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A Six-Step Model for Safety and Security Analysis of Cyber-Physical Systems

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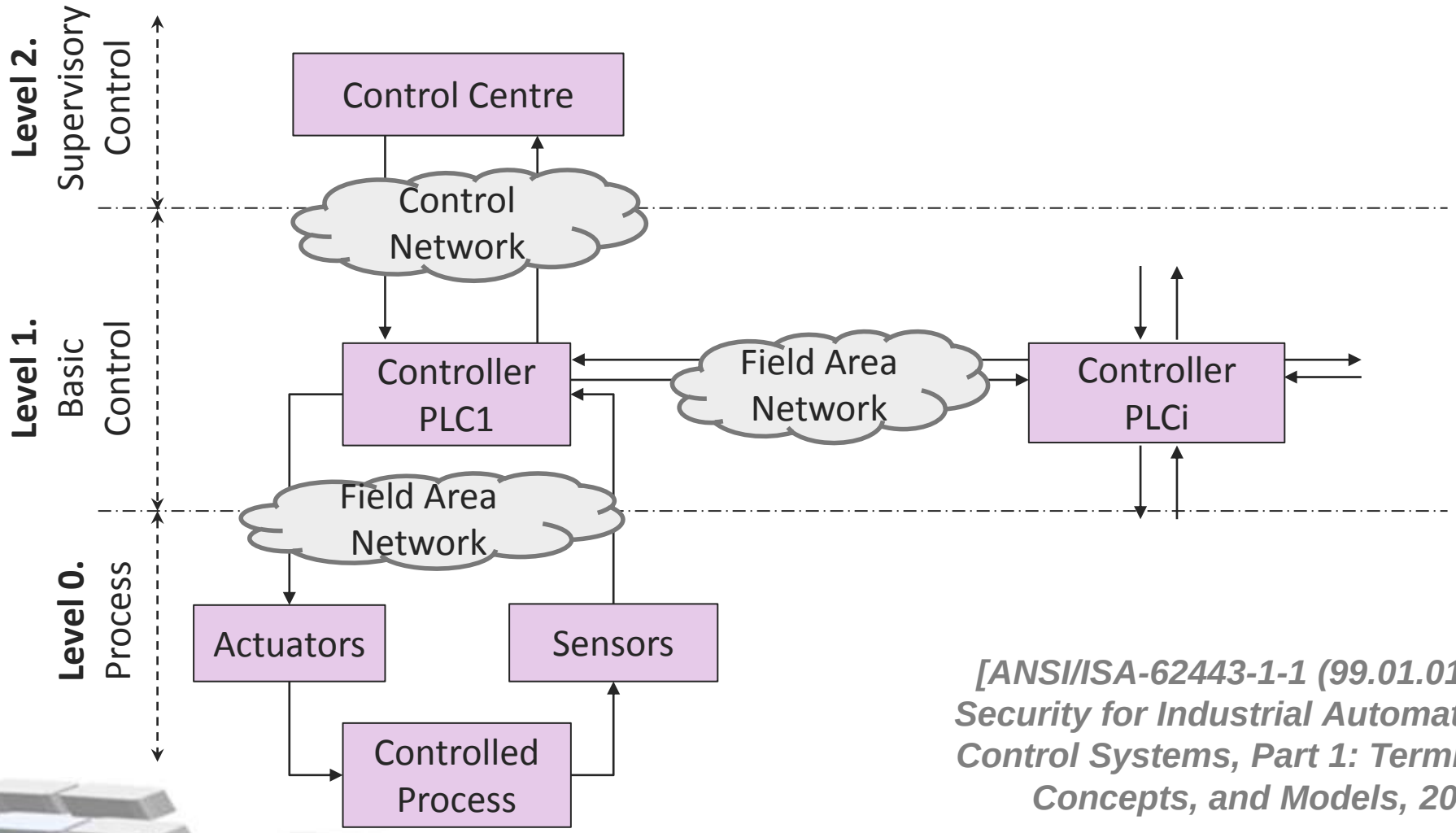
Cyber-Physical Systems (CPS)



[ANSI/ISA-62443-1-1 (99.01.01)-2007 Security for Industrial Automation and Control Systems, Part 1: Terminology, Concepts, and Models, 2007]

