EUROPEAN
SPALLATION
SOURCE

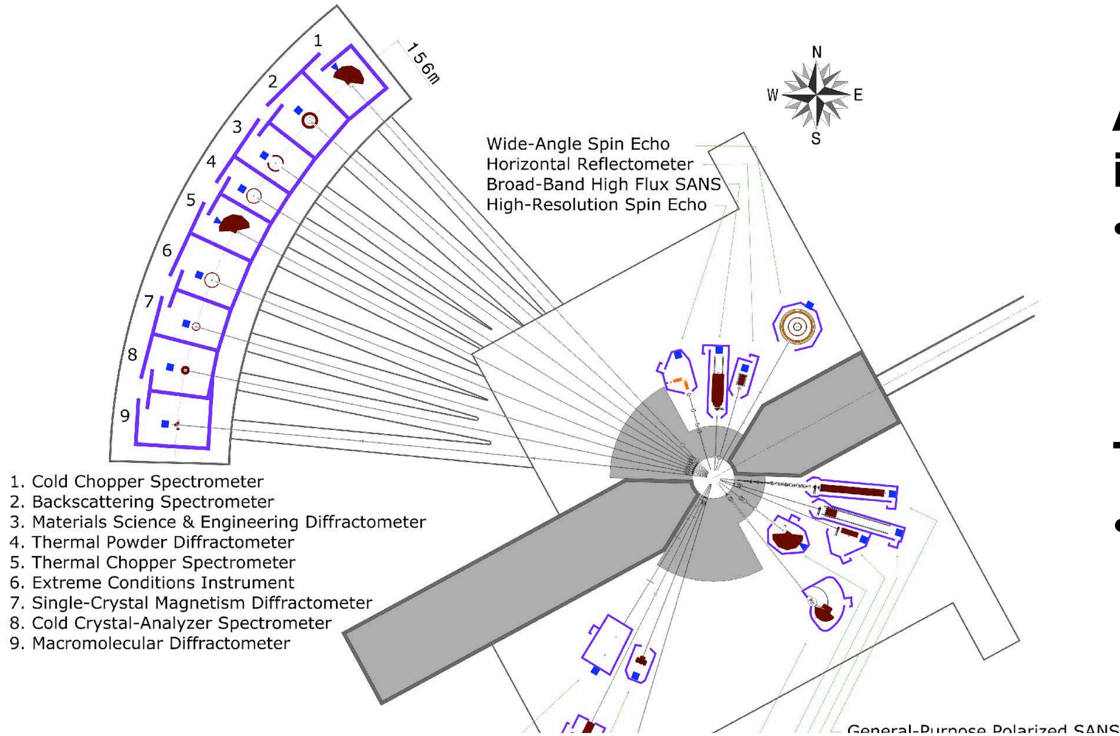
ESS Target Safety System

Issues & on going design activities

Highlights

- ESS presentation- Control issues
- TSS objectives
  - Example of TSS action
- Adopted standards
- Preliminary top level requirements
- Design tools and convergence with other ESS models – Test bench
- Topics to be discussed

ESS - Control issues

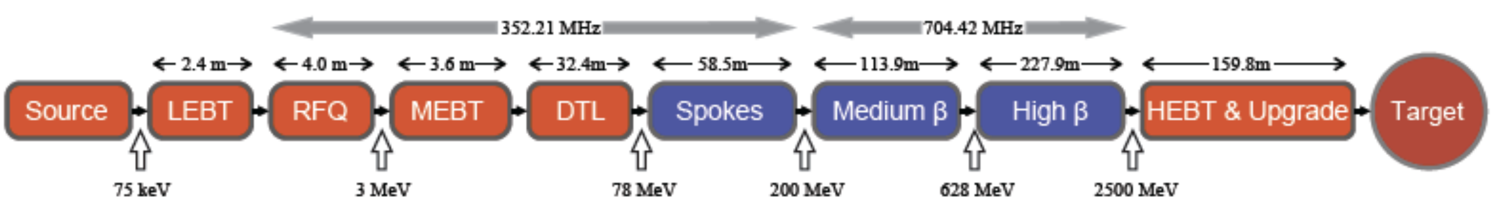


Accelerator & Neutron instrument:

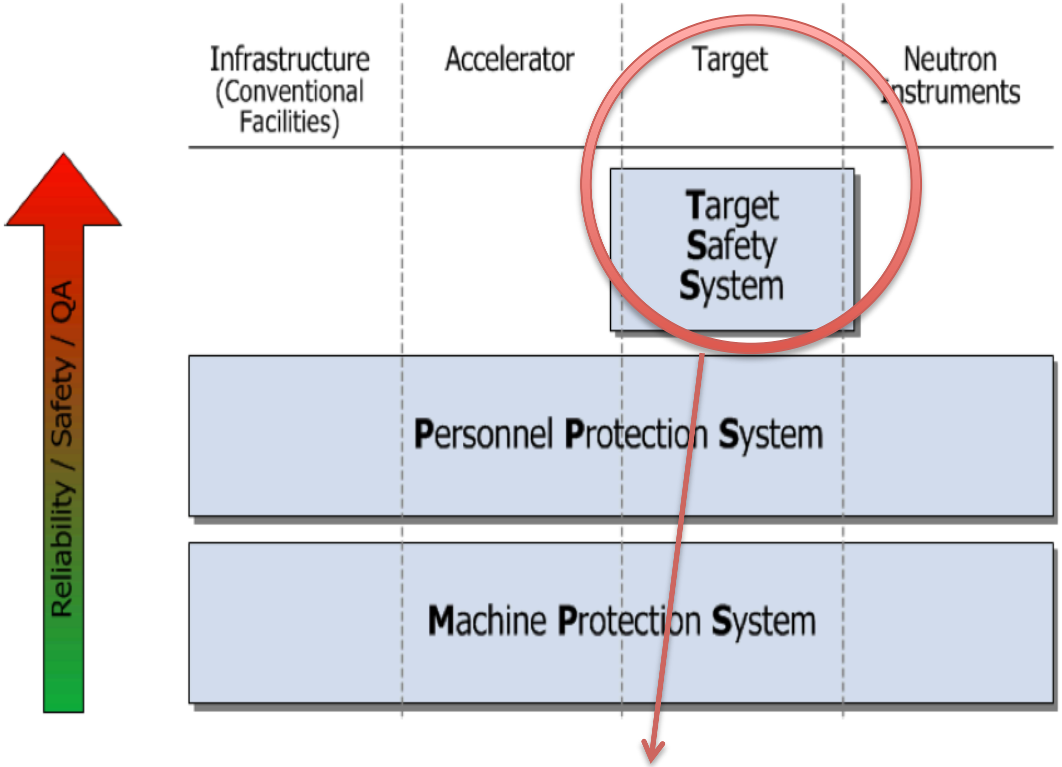
- Radiological hazards (almost completely) suppressed when cutting off the beam

