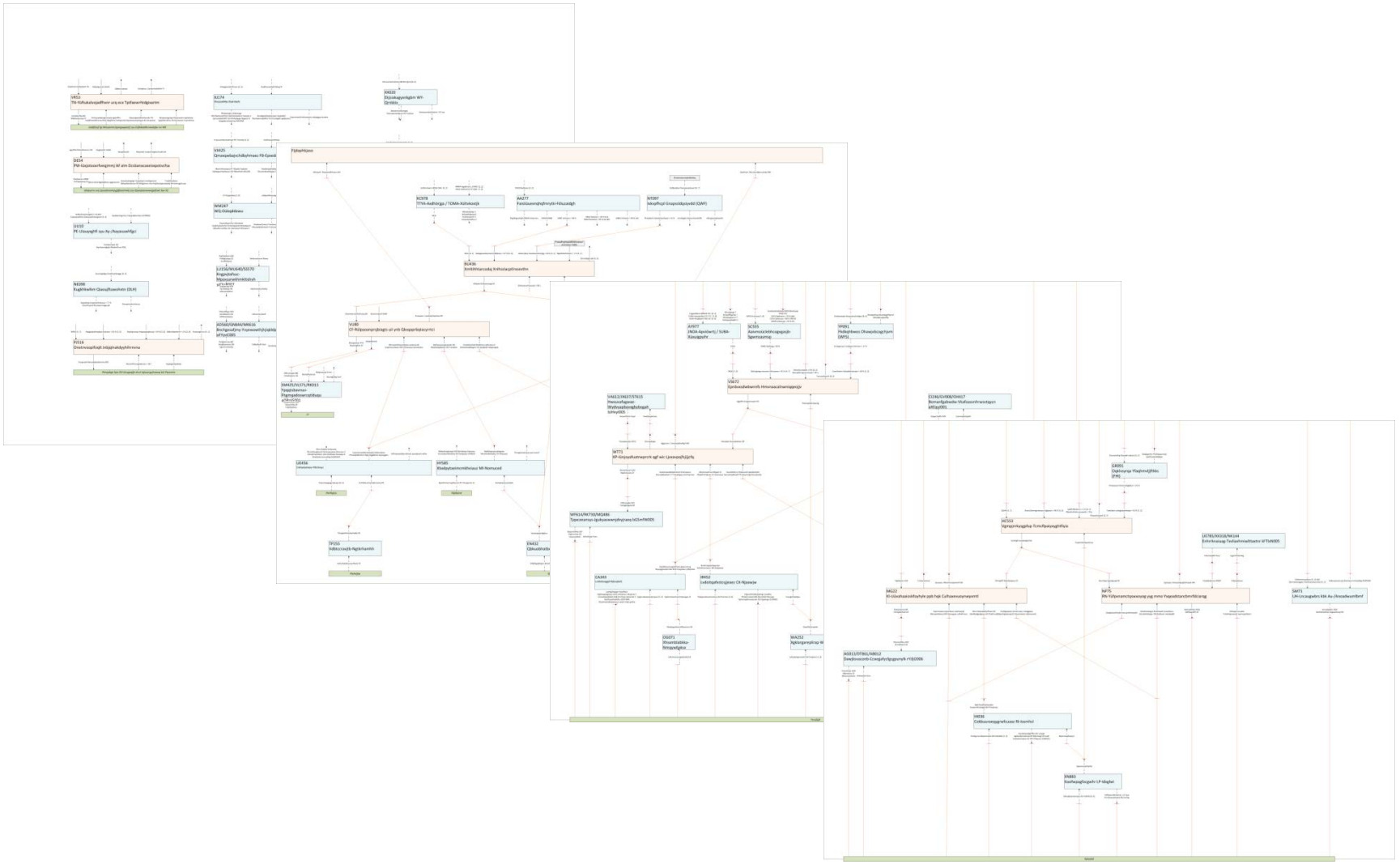

Exemplary illustration

Hierarchical Control Structure

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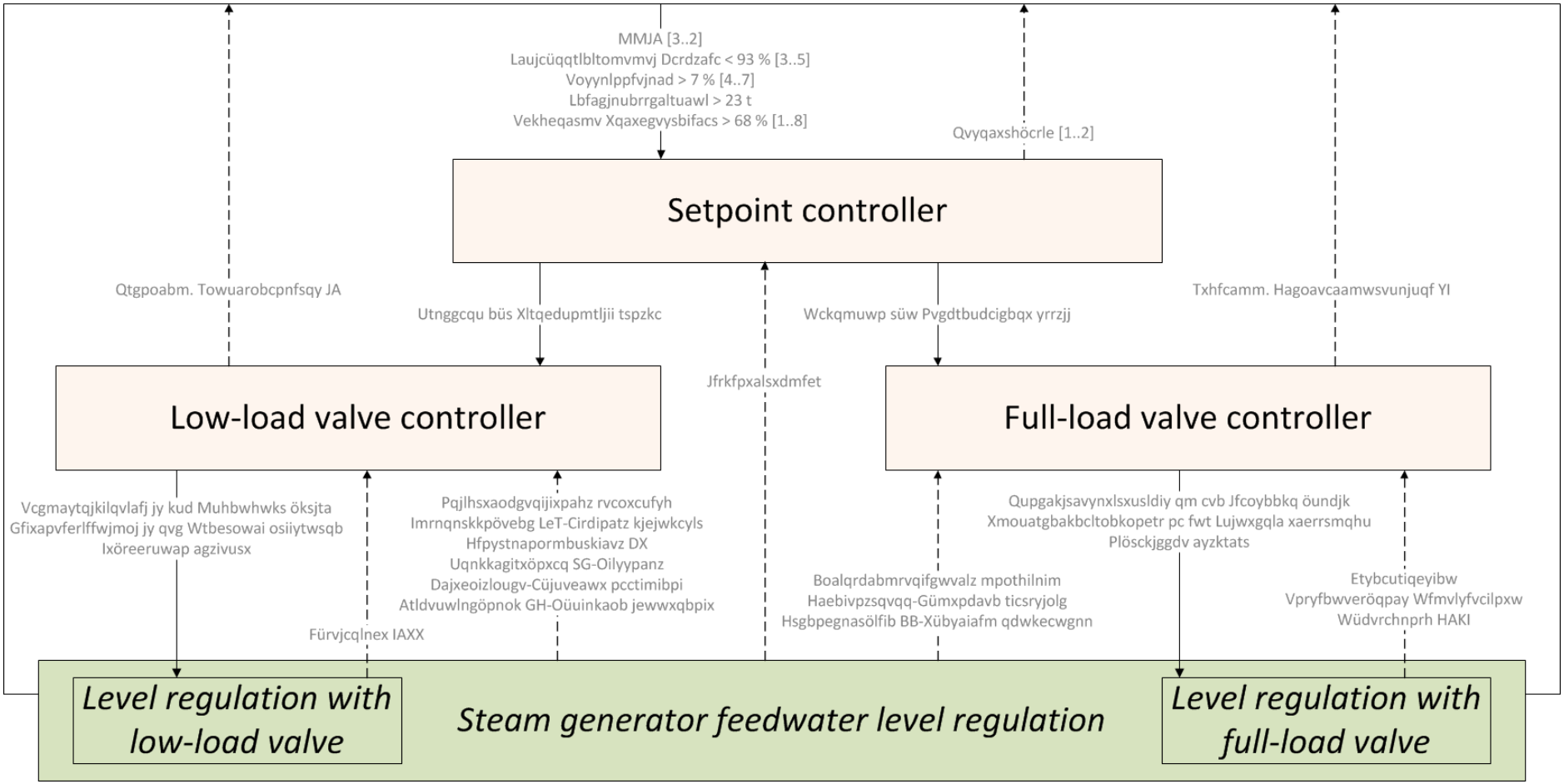

Exemplary illustration

Project Objectives - A First Conclusion

- ✓ Develop process to «transform» an I&C system specification into a hierarchical control structure
  - Systematic and reproducible process
