



ODIN Motion Safety System

- Implementation and Left to Do

Instrument Safety Readiness Review ODIN

**PRESENTED BY THOMAS GAHL
(ON BEHALF OF THE MOTION CONTROL & AUTOMATION GROUP)**

2025-12-18

ODIN Motion Safety



Instrument Hazard Analysis & Handover to Motion Safety

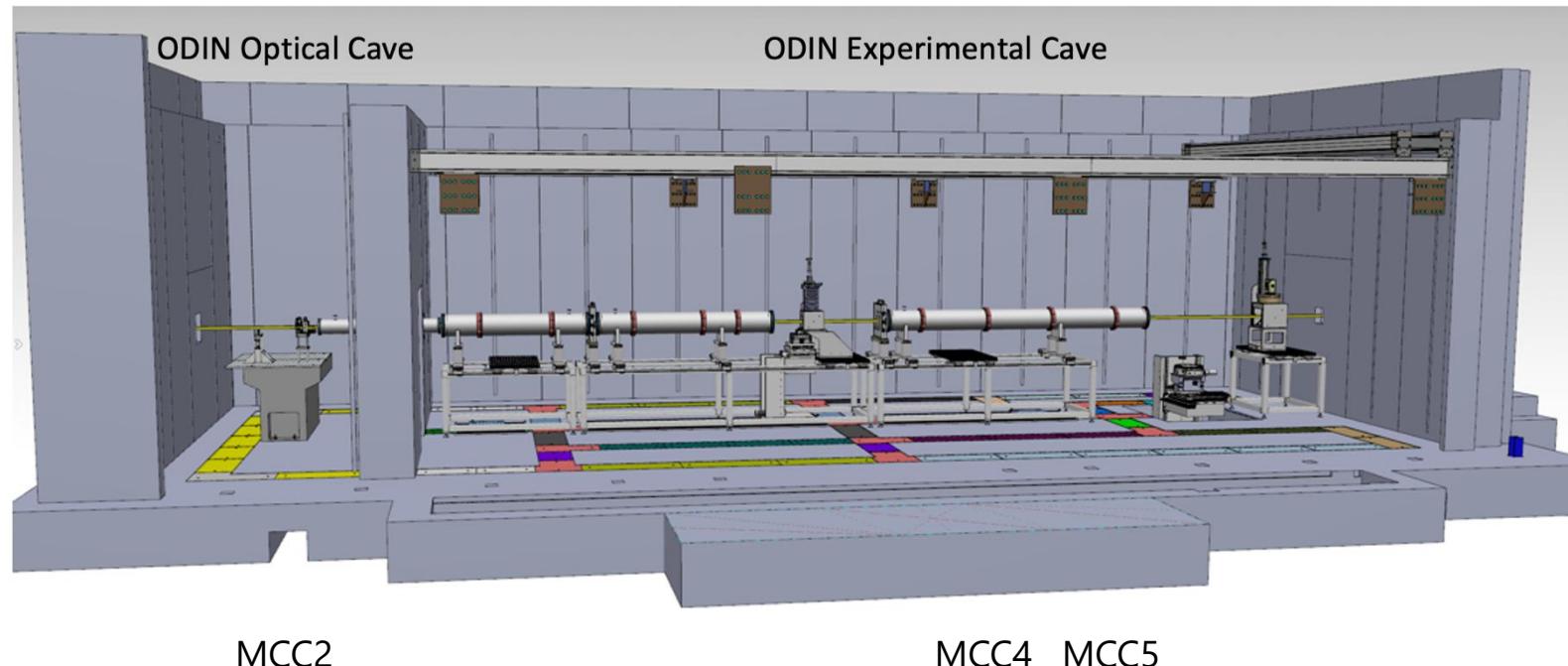
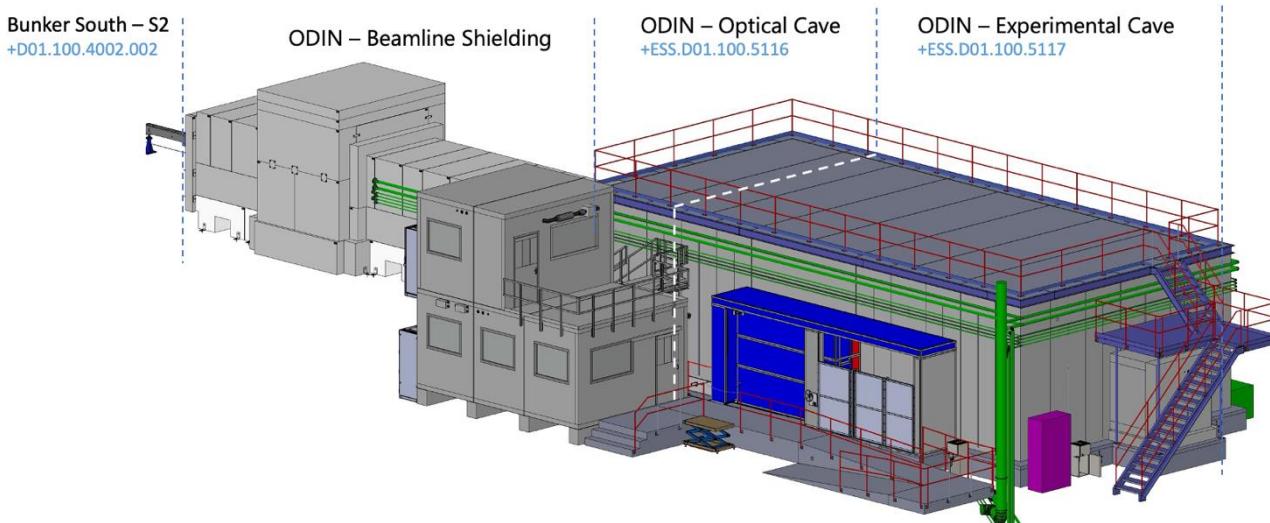
- 8 risks in the IHA identified.
- 3 are linked to operation in the cave; both related to the Sample Stage.
- Maintenance risks are mainly in areas not accessible to user personnel.
- Transferred to Motion Safety WU of CMCA.