Target:

- ***not the case…***



ESS control systems objectives



➔ Limit transfer of radioactive contamination in the environment (+ workers)

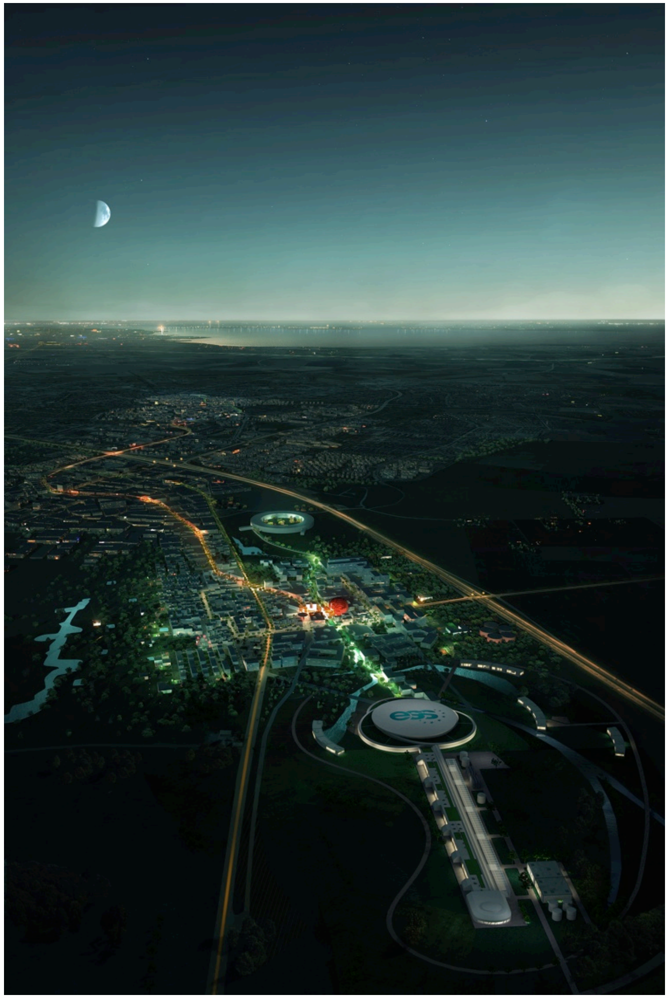
➔ Suppress radiologic hazard by the beam

➔ Protect the investment and reliability:
- ➔ Not only stop the p+ beam! (e.g. evacuate H2 from target zone etc…)

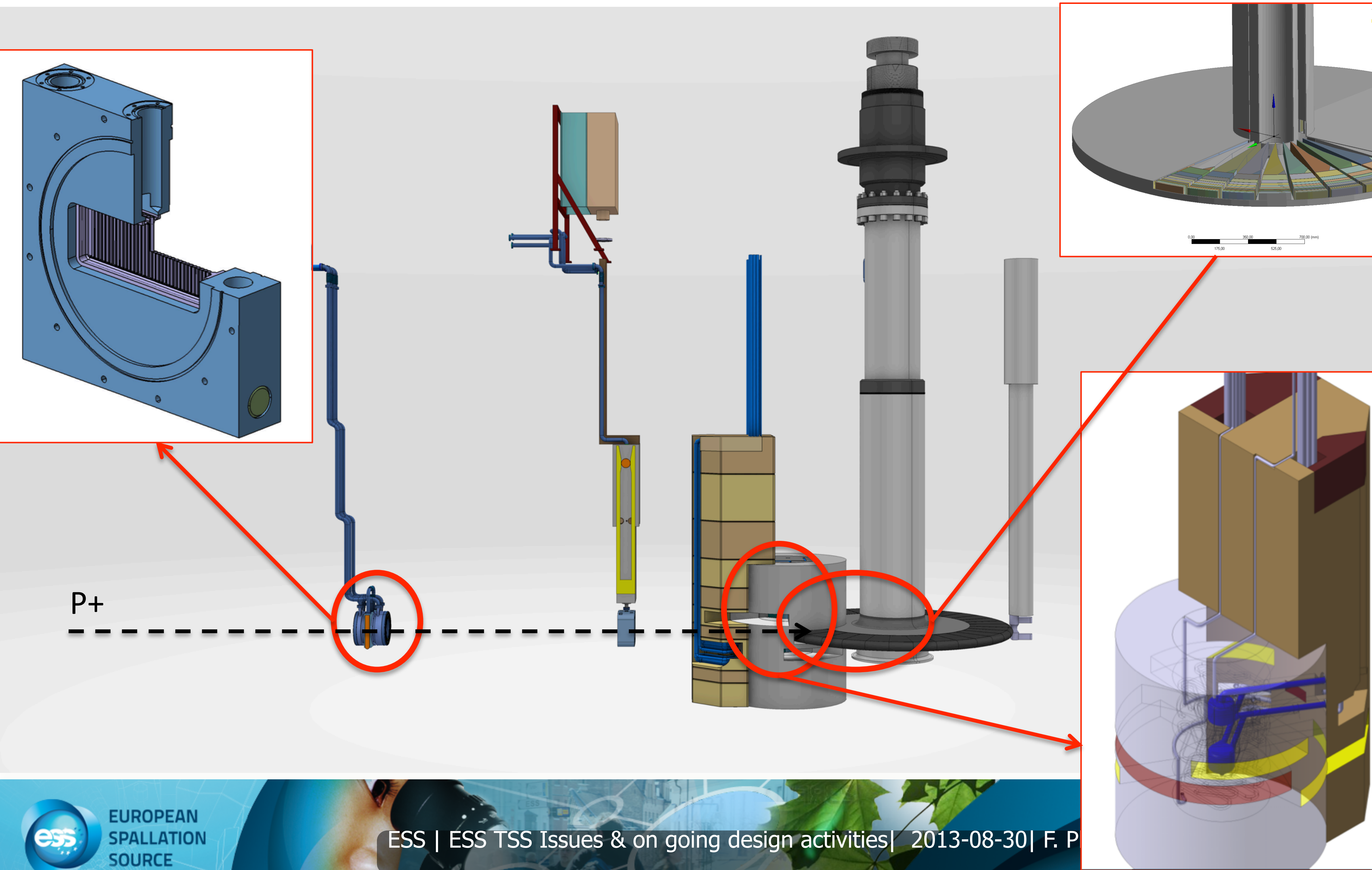
Target – Beam dump – other components highly activate by the beams (more and more accurate with high power accelerators…)

