PERSONAL SAFETY SYSTEMS AT DESY AND EUROPEAN XFEL IN TRANSITION.

From Legagy Infrastructure to Modern Safety

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HELMHOLTZ

Outline

Personal Safety Systems at DESY – An Overview

- PSS at DESY
- Legal Framework
- Safety Functions
- Annual Checks

Personal Safety Systems at DESY – Transition to Modern Safety

- Age, Technology and Mission Time of PSS
- Risk Assessment Process
- PSS for New Facilities
- Combination of Old and New Systems

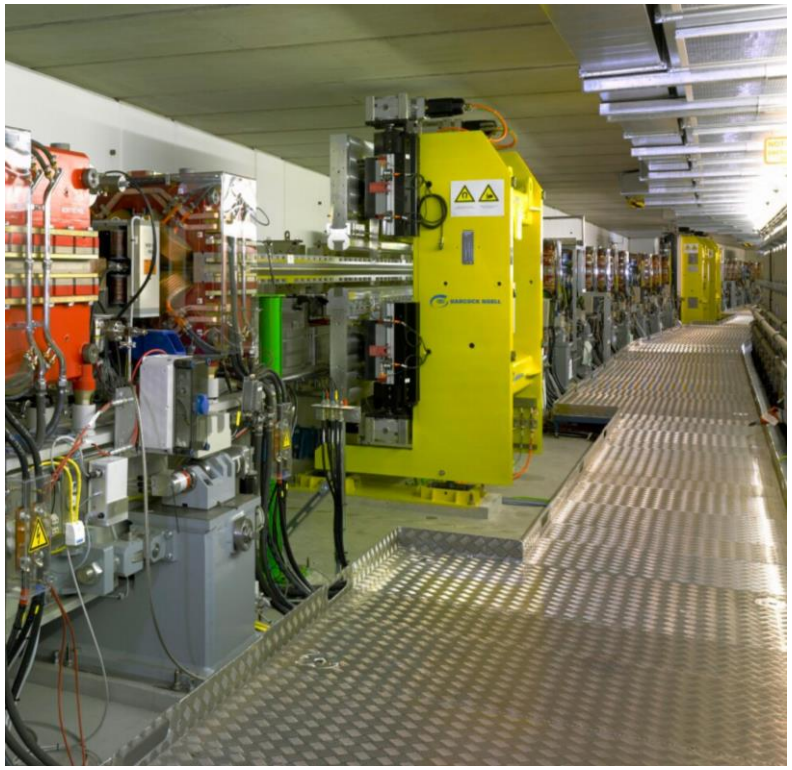
Accelerators and Test Facilities at DESY with PSS (Personal Safety System)

DESY Campus Overview

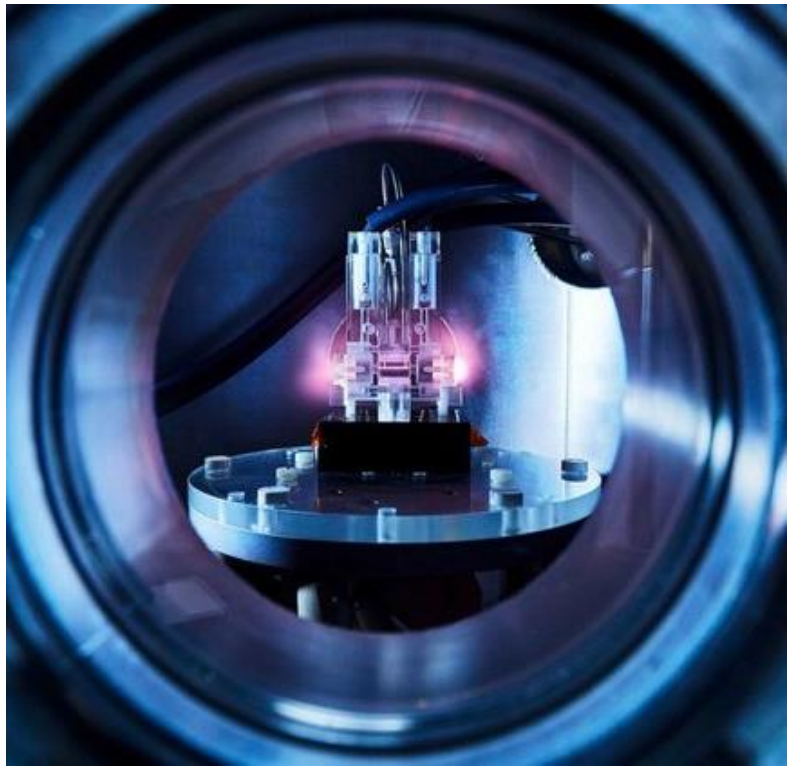
Accelerators and Test Facilities at DESY with PSS (Personal Safety System)

DESY Campus Overview - 18 facilities require PSS

Accelerators and Test Facilities at DESY with PSS (Personal Safety System)



User Facilities @ DESY



Accelerator Test Facilities @ DESY

Test Stands @ DESY

Accelerators and Test Facilities at DESY with PSS (Personal Safety System)

User Facilities at DESY

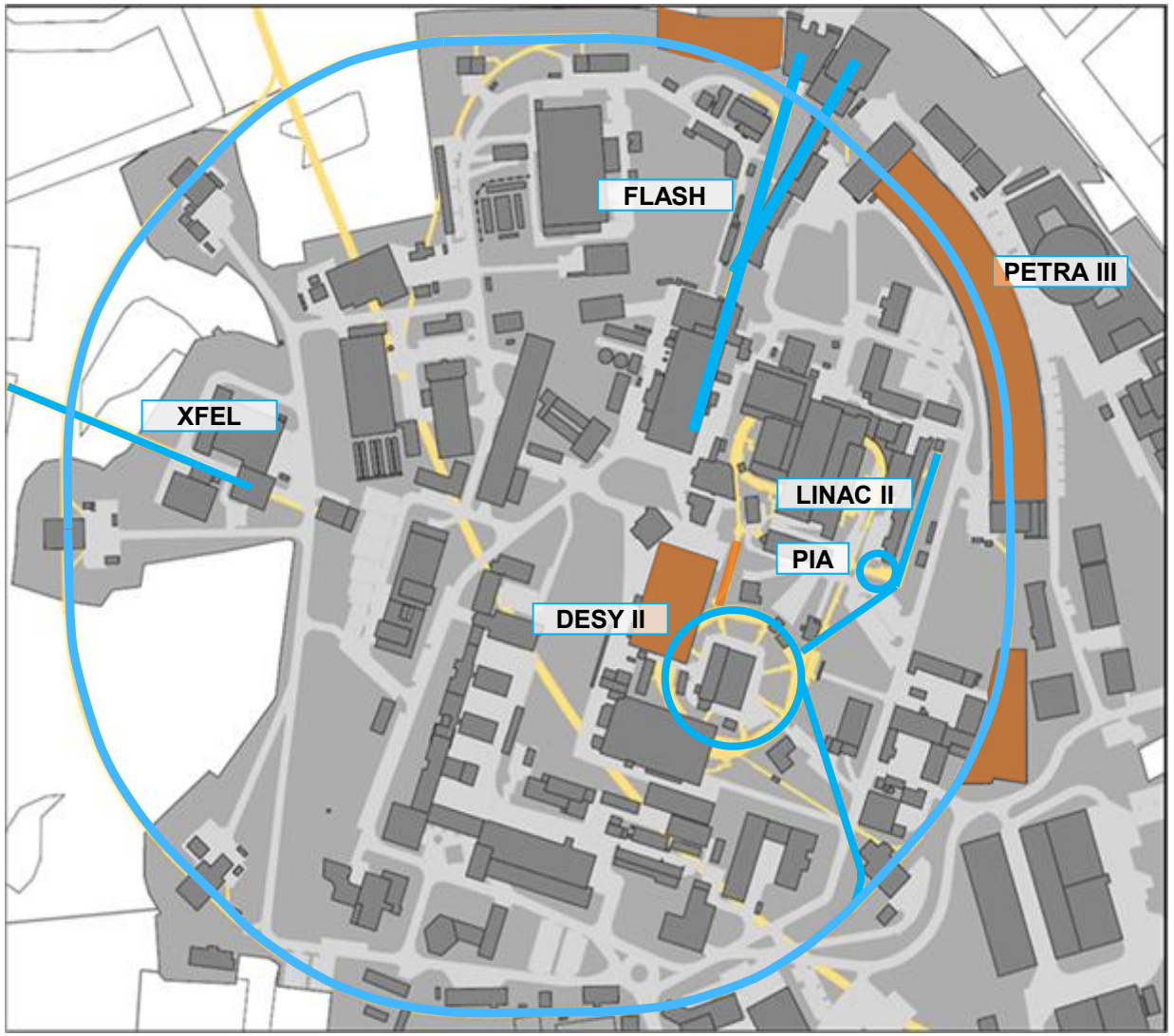
LINAC II: Electron source and pre-accelerator PETRA III