  - Could be partially automated
  - Basis: System Specification with additions
- Investigate potential of STPA by performing a case study
- Investigate potential to integrate existing analyses (FTA, ETA, FMEA, ...) into STPA (blended approach)

STPA Process - Step 1

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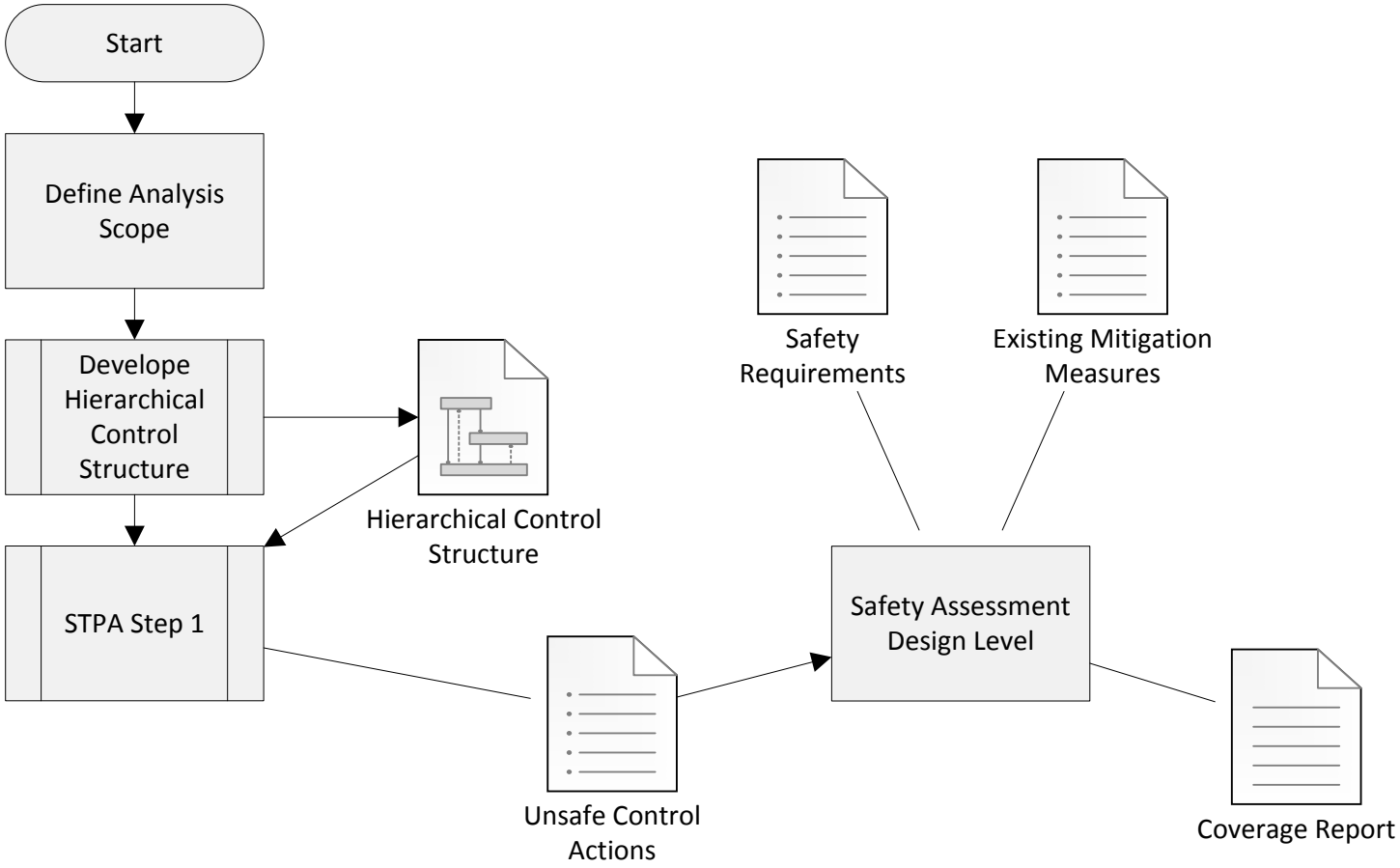

