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Engineering
IAMP Institute of Applied
Mathematics and Physics

Safety Driven Design with UML and STPA

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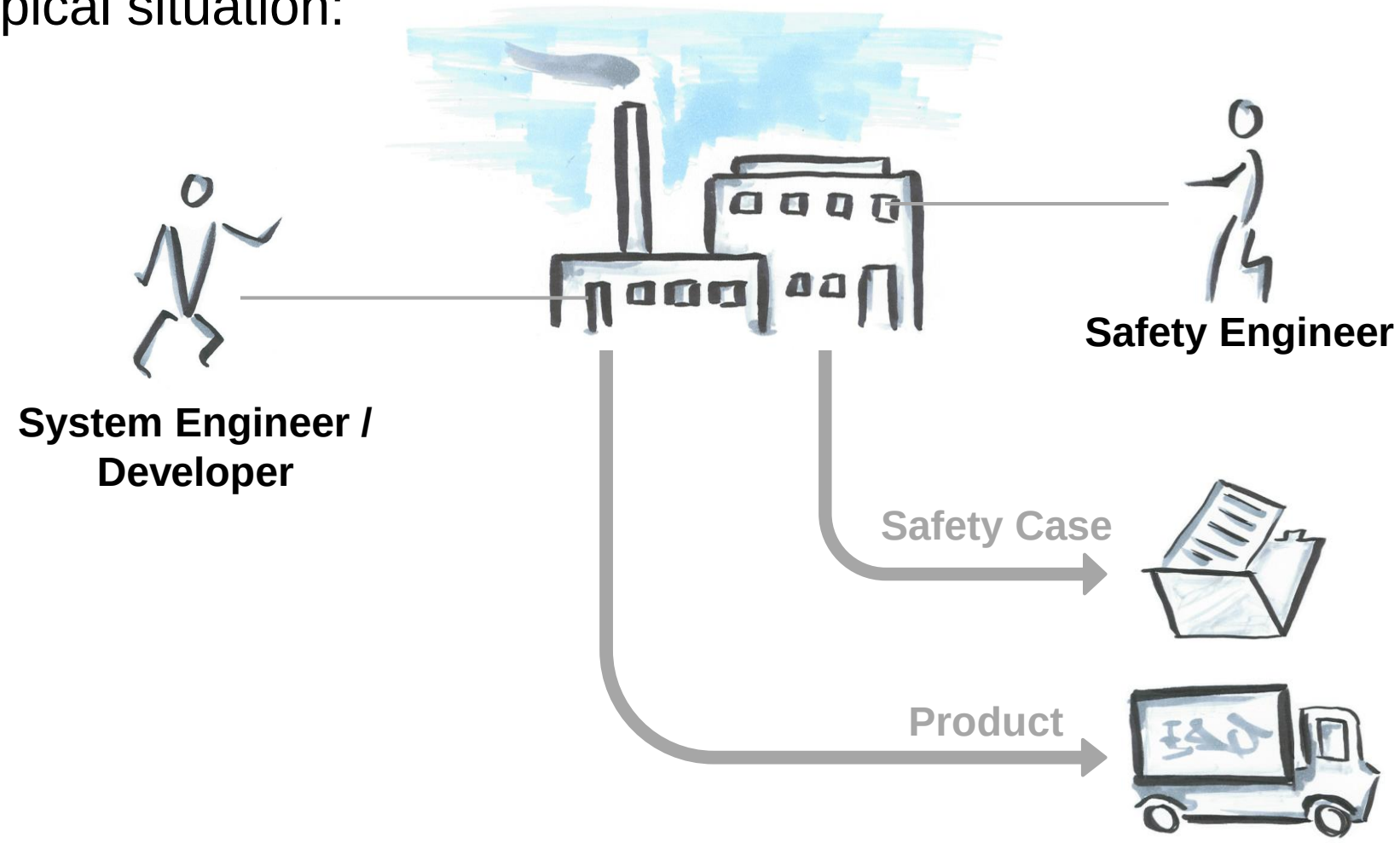
System and Safety Engineering

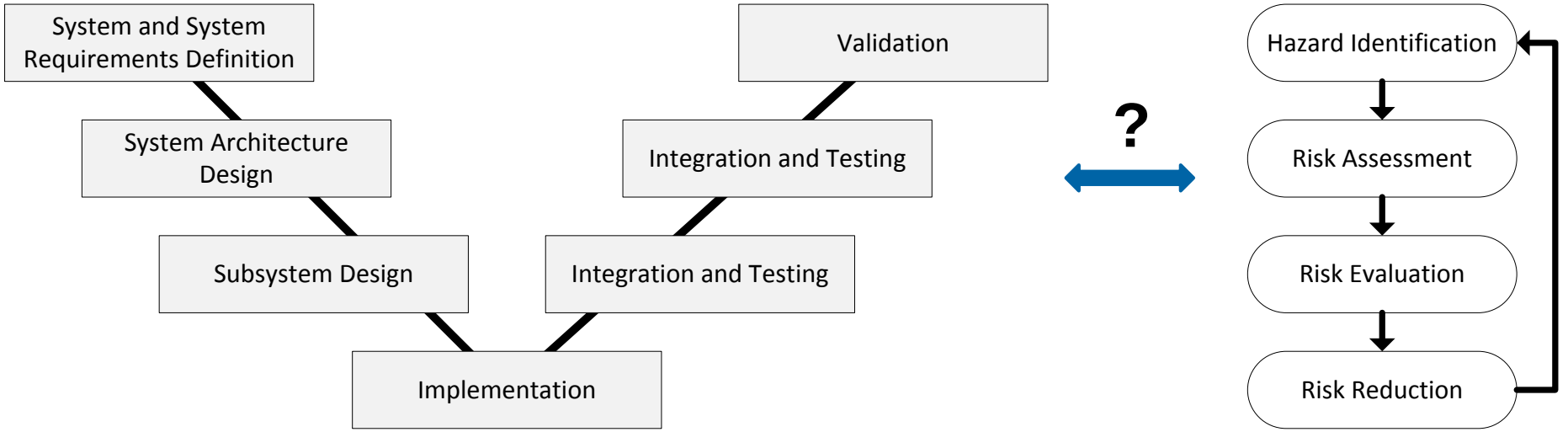
A typical situation:



System and Safety Engineering

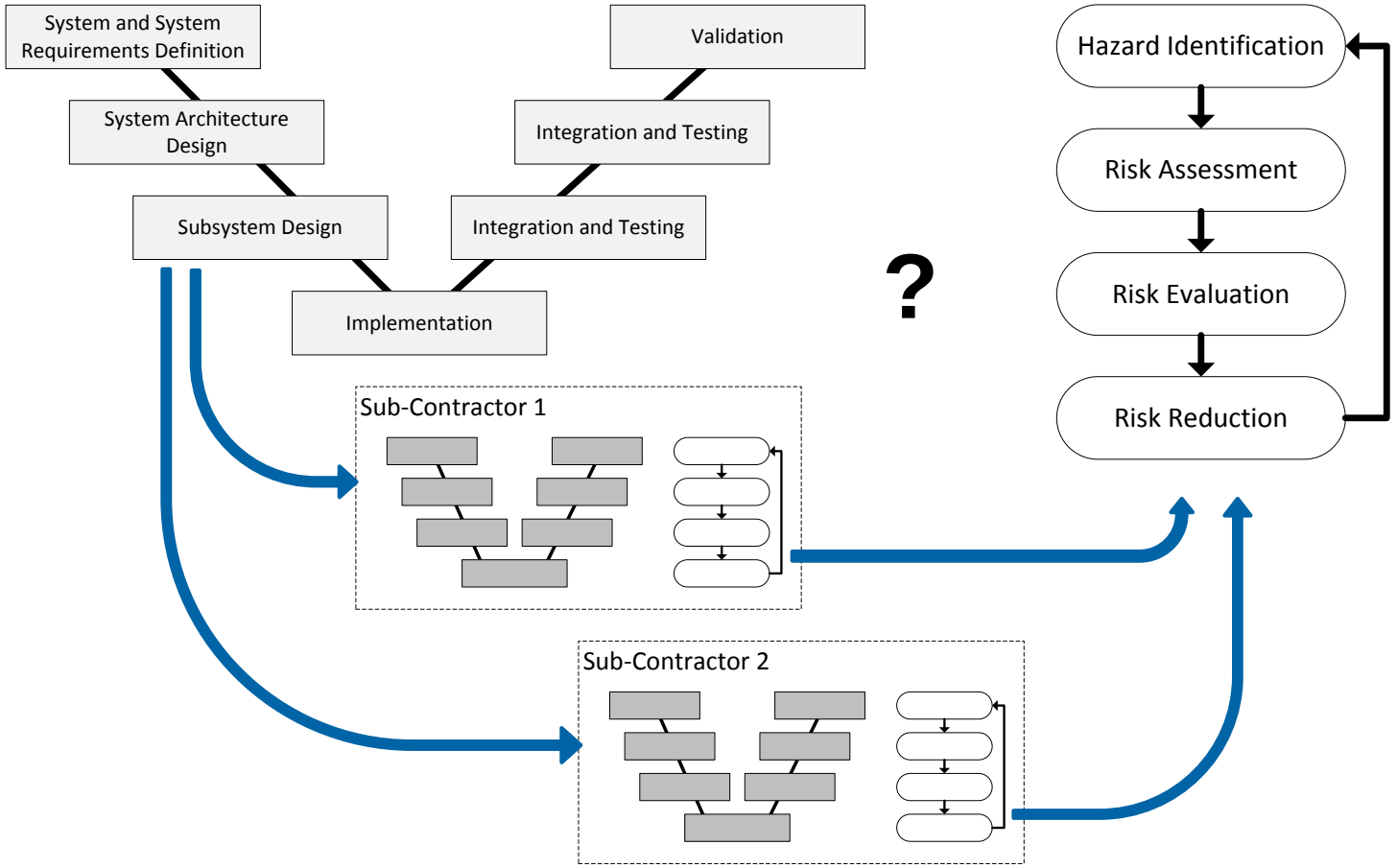
The challenges with this situation:

- Product development and safety management separated
- Different teams, methods, terminology
- Different processes and mindset



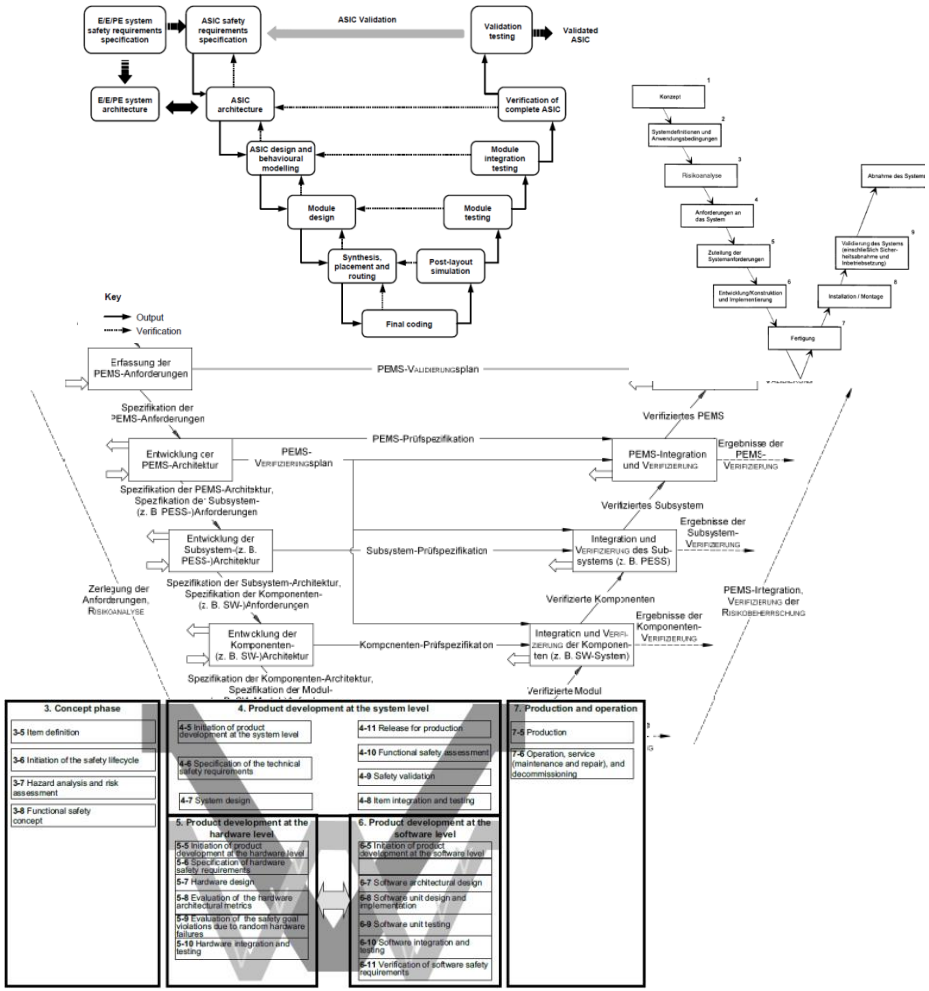
System and Safety Engineering

The challenge is even more severe for complex systems involving sub-contractors:

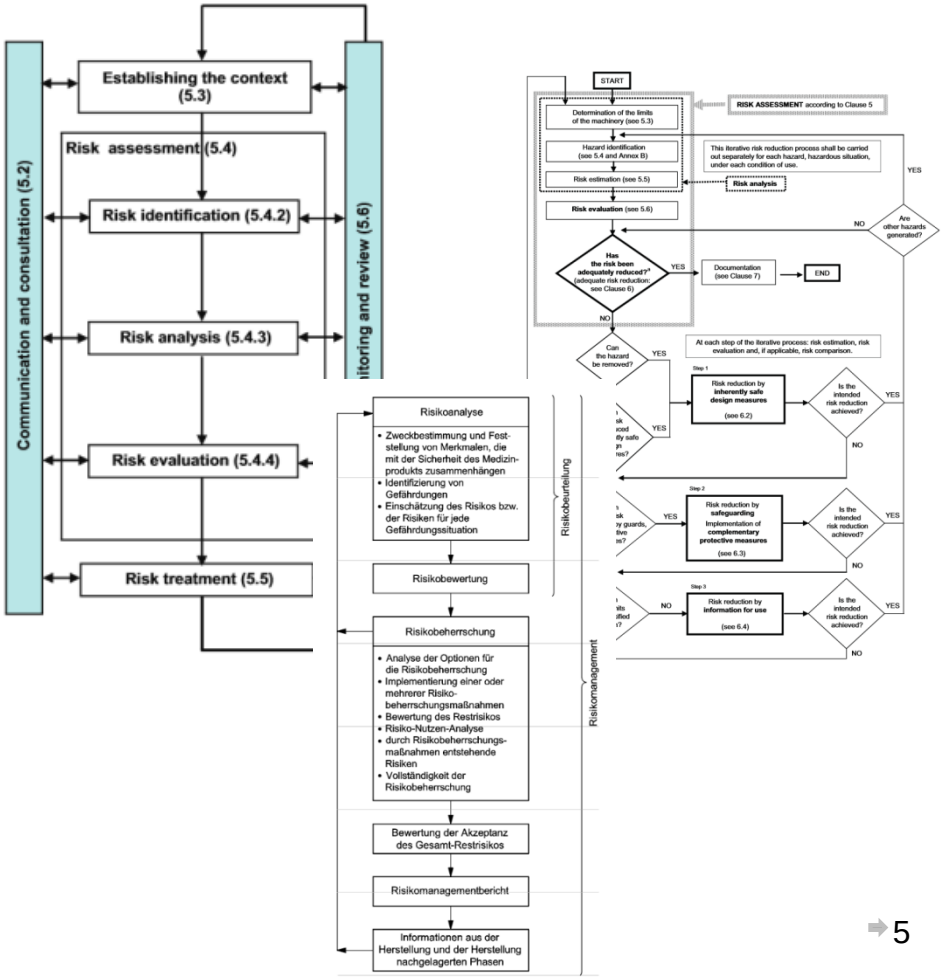


Processes

V-Model Zoo:



Risk Management Processes:



System and Safety Engineering

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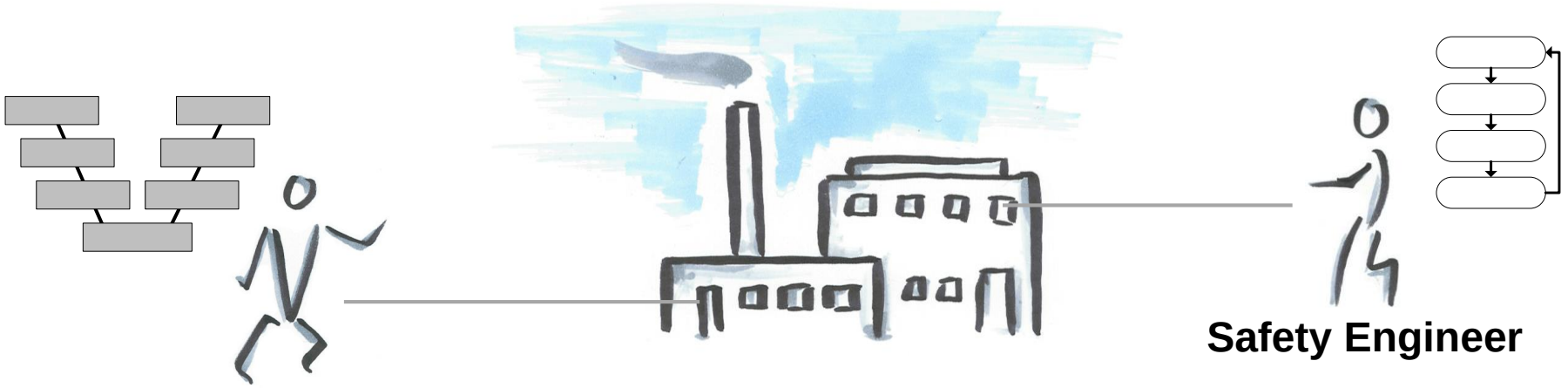