DESY II: Pre-accelerator PETRA III
User facility → 5 Experimental setups

PETRA III: 3rd generation synchrotron radiation source
with 25 user beamlines

FLASH: Free Electron Laser (FEL)
with 4 user beamlines

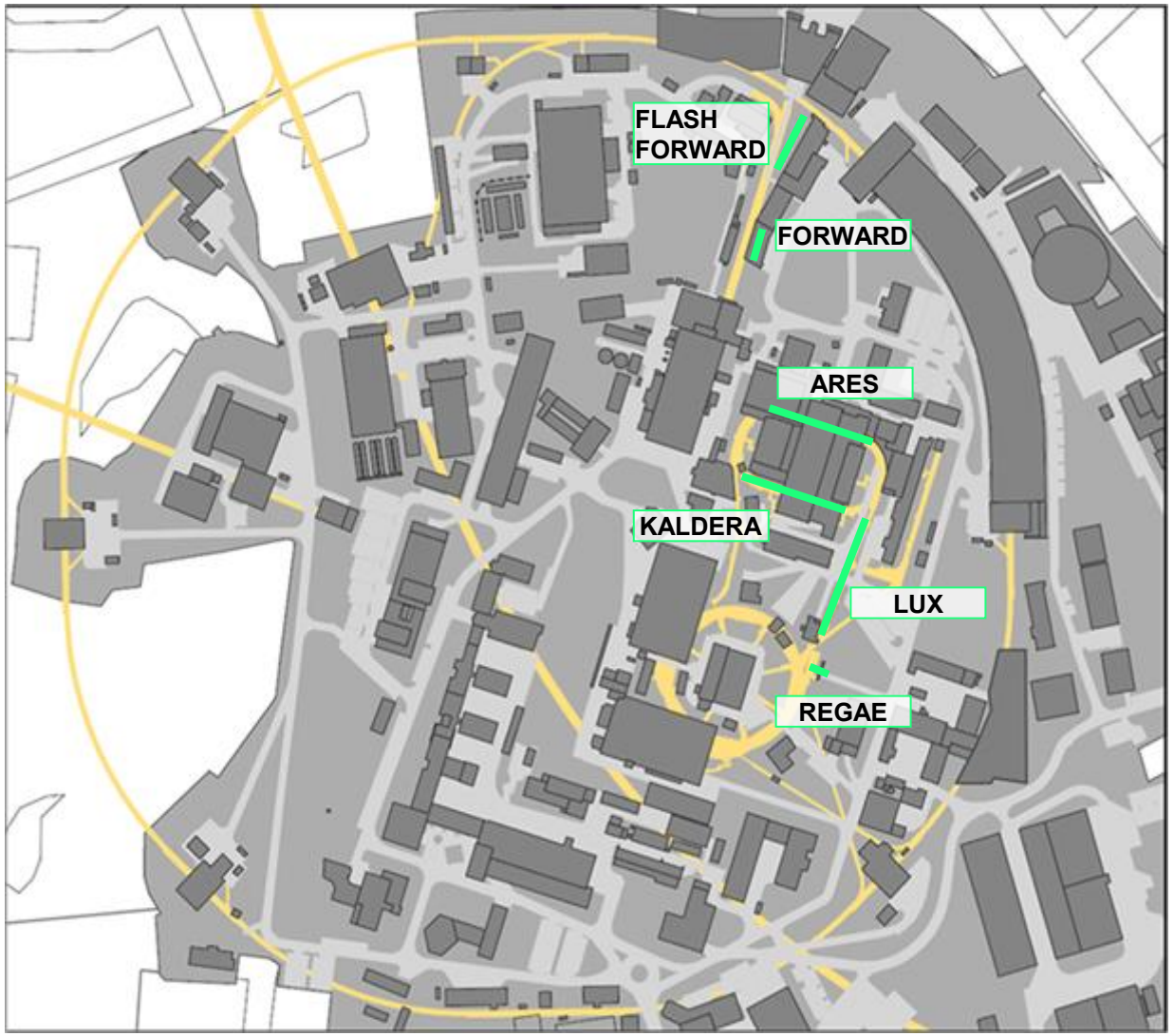
XFEL: X-Ray Free Electron Laser
with 7 experimental hutches



Accelerators and Test Facilities at DESY with PSS (Personal Safety System)

Accelerator Test Facilities at DESY

ARES:	Test accelerator for diagnostics, radiation dose experiments, e-flash therapy
REGAE:	Test facility for UED
LUX:	Laser-plasma accelerator test facility for long-time operation, FEL beam and LPA injection
KALDERA:	Laser-plasma accelerator test facility for high repetition rate operation,
FORWARD:	Laser-plasma accelerator test facility for development of accelerator schemes and diagnostics and industrial applications
FLASH FORWARD:	Beam-driven plasma accelerator test facility



Accelerators and Test Facilities at DESY with PSS (Personal Safety System)