Hazard number	Building	Instrument Area	Instrument Sub-area	Instrument System Designation	Sub-System Designation	Nr	Hazard Category (mechanical, chemical, ergonomic)	Person affected	Initiating event	Accident description	Consequence
ConHaz26	D01	In-Bunker	Heavy Shutter	Beam_Transport_and_Spatial_Conditioning	Beam cut off	26	HazElectrical	ESS Staff	Cables not protected	Cables not properly grounded	Electric shock
ConHaz52	D01	Ex-Bunker	Experimental shutter	Beam_Transport_and_Spatial_Conditioning	Beam cut off	52	HazMechanical	ESS Staff	Movement of absorber	Moves and traps on fingers while working on it	Injury
ConHaz53	D01	Ex-Bunker	Experimental shutter	Beam_Transport_and_Spatial_Conditioning	Beam cut off	53	HazElectrical	ESS Staff	Cables not protected	Personnel handle the cable	Minor discomfort
ConHaz54	D01	Ex-Bunker	Experimental shutter	Beam_Transport_and_Spatial_Conditioning	Beam cut off	54	HazMechanical	ESS Staff	Moving parts not locked during installation/maintenance	Unexpected movement of parts	Body parts are pinched
ConHaz75	D01	Ex-Bunker	Cave	Experimental_Cave	Motion Control	75	HazMechanical	ESS Staff	Movement of linear axis X,Y or Z in Sample Stage	Moves and traps on fingers while working on it	Injury
ConHaz76	D01	Ex-Bunker	Cave	Experimental_Cave	Motion Control	76	HazMechanical	User	Movement of linear axis X,Y or Z in Sample Stage	Moves and traps on fingers while working on it	Injury
ConHaz77	D01	Ex-Bunker	Cave	Experimental_Cave	Motion Control	77	HazMechanical	ESS Staff	Movement of linear axis in pinhole exchanger	Moves and traps on fingers while working on it	Injury
ConHaz78	D01	Ex-Bunker	Cave	Experimental_Cave	Motion Control	78	HazMechanical	ESS Staff	Movement of linear axis in beam limiter	Moves and traps on fingers while working on it	Injury

ODIN Motion Safety

Areas: Optical & Experimental Cave

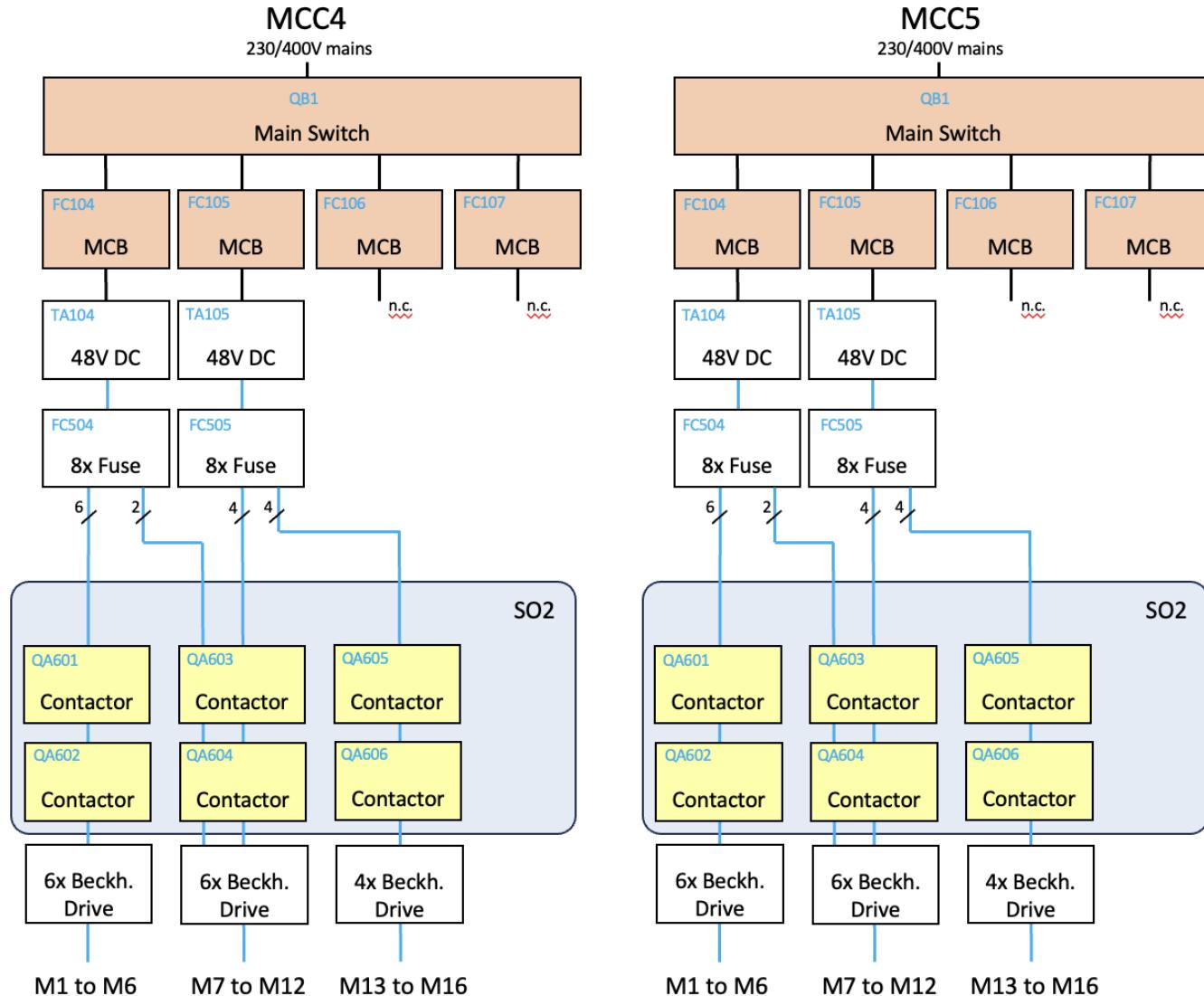
- Accessibility Experimental Cave:
 - Motorized door at the side
 - Access is for setup of experiments
- Accessibility Optical Cave:
 - Door between the two caves
 - Access of the Optical Cave from the Experimental Cave
 - Door is locked; access only for maintenance.
- PSS Access Control is for both areas
- Main Hazards:
 - Sample Stages + Camera Boxes (Experimental Cave).