CPS Safety and Security

Safety and security are two key requirements of CPSs

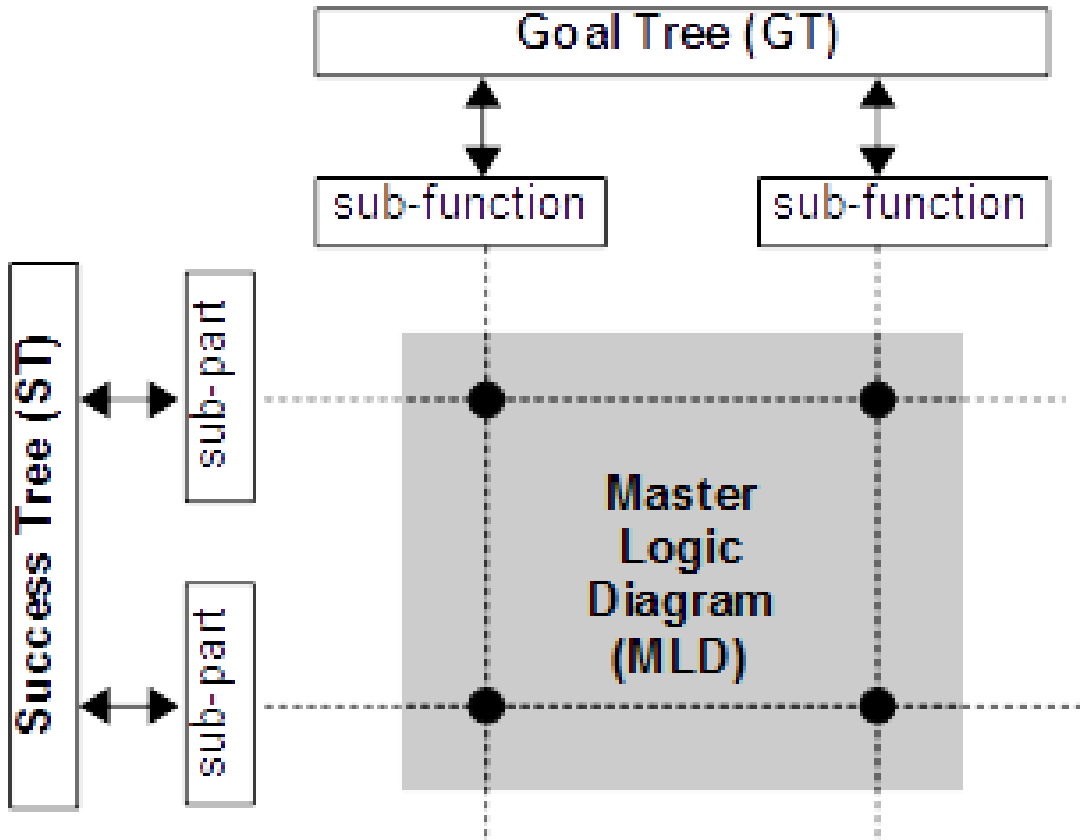
- Safety is concerned with protecting a CPS from accidental failures (safety failures)
  - Failure examples: faulty operation of the computing unit, software failures, compatibility issues, mechanical and electrical failures, etc.
- Security is aimed at protecting CPS from intentional attacks (security failures)
  - Physical attacks
  - Cyber attacks
- Safety and security share the same goal – protecting CPS from failing

Complex System Modelling (1/3)

Most complex systems are formed thr
functional, structural, behaviour, etc.