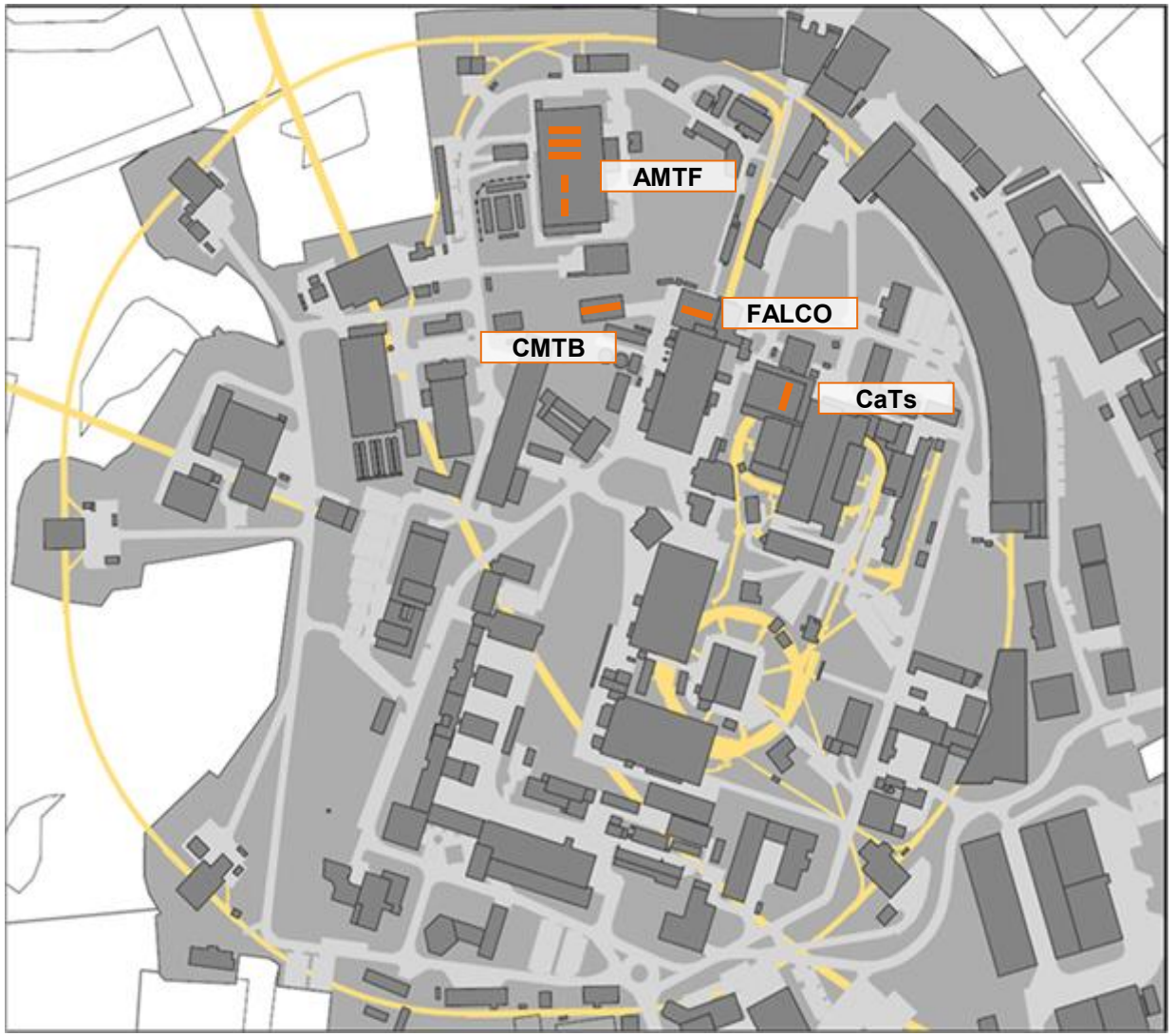
Test Stands at DESY

FALCO: Test stand for testing and conditioning RF cavities (XFEL, FLASH)

CaTs: Test stand for testing and conditioning RF cavities and RF components (DESY, PETRA)

AMTF: Test stand for performance tests of XFEL cryomodules, cold tests of RF cavities, waveguides and magnets

CMTB: Test stand for testing superconducting cryomodules in cw mode



Personal Safety Systems at DESY

Not only Safety Interlock

The Access Control System DACHS

Governs entry to (potentially) hazardous areas.

PSS

The Safety Interlock System

Ensuring fast switch off of the hazard source (electron beam, RF) in emergency situations.

The Radiation Monitoring System

Ensuring permanent monitoring of dose rate in ajacent areas of the facility.

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Framework of German Law and Standards in Radiation Protection

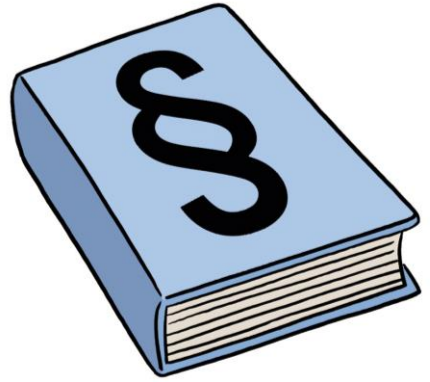
Focus on PSS and Functional Safety

Radiation Protection Act and Ordinance

- Ensure no exposure exceeds authorized limit.
- Implement measures to ensure compliance with safety regulations.
- Safety system must be maintained and inspected by an expert at least once per year.

Standards for Safety of machinery

- EU Machinery Directive (2006/42/EC)
- ISO 12100
- IEC 62061
- ISO 13849



Authorities

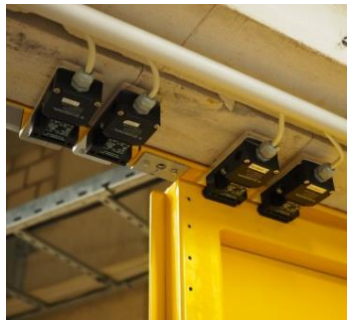
- German Agengy for Radiation Protection
- State Authorities (AfA Hamburg)

Safety Interlock System at DESY

Components within safety functions

Sensor → Safety network → Logic → Safety network → Actuator

Door contacts
Emergency-off switches
Position switches at beam shutters
Permission keys
Keys for temporal access
Safety Switch at magnets
Burn Through Monitor
Light barrier



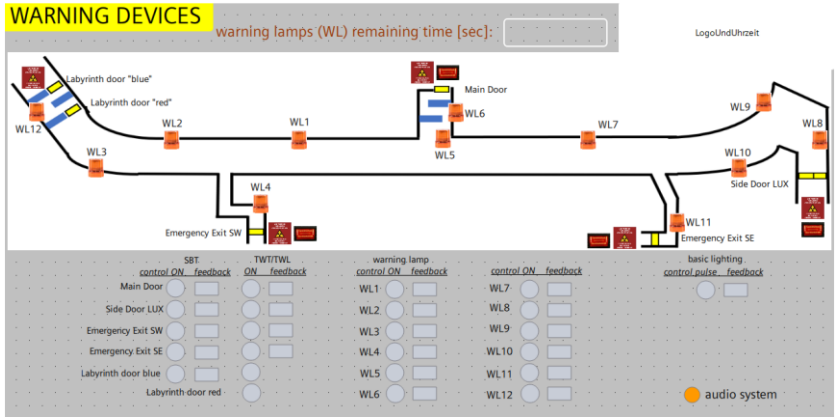
60 V Relay-based technology
Safety PLCs

Contactors of rf-modulators
Contactors of hv power supplies
Safety switches to disconnect and ground magnets.

Safety Interlock System at DESY

Supplementary functions, organizational measures

- Tunnel search before operation
  (announcement, permission key, search locks and buttons, light barrier)
- Warning signs at doors
- Warning lamps
- Announcements
- Partial lightning
- Feedback of all warning devices



Maintenance and Annual Test of PSS

§88 German radiation protection regulation

- Maintenance at least once per year as pre-tests before the annual checks by the DESY group for functional safety and technical groups.
- Annual functional test with external expert (TÜV → German certified inspection agency) led by DESY radiation protection group.
- Additional functional tests after significant modifications of the setup or the scientific goal of the facility with direct impact on radiation protection.

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PSS at DESY in Transition

Main Tasks and Challenges on our Way to Modern Safety

Different ages and technologies of safety interlock systems

Safety interlock systems at some facilities close to their mission time

Implementation of a robust risk assessment process

Design and build new safety interlock systems for new facilities

Combination of two or more facilities with safety interlock systems of different ages and technology