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Safety Output Groups (SO)

- SO1 (in Experimental Cave):
 - Axes identified as non-hazardous for operational users (behind guards or inside (vacuum) housings etc.)
 - Special procedures for maintenance apply.
- SO2 (in Experimental Cave):
 - Axes identified as hazardous for operational users.
 - Linked to special safety function.
 - Covers also maintenance scenario.
 - Special procedures apply when maintenance work makes it necessary to override these safety functions.



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MCC4

QA601/2		SO2
Pin	ID	Axis Description
11	M1	Slit 1: Lower Blade
21	M2	Slit 1: Upper Blade
31	M3	Slit 1: Right Blade
41	M4	Slit 1: Left Blade
51	M5	Slit 2: Lower Blade
81	M6	Slit 2: Upper Blade

QA603/4		
Pin	ID	Axis Description
11	M7	Slit 2: Right Blade
21	M8	Slit 2: Left Blade
31	M9	Slit 3: Lower Blade
41	M10	Slit 3: Upper Blade
51	M11	Slit 3: Right Blade
81	M12	Slit 3: Left Blade

QA605/6		
Pin	ID	Axis Description
11	M13	Small Camera Box: Distance
21	M14	Small Camera Box: Focus
31	M15	Large Camera Box: Distance
41	M16	Large Camera Box: Focus

MCC5

QA601/2		SO2
Pin	ID	Axis Description
11	M1	Large Sample Stage: Lin Z
21	M2	Large Sample Stage: Lin X
31	M3	Large Sample Stage: Lin Y
41	M4	Large Sample Stage: Rot X
51	M5	Large Sample Stage: Rot Y
81	M6	Large Sample Stage: Rot Z

QA603/4		
Pin	ID	Axis Description
11	M7	Small Sample Stage: Lin Z
21	M8	Small Sample Stage: Lin X
31	M9	Small Sample Stage: Lin Y
41	M10	Small Sample Stage: Rot X
51	M11	Small Sample Stage: Rot Y
81	M12	Small Sample Stage: Rot Z

