

Personnel Safety Systems at ESS

Denis Paulic

PLC engineer, Personnel Safety Systems

ESS/ICS/PS

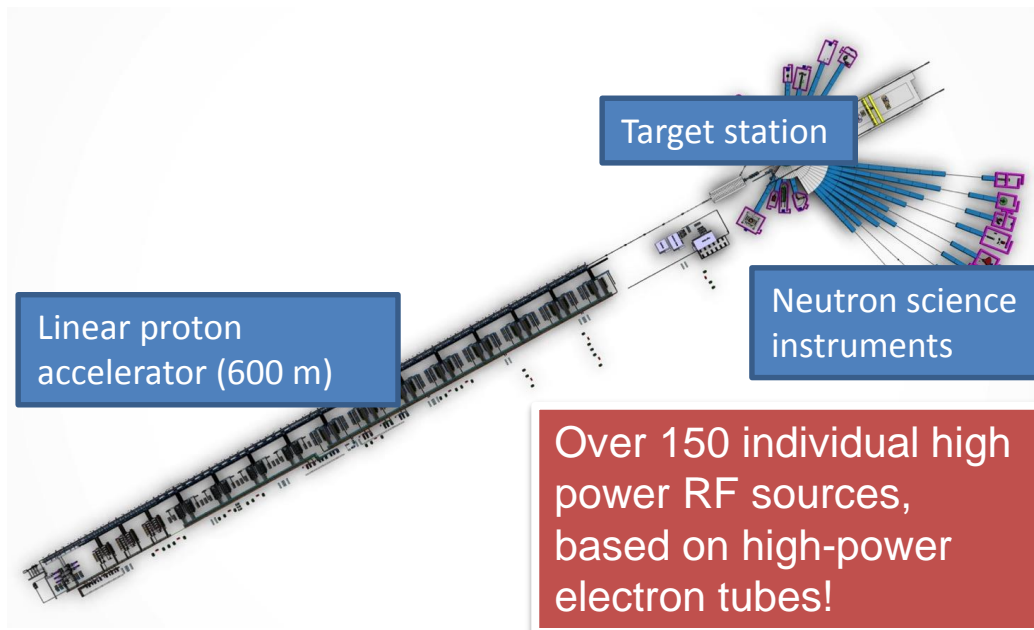
Date: 2016-02-01

Agenda

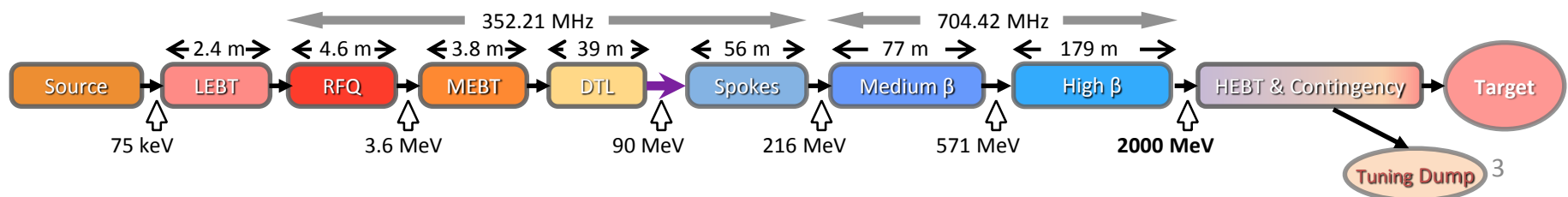
- Overview
- PSS scope of work
- PSS technical: standards, target risk and basic requirements
- PSS subsystems
- Accelerator PSS
- Methodology and implementation
- PSS planning for 2016.

ESS Overview

- The European Spallation Source (ESS) will house the most powerful proton LINAC ever built.



Parameter	Value	Units
Max energy	2	GeV
Peak current	62.5	mA
Repetition rate	14	Hz
Pulse length	2.86	ms
Average power	5	MW
RF frequency	352/704	MHz
Maximum losses	1	W/m



Hazards At ESS



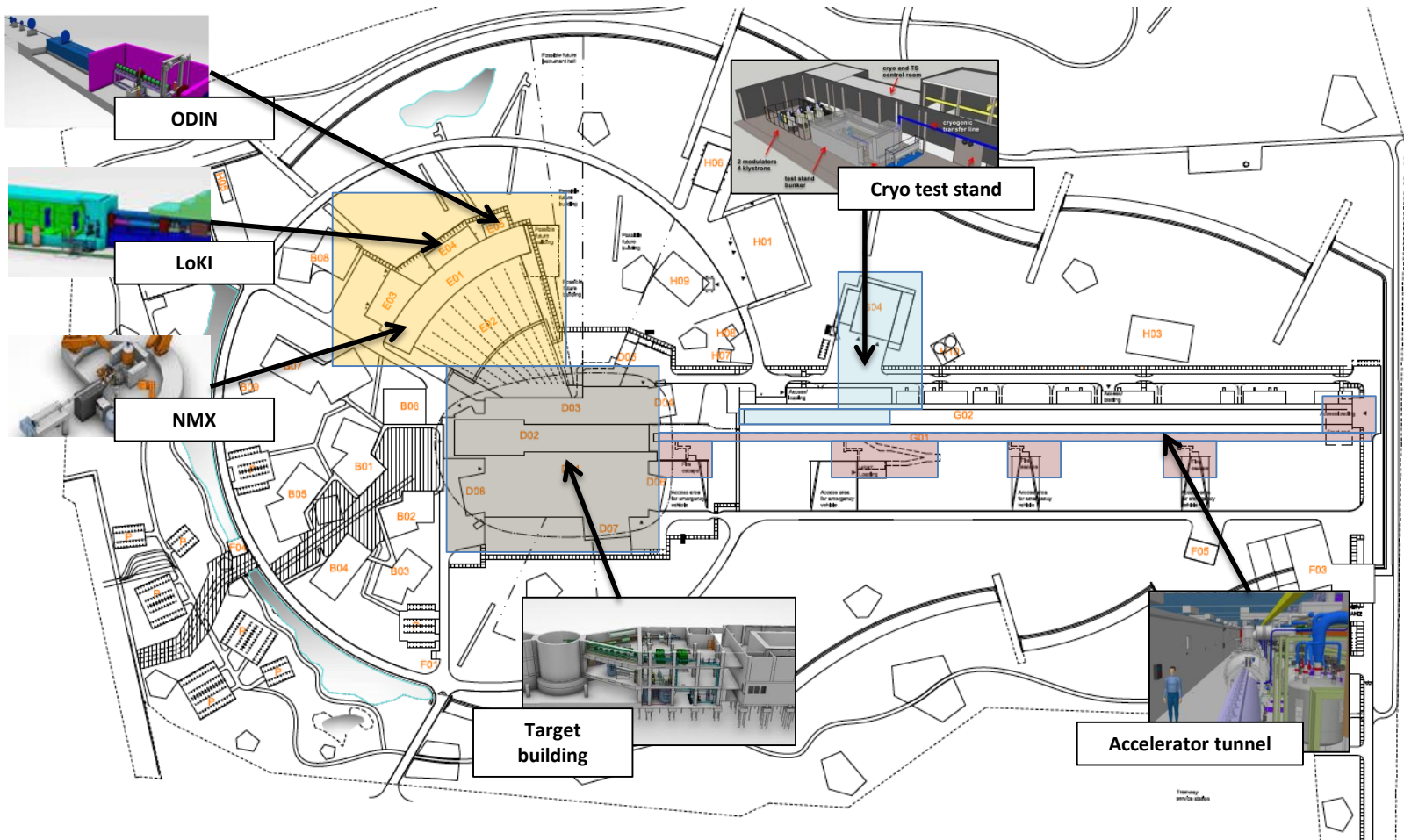
- Ionising radiation hazards:
 - Prompt
 - Beam Induced
 - Equipment induced (i.e. X rays in cavities)
 - Residual
 - Contamination
- Cryogenic hazards (direct exposure - burns, ODH)
- Electrical hazards
- Magnetic field hazards
- Laser hazards
- Motion hazards
- Gas hazards (Explosion, ODH)