STPA Process - Step 2

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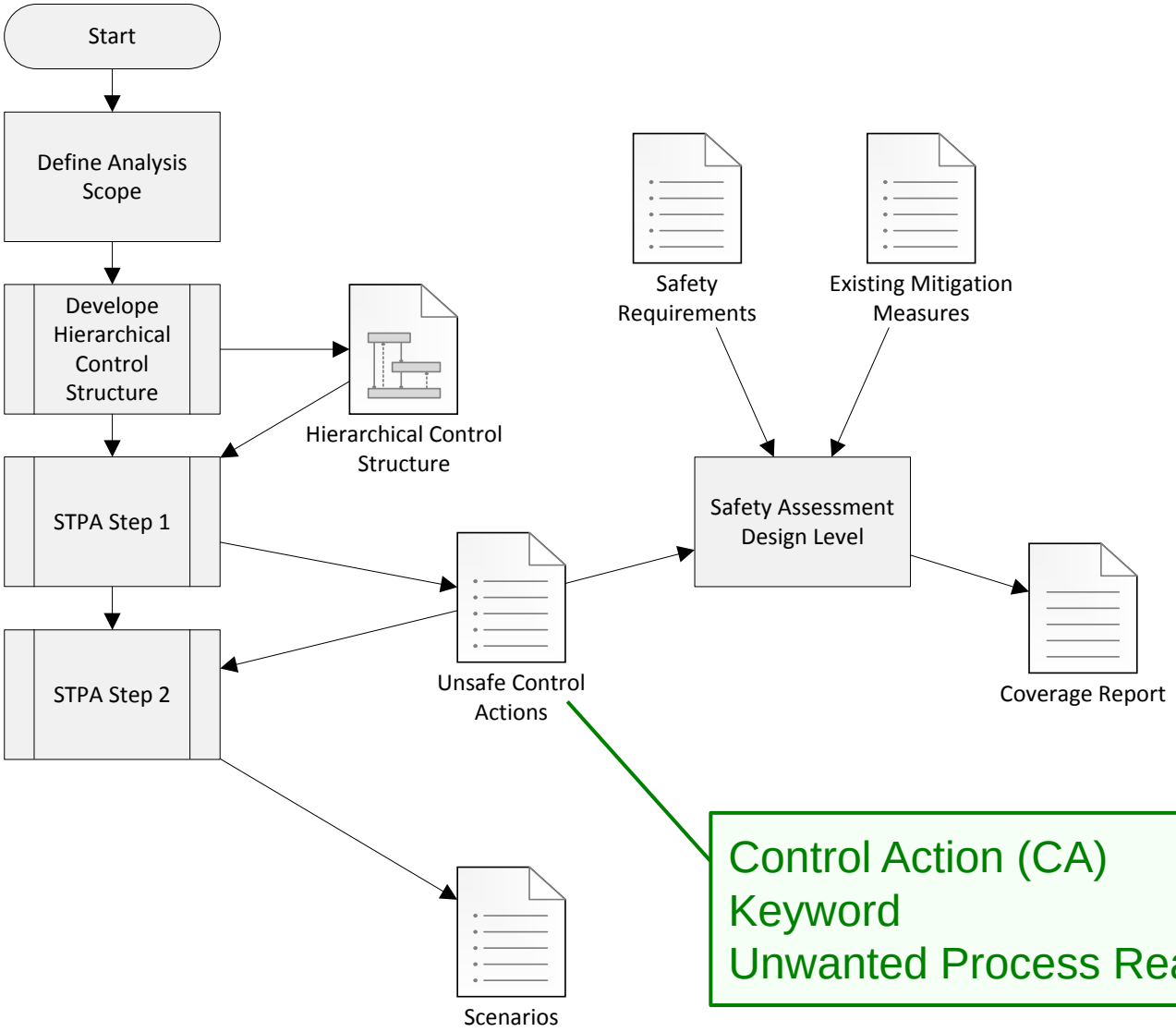

Control Action (CA)
Keyword
Unwanted Process Reaction (UPR)