ESS Characteristics

- **5 MW** long pulse spallation source
  2.86 ms, 14 Hz, **pulses of protons**
- Cold or thermal /**cold moderators**
- Target proposal: **Rotating W; 5-10 years lifetime**
  He gas cooling
  (water as backup)
- 48 possible beam line positions
- **22 instruments**
- 450 - 500 employees
- **Receiving 2000-3000 users / y**
- **Located in a 100.000 inhabitant area**



ESS Target Station



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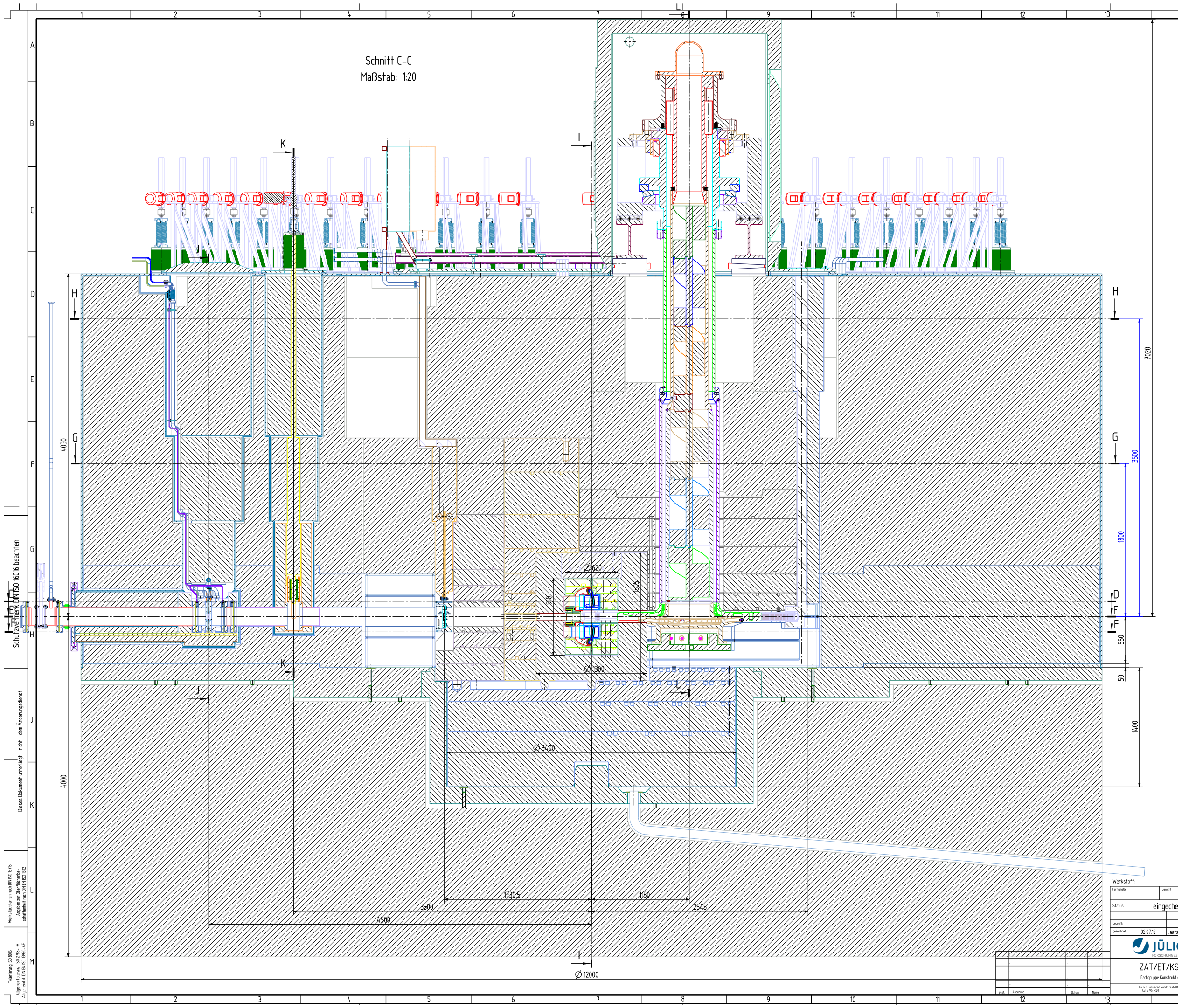
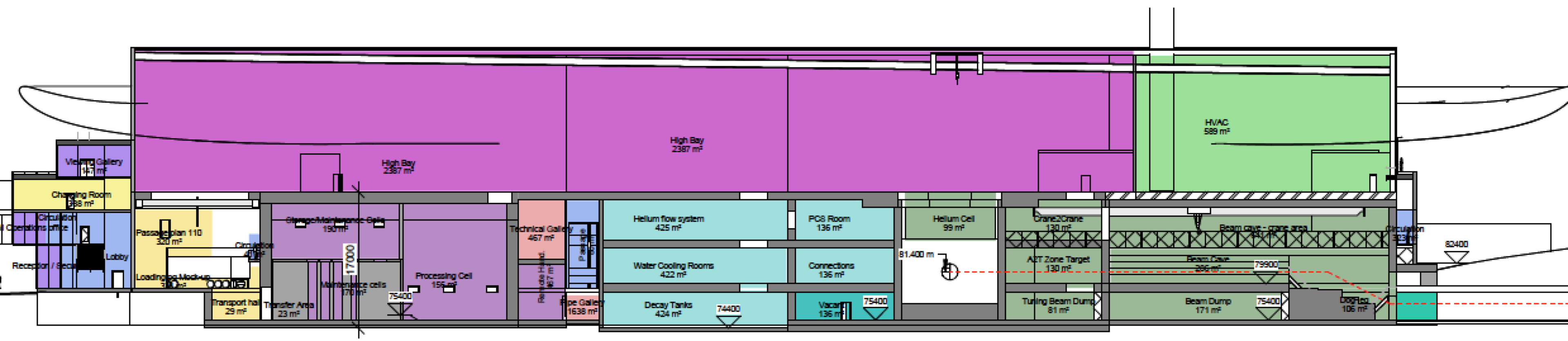
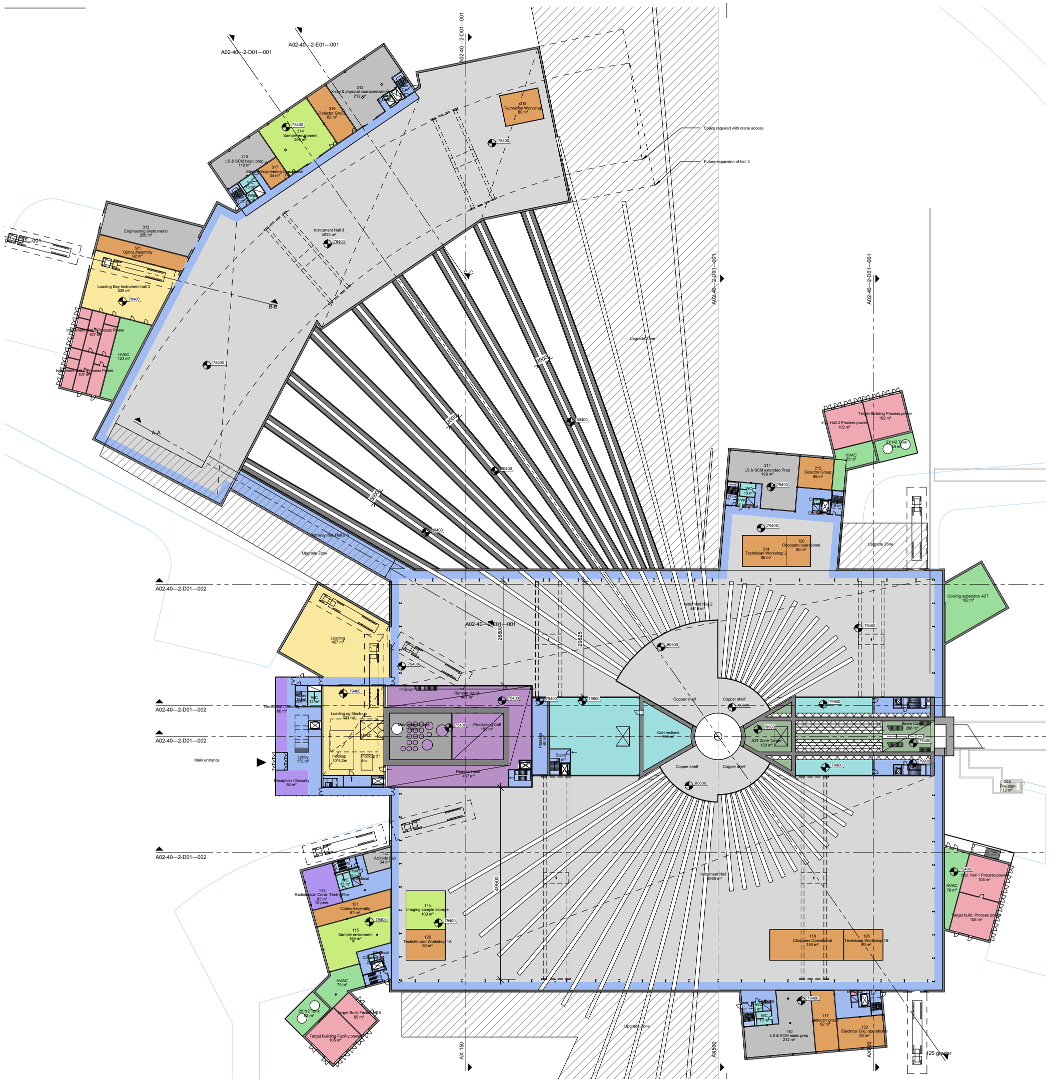