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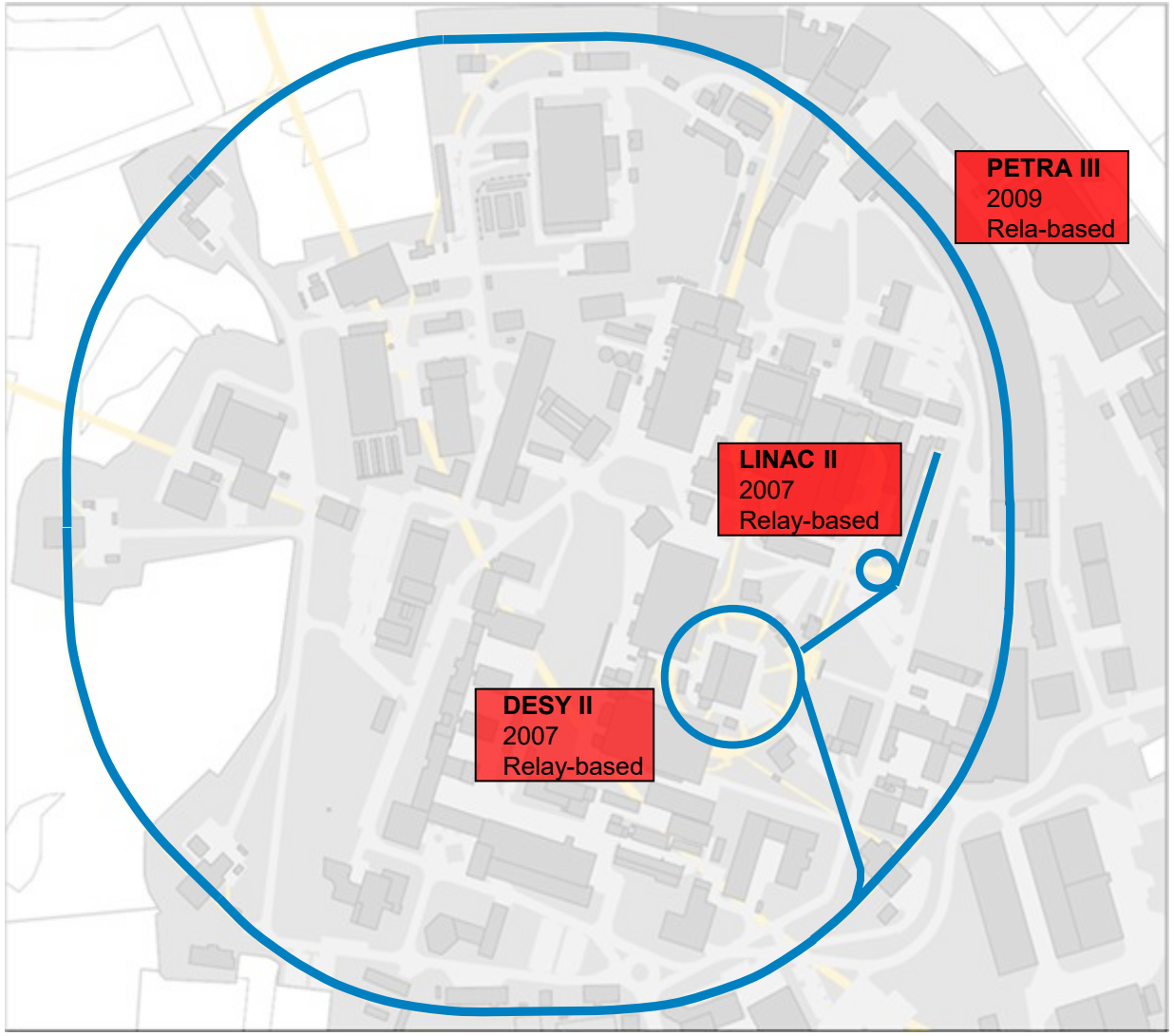
PSS at DESY

Technology and Age

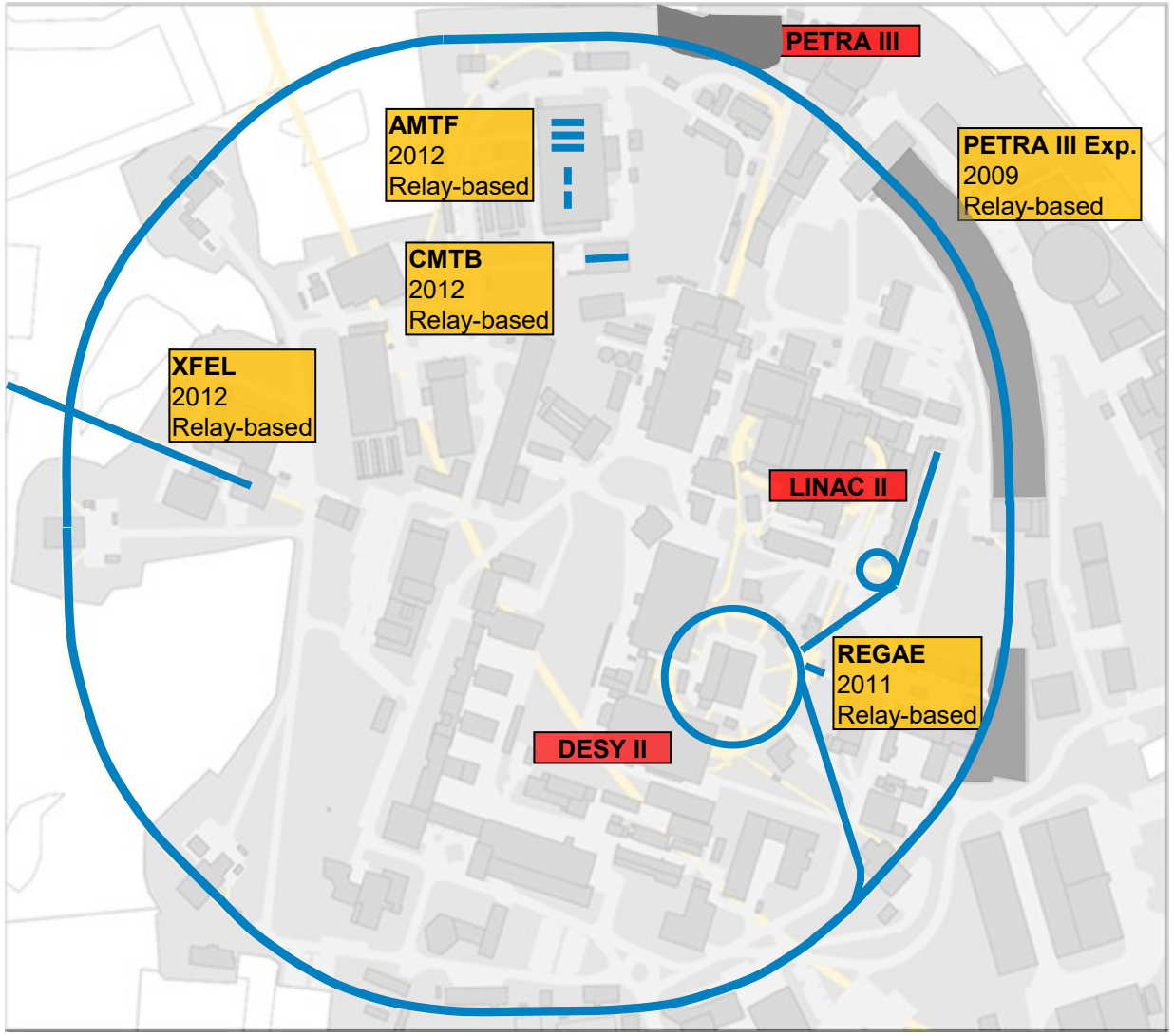
Renewal required!