In 1999, Modarres and Cheon, propos
Success Tree – Master Logic Diagran

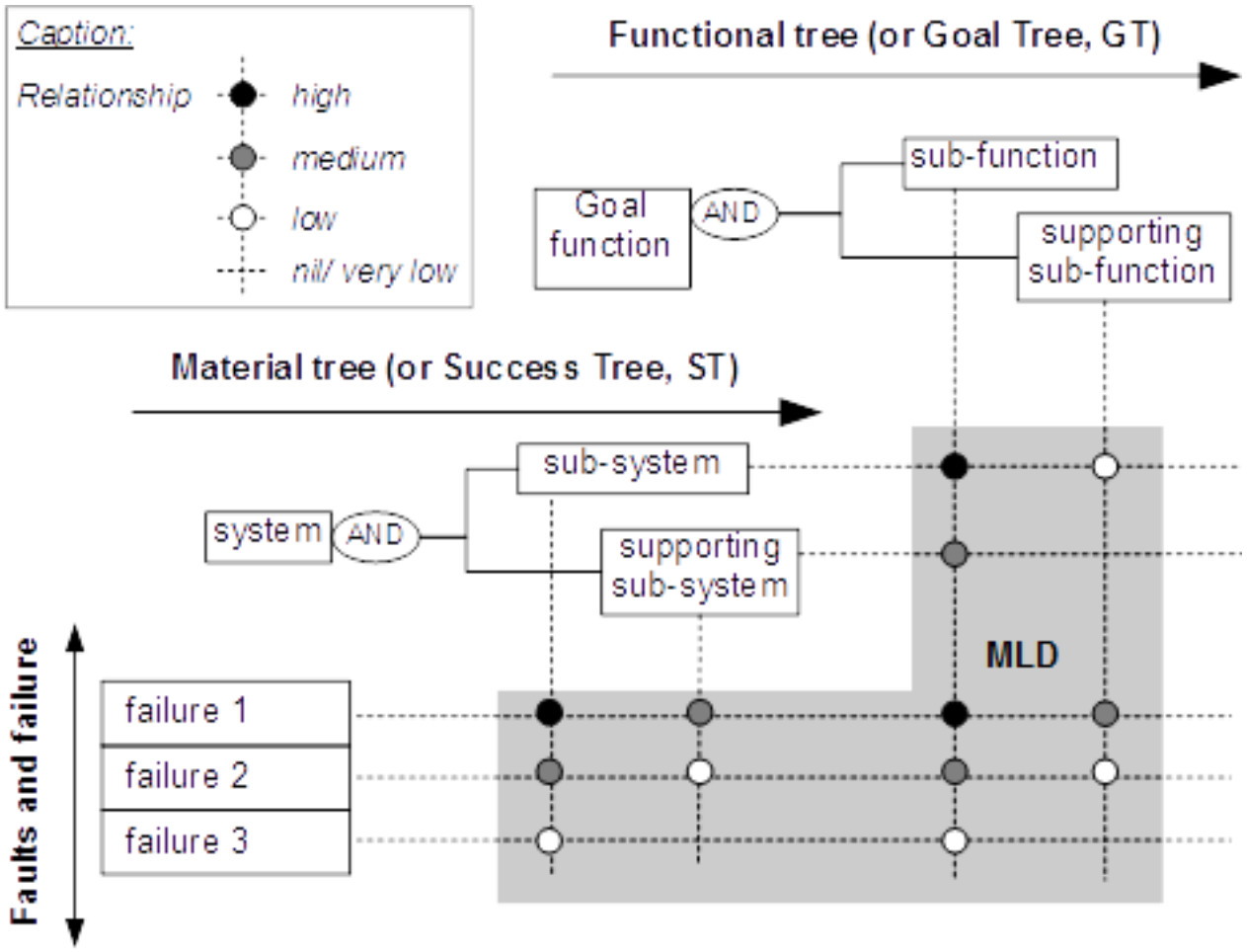
- Goal Tree GT describes system functions
- Success Tree ST – system structure
- Master Logic Diagram MLD – inter-relatic



GTST-MLD [Modarres and Cheon]

Complex System Modelling (2/3)