System Engineer / Developer

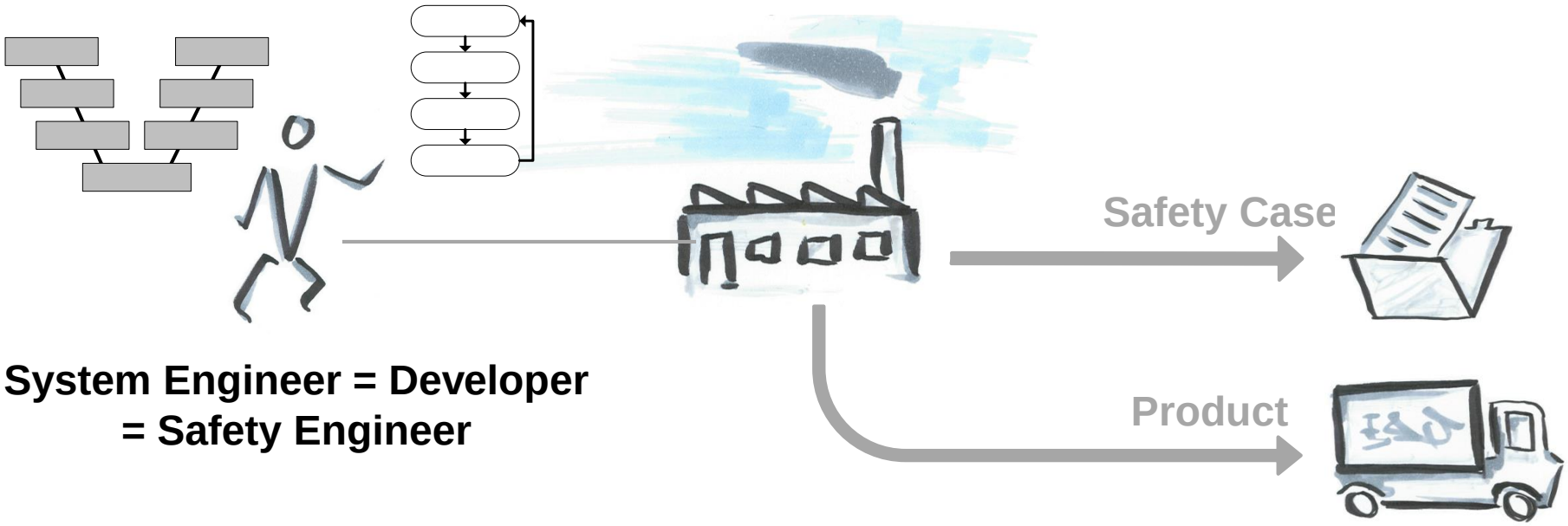
- Model based development with UML
- UML Case Tools
- Automated Code Generation

Safety Engineer

- FTA, FMEA, HAZOP, …
- Dedicated Tools

System and Safety Engineering

A typical situation in smaller companies:



System Engineer = Developer
= Safety Engineer

Developer wants to do a good job but has no chance to cope with “everything” …

Solution: Empower developer to incorporate the safety aspects right into system development

State of the Art in Systems Engineering: Model Based Development with UML

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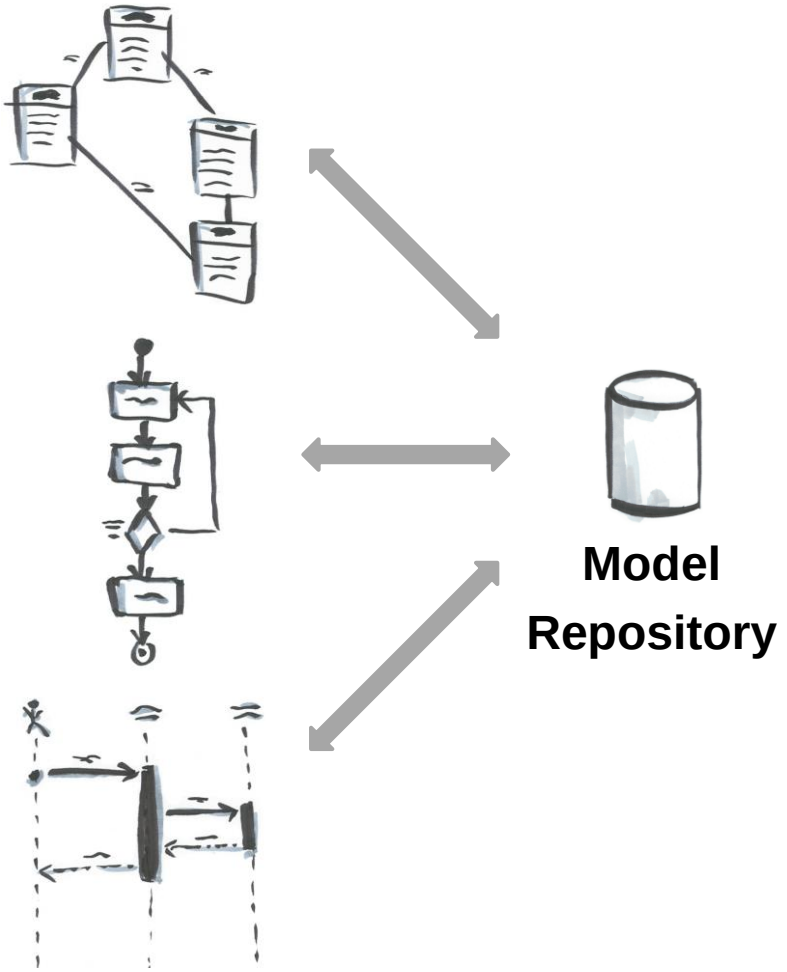
Structural:

- Class Diagram
- Object Diagram
- Package Diagram
- Component Diagram
- Composite Structure Diagram
- Deployment Diagram

Behavioral:

- UseCase Diagram
- Sequence Diagram
- Activity Diagram
- StateMachine Diagram
- Interaction (Overview) Diagram
- Communication Diagram
- Timing Diagram



Example

Fictitious example (examples from our industry partners are confidential):