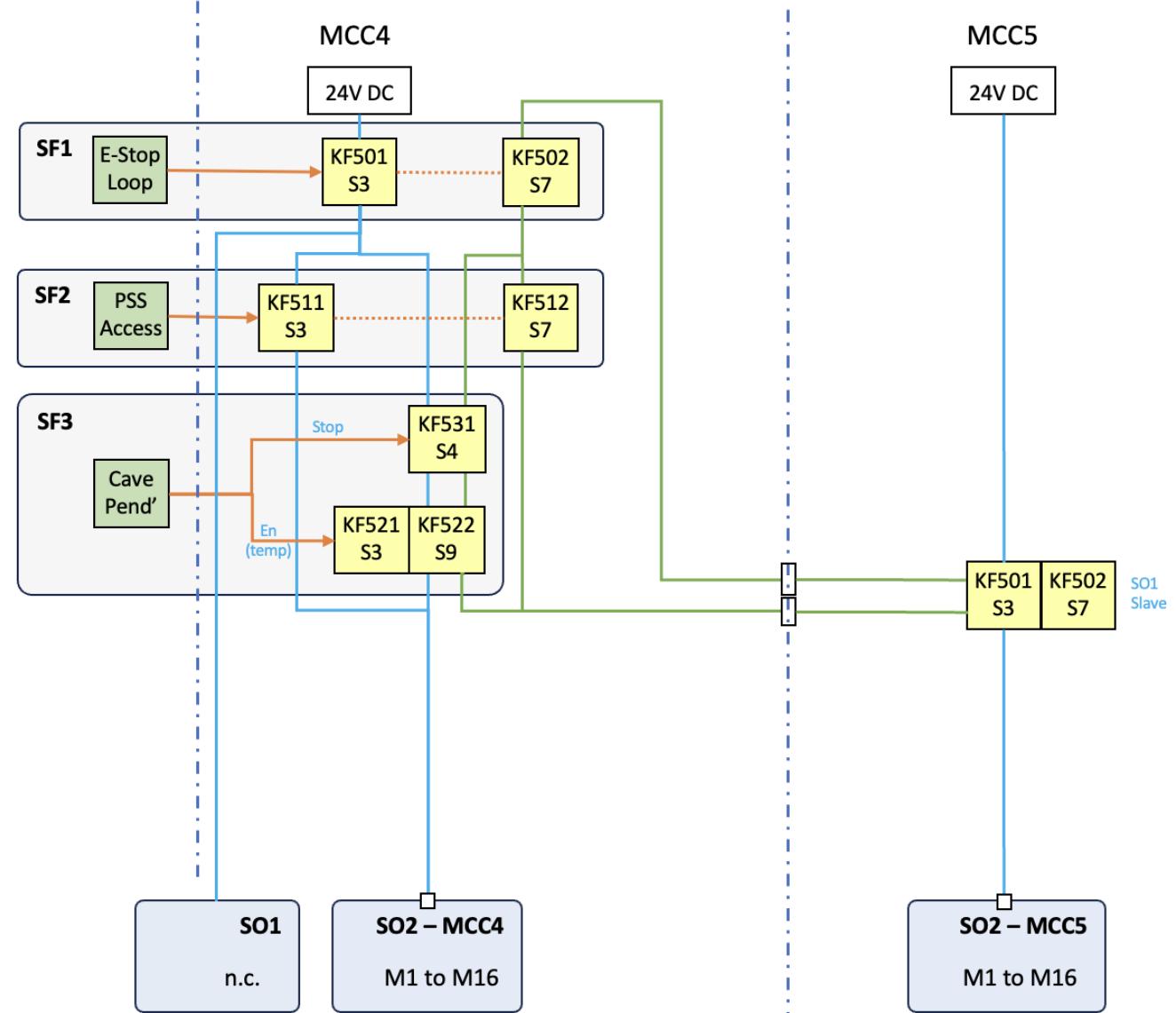
QA605/6		
Pin	ID	Axis Description
11	M13	Ancillary Stage: Lin1
21	M14	Ancillary Stage: Lin2
31	M15	Ancillary Stage: Goniometer
41	M16	Ancillary Stage: Rotary

Safety Function	SO1	SO2
SF1 – Motion E-Stop	X	X
SF2 – PSS Access		X
SF3 – Access Override Cave		X

ODIN Motion Safety

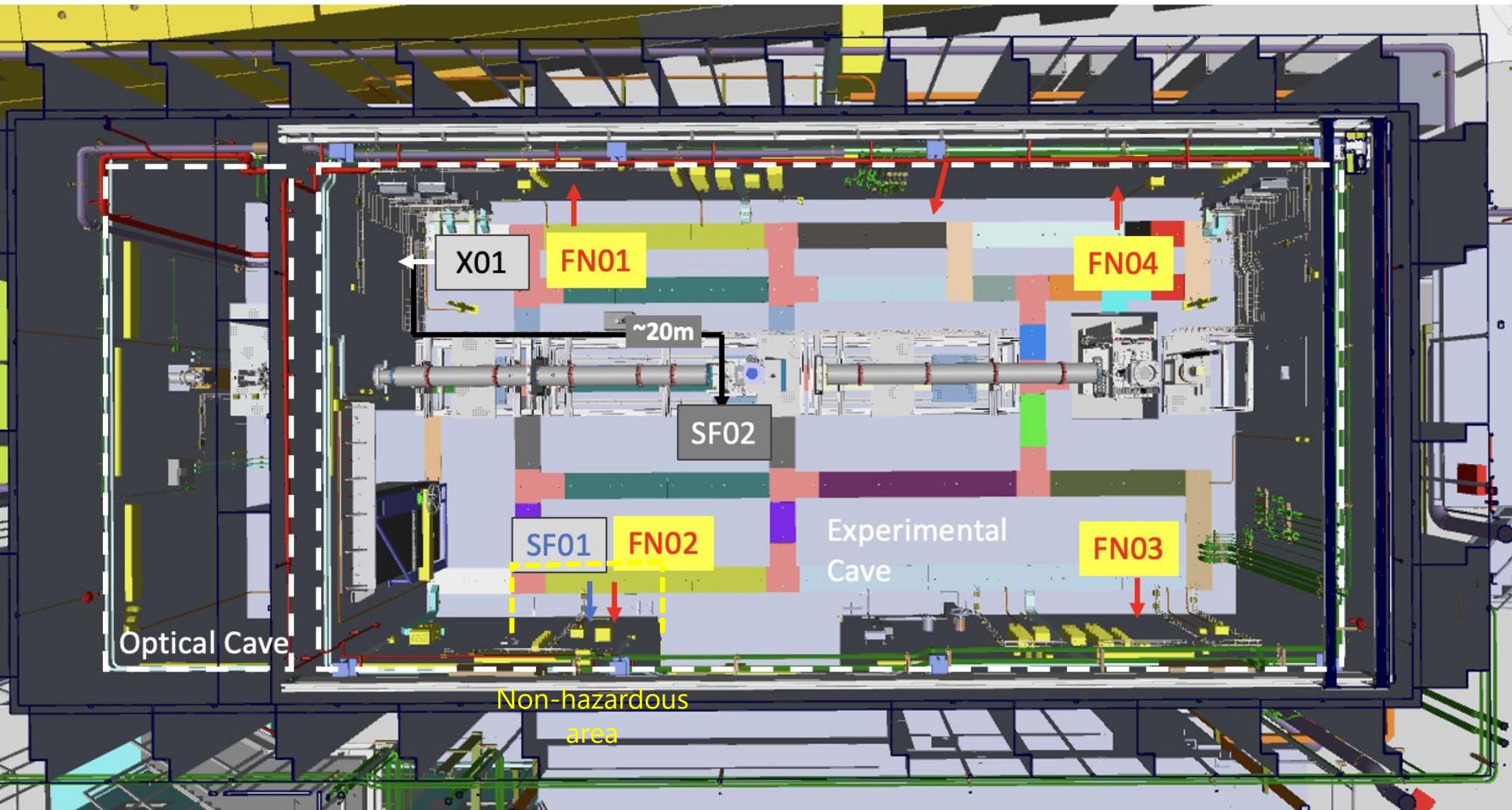
Safety Functions (SF)