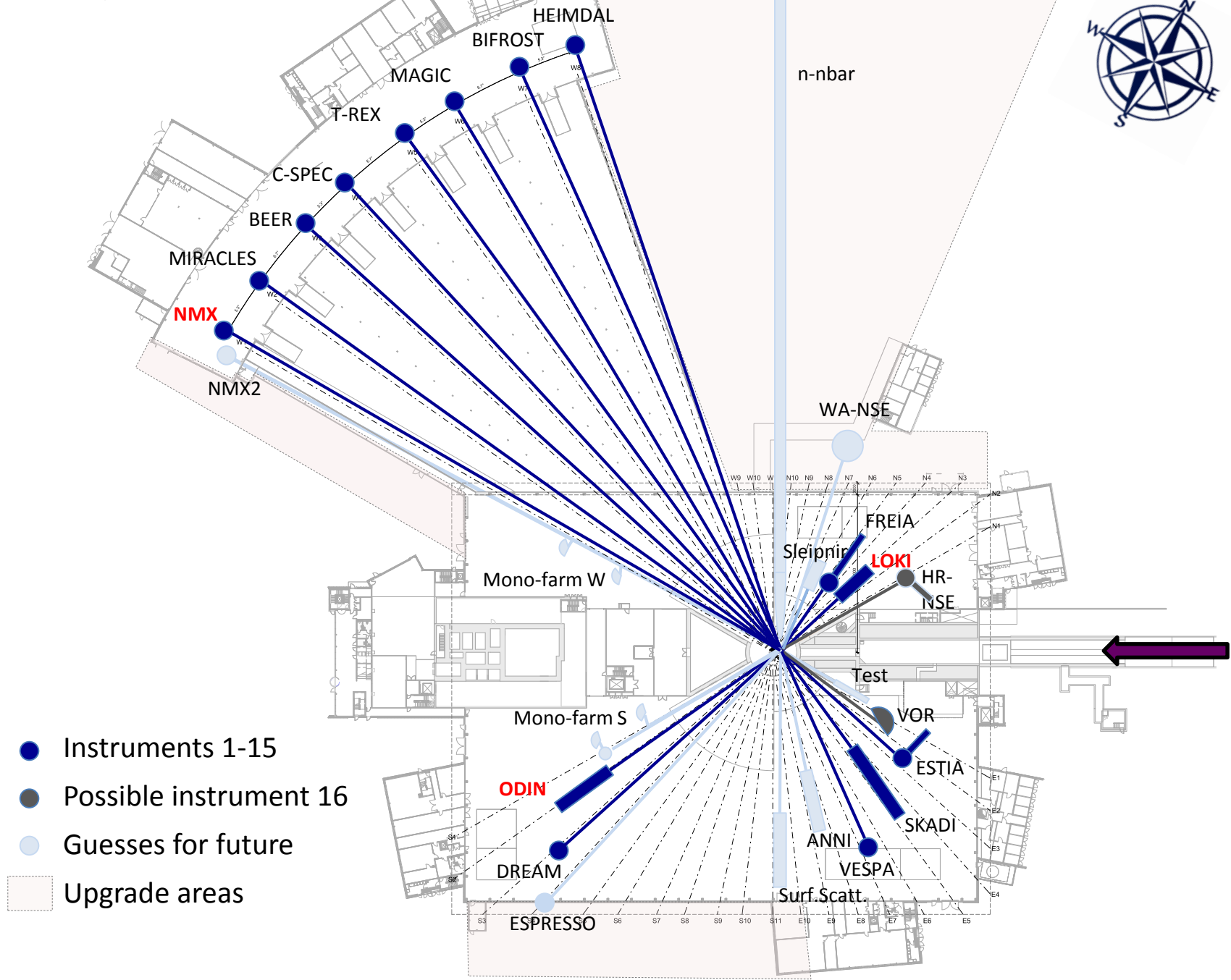
PSS primarily prevent both the public and workers from the facility's ionising radiation hazards, but also identify as well as mitigate against all other hazards!

PSS Scope Of Work

- November 2014, approved by both Change Control Board and ESS Programme Group (EPG).
- 10 initial systems for first beam to target in 2019:
 - The PSS for the on-site Cryogenic module test stand
 - The Accelerator Personnel Safety System
 - The Accelerator Radiation Monitoring System
 - The Accelerator Oxygen Depletion System
 - The Target Personnel Safety System
 - The Target Radiation Monitoring System
 - The Target Hot/Maintenance Cell Personnel Safety System
 - The Neutron Instrument LoKI Personnel Safety System
 - The Neutron Instrument NMX Personnel Safety System
 - The Neutron Instrument ODIN Personnel Safety System

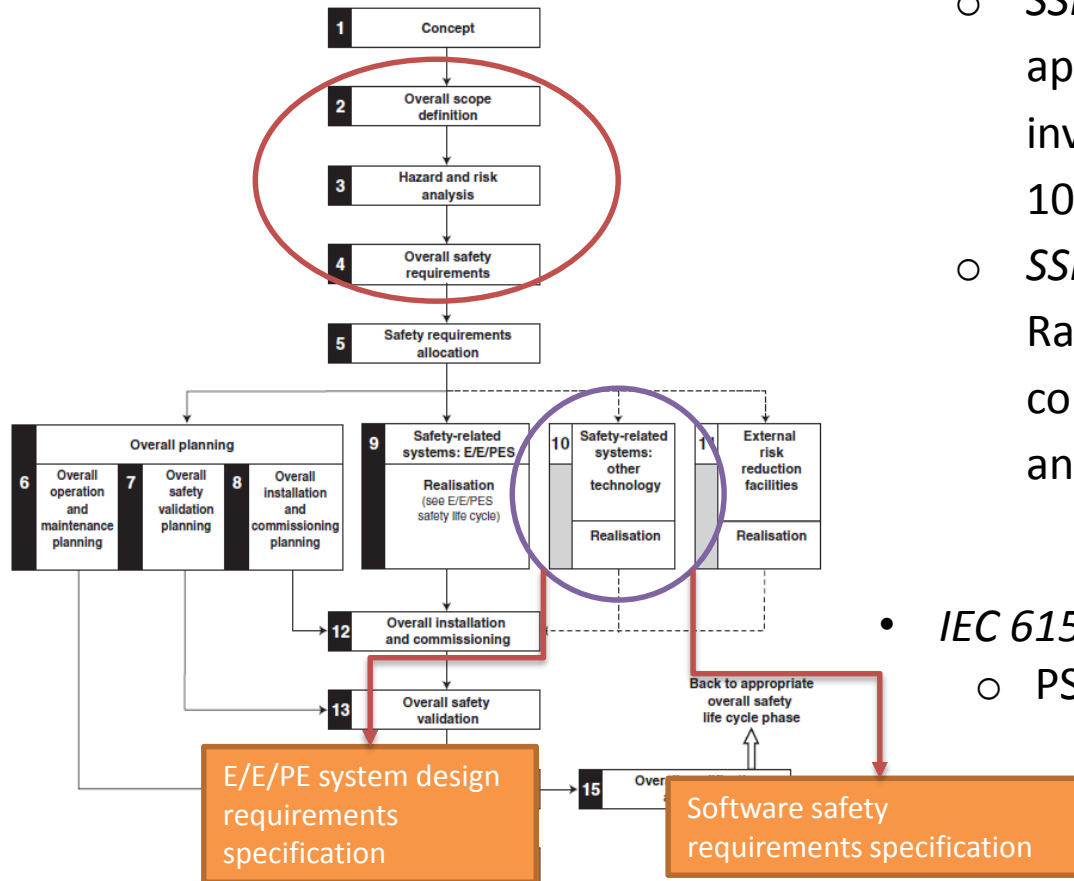
PSS Scope Of Work





- Instruments 1-15
- Possible instrument 16
- Guesses for future
- Upgrade areas

- IEC 61508 : 2010



- The Swedish Radiation Authority (SSM)
 - SSM2014-127-1: “Review of application for licence for activity involving ionising radiation” chapter 10 “review of control systems”,
 - SSMFS 2008-27: The Swedish Radiation Authority’s “regulations concerning operations at accelerators and with sealed radiation sources”.
- IEC 61511 – new revision coming soon
 - PSS application software

Standards: SSM Summary

The PSS systems will be designed to take into account the following:

- **External events**
- **Single failure**
- **Common cause failure**
- **Redundancy**
- **Diversity**
- **Separation**
- Maintenance, design change and annual system testing of PSS will only be carried out during shutdown periods.
- **Radiation risk analysis** will be carried out before the facility is taken into operation.
- Design of the PSS will take into account the **risk analysis**.
- A **formalised search** of each PSS controlled area will be carried out before the facility is operated.
- **Two independent** technical design **solutions** will be used in each system.

Hazard Identification

Risk Management

Identify Hazard

Assess the Risk

Control the Risk

Is Risk acceptable

Operate system

Is system functioning

Continue operation

Decommission



ESS PSS HAZARD REGISTER.