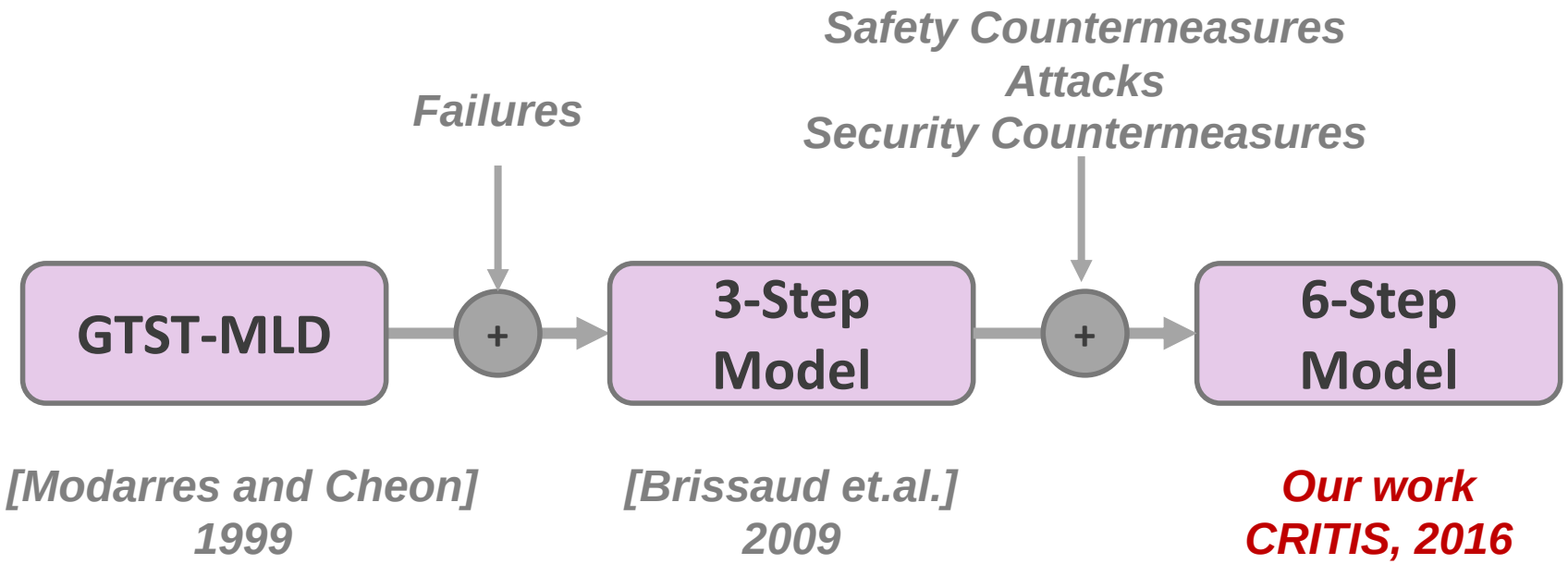
In 2009, Brissaud et al. extend
developed the 3-Step Model



The 3-Step [Brissaud et.al.]

Complex System Modelling (3/3)

In this work, we further extended the 3-Step Model and added safety countermeasures, attacks, and security countermeasures to fit the Cyber-Physical System needs



The Six-Step Model (SSM)

SSM consists of the following six steps:

Step 1. Define Functions

Step 2. Define Structure

Step 3. Identify Failures

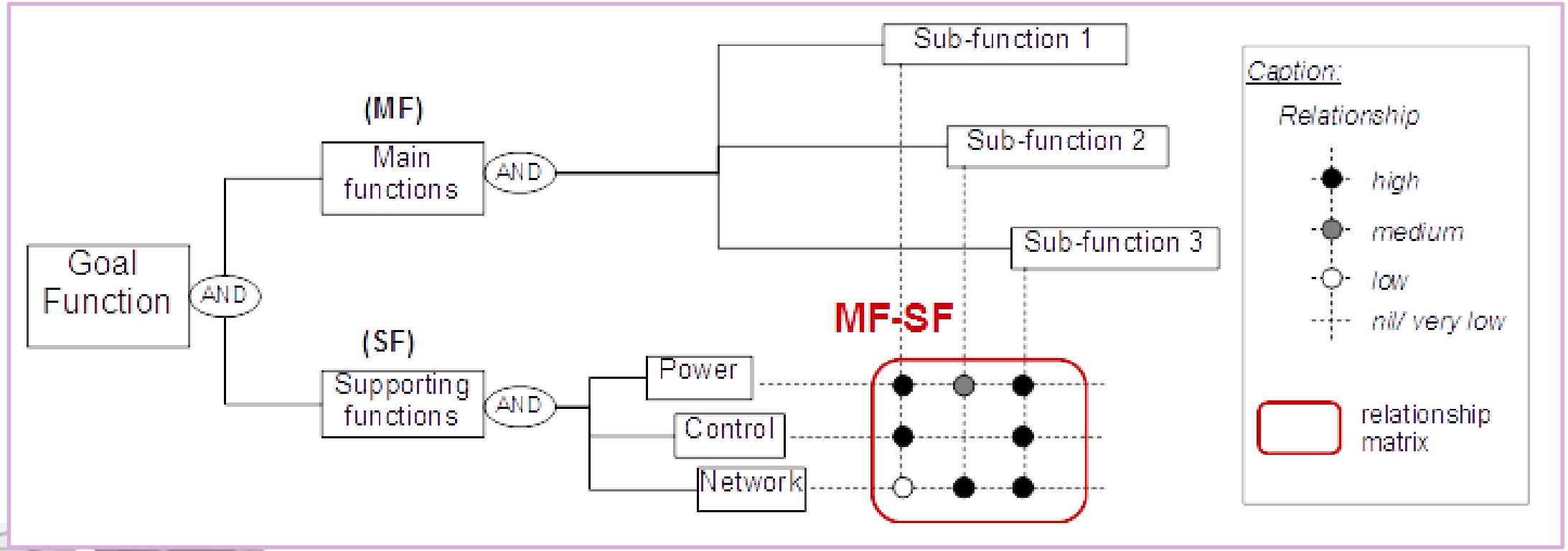
Step 4. Add Safety Countermeasures

Step 5. Identify Attacks

Step 6. Add Security Countermeasures

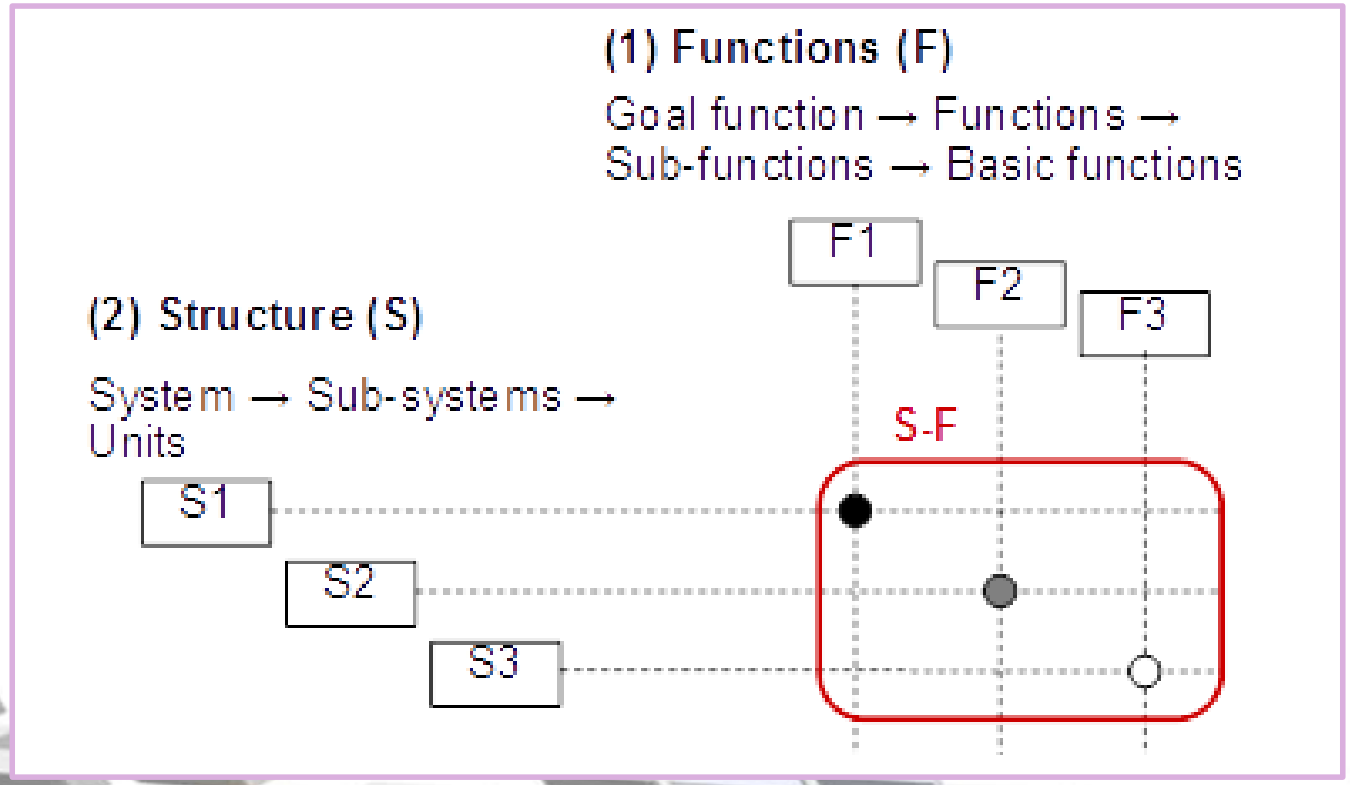
SSM Step 1: Define Functions

- System's goal tree, which includes main and supporting functions, is constructed
- Relationships between the functions are identified (relationship matrix MF-SF)