ESS Target Station



ESS Target Station & Experimental halls



ESS Target Station – TSS barriers

Stop energy production

-> p+ beam shut down

Evacuate stored/potential energy

-> After heat management

-> Evacuate H2 inventory

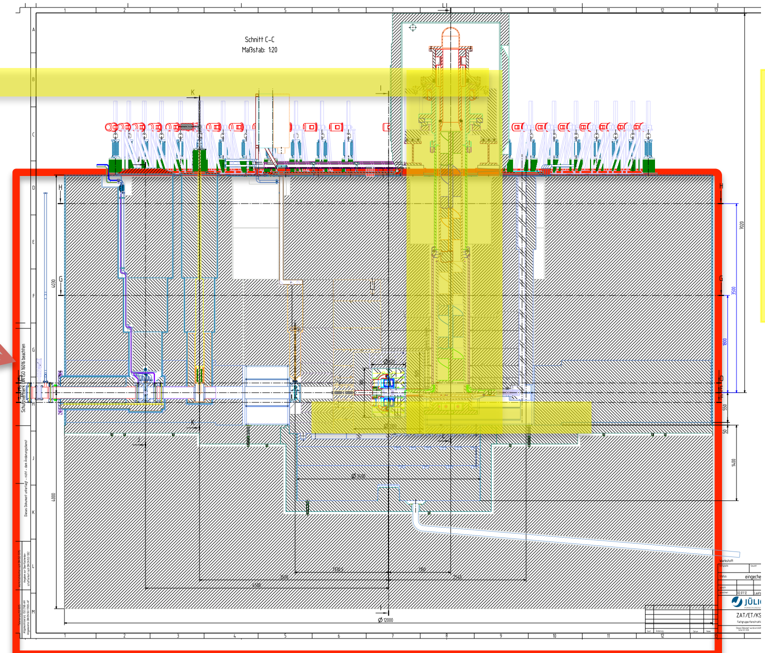
Confine radioactive material

-> Isolation of some active circuits

-> Dynamic confinement

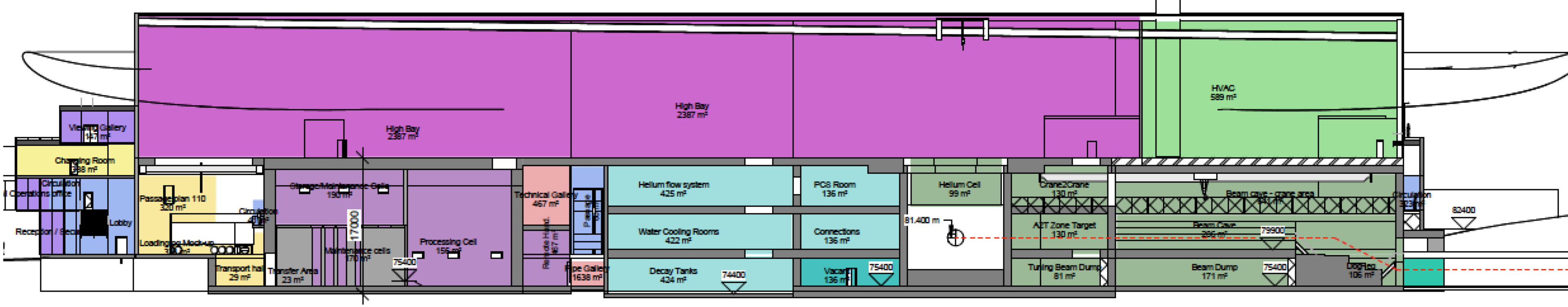
ESS Target Station – TSS actions

2[nd] confinement barrier: **monolith liner**



1[st] confinement barrier: target circuit

3[rd] confinement barrier: **TS building**



TSS – example of actions

Hazards	Initiating events	Top Event	Consequences	triggers	Prob	Sev	RR	Barriers	Cat	Sys
Cryogen - Hydrogen	Mechanical failure - Structural problem of the circuit itself - Mechanical stresses (temperature changes possibly start-up/shut-down) -Irradiation damage to material - Circuit pump failure	T.2. Cryogenic circuit H2(l) ruptures in connection cells	H2 mixes with air forming an explosive atmosphere outside the monolith in the connection cells where the circuit is drawn. This is a more severe consequence than if it happens inside monolith due to the potential air mixing with H2. Ignition and explosion. Damage target wheel	Pressure sensors in H2 circuit and vacuum guard	H3	Maj		Stopping of the flow in circuit - Valves on cryogen circuits that can be shut off to mitigate on leakage - Target instrumentation - detecting broken vacuum - Automatic shutdown of proton beam		TSS

Inputs and outputs for the TSS
Categorization of functions
Classification of TSS systems
Global analysis and reliability analysis = Architecture (redundancy)

Safety analysis

Hazards	Initiating events	Top Event	Consequences	Triggers	Risk Ranking - Before Safety Barriers			Barriers
					Prob	Sev	RR	
Water	pump malfunction, loss of control, valve closure, temperature increase, fluid niugress fro intermadiate cooling loop	M1. pressure increase in the circuit	damages on mechanical components (incl. vessels, pipes, and sensors)	pressure sensor 1 (outside monolith)	frequent	Major	5	pressure relieve valve (passive) in the thermal mod circuit - mechanical design, MPS system stops the proton beam
Water	pump malfunction, loss of control, valve closure, temperature increase, fluid niugress fro intermadiate cooling loop	T1. pressure increase in the circuit	leak of active water in He monolith atmosphere, on target vessel, loss of coolant for the Thermal mod., water leak in the utility rooms, increase of heat deposition in cold mod. - check the hot spot increase in the Be moderator in case of loss of water in the thermal mod. (acting as a protective layer). cracks in the vacuum vessel of cold mod. leads to warm chock (He monolith) on cold vessel of cold mod.	pressure sensor 2 (outside monolith)	H1	mod		pressure relieve valve (passive) in the thermal mod circuit - mechanical design, TSS system, proton beam stop

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Standard to be used

- IEC 61226: Instrumentation and control systems important to safety: This standard is used to assign the instrument and control functions of a nuclear power plant to one of three categories.