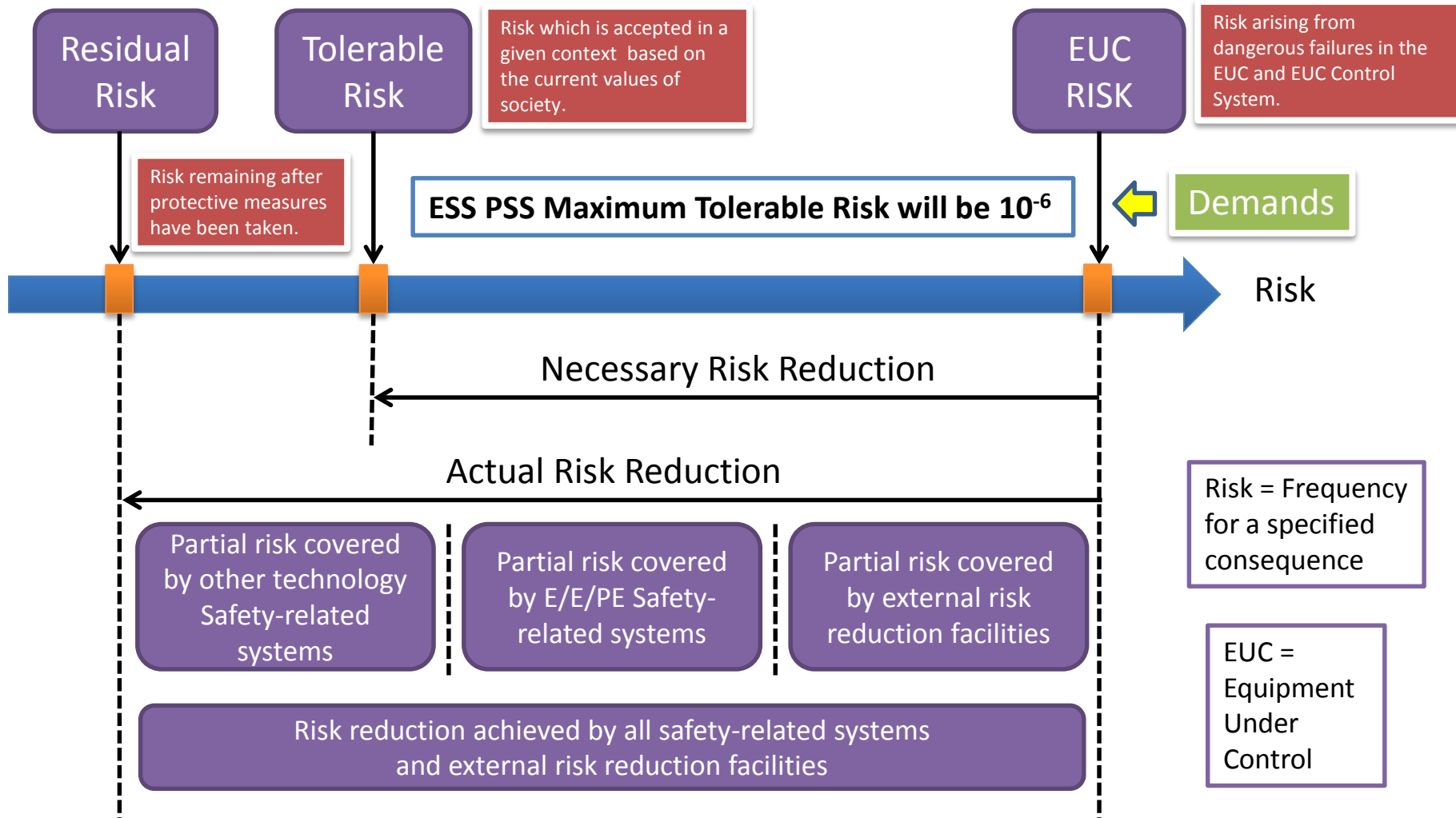
Hazard Number	Component Description	Location	Hazard	Hazard Value	Risk assessment number	Risk assessment Result	PSS Mitigation required Yes/No	Mitigation
1001	Accelerator Tunnel	Accelerator Tunnel	Personnel in accelerator tunnel when beam turned on. "Beam On" Ionizing Radiation				Yes	
1002	Accelerator Tunnel	Accelerator Tunnel	Personnel attempting to enter the accelerator tunnel when beam turned on. "Beam On" Ionizing Radiation				Yes	
1003	Proton Source	Accelerator Tunnel PSS (Zone 1) (Front end)	High voltage				Yes	Turn off High voltage
1004	Proton Source	Accelerator Tunnel PSS (Zone 1) (Front end)	High Voltage X rays				?	Turn off High voltage
1005	Electrode 1	Accelerator Tunnel PSS (Zone 1) (Front end)	High voltage				Yes	Turn off High voltage by removing incoming power to PSU
1006	Iris	Accelerator Tunnel PSS (Zone 1) (Front end)					No	
1007	Solenoid 1	Accelerator Tunnel PSS (Zone 1) (Front end)	High voltage				Yes	



ESS PSS EVENT REGISTER.

Event Number	Date	Event Description	Location	Event Hazard	Event Mitigation	IEC61508 Lifecycle Return	Modification Requirement	Modification carried out By	Modification Approved By:
1001									
1002									
1003									
1004									
1005									
1006									
1007									
1008									

Risk Model

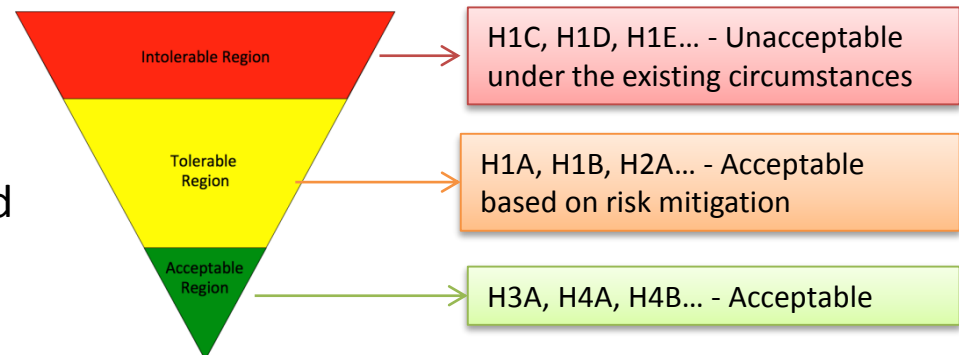


Stuart Birch, ESS-0047614

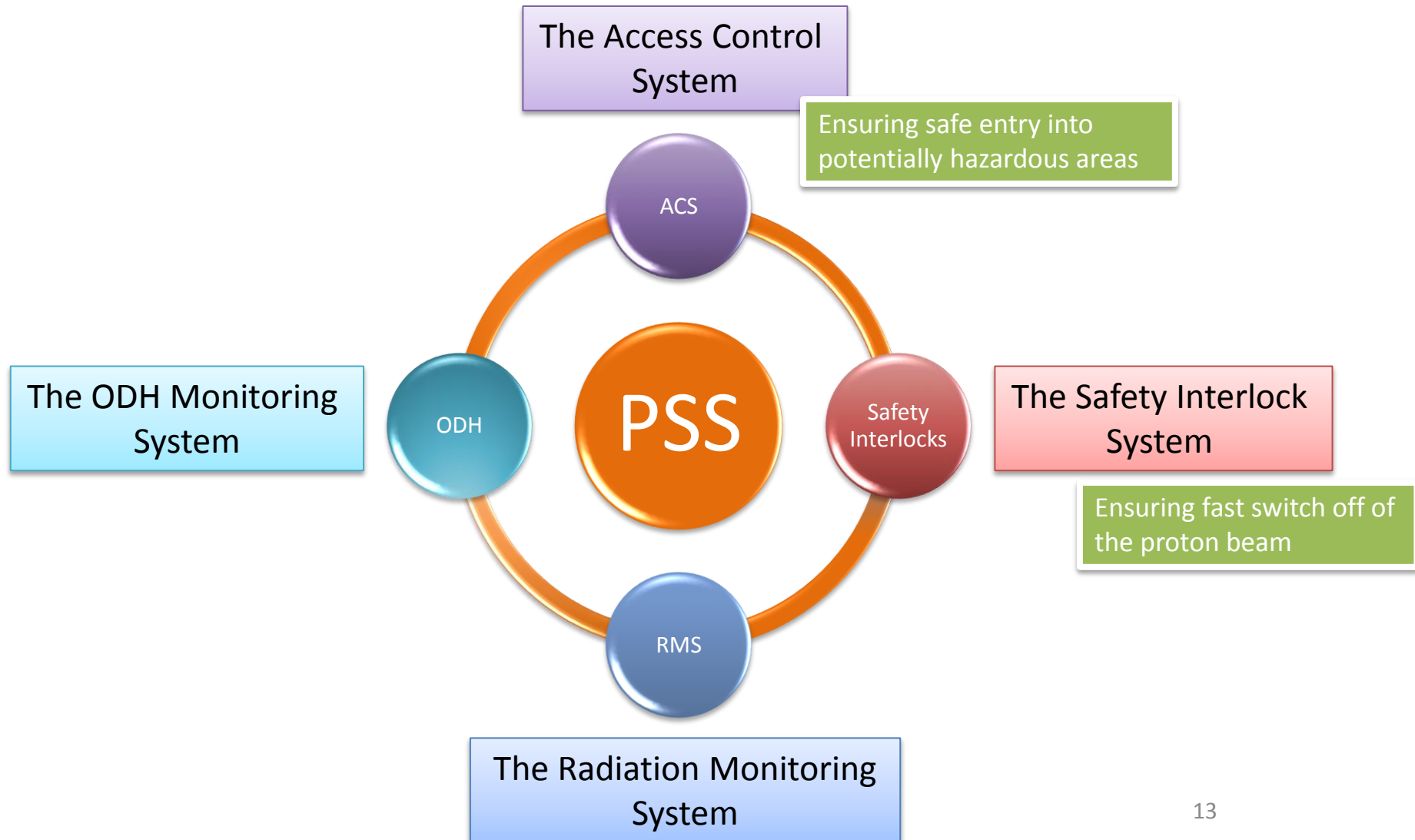
- SSM requirements for the Radiation safety functions will be identified and categorised in accordance with ESS-0016468 document.
 - IEC 61508 methodologies will then follow

Radiation Safety Function Risk Matrix			Consequence				
			Negligible	Minor	Major	Hazardous	Catastrophic
Likelihood			A	B	C	D	E
Probability			<2mSv	≥2mSv<10mSv	≥10mSv<20mSv	≥20mSv<50mSv	≥50mSv<200mSv
Frequent	H1	Normal Operation	H1A	H1B	H1C	H1D	H1E
Occasional	H2	>10 ⁻²	H2A	H2B	H2C	H2D	H2E
Remote	H3	>10 ⁻⁴ ≤10 ⁻²	H3A	H3B	H3C	H3D	H3E
Improbable	H4	>10 ⁻⁶ ≤10 ⁻⁴	H4A	H4B	H4C	H4D	H4E
Extremely Improbable	H5	≤10 ⁻⁶	H5A	H5B	H5C	H5D	H5E

- All other safety functions will be identified in accordance with IEC61508.