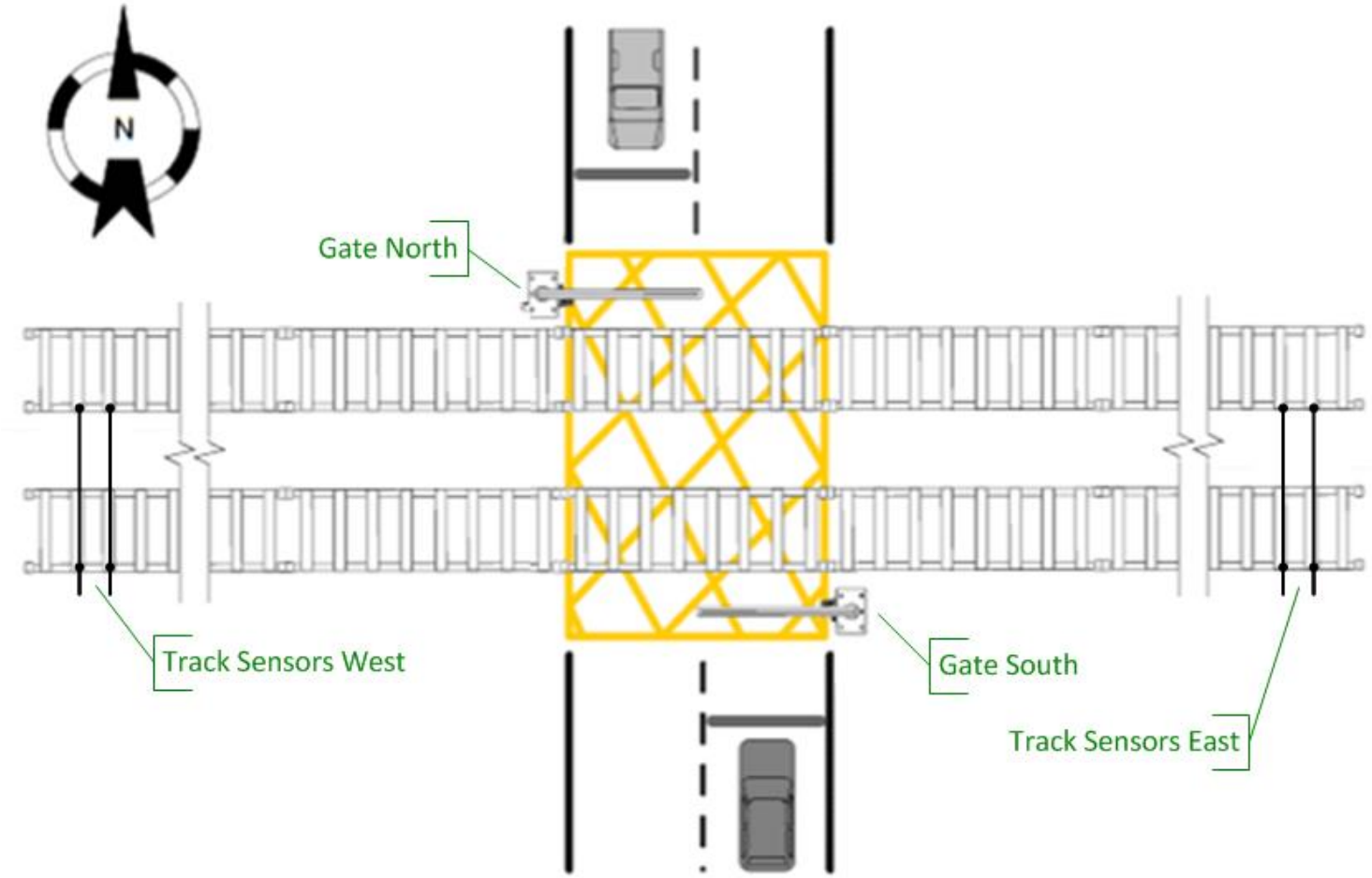
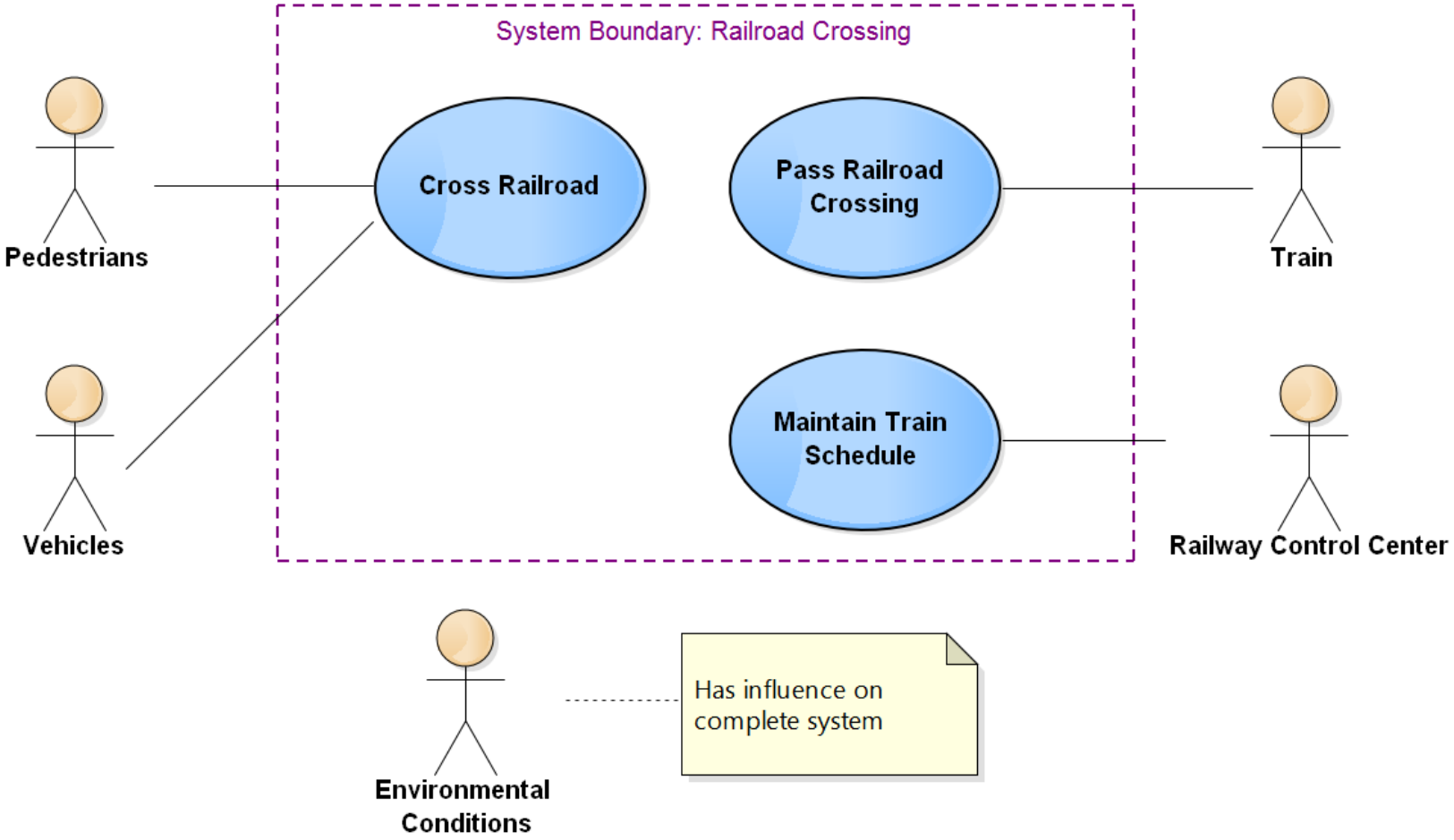


Illustration adapted from Y.S. Weng, et al., *Design of Traffic Safety Control Systems for Railroads and Roadways Using Timed Petri Nets*

System Concept Development: System Definition

Model system requirements as UML UseCase diagram



System Concept Development: System Architecture

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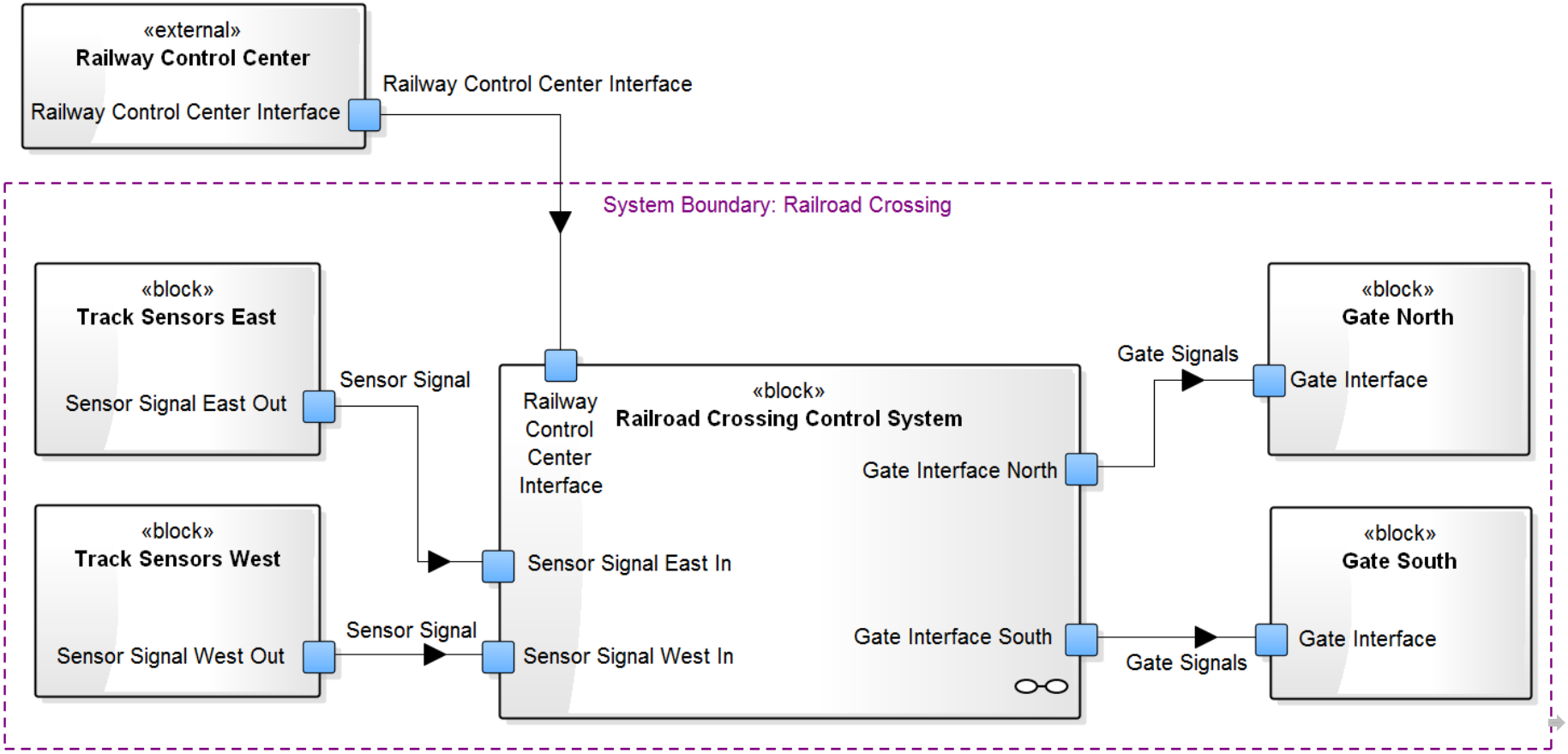
Initial architecture concept as SysML Block diagram