STPA Step 2 - Generic Control Loop

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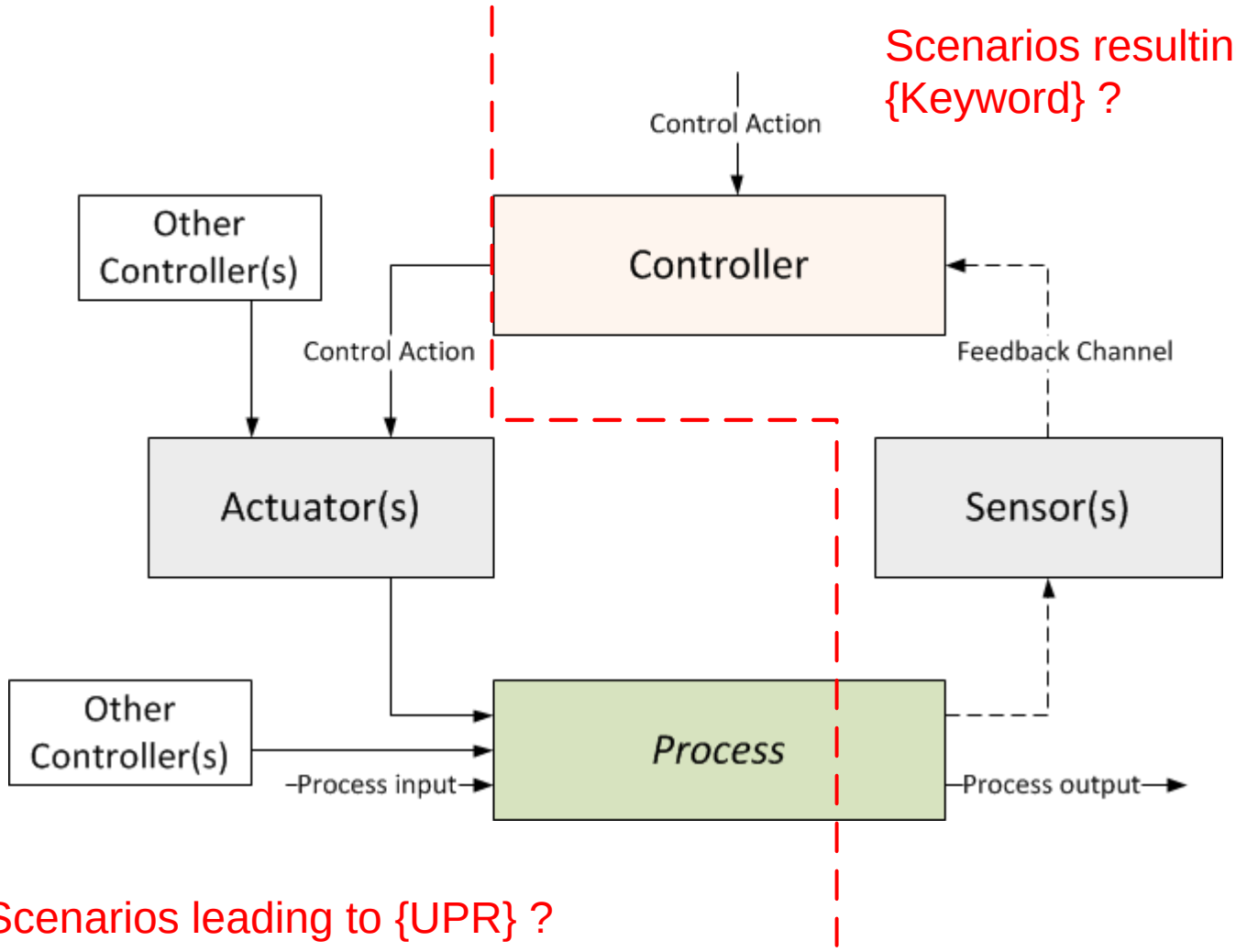
Scenarios resulting in {CA} {Keyword} ?



Scenarios leading to {UPR} ?

STPA Step 2 - Control Loop Example

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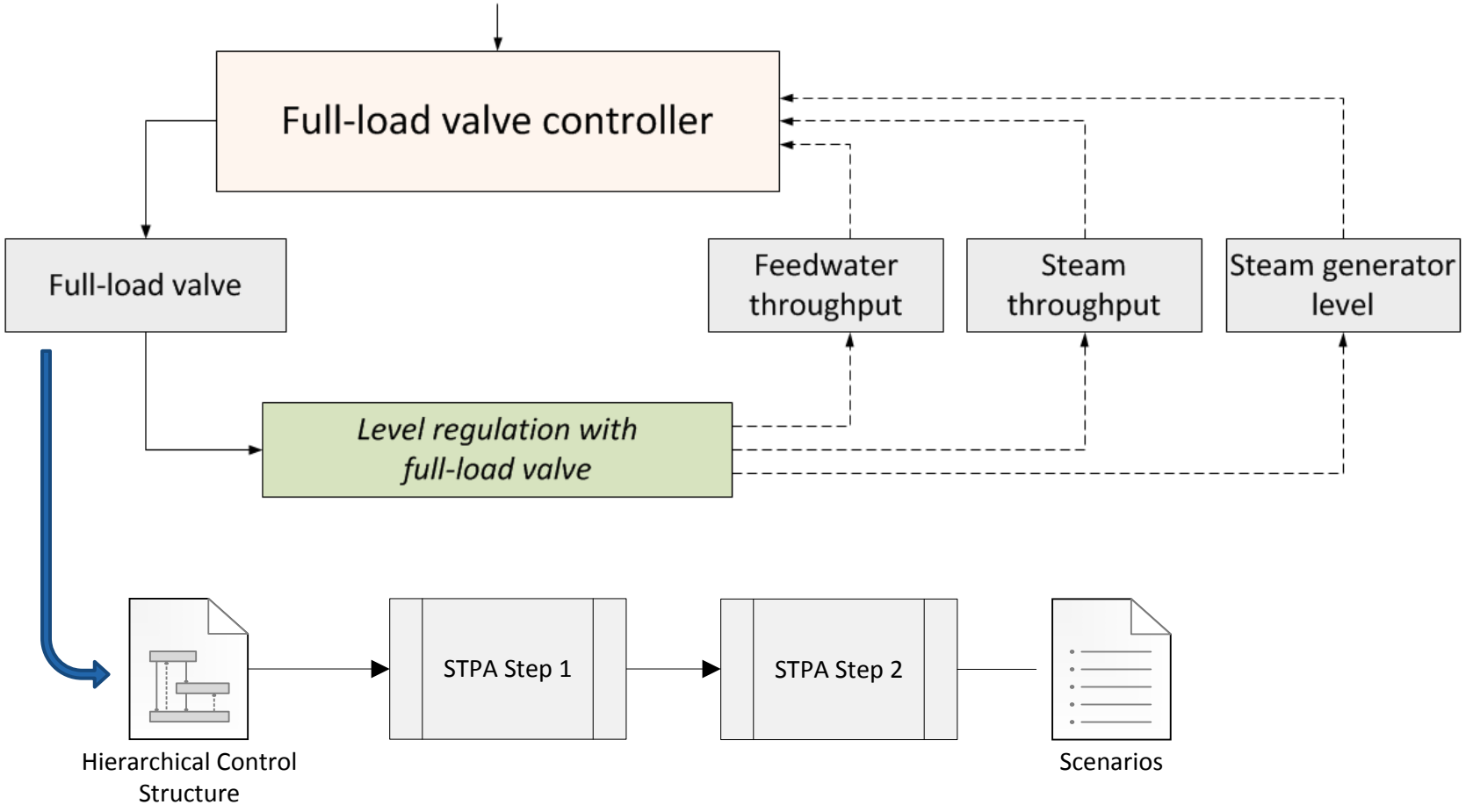
UCA: Command to open full-load valve by one increment is not given