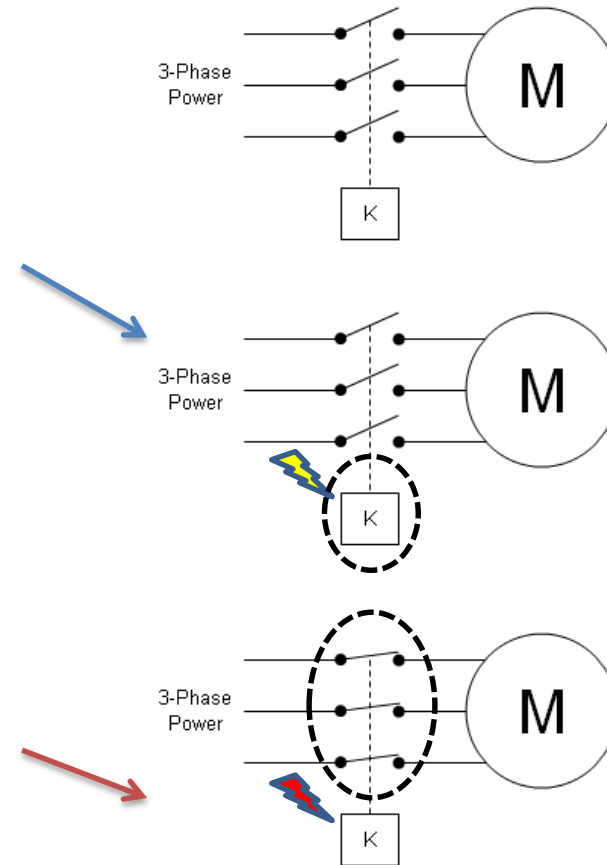
PSS Subsystems



Safety Interlock System - De-energise To Trip

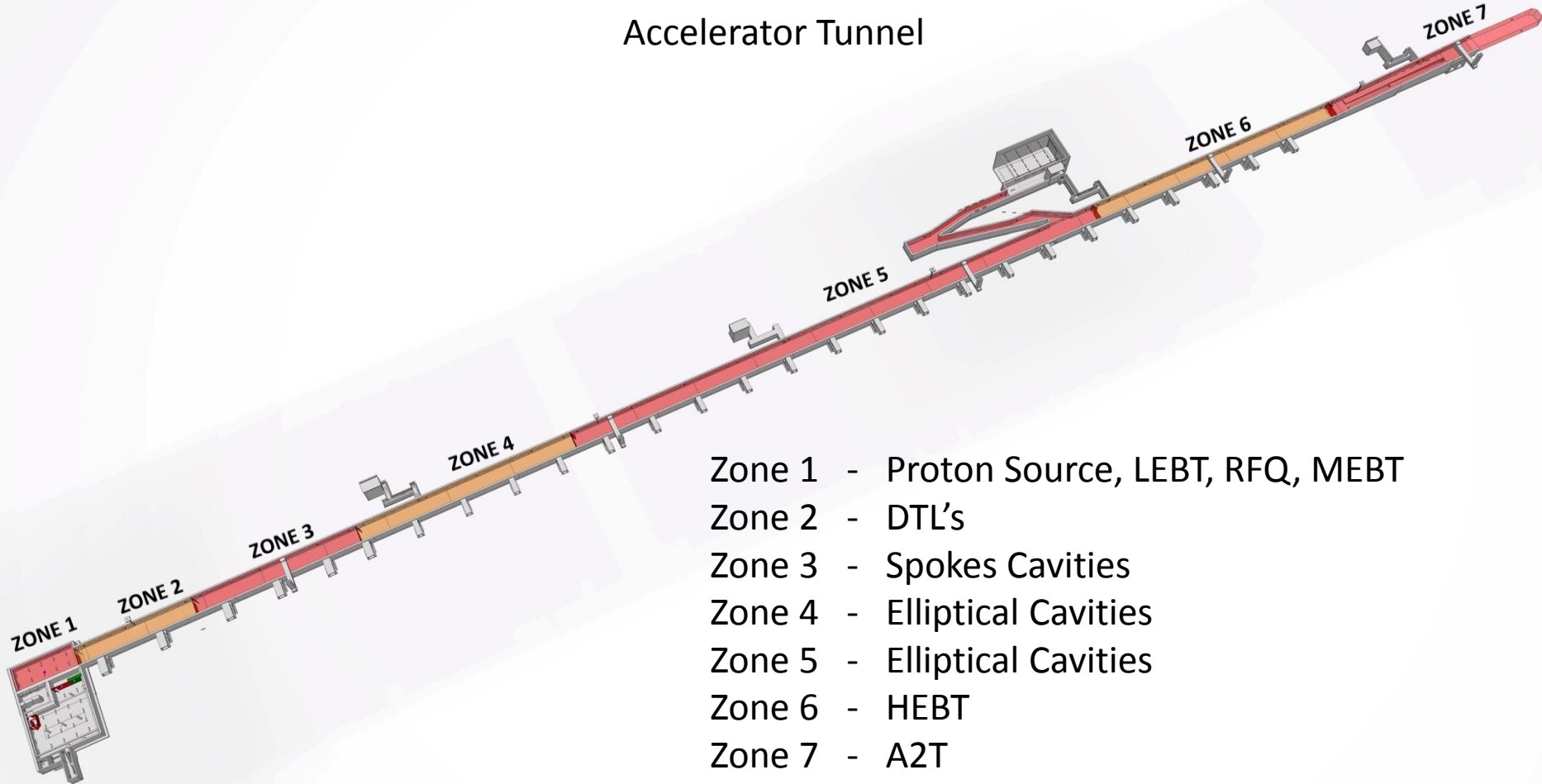
A loss of power to the coil will result in a spurious trip and loss of production... (Safe Failure) for specified Safety Function

Welded contacts will result in a failure to operate on demand (Dangerous Failure) for specified Safety Function



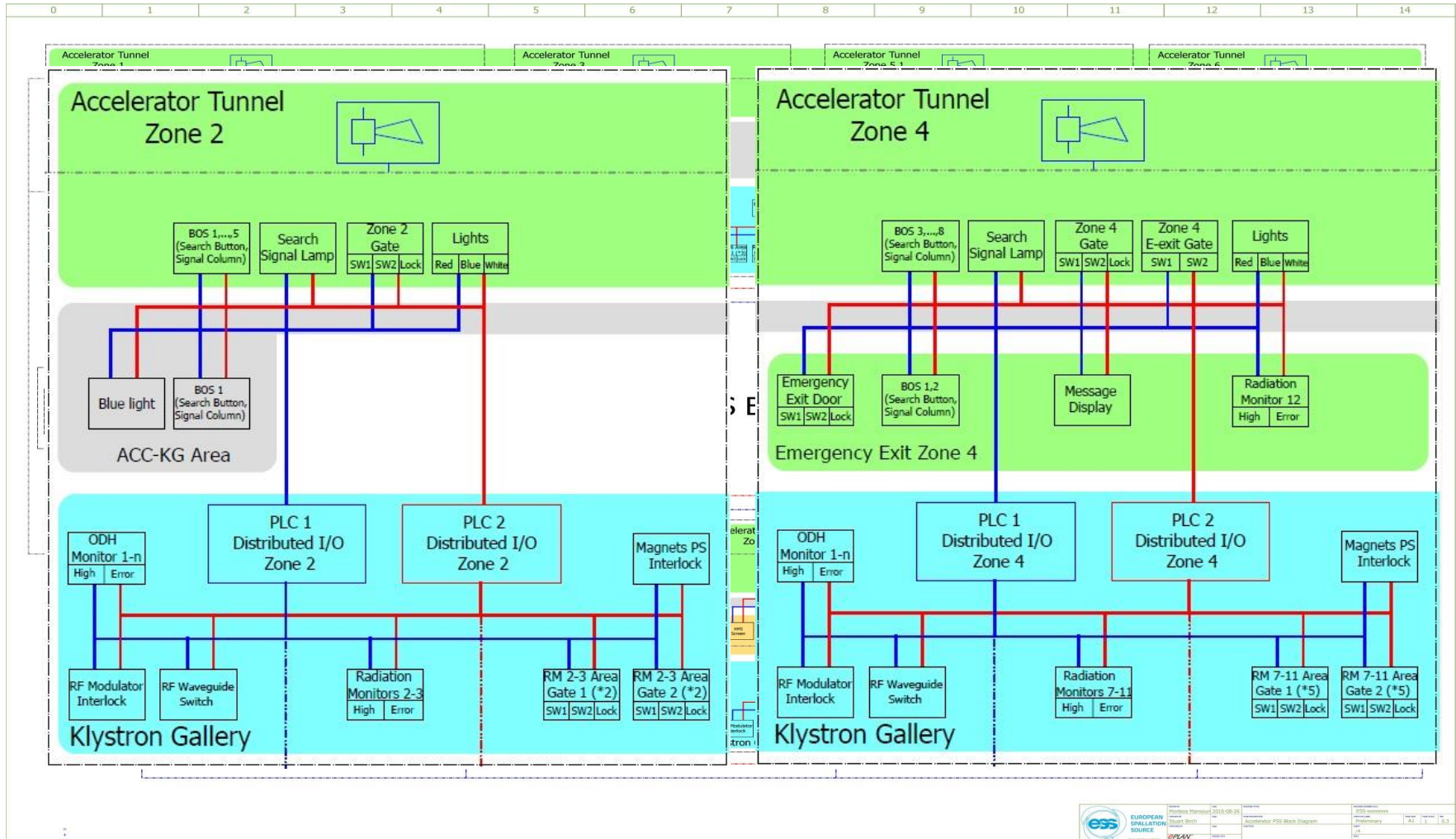
Accelerator PSS

Accelerator Tunnel

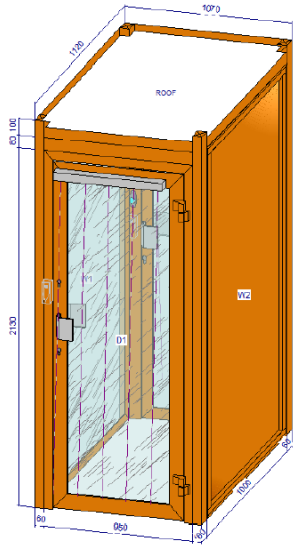


Gated fence between each zone.