- IEC 61513: Instrumentation and control important to safety: This standard provides requirements and recommendations for the instrumentation and control of systems important to the safety of nuclear power plants.

- IEC 61511: Functional safety: Safety instrumented systems for the process industry sector.

- IEC 61508: Functional safety of electrical/electronic/programmable electronic (E/E/PE) safety-related systems

- IEC 60880: Instrumentation and control systems important to safety: This standard serves as a reference for IEC 61513, which deals with the system aspects of high integrity computer-based I&C used in safety systems of nuclear power plants

TSS – adopted standard

- IEC 61513: ”as far as necessary” (compare with 61508 ?)

- Any feed back or opinion about the use of this standard?

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Preliminary top level requirements

- "Normal method"

Risk categorization (classification)

\+

"Consequences"

global architecture & requirements

- Choices are already proposed for TSS…

Preliminary top level requirements

Safety category of functions following IEC 61226

- Category A – any function that plays a principal role in ensuring nuclear safety
- Category B – any function that makes a significant contribution to nuclear safety
- Category C – any other safety function (e.g. monitoring…)

Preliminary top level requirements

Single failure criterion :
- redundancy
- architecture
- independence
- physical separation adapted to different aggressors (zoning concept)
- electrical isolation

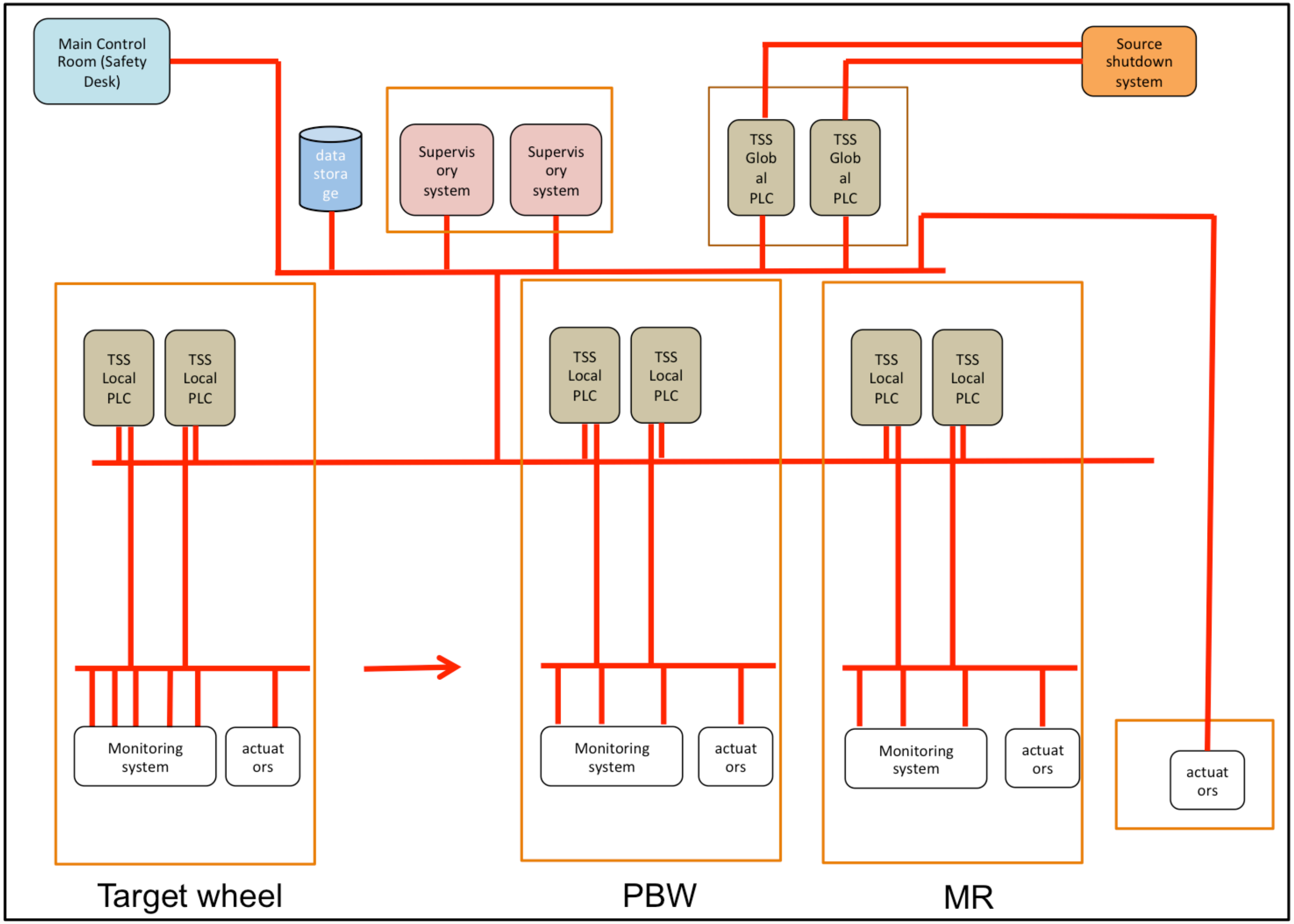
Fail safe principle:
- safe state must be clearly identified
- loss of power +> actuators to “safe position”
- actuators commands must be “de-energize to trip”

Emergency power supply ,especially for “monitoring” functions

Qualified for “extreme” operating conditions:

-> Seismic classification for a sub set of functions (“Seismic class”)