PSS at DESY

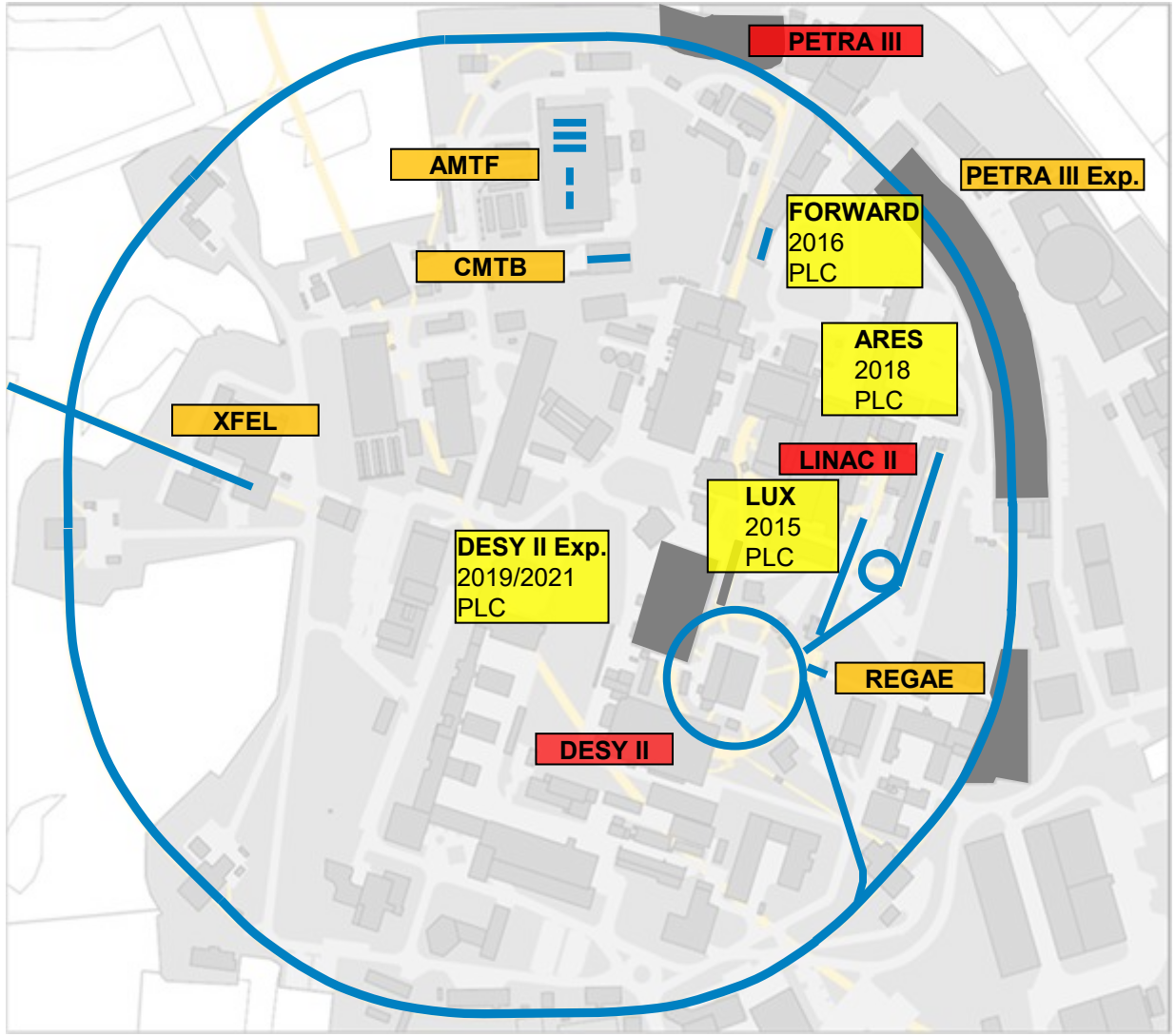
Technology and Age

Renewal wherever possible.



PSS at DESY

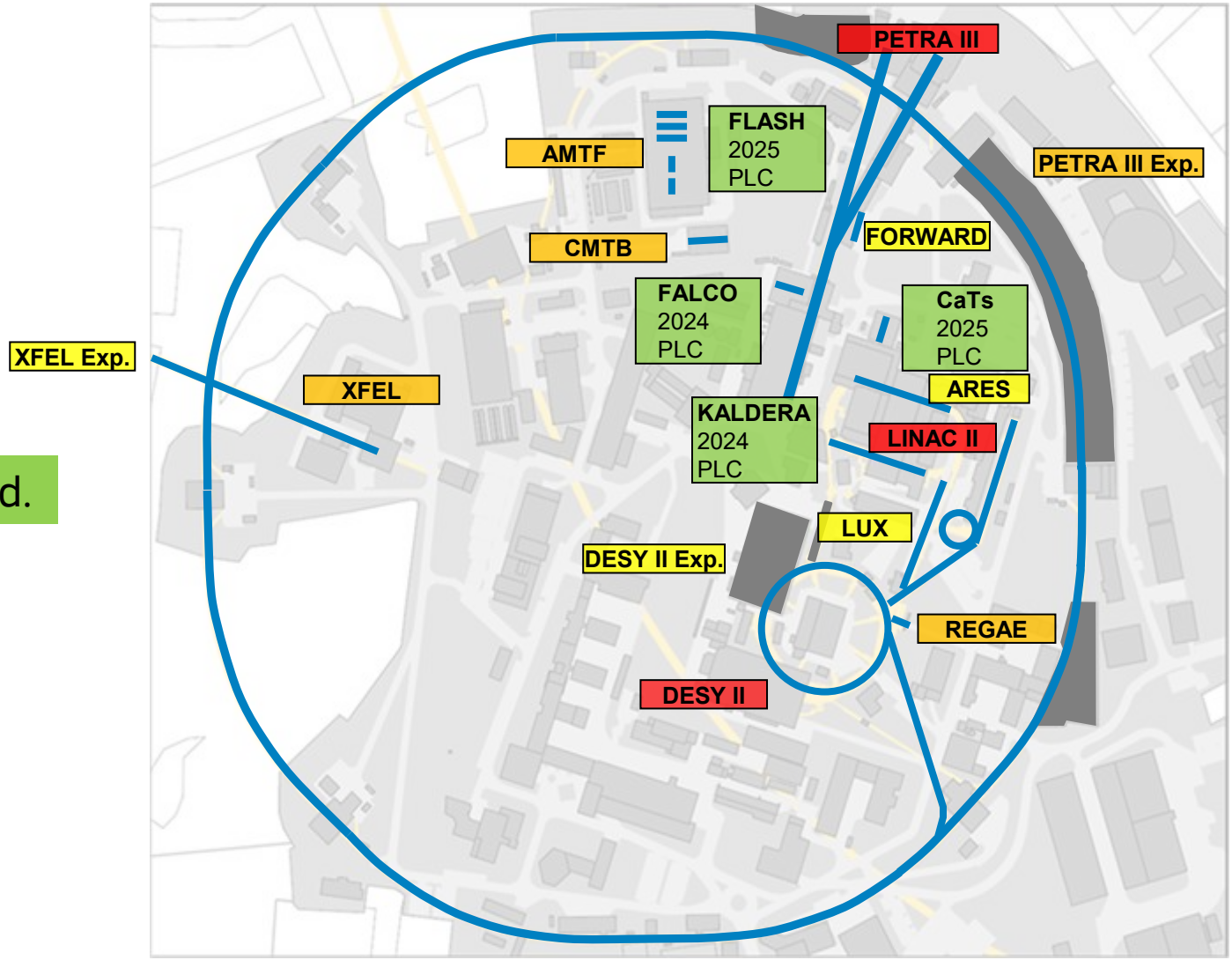
Technology and Age



Upgrade only after major changes or in case of failure.

PSS at DESY

Technology and Age



No upgrade needed.

PSS at DESY in Transition

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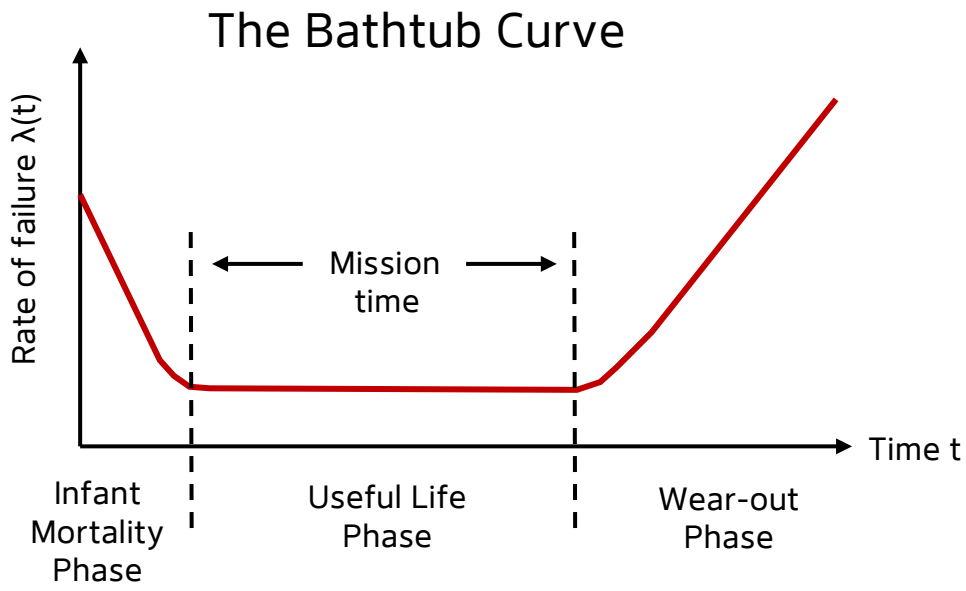
Mission Time

A Key Safety Parameter in Functional Safety Design

- The mission time of components is defined as the time of constant rate of failure (→ Bathtub Curve).
- Standards ISO 62061 and ISO 13849-1 assume a mission time of 20 years typically.
- The mission time of components must be specified by the manufacturer in the product data sheet.
- Beyond stated mission time, safety parameters in the product data sheet are no longer valid.
- The mission time (normally 20 years) is used at DESY to calculate the PL for safety functions.