Bridge between STPA Step 2 and Step 1 - Analyzing Subsystems

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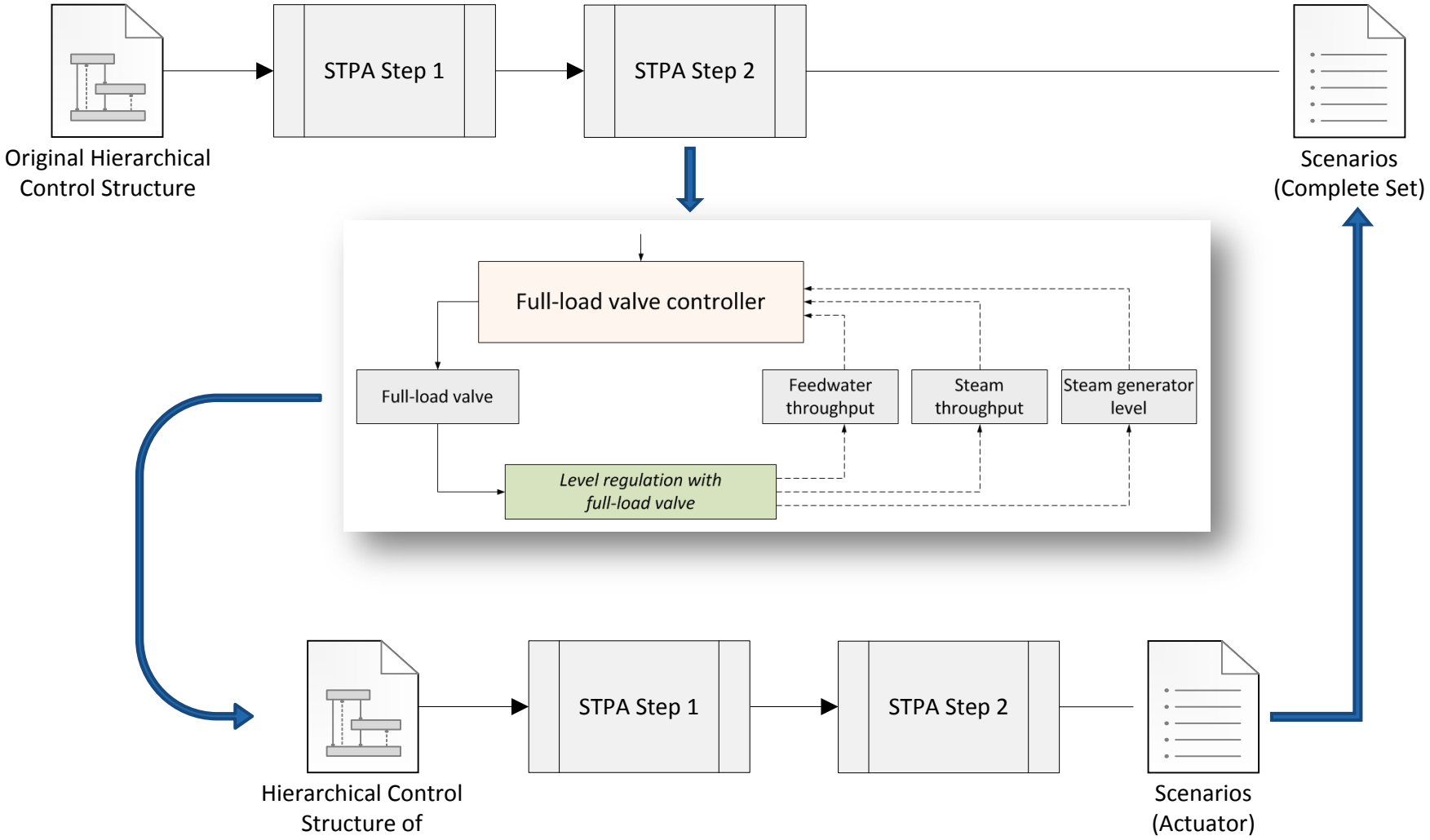