TSS architecture



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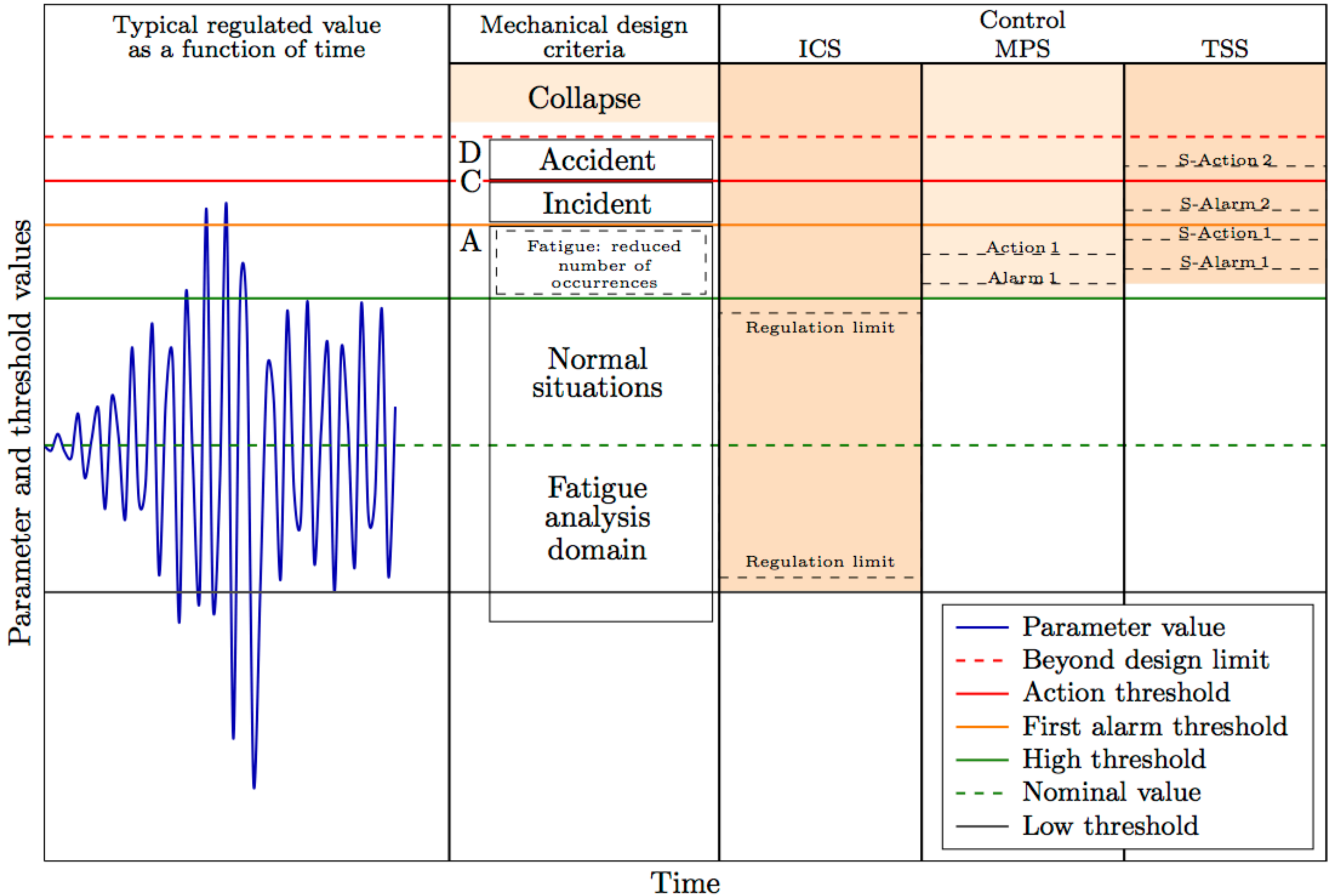
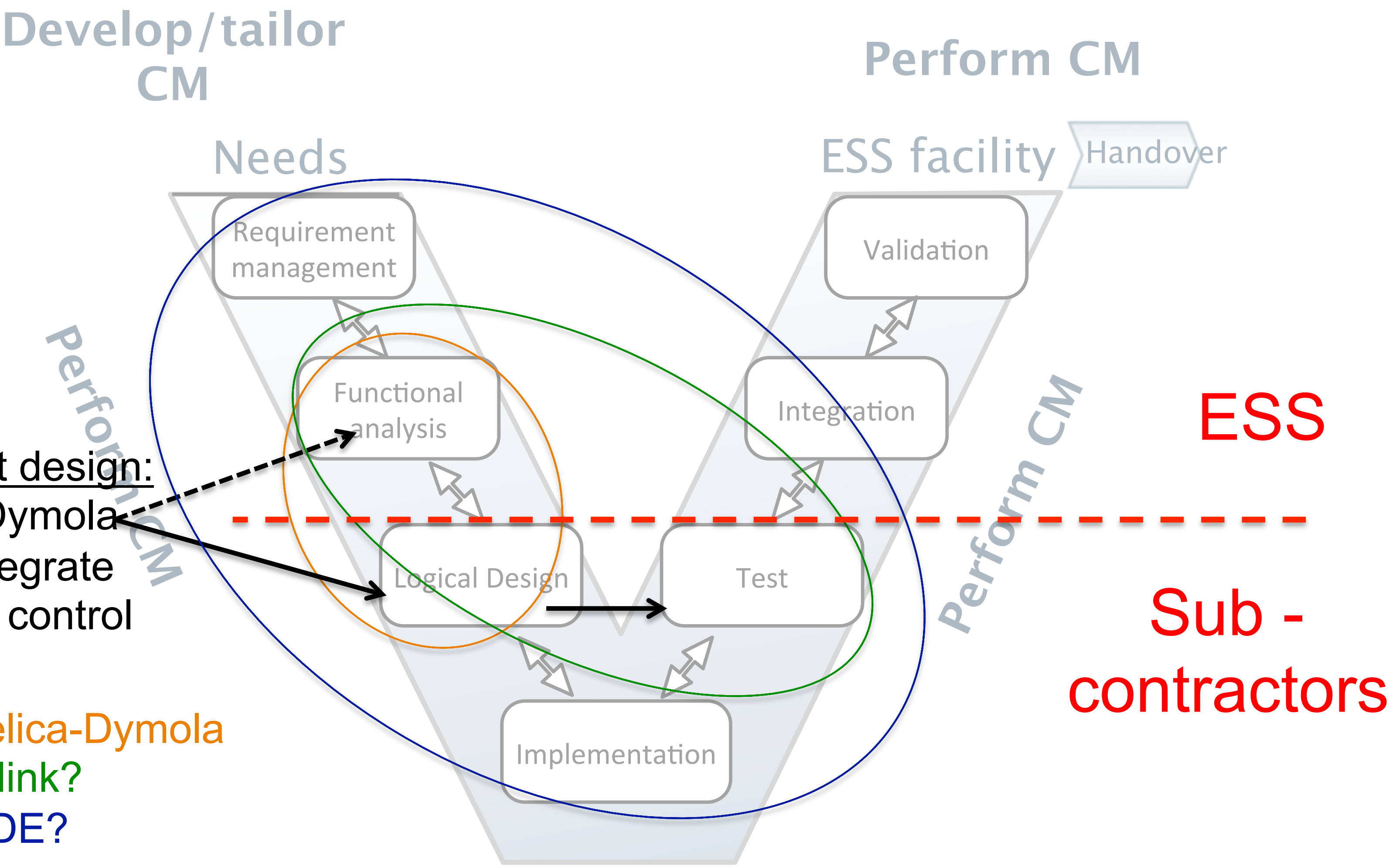
Relationship between ICS <-> MPS <-> TSS