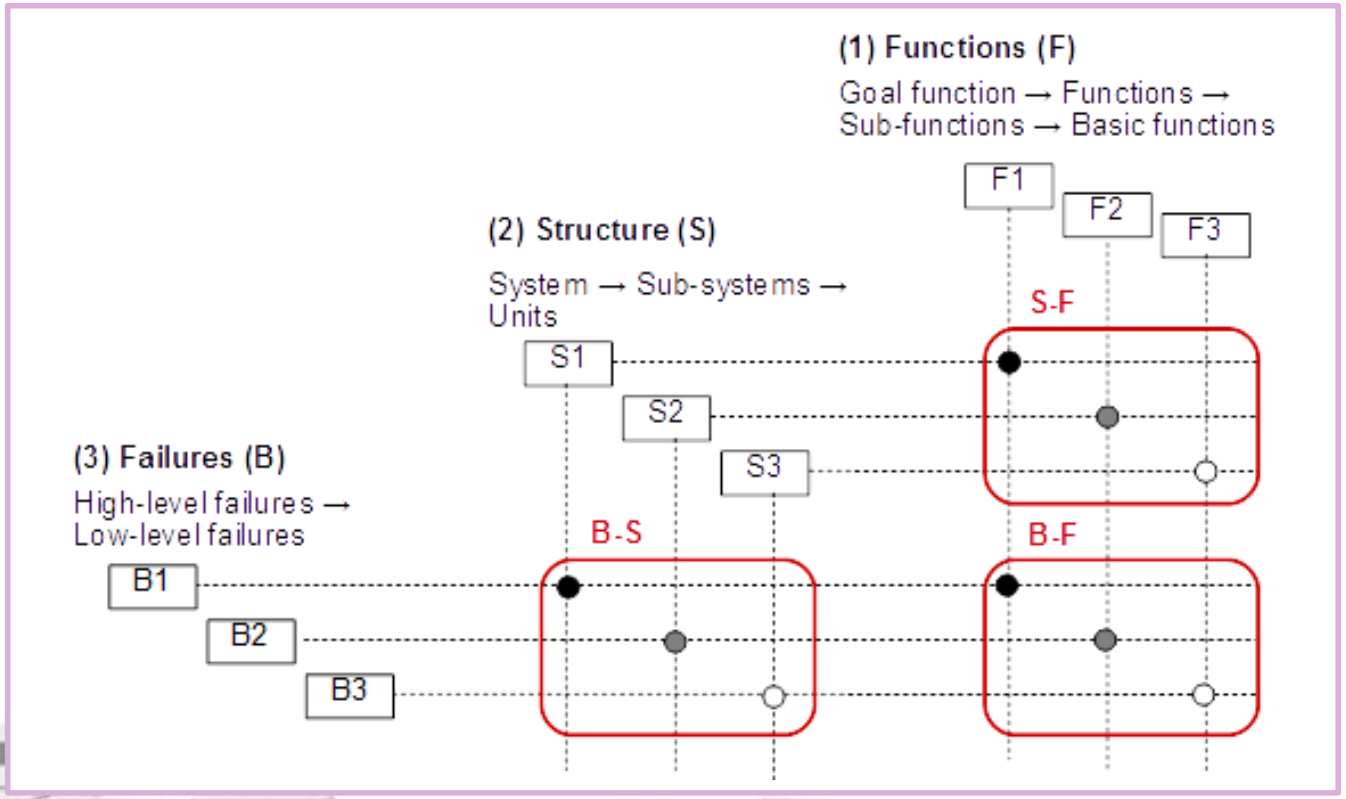
SSM Step 2: Define Structure

- System's success tree, which includes function, sub-functions and units, is constructed
- Relationships between structure and functions are identified (relationship matrix S-F)