The replacement of the components is mandatory before the end of their mission time.

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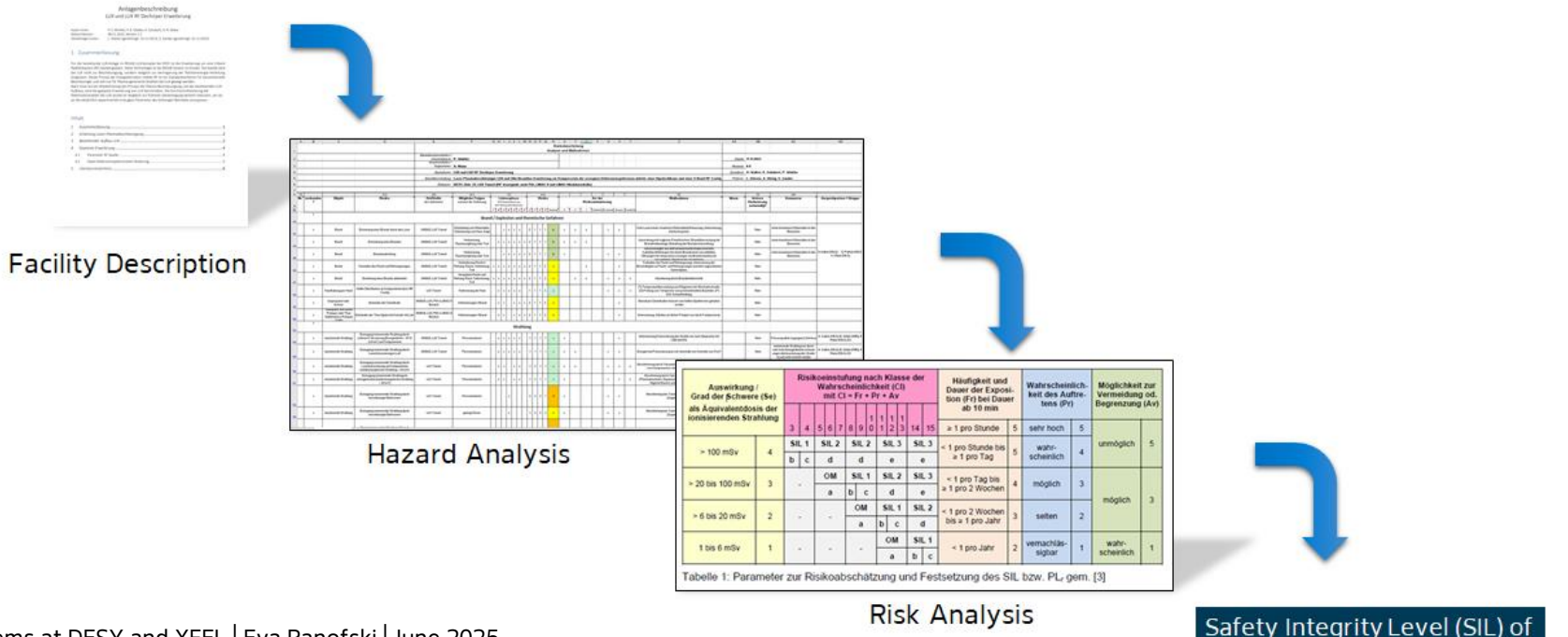
The way to PSS at DESY

Risk assessment process in a nutshell

The official "**Guidelines for the Organization of Safety in Accelerator Projects at DESY**"

- defines roles (governing board, project leader, safety team, project management office) and their
- tasks in different, typical accelerator-related project phases (CD, TD, setup, commissioning, operation),
- ensures conformity with applicable laws, standards, and DESY safety regulations,
- specifies the risk assessment process in projects.

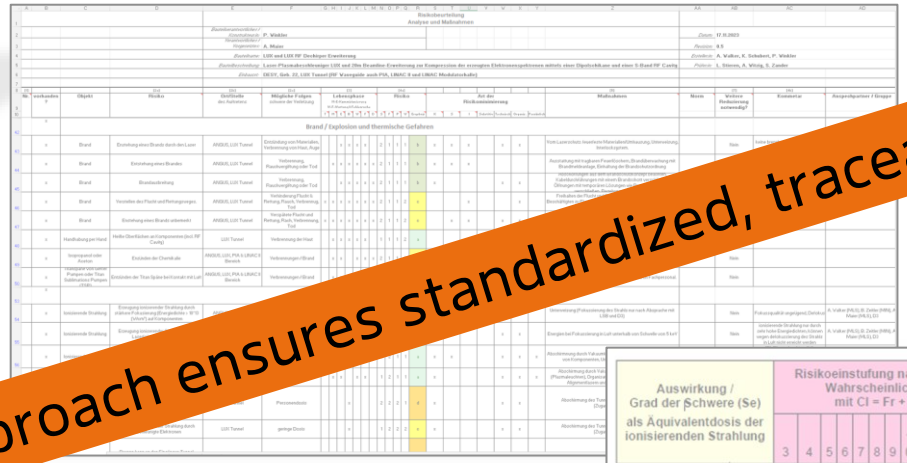


Risk assessment at DESY

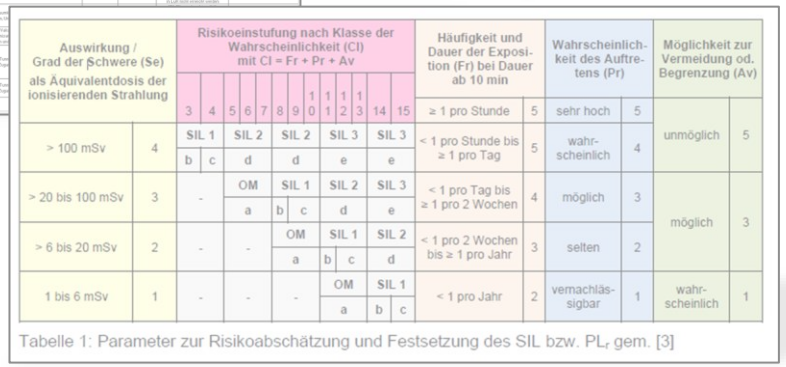
Risk assessment process in a nutshell


Anlagenbeschreibung
LUX und LUX RF Dechirper Erweiterung

Facility Description



Hazard Analysis



Auswirkung / Grad der Schwere (Se) als Äquivalentdosis der ionisierenden Strahlung		Risikoeinstufung nach Klasse der Wahrscheinlichkeit (Cl) mit Cl = Fr + Pr + Av													Häufigkeit und Dauer der Exposition (Fr) bei Dauer ab 10 min		Wahrscheinlichkeit des Auftretens (Pr)		Möglichkeit zur Vermeidung od. Begrenzung (Av)	
		3	4	5	6	7	8	9	10	11	12	13	14	15						
> 100 mSv	4	SIL 1		SIL 2		SIL 2		SIL 2		SIL 3		SIL 3			≥ 1 pro Stunde	5	sehr hoch	5	unmöglich	5
		b	c	d		d		d		e		e			< 1 pro Stunde bis ≥ 1 pro Tag	5	wahrscheinlich	4		
> 20 bis 100 mSv	3	-		OM		SIL 1		SIL 2		SIL 3					< 1 pro Tag bis ≥ 1 pro 2 Wochen	4	möglich	3	möglich	3
				a		b	c	d		e										
> 6 bis 20 mSv	2	-		-		OM		SIL 1		SIL 2					< 1 pro 2 Wochen bis ≥ 1 pro Jahr	3	selten	2		
						a		b	c	d										
1 bis 6 mSv	1	-		-		-		OM		SIL 1					< 1 pro Jahr	2	vernachlässigbar	1	wahrscheinlich	1
								a		b	c									

Tabelle 1: Parameter zur Risikoabschätzung und Festsetzung des SIL bzw. PL_r gem. [3]

Risk Analysis

Safety Integrity Level (SIL) of the Safety Function

The structural approach ensures standardized, traceable safety decisions across projects.