- Suitable for a systematic safety analysis? … No



STPA Hierarchical Control Structure for System Concept Development

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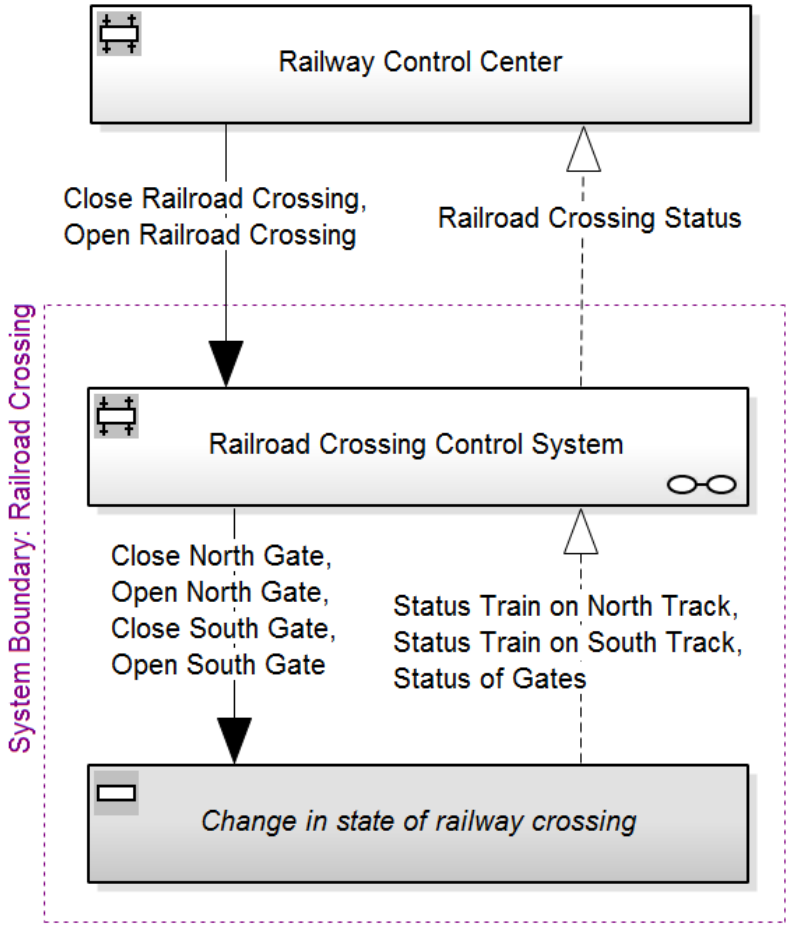
We propose to use a Hierarchical Control Structure for system concept development instead



STPA Hierarchical Control Structure: Support for Multiple Levels of Detail

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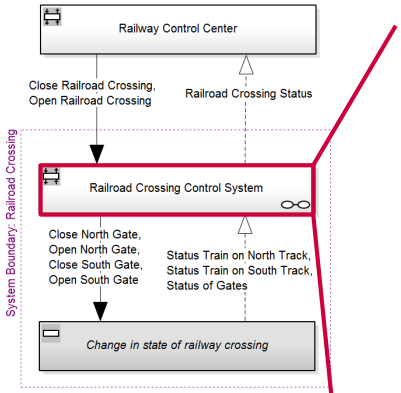

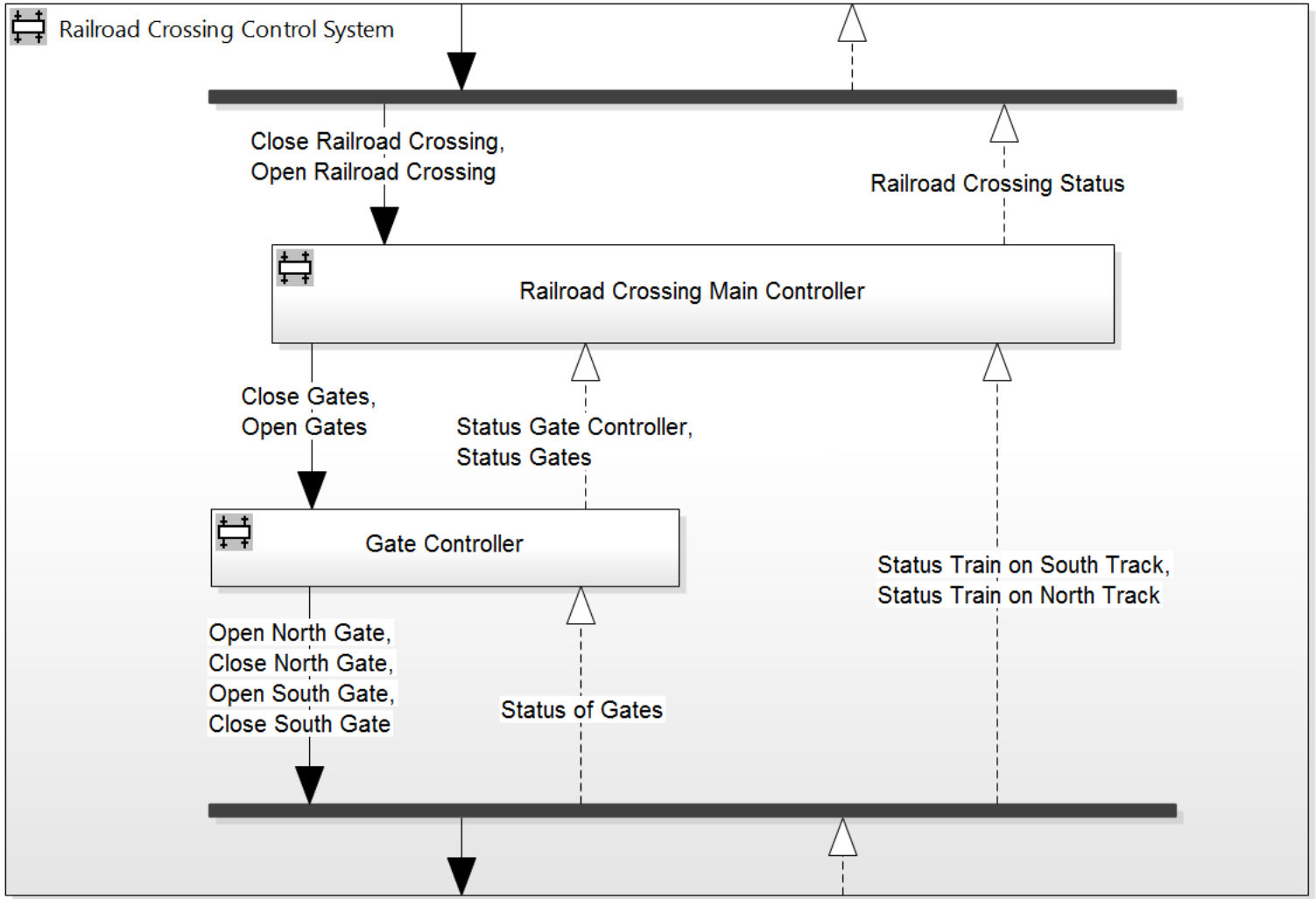

Top Level HCS : Railroad Crossing

Block Diagram vs. Hierarchical Control Structure (HCS)