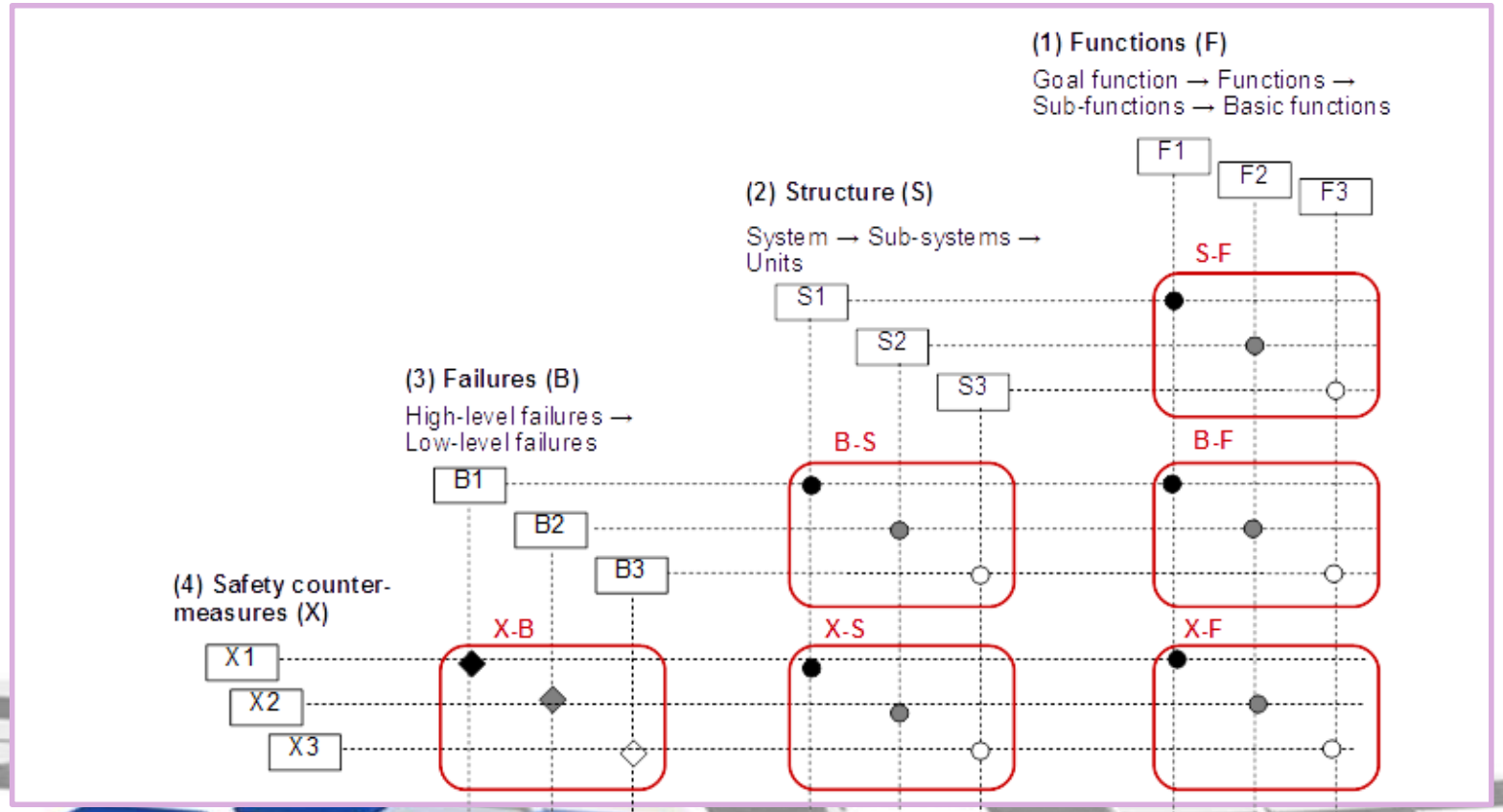
SSM Step 3: Identify Failures

- System's failures are identified and added to the model
- Relationships between failures and system's structure and functions are identified (relationship matrices B-S and B-F)



SSM Step 4: Add Safety Countermeasures

- Safety countermeasures are added to the model
- Relationships between them and the failures, as well as system structure and functions, are defined (relationship matrices X-B, X-S, and X-F)



SSM Step 5: Identify Attacks

- Attacks are added to the model, and their relationships with another elements of the model are identified