Refurbishment of the PSS at FLASH from 2013

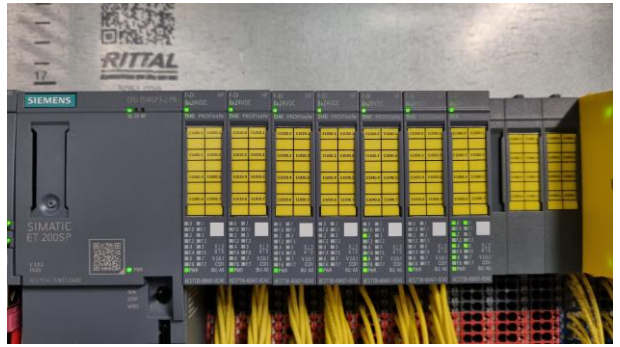
- Refurbishment of the whole safety interlock system at FLASH
- 1 year shutdown time
- Formal risk assessment process completed
- Implementation of a SIL 3 safety interlock system

  → Talk A. Rathjen

  Challenge: Modernization of existing systems to meet

  SIL 3 requirements.
- New testing methodology

  ➡ Only I/O signals and switch-off, no test of logic



Lessons learned from test-rehearsal:

Compliance with SIL 3 requires more than the use of a certified component — the entire system architecture, the validation process, and the expertise of qualified personnel must meet the standard.

PSS at DESY in Transition

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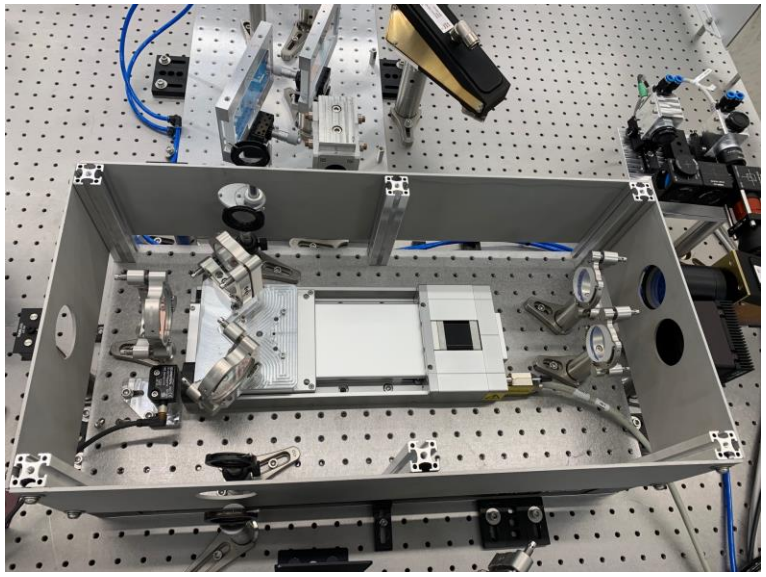
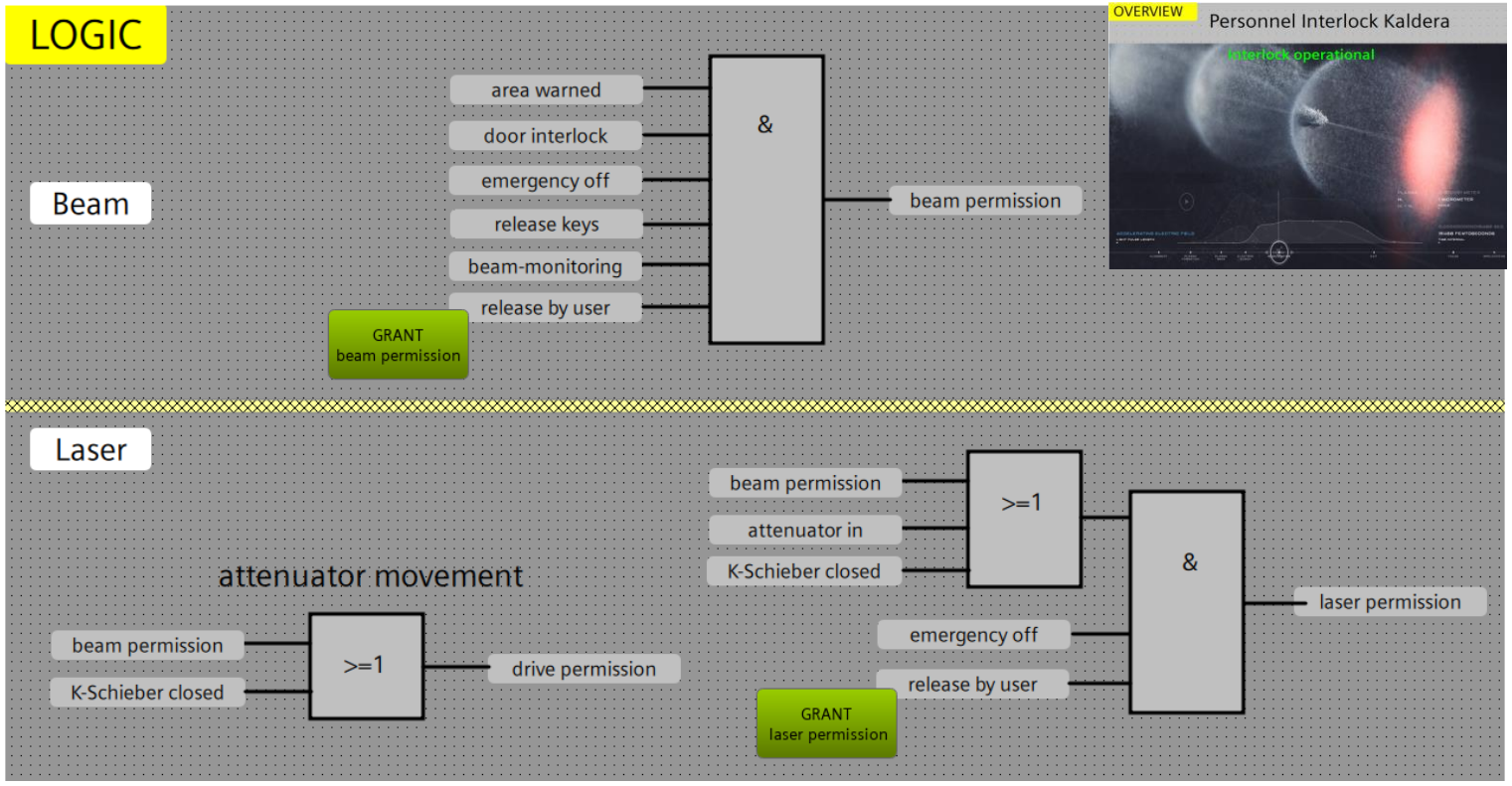
Example: KALDERA