Bridge between STPA Step 2 and Step 1 - Analyzing Subsystems

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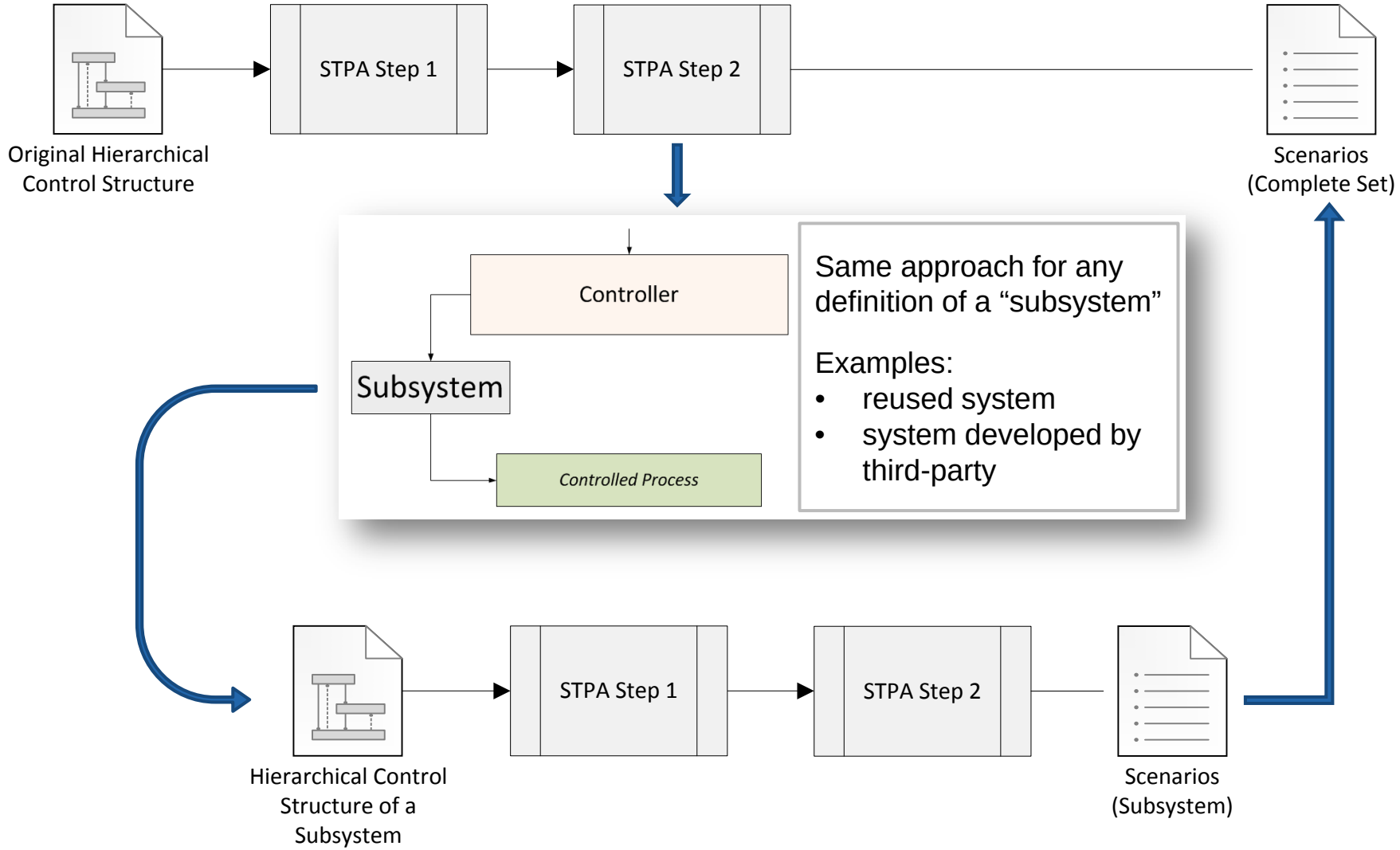