- SF1: Motion E-Stop
 - Stops all axes in the cave and detector area.
- SF2: PSS Access
 - Stops all axes in the cave and detector area identified as hazardous and grouped in SO2.
- SF3: Cave Pendant
 - Overrides SF2 and enables all axes in SO2 for a defined time (currently 2 min); re-triggerable.



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Implementation



E-Stop

FN01

Reset

SF01

Op-Control

SF02

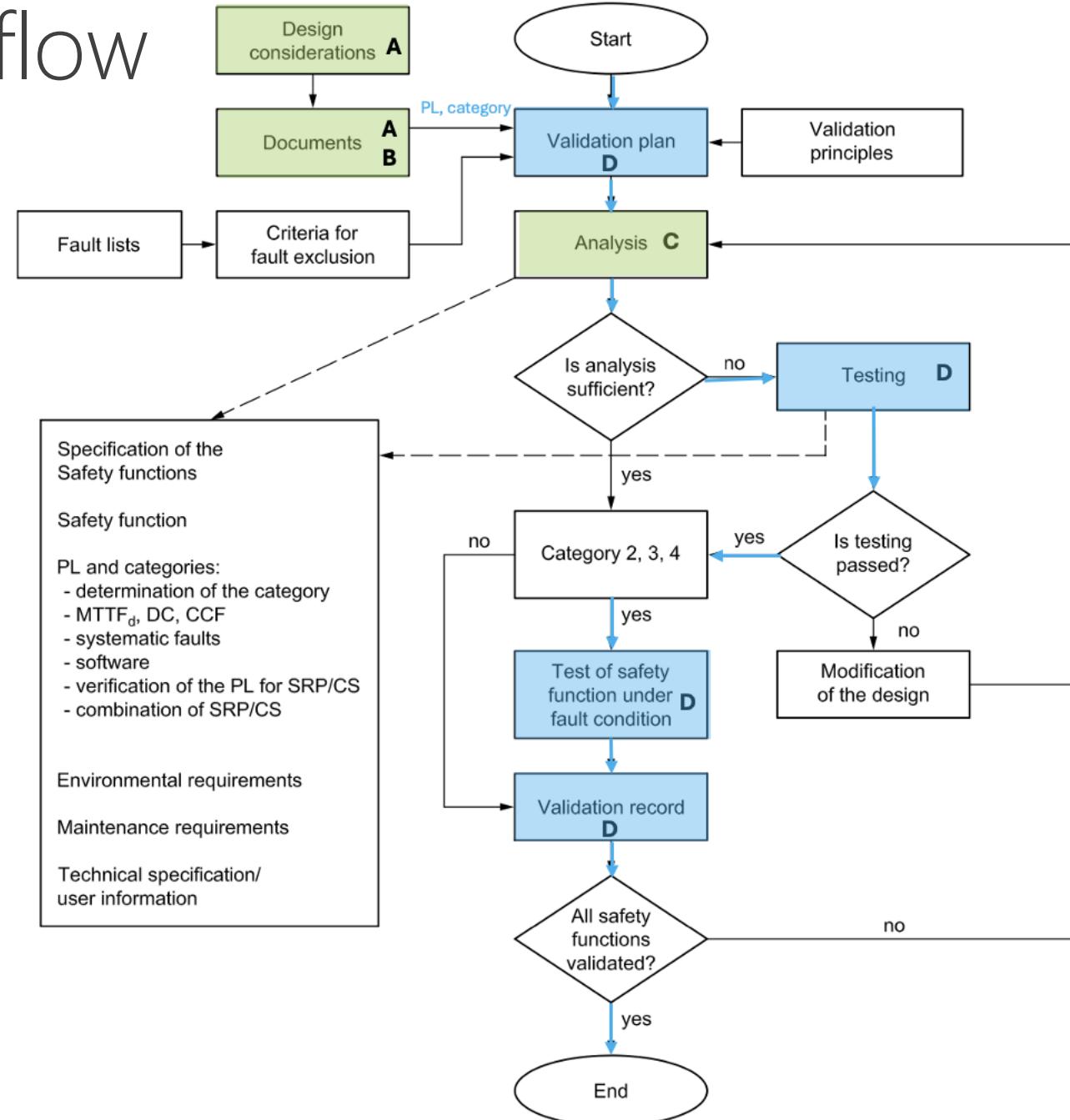
Junction Box

X01

Validation Workflow

SS-EN ISO 13849-2

- A. ESS-5467337 - Motion Risk Analysis of Neutron Instruments.
- B. ESS-3431616 - ODIN ToM, Table-of-Motion, sheet 3
- C. ESS-5951968 - Design Verification Calculation (SISTEMA) for ODIN Motion Safety
- D. ESS-5951664 - Motion Safety Validation Plan for ODIN
ESS-5951666 - Motion Safety Validation Report for ODIN