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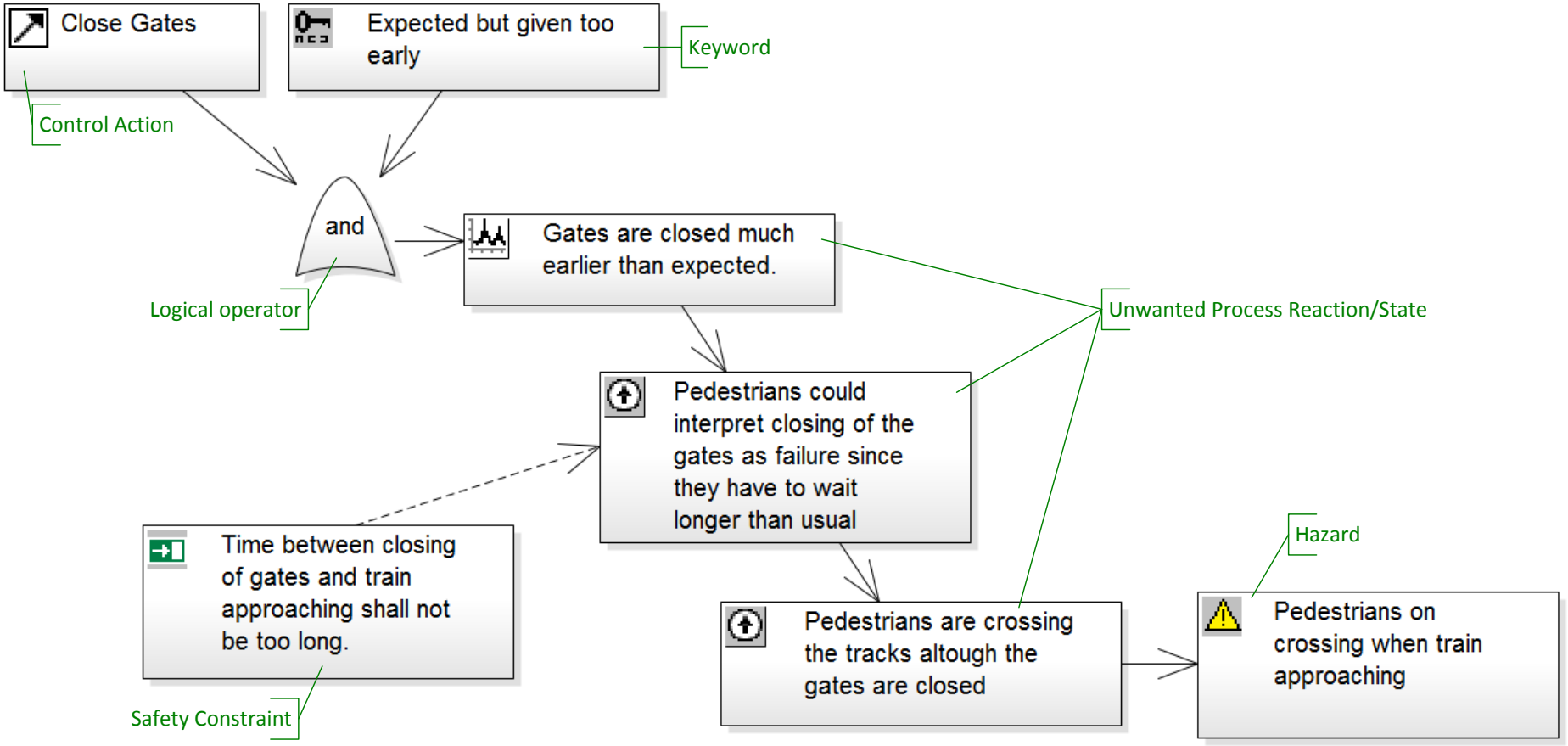
- Block diagram
  - Focus on components emphasizes component failures
  - Was not designed as a basis for systematic safety analysis
- Hierarchical Control Structure:
  - Is designed as basis for safety analysis with STPA Step 1
  - Step 1 questions correspond to questions developer would naturally ask
- Critical challenge: do not force developer to change scope/mindset. Therefore…
  - Capture HCS, perform Step 1 in the same UML case tool
  - Invent new UML diagram types for HCS, Step 1

STPA Step 1

Proposal for STPA Step 1 diagram:



System Development and Traceability

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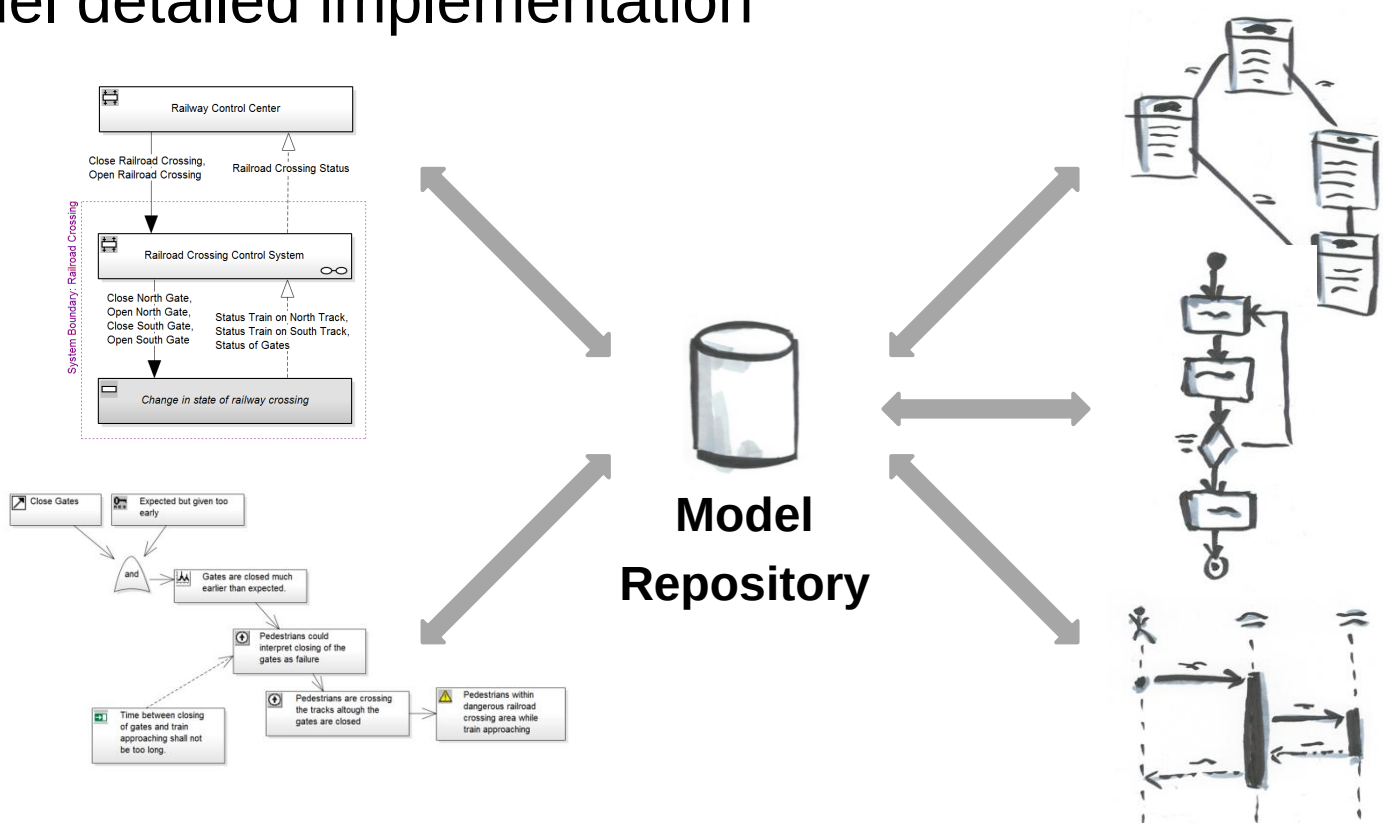
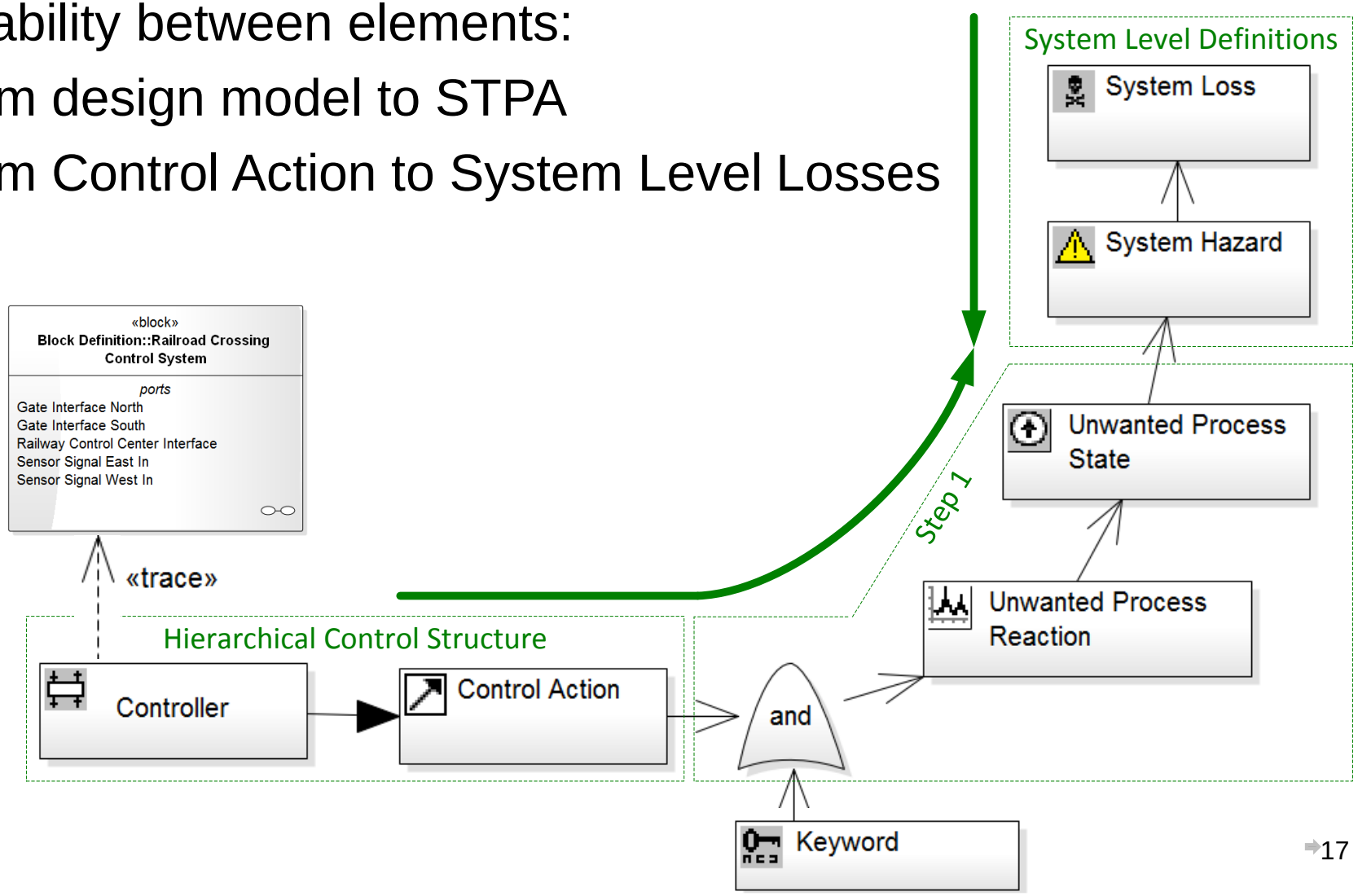
- New diagram types to model functional architecture and safety analysis
- Standard UML diagrams to progress system development and model detailed implementation