STPA Step 2 - Generic Control Loop

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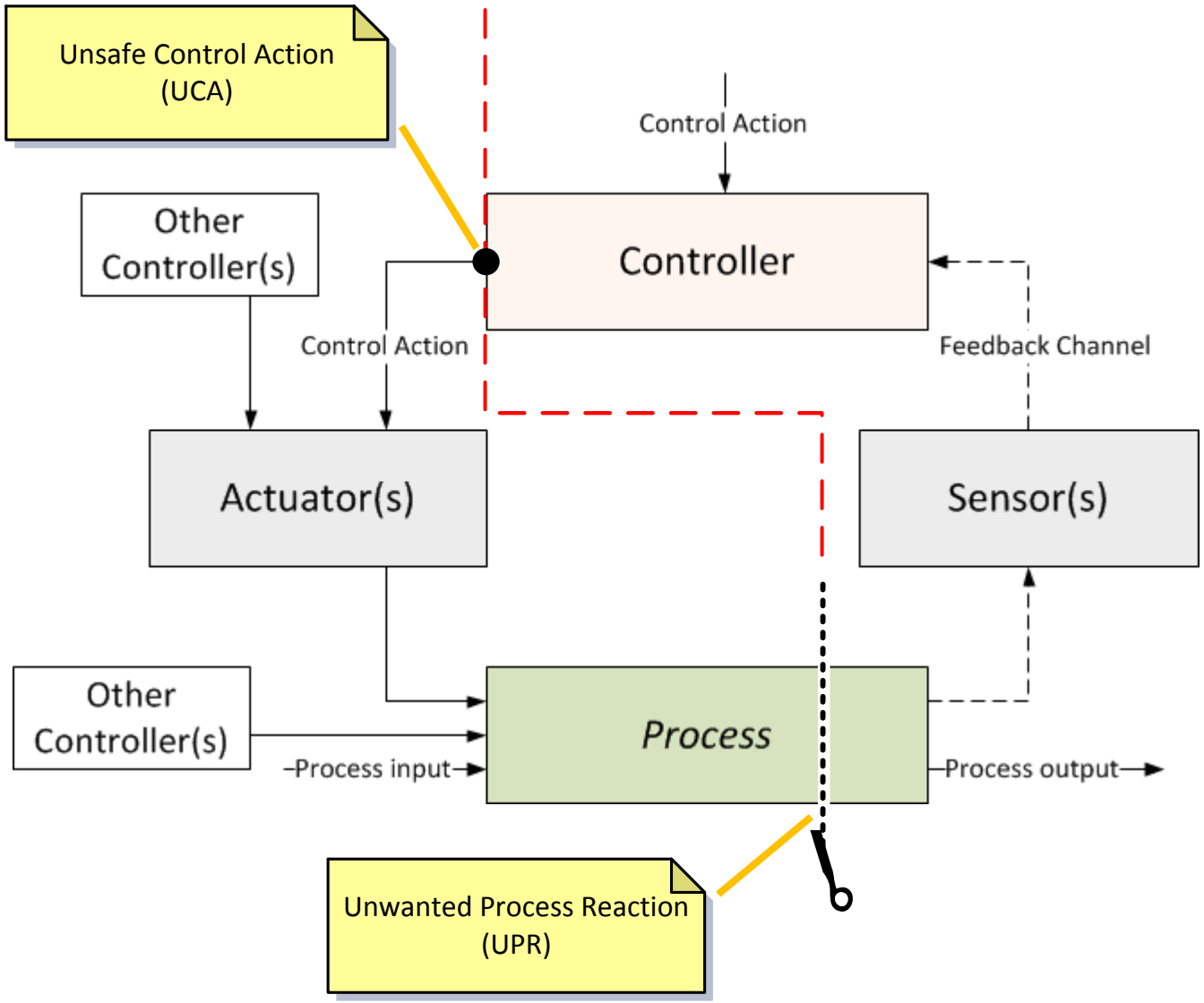
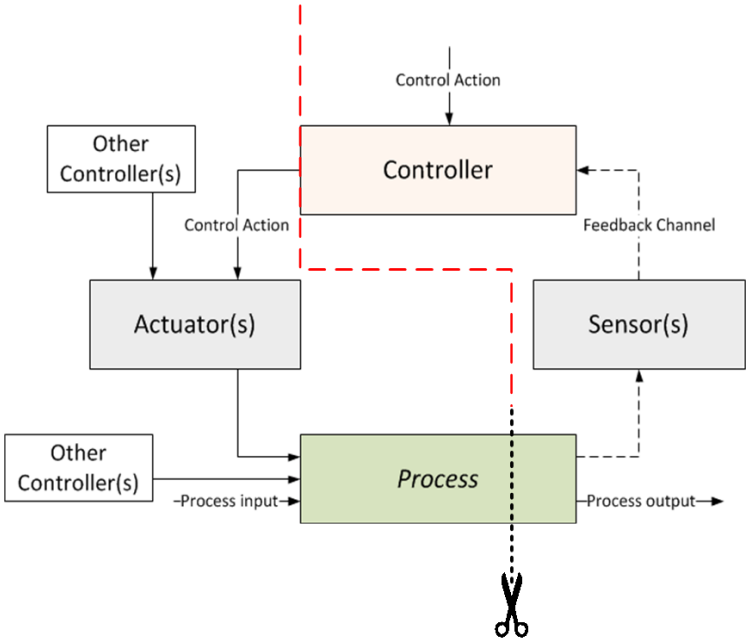
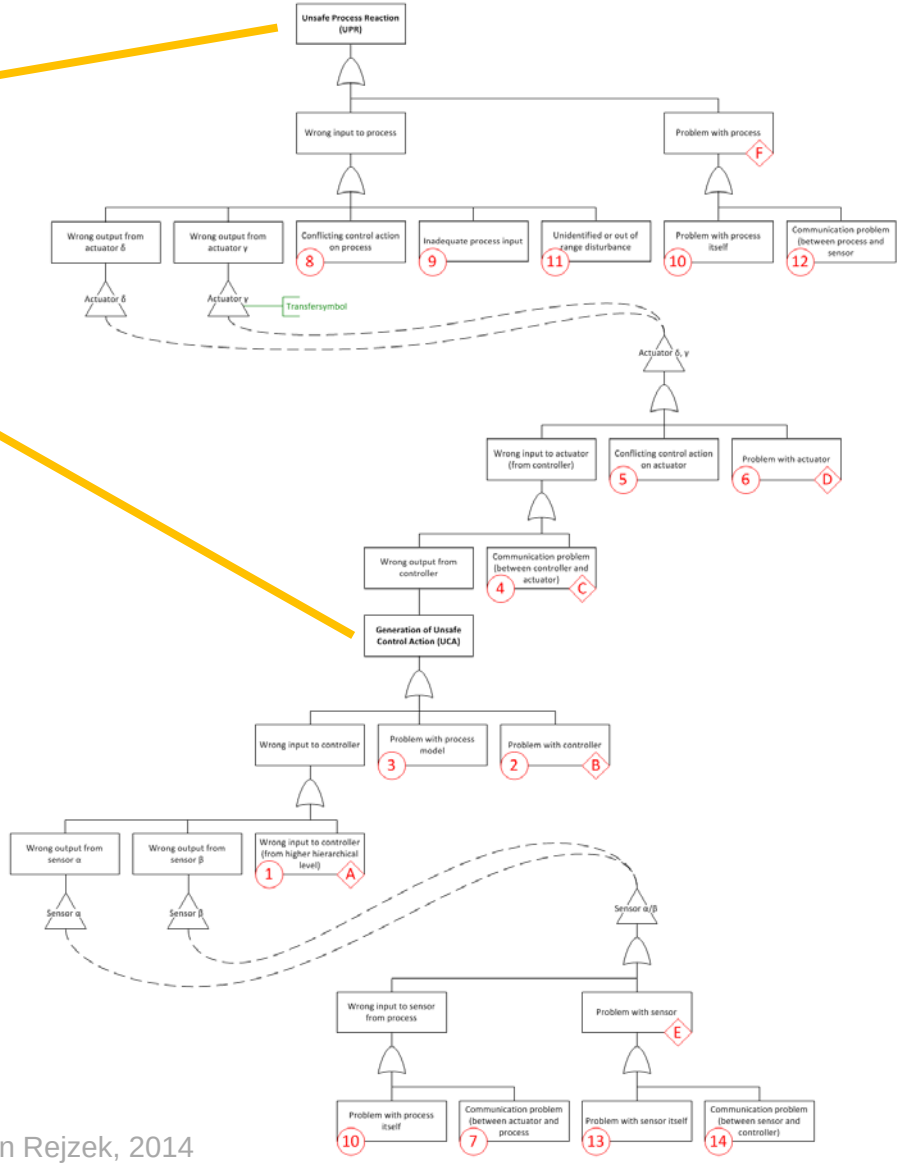