ODIN Motion Safety

Validation Test Plan / Validation Test Report

Document Type: Validation Report
Document Number: ESS-5937539

Document Date: Nov 24, 2025
Revision: 1(1)
State: Preliminary

Document Date: Dec 16, 2025
Revision: 1
State: Released

8 FUNCTIONAL TESTS

Description		Fail	Pass	N/A
The following tests prove the behaviour of the safety functions under normal operating conditions.				
Requires temporary switch/bridging wires installed to simulate external signals.				
If using jumper wires, be aware that "bouncing" while connecting the second channel may be detected as a fault.				
No other special tools or wiring required.				
All devices are located in the field or inside MCC3 unless otherwise specified.				
Not all steps check all possible LEDs. Any listed indicators are important and must be checked.				

Motion E-Stop

Step Element Action					
	On/Enabled	Off/Disabled	Other	Pass/Fail	Notes
0	Pre-Check	Ensure safety relays in initial state	Safety Relay indicators as per LED Chart	Pass	
1	Contactors	Confirm all contactors/ Relays are off/disabled	QA601-604 MCC4 KF340 MCC5 KF501	Pass	
2	E-Stop FN01	Press E-Stop	E-Stop LED KF501 In1,In2 SF01 Reset	Pass	
3	E-Stop FN01	Release E-Stop	KF501 In1,In2 SF01 Reset	Pass	

Page: 1 of 6

8-FuncTests

Validation test has been passed and approved:

- No test case failed
- No punch list items listed

Document Type: Validation Report
Document Number: ESS-5951666

Document Date: Dec 16, 2025
Revision: 1
State: Released

TEST SUMMARY & APPROVAL

Validation Test Execution	<input checked="" type="checkbox"/> Approved	<input type="checkbox"/> Rejected
Date:	2025-12-15	Signature: Ruben Martinez Garcia
Comment:	This has been executed according the descriptions in this document and instructions given by Jacob Gilles. I can not assure that the different test setups were totally correct as lack of knowledge.□	

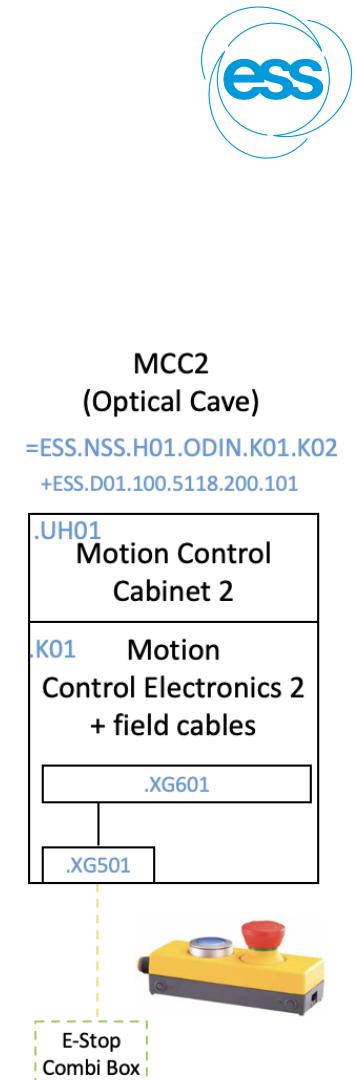
Validation Approval	<input checked="" type="checkbox"/> Approved	<input type="checkbox"/> Rejected
Date:	2025-12-12	Signature: Jacob Gillies
Comment:		

Test Cases performed	Summary Findings					
	Pass	Fail	N/A	Signatures of testers	Date	Comments
1 Hardware Check	x			RMG	2025-12-12	
2 Output Tests MCC5	x			RMG	2025-12-11	
3 Fault Tests MCC5	x			RMG	2025-12-11	
4 Output Tests MCC4	x			RMG, Erdinch Ahmed	2025-12-12	
5 Fault Tests MCC4	x			RMG, Erdinch Ahmed	2025-12-12	
6 Output Tests MCC2	x			RMG	2025-12-12	QA605/606 not tested, Contactors not used
7 Fault Tests MCC2, Functional Tests MCC2	x			RMG, Safaa Zaki	2025-12-12 2025-12-15	
8 Functional Tests MCC4 An	x			RMG, Erdinch Ahmed	2025-12-12	

ODIN Motion Safety

Exclusions

- MCC1 (for in bunker):
 - Instrument Shutter (Pneumatics), Chopper Positioning Table (Motor): Access only for maintenance, trained personnel, LOTO, RAMS; provision to temporarily connect an operator stop (Motor only).
- MCC2 (Optical):
 - Pin Hole Slit Sets + Filter Bank + Experiment Shutter (in the locked Optical Cave): Access only for maintenance, trained personnel, LOTO, RAMS; provision to temporarily connect an operator stop.
- MCC3, MCC6:
 - Future Options: Currently energised and switched off under LOTO; no subsystems connected. Prepared to be connected to MCC4 as motion safety slave after hazard evaluation and safety requirement specification.