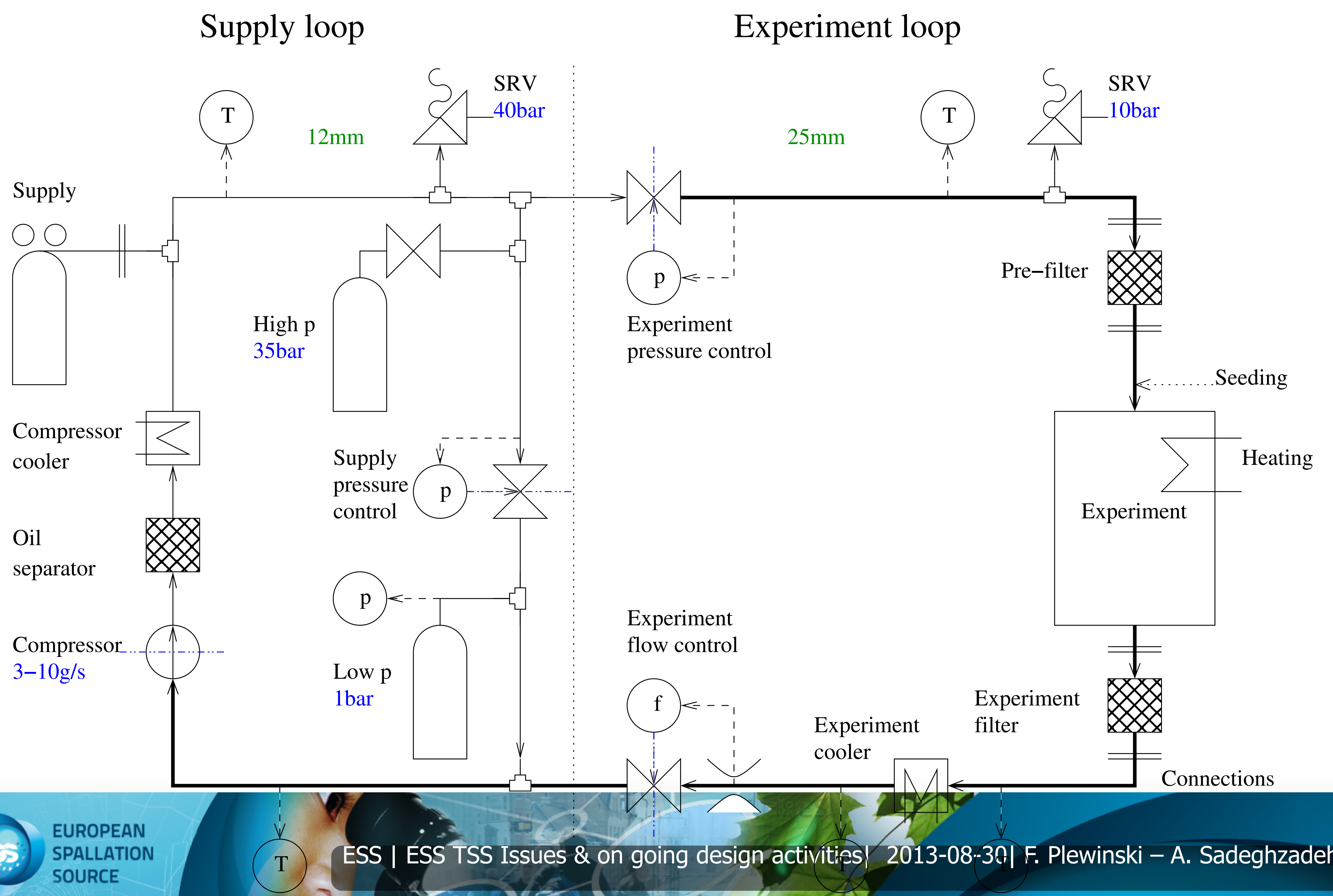
How to cover V cycle



Fluid circuit design:
Modelica-Dymola
(How to integrate associated control functions?)

- Modelica-Dymola
- Simulink?
- SCADE?

Test bench: He test loop



Lessons to be learned from the test bench

- Getting experience with the procedure of implementation of the safety control system which covers the hole life-cycle
- Follow standard
- Evaluate different instrumentation
- Evaluate services which is to be out-sourced
- Evaluate ESS team efforts all along the construction phase
- How to set thresholds of ICS/MPS/TSS
- …

Points for discussions

Standard and consequences:

- Cost
- Design
- sub-contractor “too short” list?

Design tools for efficient integration?

“Home made”/ “Sub-contracted tasks”?