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Realization of the requirements for a safe operation of Wendelstein 7-X (W7-X)

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Motivation

- A safe and reliable operation of the fusion experiment W7-X is a fundamental requirement for the successfully execution of research programs.
- During the completion phase CP2 of W7-X, the safety control systems will be modified to be ready for the upcoming operational phase OP2.0.

Wendelstein 7-X operation

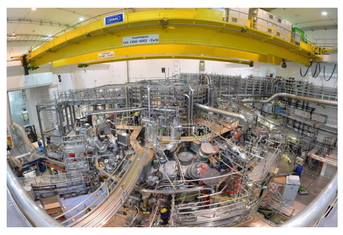

Fig.1. W7-X device in the torus hall

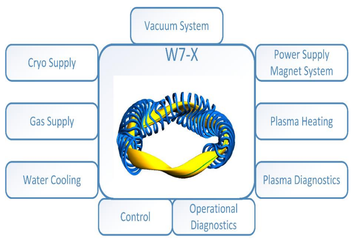

Fig.2. Main control components of W7-X device

Risk analysis:

- Identification and analysis of potential hazards for personnel, for the W7-X device and for the environment.

Examples for hazards of W7-X:

- Operation with high voltages and high currents in ranges of kV/ kA.
- Certain working gas types are explosive and / or toxic.
- Plasma heating systems produce radio waves (ICRH: 2 MW), microwaves (ECRH: 10 MW) or high energy particles (NBI: 5 MW).
- Some diagnostics use laser systems with high laser beam power (laser class 4).
- The superconducting coils of magnet systems uses 4K Helium as coolant.
- Production of fast neutrons during Deuterium plasma discharges.

Safety lifecycle

Legal Requirements for W7-X operation:

- Industrial safety regulation,
- German occupational safety and Health act.
- Product safety act,
- European harmonized standards, and
- Technical Standards: e.g. Functional safety EN61508 / EN 61511:
  - Basis for setup of the safety management and setup of the Safety Instrumented System (SIS) for W7-X.

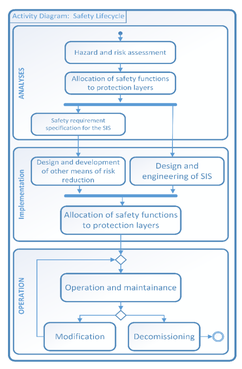

Fig.3. Activity diagram of safety live cycle at W7-X

Measures for risk mitigation

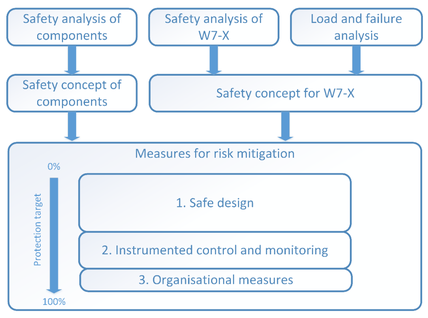

Fig.4. Safety analysis for control components and for the W7-X device

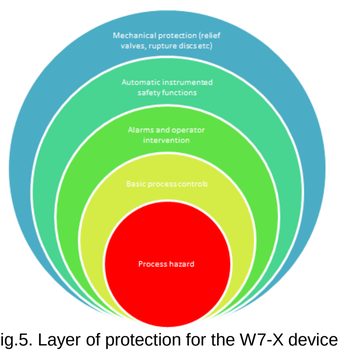

Fig.5. Layer of protection for the W7-X device

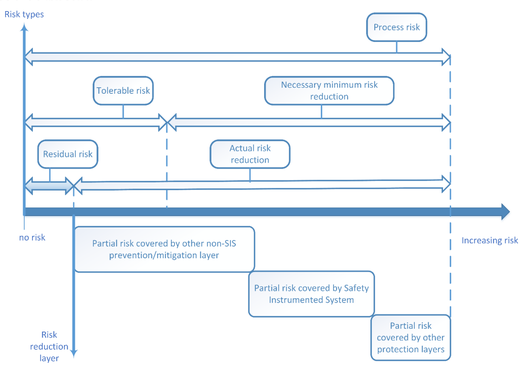

Fig.6. Definition of risk types and risk reduction

Special features of W7-X operation:

- W7-X is an experiment being be modified for every new operational phase. As a result, existing safety requirements or new requirements must be taken into account.
- A fusion experiment is a very complex technical system with a high potential of risks.
- Not all of the required Safety Instrumented Functions can be realized with the required Safety Integrated Level (SIL), since plasma diagnostic which are providing signals used as sensors and also some actuators used in the safety systems are usually not certified according to EN61508 / EN61511.

Overview W7-X control system

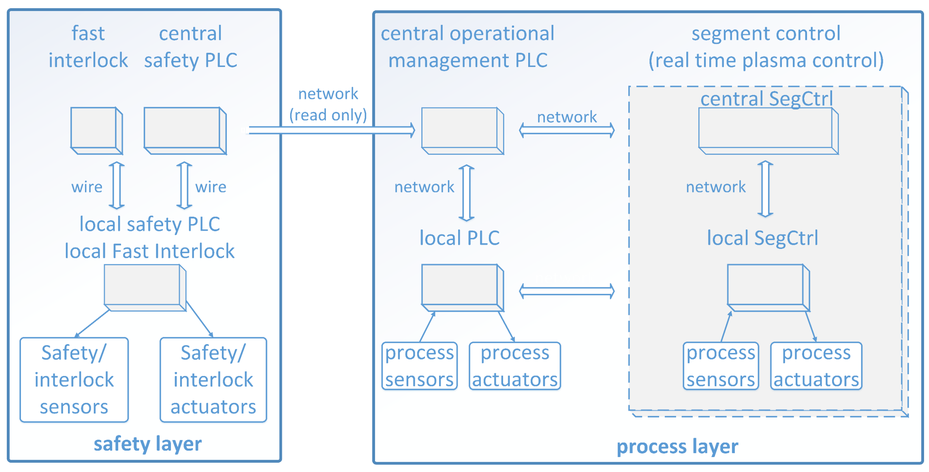

Fig.7. Main control components of W7-X device

W7-X control system:

- Hierarchical structure: Central systems and a large number of local control components,
- Central control systems:
  - Central Fast interlock system (cFIS),
  - Central Safety system (cSS),
  - Central Operational Management (cOPM),
  - Central Segment Control system (cSegCtrl).
- Local control systems of:
  - Technical systems (e.g. Vacuum system, water cooling system, …),
  - Diagnostics (e.g. Magnetics, Interferometry, Thomson Scattering,…)
  - Plasma Heating systems (e.g. ECRH, NBI, and ICRH),

Realization of control and monitoring for risk mitigation

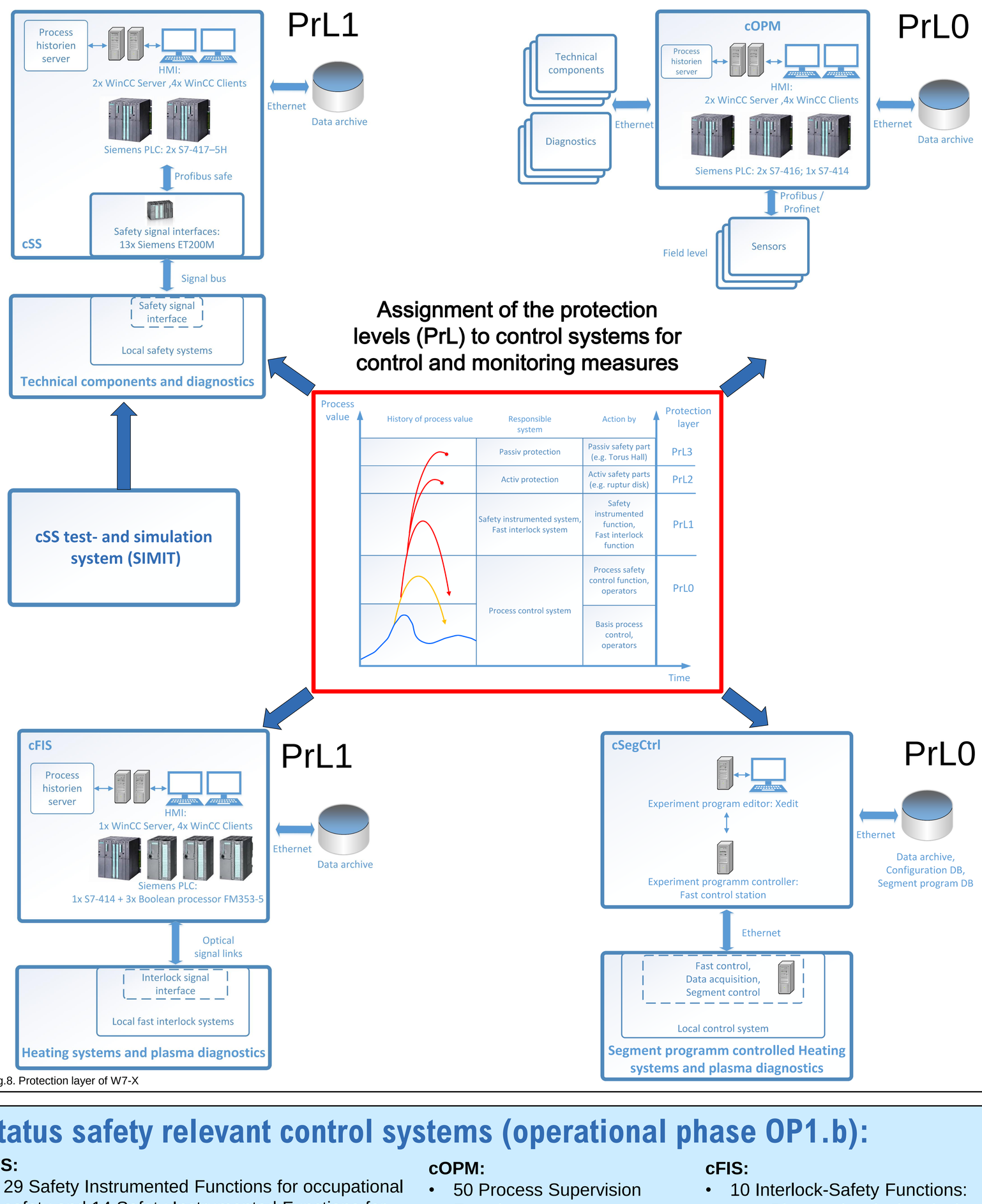

Fig.8. Protection layer of W7-X

Status safety relevant control systems (operational phase OP1.b):

cSS:

- 29 Safety Instrumented Functions for occupational safety and 14 Safety Instrumented Functions for device safety,
- Safety related function:
  - Control of safety levels of W7-X,
  - Gas warning system,
  - Access control system of radiation protection area and radiation protection system,
  - Signalization system,
  - Standard safety signalization interfaces (Emergency Stop, enable signals, status signals), …

cOPM:

- 50 Process Supervision Functions,
- Status of control components and status of W7-X,
- Control of operational States of W7-X, …

cFIS:

- 10 Interlock-Safety Functions:
  - Plasma density interlock,
  - Temperature supervision of plasma facing components,
  - Stray radiation interlock,
  - Plasma heating interlocks,

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EUROfusion

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