ODIN Motion Safety



Left to do

- Current situation
 - Largest generic hazard is the “Unexpected Startup/Motion of Axes” while people are in the Experimental Cave.
 - This is addressed by PSS Access and Override/Enable functions.
 - **This is good and safe enough for next phase (trial operation = hot commissioning) with skilled and trained users familiar with the system.**
- Next steps
 - Be available and support the hot commissioning phase for troubleshooting.
 - Evaluate the suitability of the system for daily routine.
 - Get feedback from the users of the acceptance and the user-friendliness of the system.
- Improvements: A question for all T1 instruments
 - Design improvements for the safety control system are in the pipeline for later instruments.
 - Decide how much of this is worth to retrofit (and when) on T1 instruments.

ODIN Motion Safety



Reference Documents

Analysis & Requirements

- ESS-1075652 - ODIN Instrument Hazard Analysis (IHA)
- ESS-5467337 - Motion Risk Analysis of Neutron Instruments
- ESS-3431616 - ODIN ToM, Table-of-Motion, sheet 3

Design

- ESS-5513696 - ODIN Motion Control System – System Block Diagram
- ESS-4970035 - ODIN Motion Control 1 ePlan
- ESS-4970036 - ODIN Motion Control 2 ePlan
- ESS-4970038 - ODIN Motion Control 4 ePlan
- ESS-4970039 - ODIN Motion Control 5 ePlan
- ESS-5516373 - System Design Description - ODIN Motion Control System
- ESS-5951968 - Design Verification Calculation (SISTEMA) for ODIN Motion Safety System

Installation

- ESS-5546266 - Electrical inspection ODIN MC Cabinets
- ESS-5951553 - MCA Self-Inspection Report for ODIN Motion Control
- ESS-5513745 - Inspection and Test Report for ODIN Motion Control

Validation

- ESS-5951664 - Motion Safety Validation Plan for ODIN
- ESS-5951666 - Motion Safety Validation Report for ODIN
- ESS-5669198 - Operation Manual - MCU5001: 16Ax. Motion Control Cabinet
- ESS-5166392 - Motion Control Risk Assessment (RAMS)

ODIN Motion Safety

Applicable Directives and Standards



- EU Directive 2006/42/EC (European Machinery Directive)
- Replaced by: Regulation (EU) 2023/1230 of the European Parliament and of the Council of 14 June 2023 on machinery
- SS-EN ISO 12100 Safety of Machinery – General Principles for design – Risk Assessment and Risk Reduction
- SS-EN ISO 13849 Safety of Machinery – Safety Related Parts of the Control System (Parts 1 and 2)
- SS-EN ISO 13850 Safety of Machinery - Emergency stop function - Principles for design
- SS-EN EN 60204-1 Safety of Machinery – Electrical Equipment of Machines
- SS-EN 61800-5-2 Adjustable Speed Electrical Power Drive Systems Part 5-2: Safety Requirements - Functional



Thank You!

2025-12-18

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Additional Information

Safety Requirements Specification



Table-of-Motion, Sheet 3

Bunker Area

Axes listing

Cave Area

Safety Requirements Specification



Evaluation

Mitigation	Mitigation description
None	Not accessible (behind closed walls or enclosures)

Severity	Mitigation	Mitigation description	Treatment of Residual risk
HARMFUL	Safeguarding	Procedure, RAMS: LOTO and/or fence off	Training, signs, procedures
Harmless	Other	Procedure, RAMS: LOTO and/or fence off	N/A

Circuit/Zone	Placement of E-Stop Buttons
MCC2 (bunker)	Temporary E-Stop; to be placed nearby the motion

Circuit/Zone	Placement of E-Stop Buttons
MCC3 + 4 (cave)	2 E-Stop buttons +Reset button on the cave table

Bunker Area

Mitigation	Mitigation description
None	No subsystem installed

Cave Area

Risk Analysis & Treatment



ESS-5467337 - Motion Risk Analysis of Neutron Instruments

■ Limits of System

1. Area: Motion Safety focusses on areas accessible to instrument users (typically in the cave).
2. Life phases: Experiment Setup & Local Maintenance considered.

Life phases	Cave (User Access, controlled by PSS)	Cave (Service & Maintenance Access, controlled by PSS)	Beam Line, Bunker (Service & Maintenance Access, controlled by procedures)
	TBL Areas	TBL Cave	TBL Cave
Installation, commissioning and testing	excluded	excluded	excluded
Experiment Run	no risks	no risks	no risks
Experiment Setup	included	N/A (no access)	N/A (no access)
Local maintenance	included	included	excluded
External maintenance (in workshop)	excluded	excluded	excluded