System Development and Traceability

Traceability between elements:

- From design model to STPA
- From Control Action to System Level Losses



Graph Visualization

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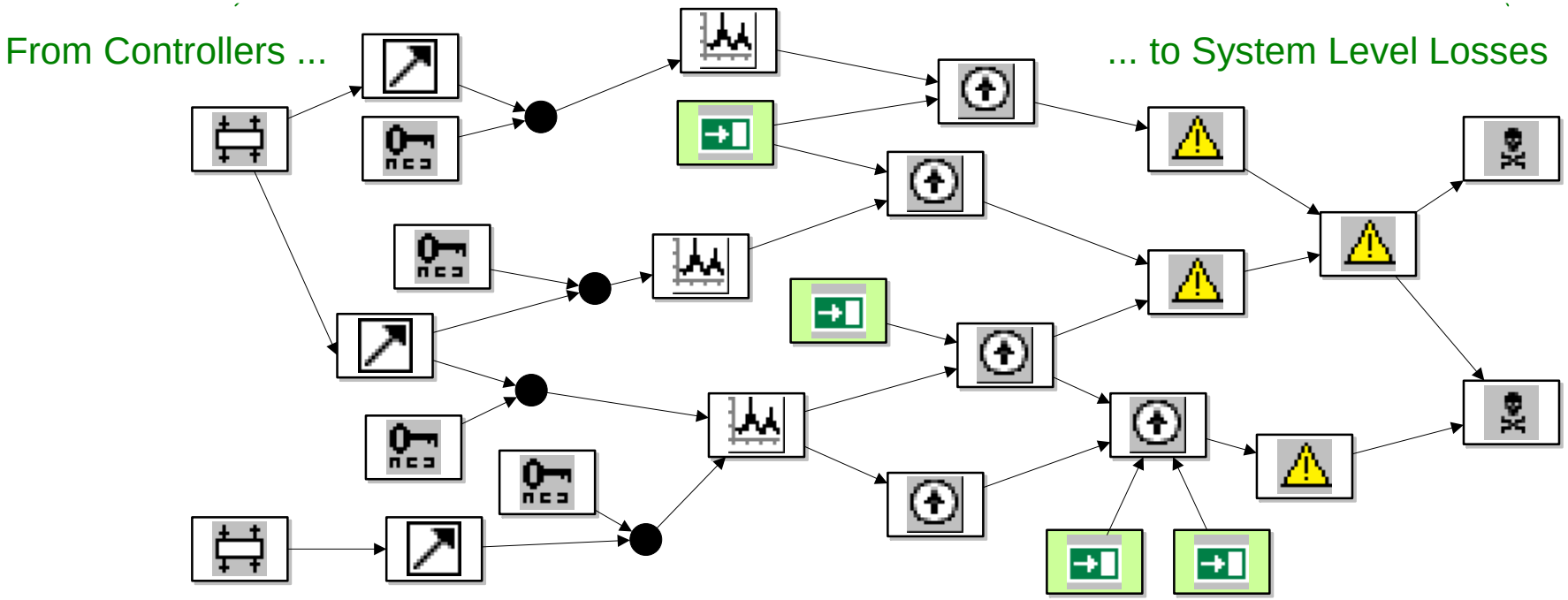
Visualizing elements and relationships as graph allows:

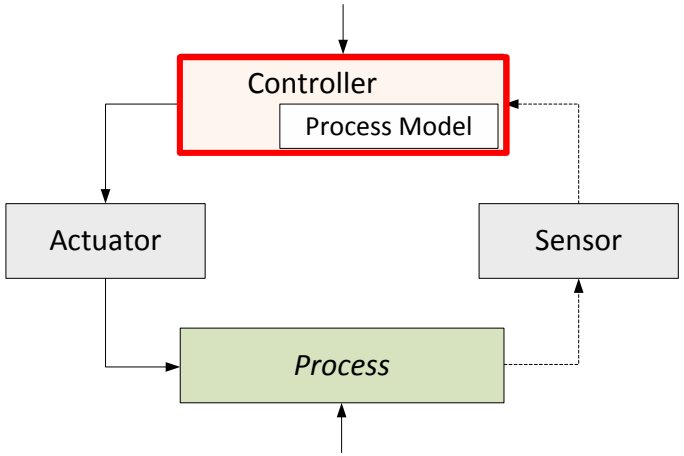
- Seeing the “big picture”
- Analyzing the relevance of controllers
- Doing a safety constraint impact analysis

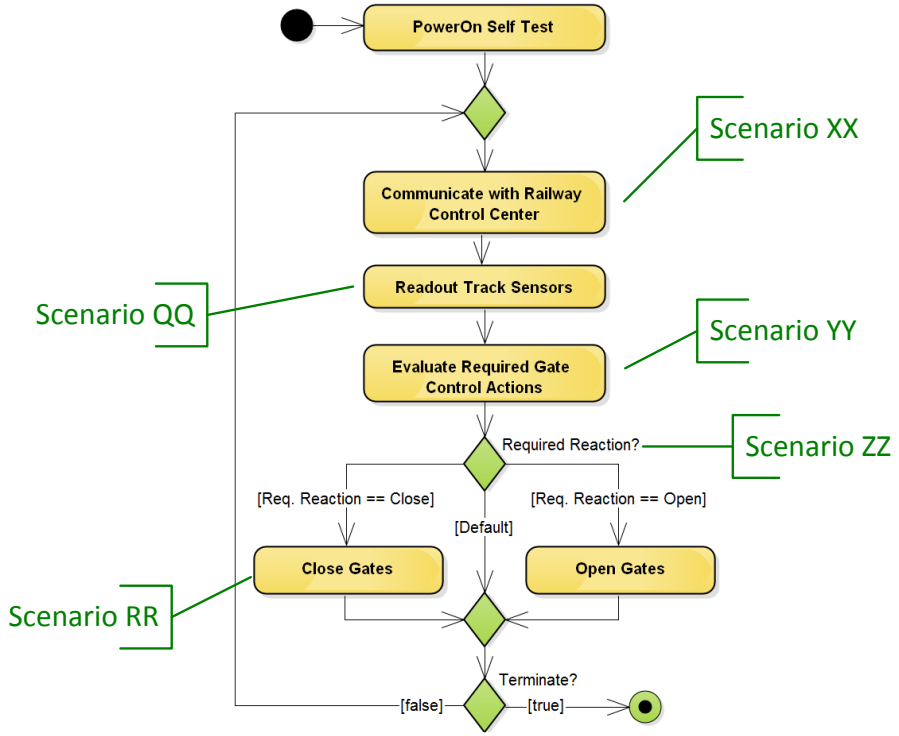


STPA Step 2 – Methods

Methods to identify accident scenarios:

- For simple actuators, sensors, data transmission: FTA, FMEA,
- For complex actuators, sensors: dedicated subsystem STPA
- For controller algorithm: Annotation of Behavioral diagrams