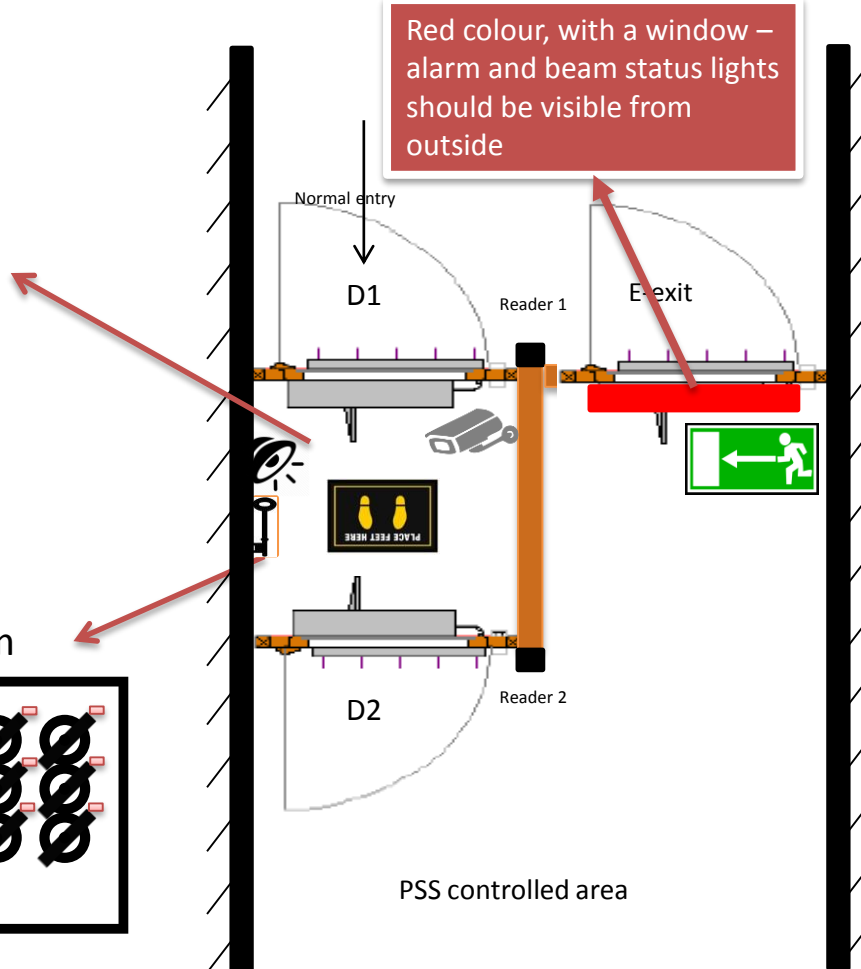
Accelerator PSS – FBD





ACS - Entry Station





Red colour, with a window – alarm and beam status lights should be visible from outside



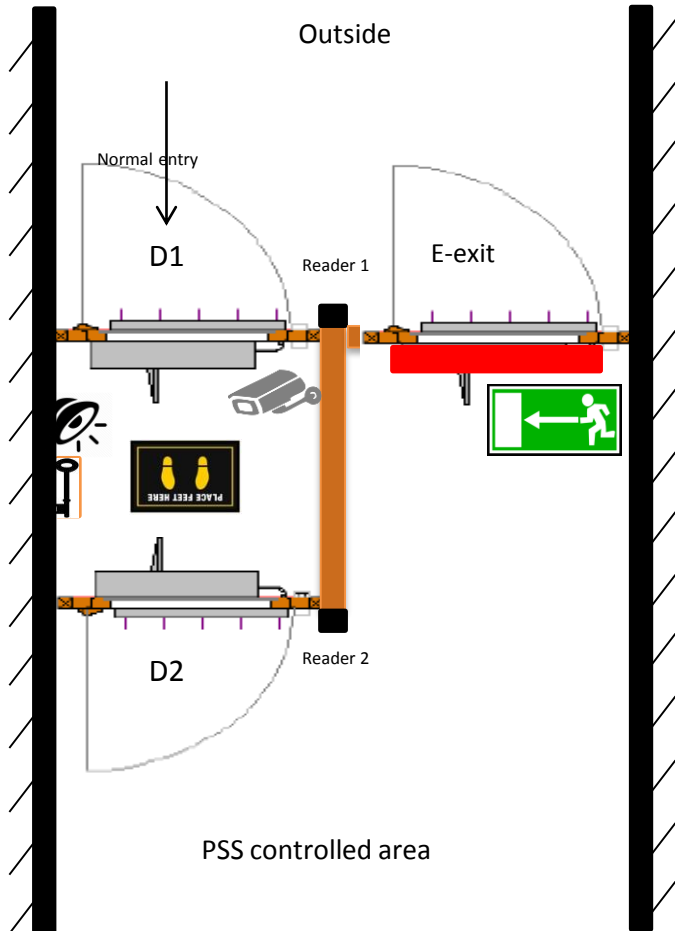
Door position monitoring
SIL 3 (IEC 61508):

- D1** RFID Safety Switch + actuator
- 
- Safety hinge switch
- 

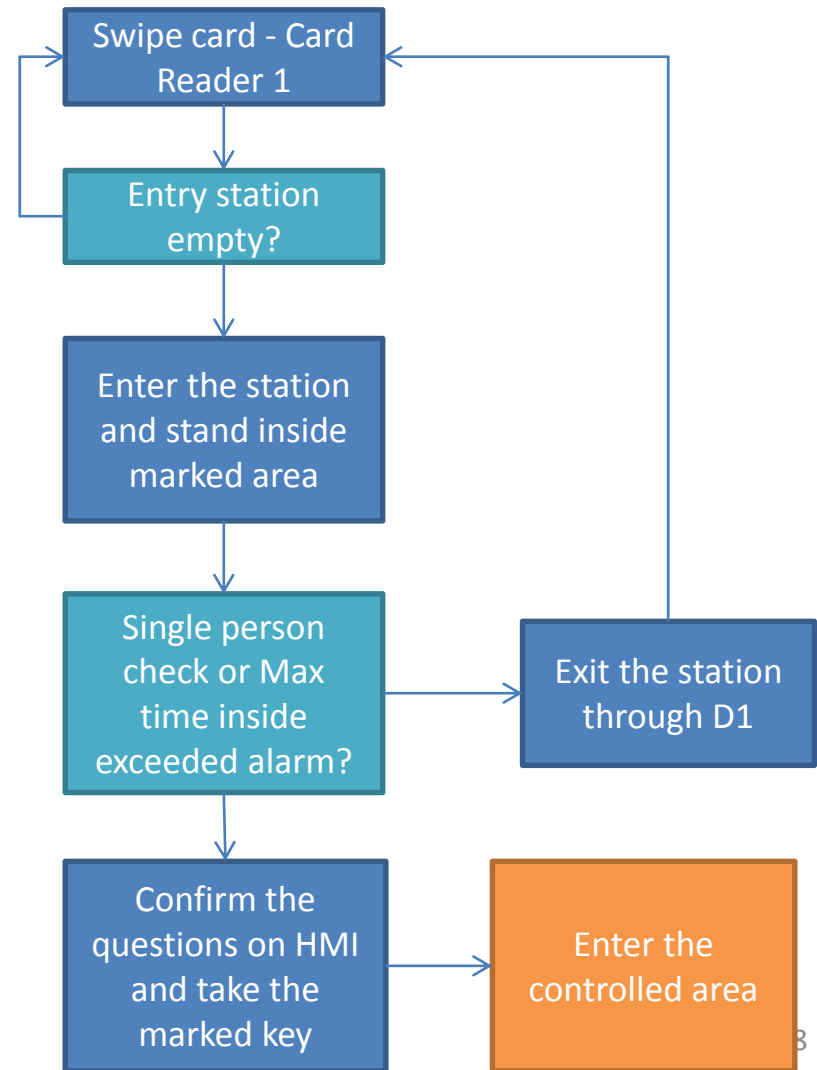
- D2** Magnetic Safety Switch
- 
- Safety hinge switch
- 

D1 cannot be unlocked at the same time as D2!

ACS - Entry Sequence

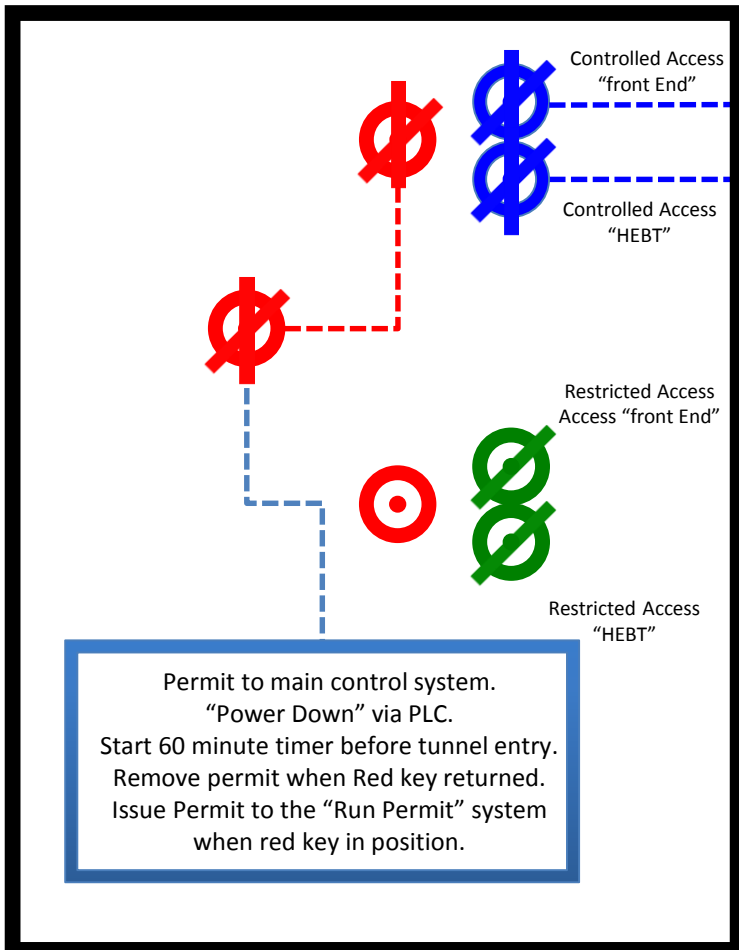


Entry:

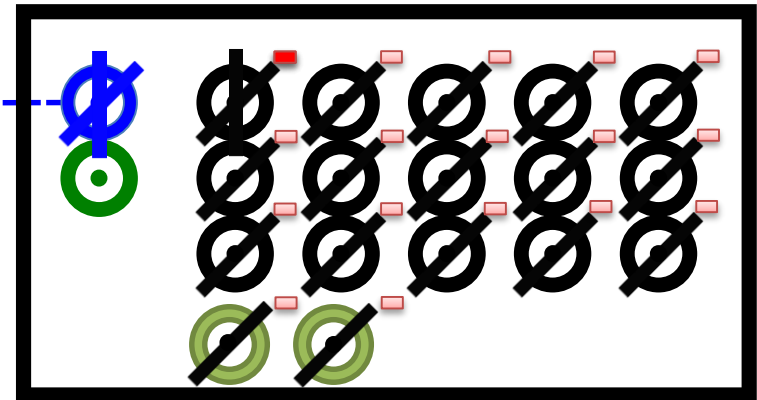


ACS - Key Exchange System

PSS Control Room



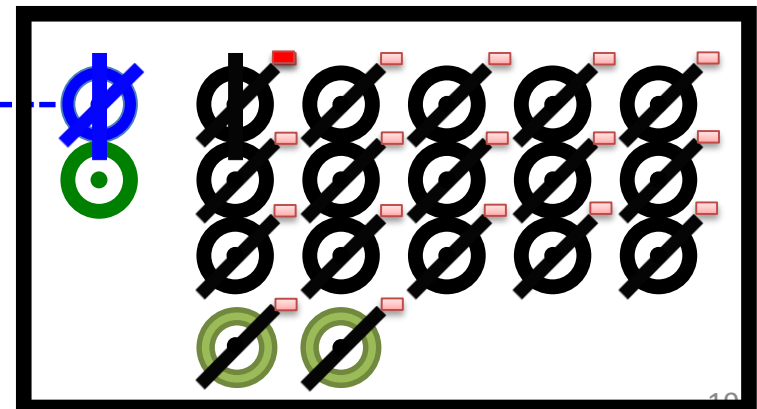
Front End Entrance Key Exchange



Action of taking blue key will lock the red key in position.
Red key will not be released until BOTH blue keys are returned to key exchange .

Action of taking black key will lock the blue key in position.
Blue key will not be released until LAST black key is returned to key exchange.

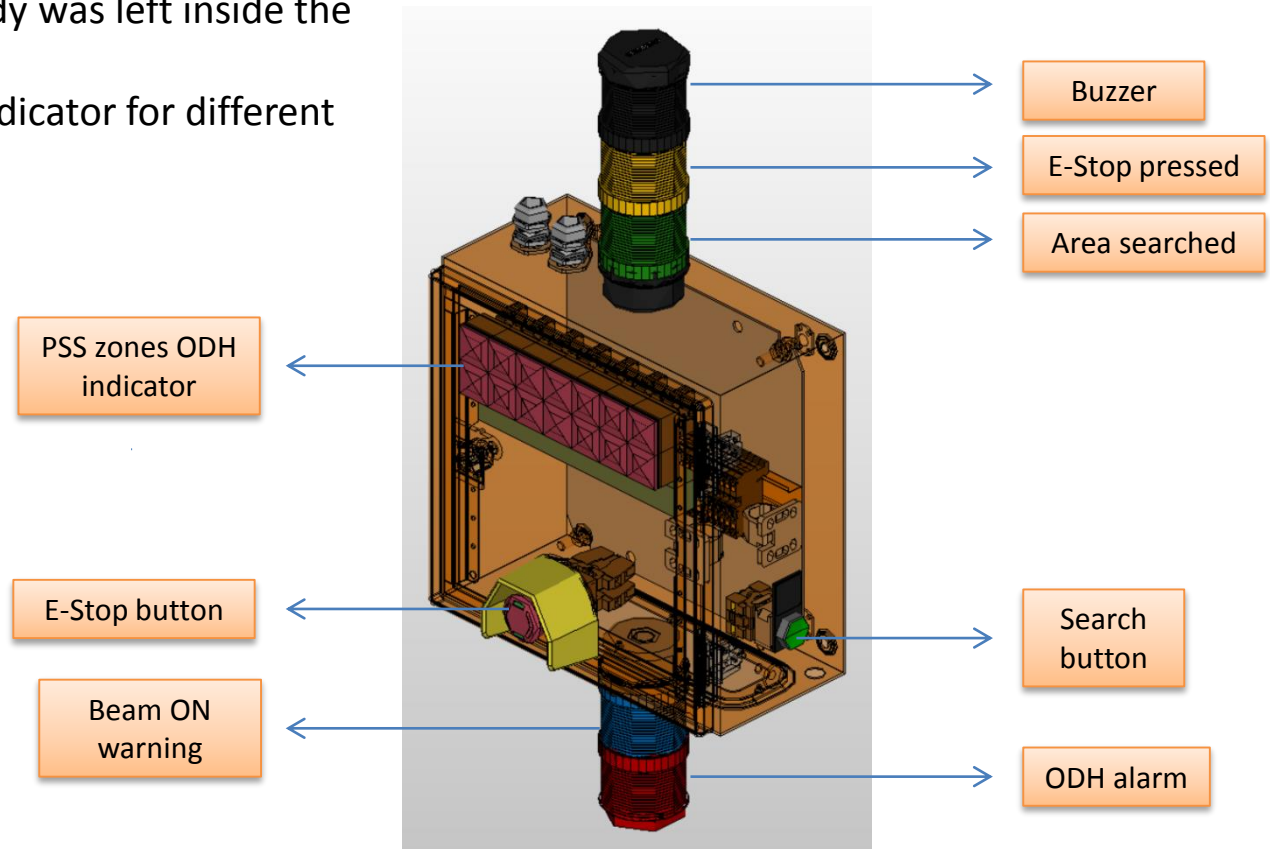
HEBT Entrance Key Exchange



- Controlled Access is regular access for authorised personnel.
- Search is broken on entry.

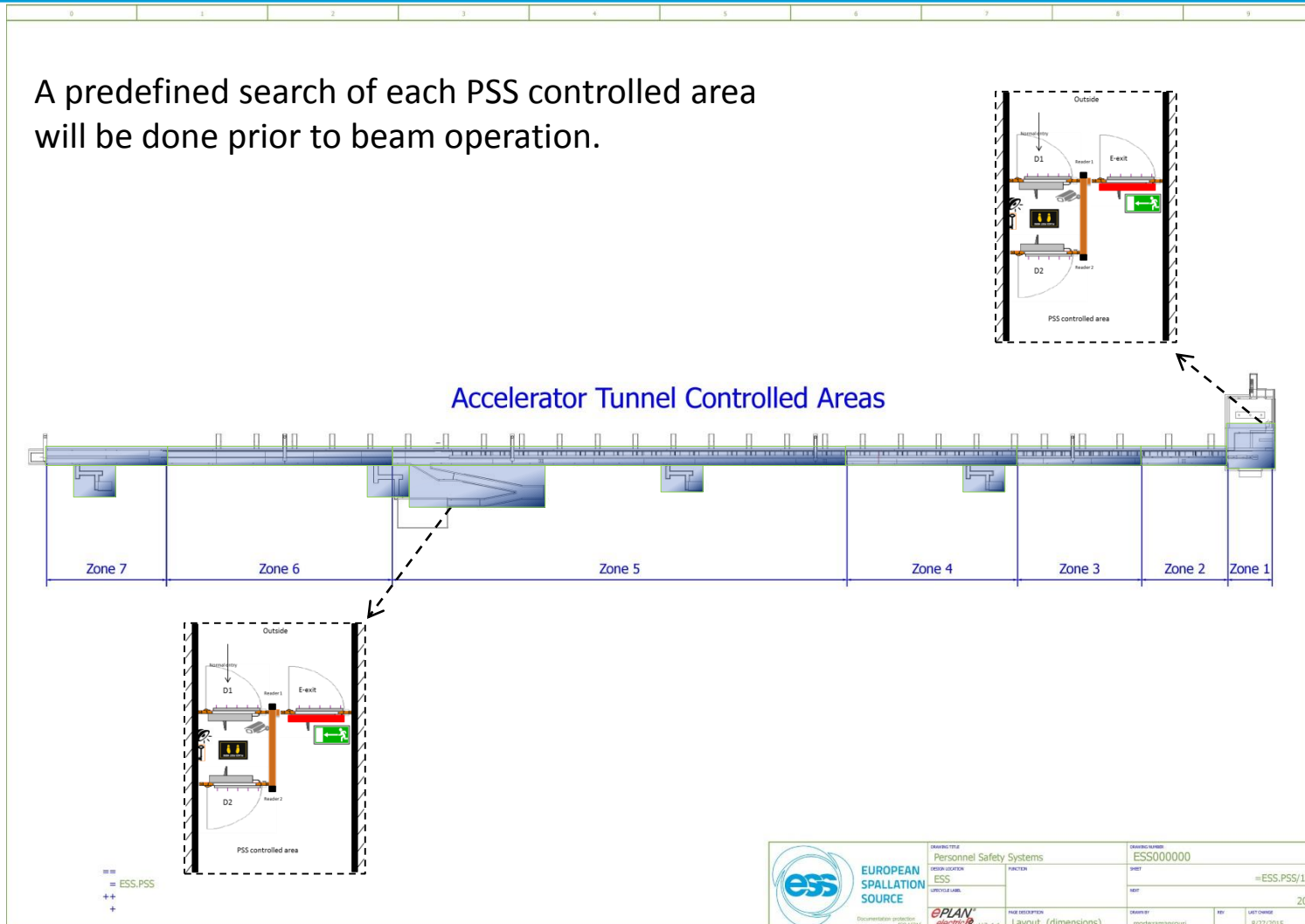
Safety Interlock System - Beam OFF Station

- Beam-off stations installed in 76 points of the accelerator tunnel to switch off the beam in case of emergency (e.g. somebody was left inside the tunnel during the search).
- Oxygen deficiency hazard indicator for different zones.
- Search button and siren.