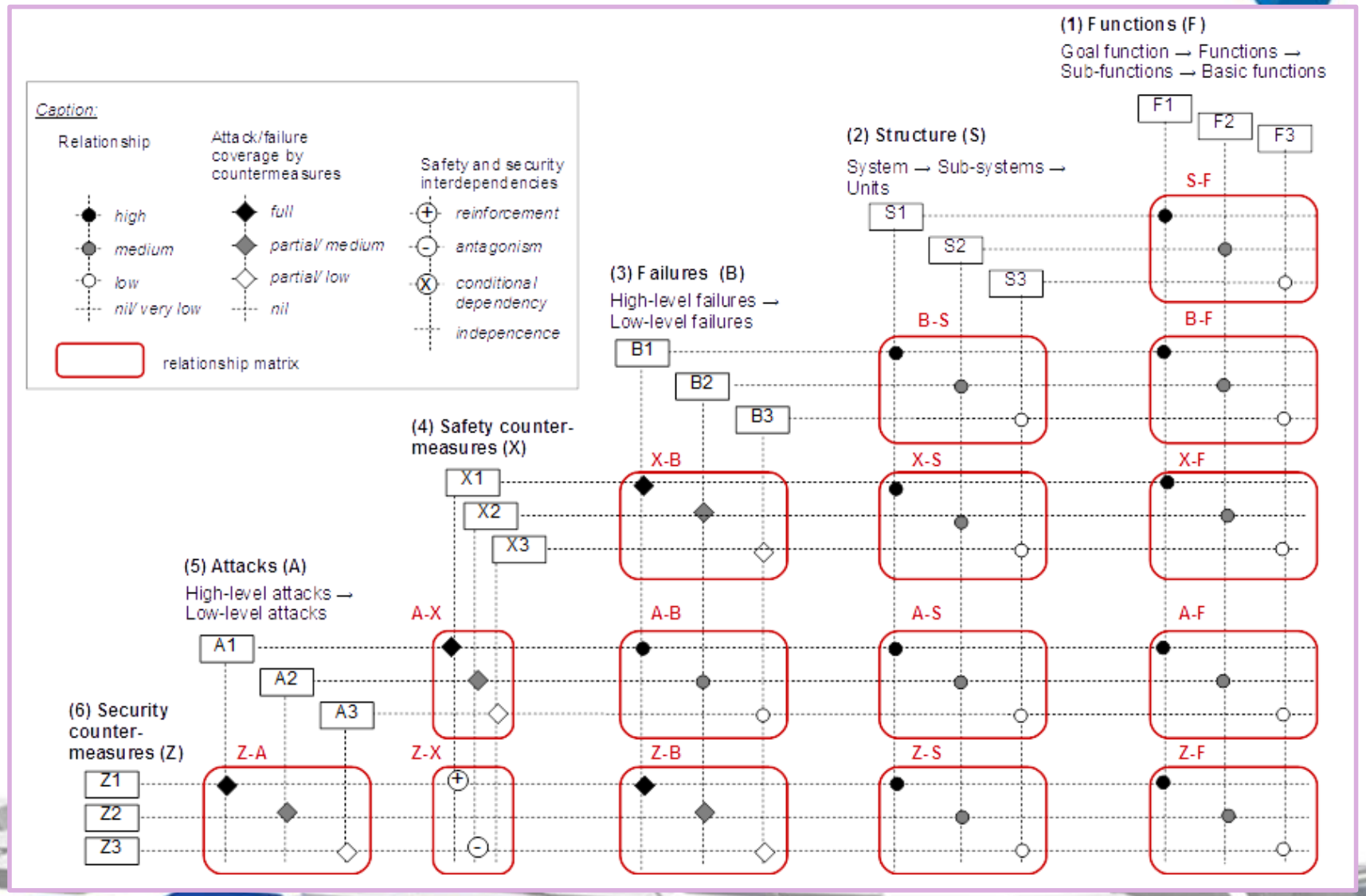
- After completion of step 5, it is necessary to go back to steps 3 and 4 to verify if there are no changes in failures and safety countermeasures due to attacks identified in this step

SSM Step 6: Add Security Countermeasures

- Security countermeasures are added to the model, and the relationships between them and the other elements of the model are identified

- Same as in step 5, after completion of step 6 it is necessary to go back to steps 3 and 4 to verify if there are no changes due to selected security countermeasures

Complete Six-Step Model



SSM case study

- Applied to a realistic testbed.
- Details are in the paper.
- The resulting model was used for cost analysis of alternate measures for safety and security.

Conclusions

The Six-Step Model [SSM] for safety and security modelling of CPS is proposed that:

- incorporates six hierarchies of a CPS: functions, structure, failures, safety countermeasures, cyber-attacks, and security countermeasures,
- facilitates the analysis of their inter-relationships, and
- enables comprehensive analysis of the safety and security of CPSs.

Future Work

Integration of the Six-Step Model with other models, such as Information Flow Diagrams to facilitate identification of failures and attacks, and selection of safety and security countermeasures

Thank You!

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