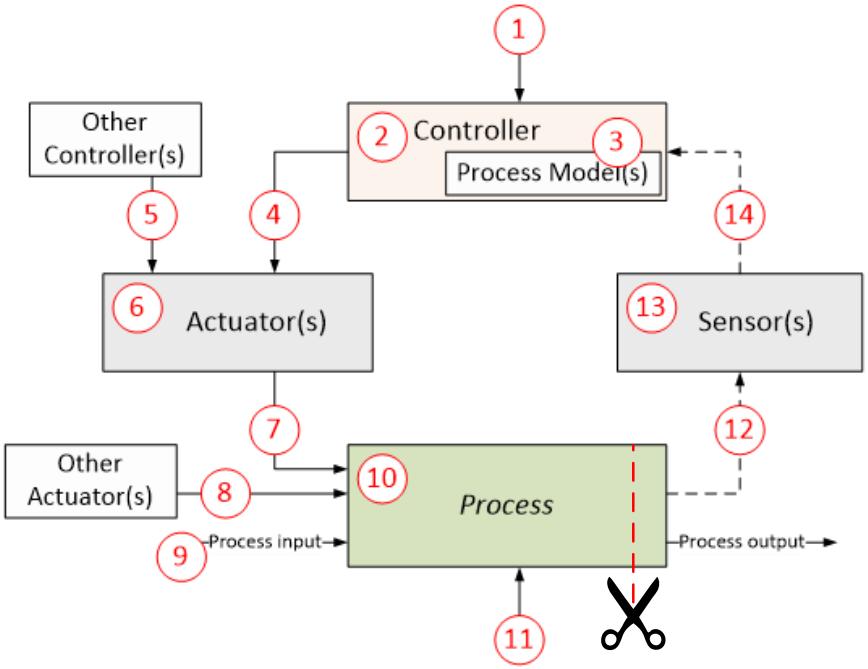


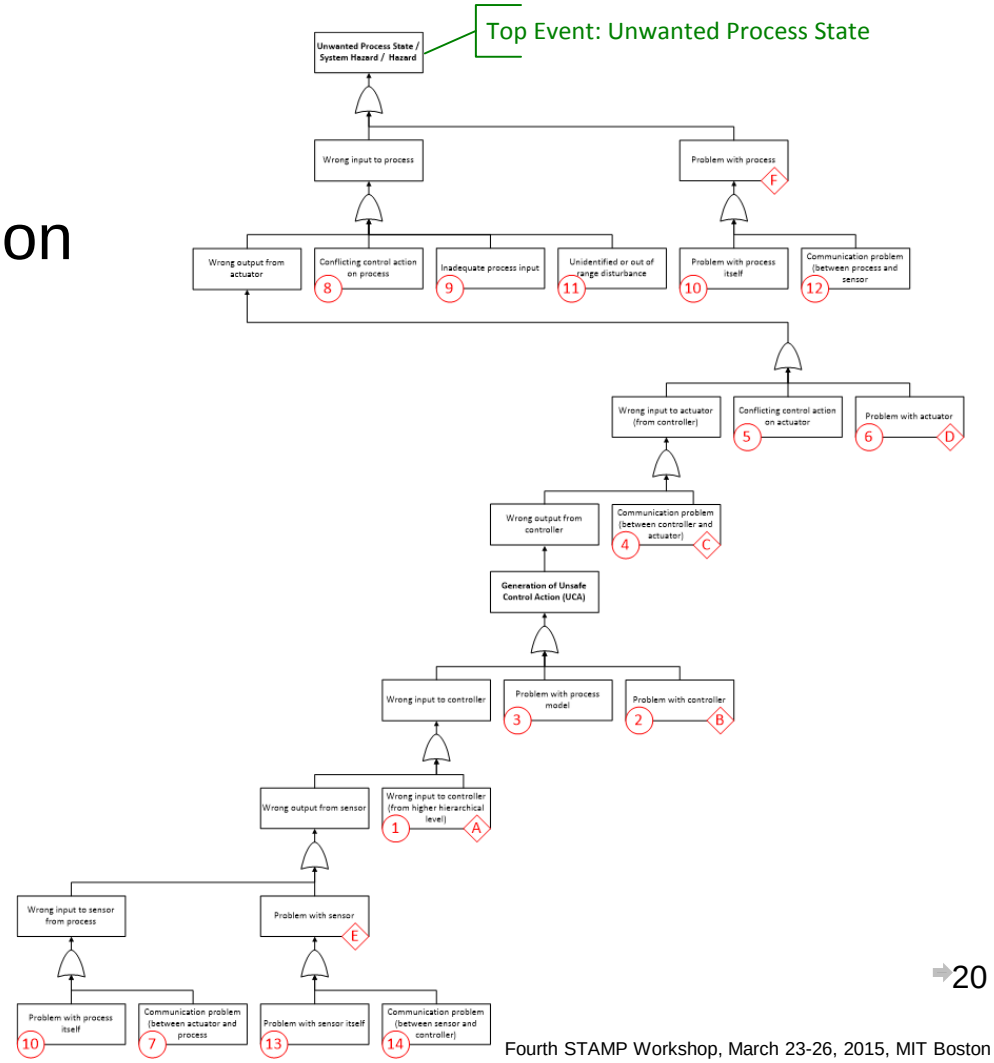
STPA Step 2 – Structured Organization

Organization of accident scenarios with generic fault tree:

- Structured documentation
- Interface to other tools

In principal: allows quantification of accident scenarios





Conclusion and Outlook (1/2)

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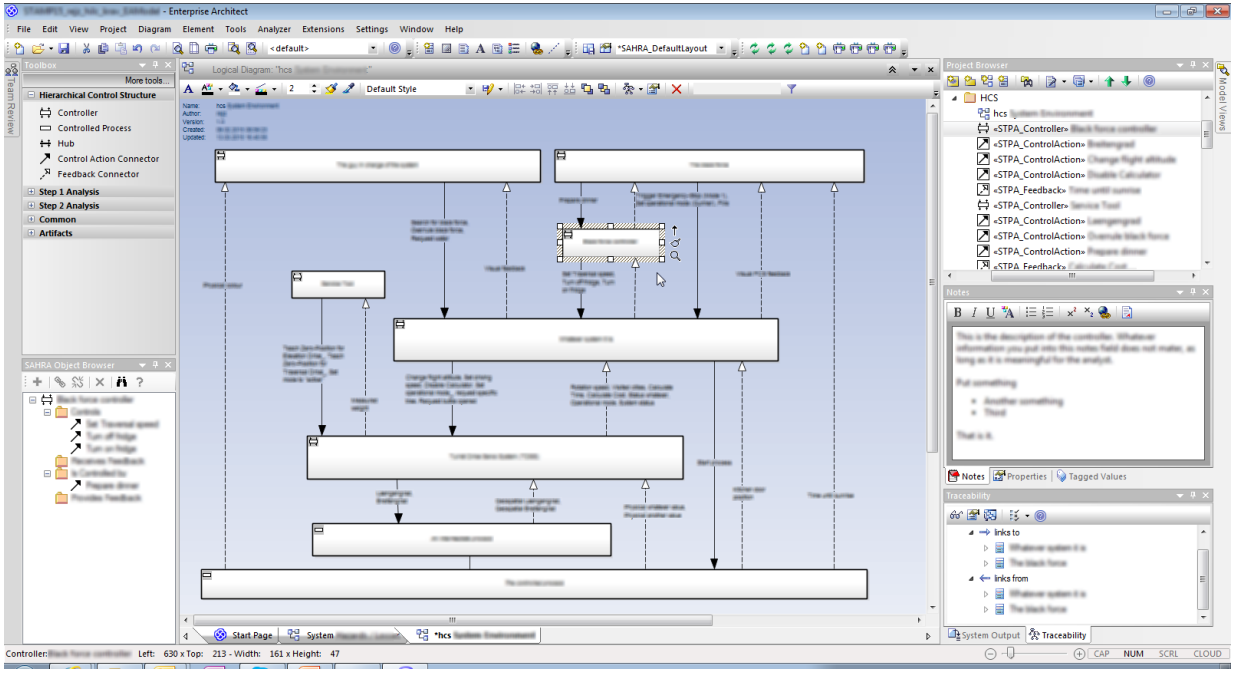
We developed a practical approach to safety driven design: the integration of system and safety engineering

- Extended UML with profile for STPA diagrams
  - Hierarchical Control Structure
  - STPA Step 1 diagrams
- Augment behavioral and structural diagrams with annotations to capture accident scenarios
  - STPA Step 2
- Realize and maintain traceability between system design, system implementation and hazards, accidents
- Organize accident scenarios with generic fault tree

Conclusion and Outlook (2/2)

- Project in collaboration with Curtiss Wright Drive Technology, Schaffhausen, Switzerland and funded by Swiss Commission of Technology and Information
- Tool Development:
  - Plan to present the tool at the European STAMP Workshop 2015



SAHRA
STPA based hazard and risk analysis

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