STPA Step 2 - Scenario Organization

Unwanted Process Reaction (UPR)

Unsafe Control Action (UCA)





Conclusion

- Process to «transform» an I&C system specification into a hierarchical control structure
  - Found a systematic and reproducible process
  - Generation of HCS could be partially automated
  - Based on system specification with (little) additions
- Formalization of the STPA step 2 questions:
  - «Scenarios resulting in {CA} {Keyword}»
  - «Scenarios leading to {UPR}»
- Explicit process to handle «subsystems»
  - Prioritization possible at each level
  - Organization of the scenarios in a generic fault tree
  - Link to results from other hazard analyses (FTA, ETA, …)

Current Activities

- Advance the case study
  - Complete STPA step 1 for all control actions
  - Continue with STPA step 2 for selected UCA's
- Advance investigation of "blended-approach"
  - With respect to systems and subsystems
  - With respect to different analysis methods

Anamorphosis

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Certain things can only be seen
from a different standpoint!

Anamorphosis

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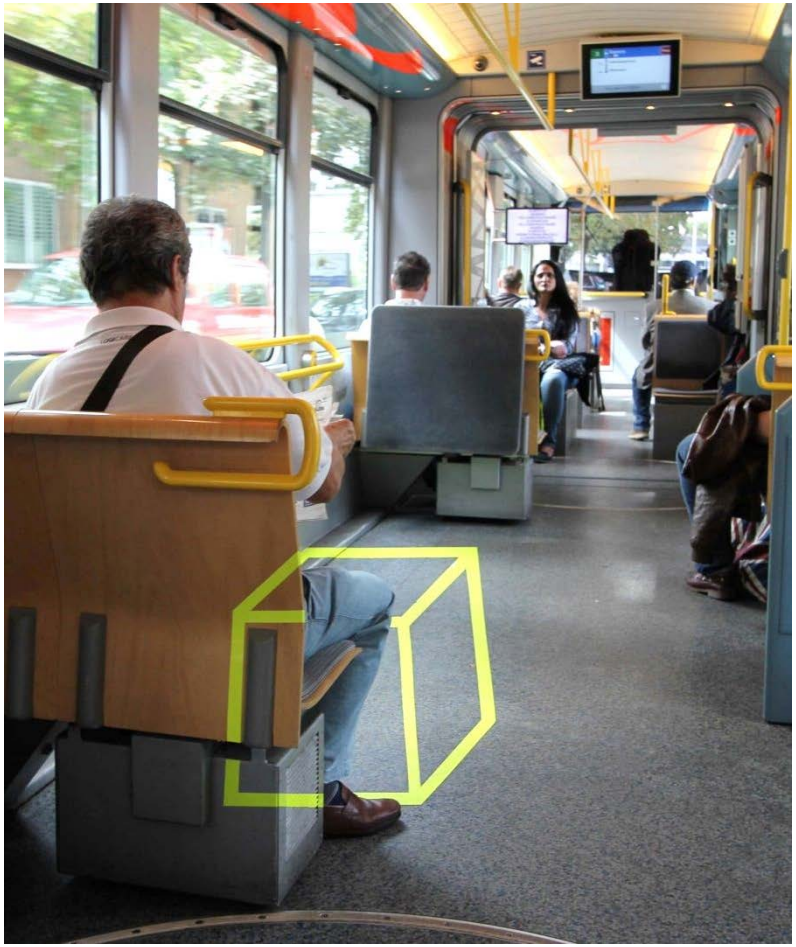

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