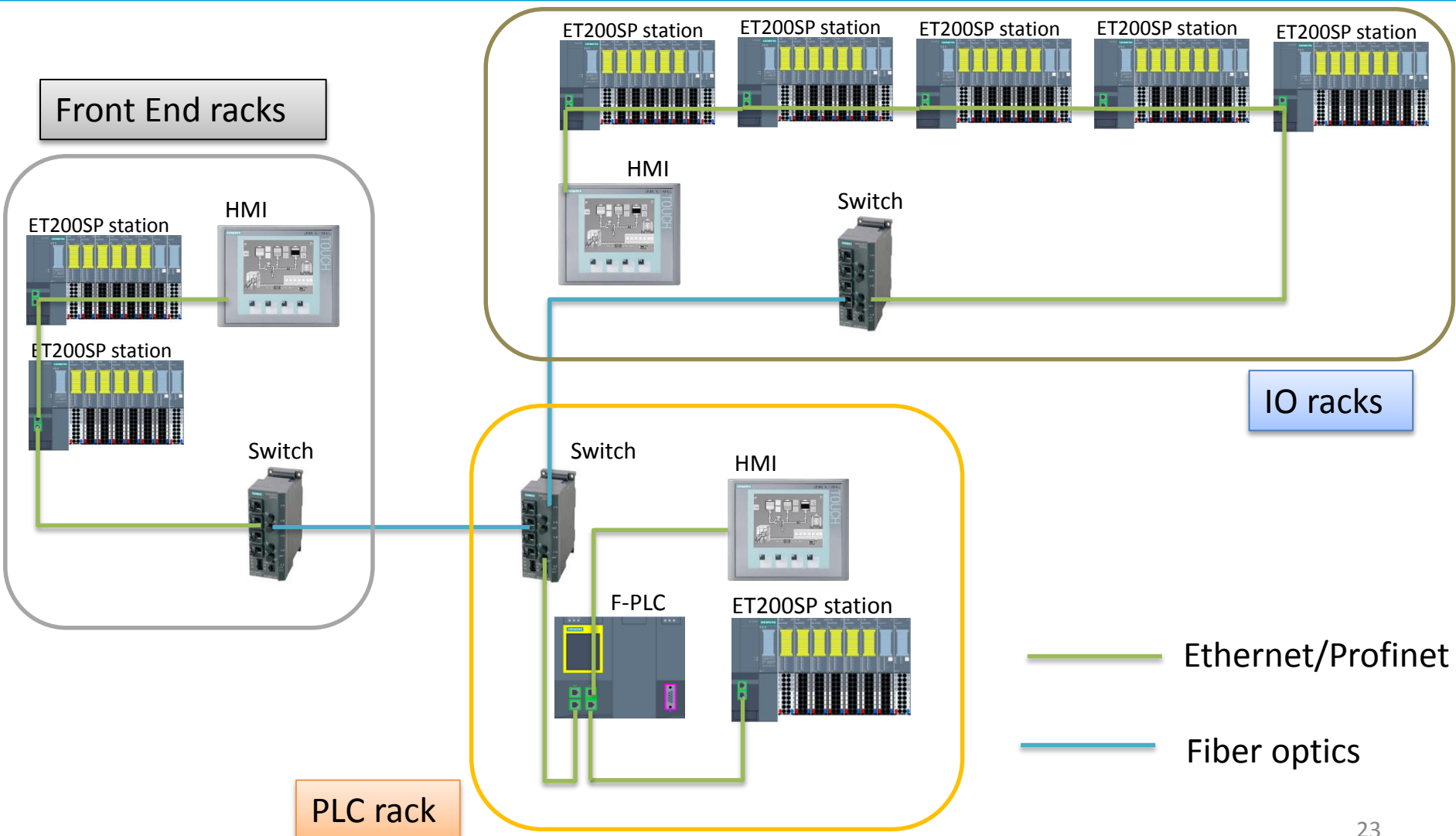
Search Patrol

A predefined search of each PSS controlled area will be done prior to beam operation.

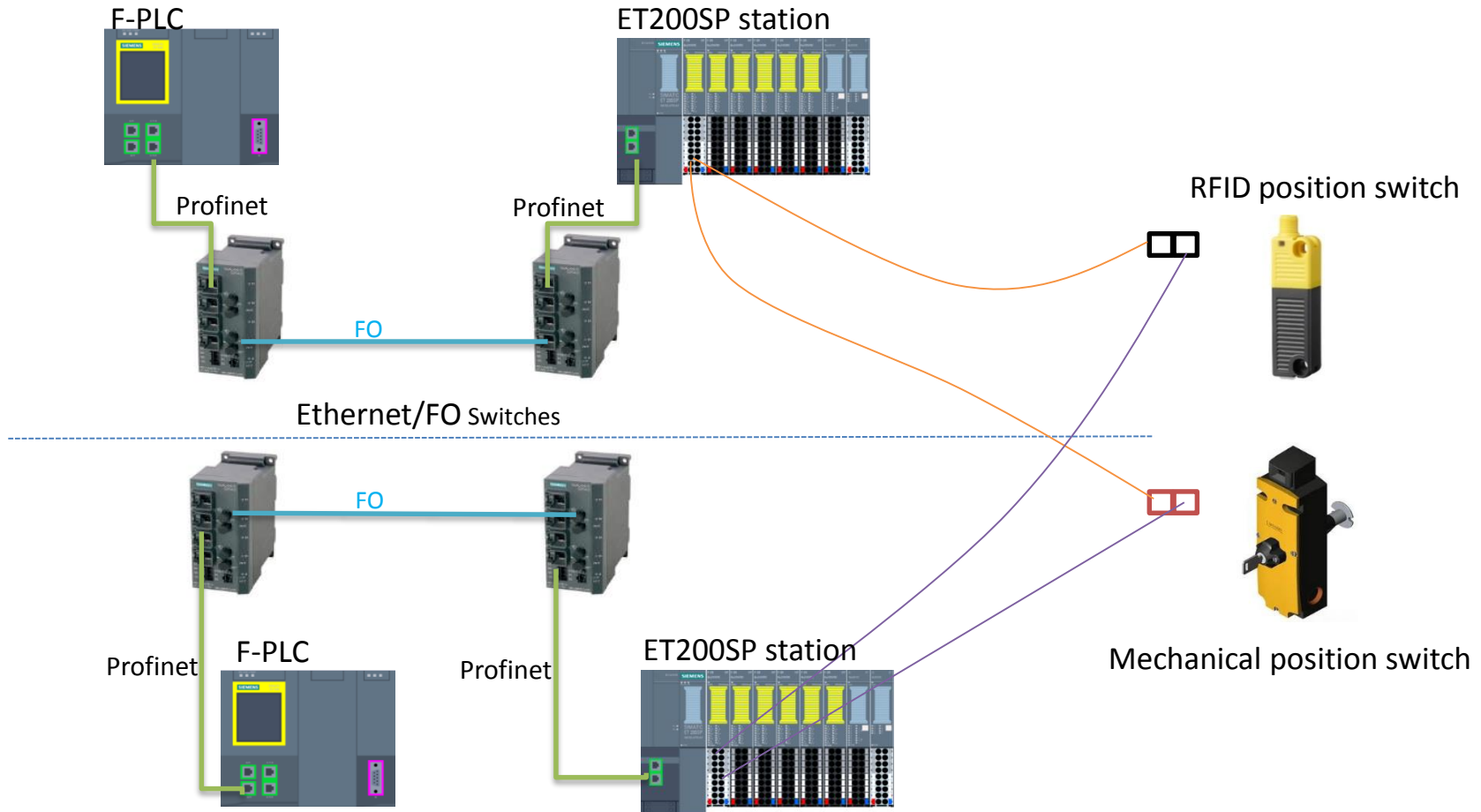


- Total of 2200 I/O-s for Accelerator PSS, around 700 F-I/O-s.
- All safety equipment will be powered by Uninterruptible Power Systems (UPS).
- Two independent Siemens S7-1518 F-PLCs will be used for functional safety implementation, principally through safety functions in the software (TIA Portal V13).
- All sensors and actuators for PSS will be connected locally to the Siemens ET200SP distributed I/O stations with fail-safe I/O modules.
- A general safety function block will be implemented for each type of the important safety element.