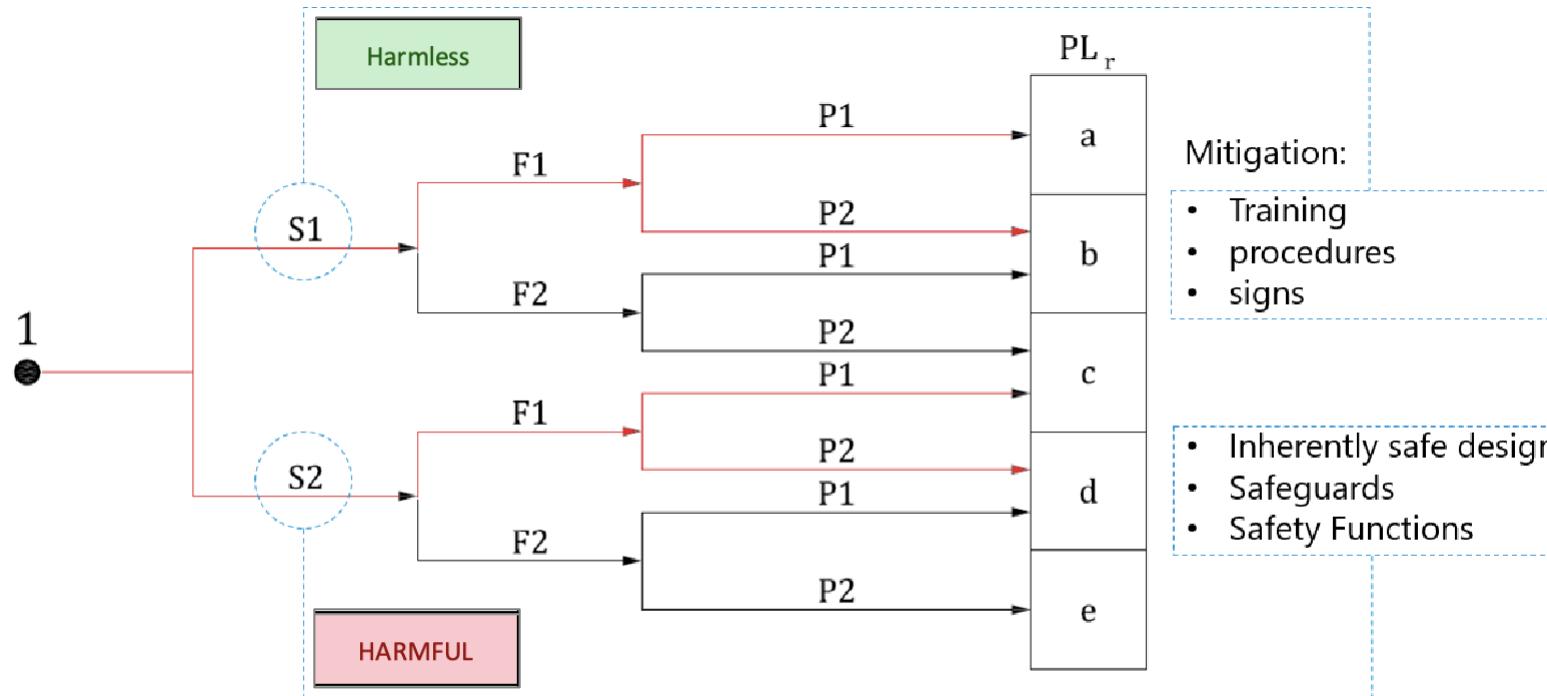
MOTION RISK ANALYSIS OF NEUTRON INSTRUMENTS									
Document Type	Risk Assessment								
Document Number	EIS-5467337								
Date	Aug 23, 2024								
Revision	1								
Page	Released Internal 1 (17)								
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Name	Role/Title								
Owner	Alexandre Goncalves Gerk								
Reviewer	Maurice Loft Jorgen Johnson Frederico Rojas								
Approver	Thomas Gahl								

ESS-5467337

Risk Analysis & Treatment

ESS-5467337 - Motion Risk Analysis of Neutron Instruments

- Simplified approach for hazard analysis and mitigation.
 1. Motion Safety focusses on areas accessible to instrument users (typically in the cave).
 2. Only two levels defined following the severity path; required Performance Levels a/b and c/d.



MOTION RISK ANALYSIS OF NEUTRON INSTRUMENTS															
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MOTION RISK ANALYSIS OF NEUTRON INSTRUMENTS																			
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Template Report (ESS-0000987 Rev. 4, Active date: Feb 20, 2020)																			

Figure 8 - Risk evaluation

ESS-5467337

E-Stop Design

Design Principle



- Modularity: Define different areas; match the area with the respective control cabinets; this includes standardised circuits in the cabinet and a Master/Slave hierarchy between (if applicable).
- Scalability: A scalable number of fixed installed E-Stop buttons + one Reset button in the areas accessible to normal users (i.e. the cave).
- Performance Level d as a matter of principle.
- Currently Stop Category 0 (STO); design work is ongoing for Stop Category 1 (SS1).

EN 60204-1	EN 61800-5-2
Stop category 0	Safe torque off (STO)
Stop category 1	Safe stop 1 (SS1)
Stop category 2	Safe stop 2 (SS2)

Design Verification

SISTEMA calculation

The SISTEMA analysis for the Motion Safety – E-Stop Circuit has been successfully completed according to EN ISO 13849-1:2023 and ISO 13850:2015.

- The required Performance Level determined by the risk graph was PLd, with a calculated PFH = 1.45E-7 [1/h]; PLd was achieved.
- All subsystems (Pilz E-Stop Boxes, Pilz PNOZ relay, and Siemens SIRIUS contactor relays) demonstrated compliance with relevant requirements for Category 3 or 4 architectures, with high MTTFD values, diagnostic coverage $\geq 90\%$, and fulfilled Common Cause Failure (CCF) measures.
- No warnings or non-conformities were reported in SISTEMA's evaluation.
- Design of the Motion Safety E-Stop function meets the required safety integrity level.