Designing a PSS for a new laser-plasma facility

- Laser-plasma accelerator test facility for high repetition rate (100 Hz).
- Experimental setup in the old DORIS tunnel ➡ PSS infrastructure must be entirely re-engineered.
- Implementation of a SIL 3 safety interlock system
- Source of risk: High-power laser driving a plasma.
- Specific features of KALDERA PSS:
  - Switch-off laser oscillator
  - Laser attenuation for alignment mode





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Future Project in 2026: LPA Injector into DESY II

Challenge: Significant Change of Facilities with PSS

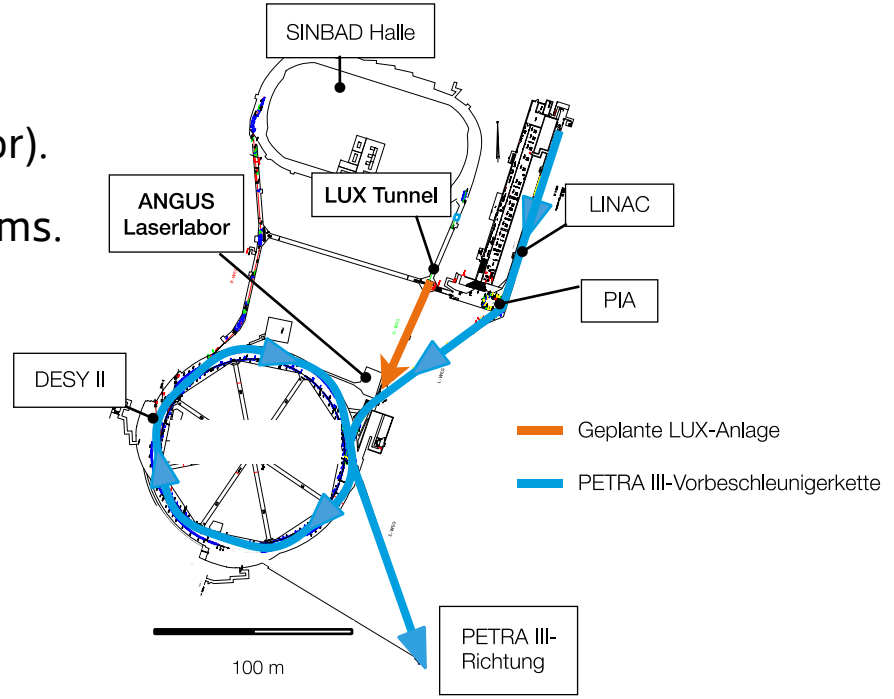
Scientific Goal:

Demonstrate injection of laser-plasma injector beam into storage ring

Challenge:

- Tight time schedule: 1 year from kick-off to start injector commissioning.
- Combination of three personal safety systems (LINAC II, DESY II, LPA injector).
- Integration of old (relay-based) and new (PLC-based) safety interlock systems.
- Interpretation of results from risk assessment process needed.
- Modification during user operation in short maintenance intervals

  — limited time for installation and pre-testing.
- Pre-tests and §88-tests — require additional time and careful coordination.



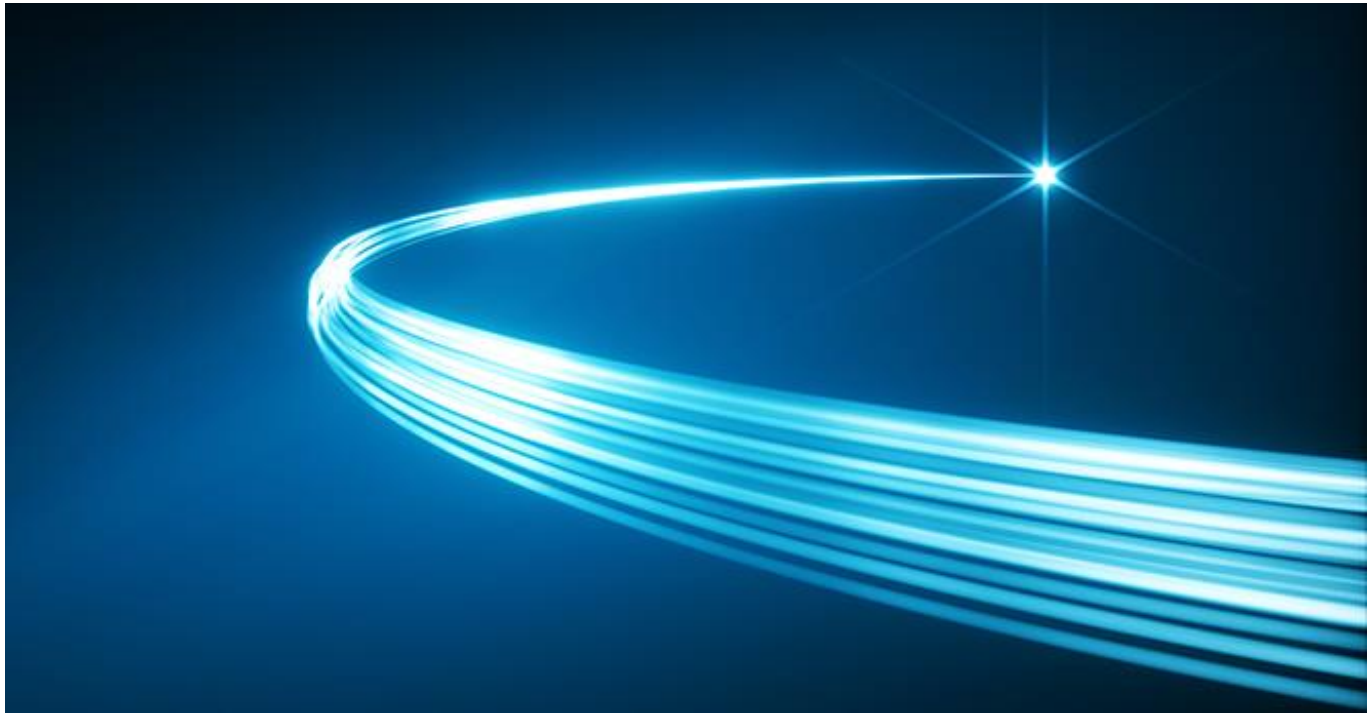
Summary and Outlook

Some challenges due to significant changes, e.g. linking multiple facilities and their existing PSS.

Future machines can be equipped with SIL 3-rated components by default.

PSS approaching end of their mission time are being upgraded.

Next step: Refurbishment of the PSS at LINAC II and DESY II in 2026.



A risk assessment process has been implemented.

Various PSS of different ages and technologies at DESY.

Long expertise in PSS design and operation at DESY.

Thank you for your attention

Kontakt

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Example: Safety function door interlock (IEC 62061)

Door contacts → SIL 3

Risk scenario: Someone enters the accelerator tunnel during operation of the accelerator

Severity of injury S: 4 (high dose rate, irreversible injury)
Frequency and duration of exposure F: 4
Probability of occurence of a hazardous event W: 4
Probability of avoiding or limiting harm P: 5

Consequences	**S**	**C**					**F**		**W**		**P**	
	S	4	5-7	8-10	11-13	14-15						
Death, loosing an eye or arm	4	SIL 2	SIL 2	SIL 2	SIL 3	SIL 3	≥ 1 per h	5	Very high	5		
Permanent injury, loosing fingers	3		OM	SIL 1	SIL 2	Sil 3	< 1 per h up to ≥ 1 per d	5	Likely	4		
Reversible injury, medical attentation	2			OM	SIL 1	SIL 2	< 1 per d up to ≥ 1 every 2 w	4	Possible	3	Impossible	5
Reversible injury, first aid	1				OM	SIL 1	< 1 every 2 w to ≥ 1 per a	3	Rarely	2	Rarely	3
							< 1 per a	2	Negligible	1	Probable	1


PETRA III
European XFEL
DESY II
REGAE
KALDERA
PIA
CaTs
LUX
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ARES
FALCO
CMTB
XATC 1+2
FLASH
XATB 1-3
FORWARD
FLASH II