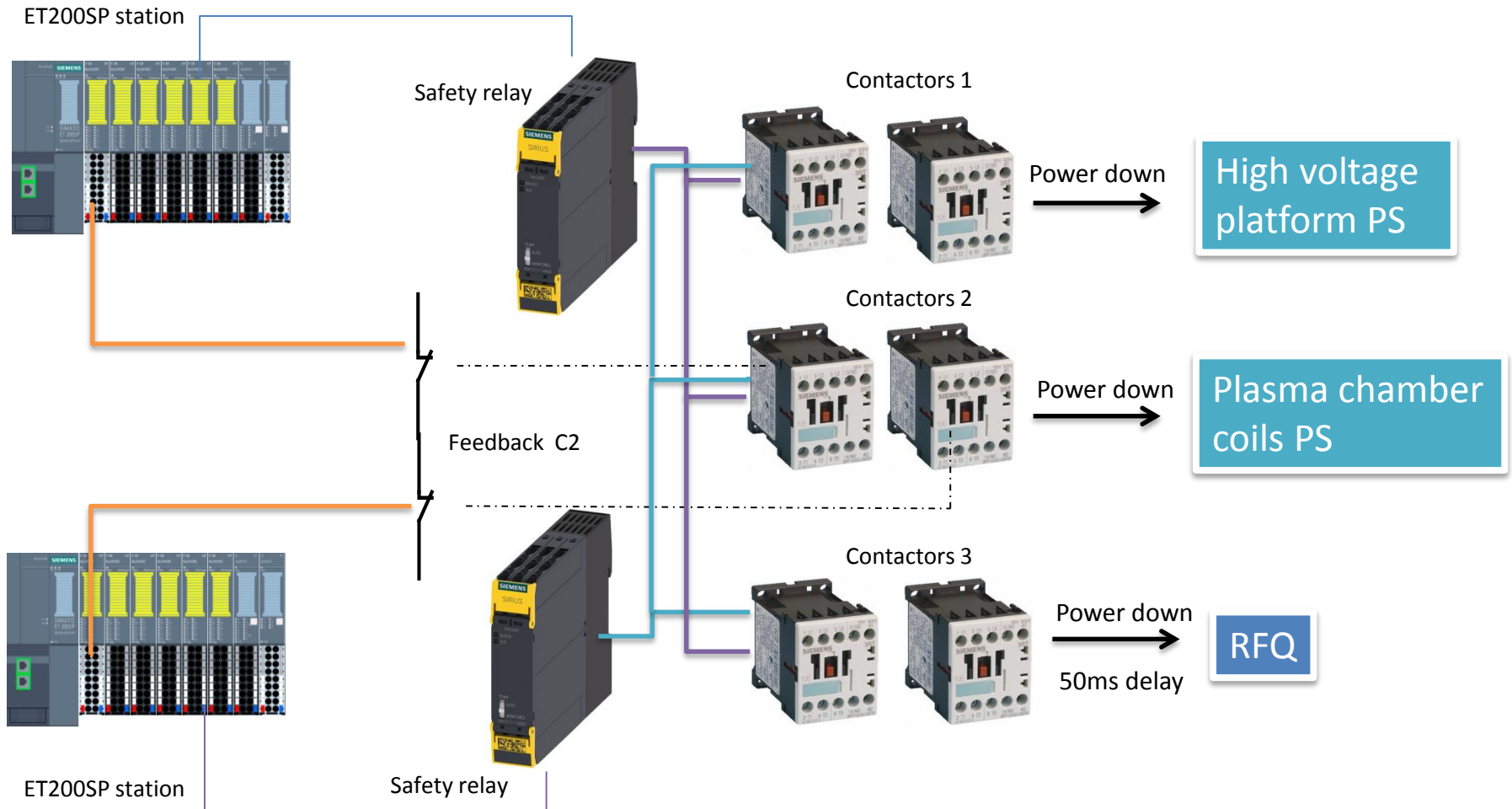
Accelerator PSS – PLC Architecture



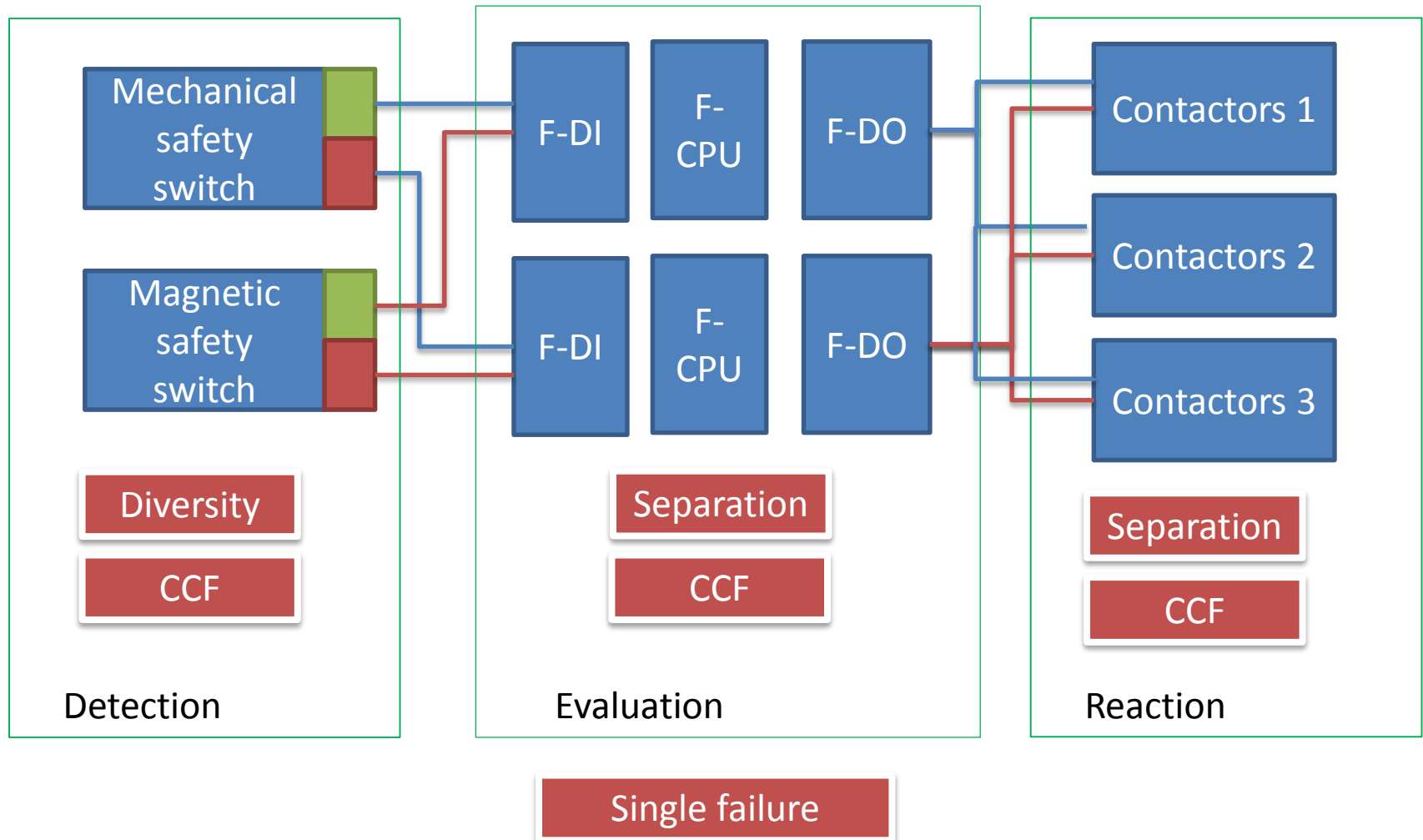
Example: Door Position Monitoring



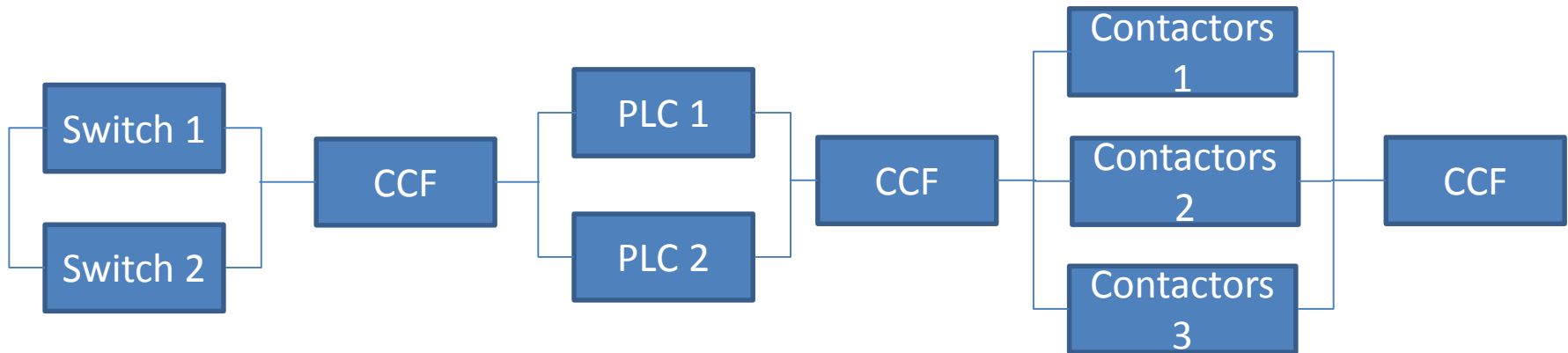
Door Position Monitoring - Reaction



Door Position Monitoring: SIL Evaluation



SIF Door Position Monitoring



SIF:

Upon detecting abnormal entry/exit via 2 safety position switches on the door (10o2), the safety PLC (10o2) sends the signal to switch off proton source and RFQ power supplies (PS):

- High voltage platform PS (Contactors 1)
- Plasma chamber coils PS (Contactors 2)
- RFQ (Contactors 3).

Stopping one of these 3 pair of contactors would stop the beam!

PSS Planning For 2016

- Documentation
- Complete Accelerator PSS analysis
- Complete Accelerator PSS
- Purchase all Accelerator equipment
- Complete Target design
- Complete Target design
- Start hazard identification on 3 initial neutron instruments: LoKI, ODIN, NMX

2016 = Year Of Documents!

Thank you!