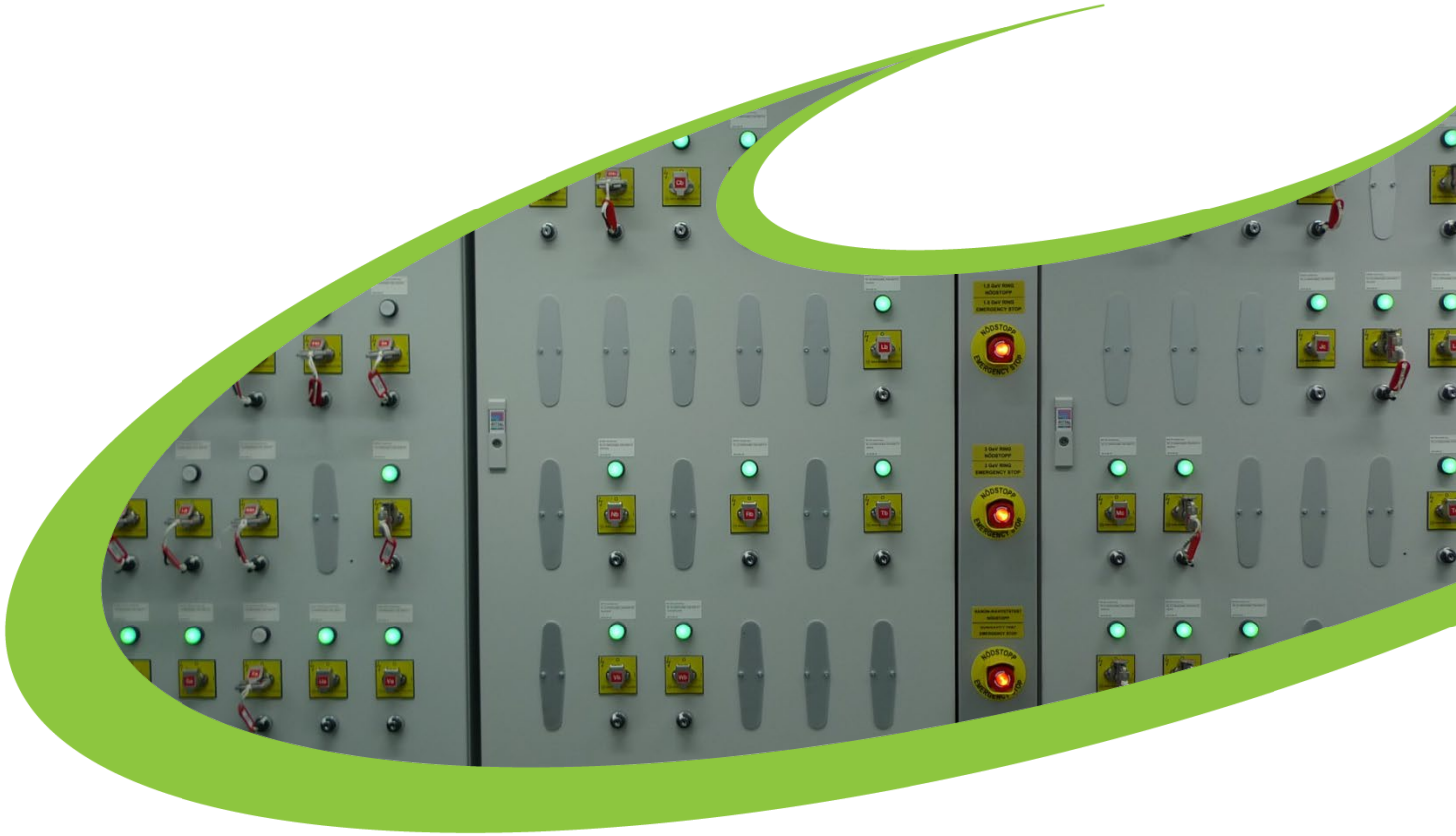


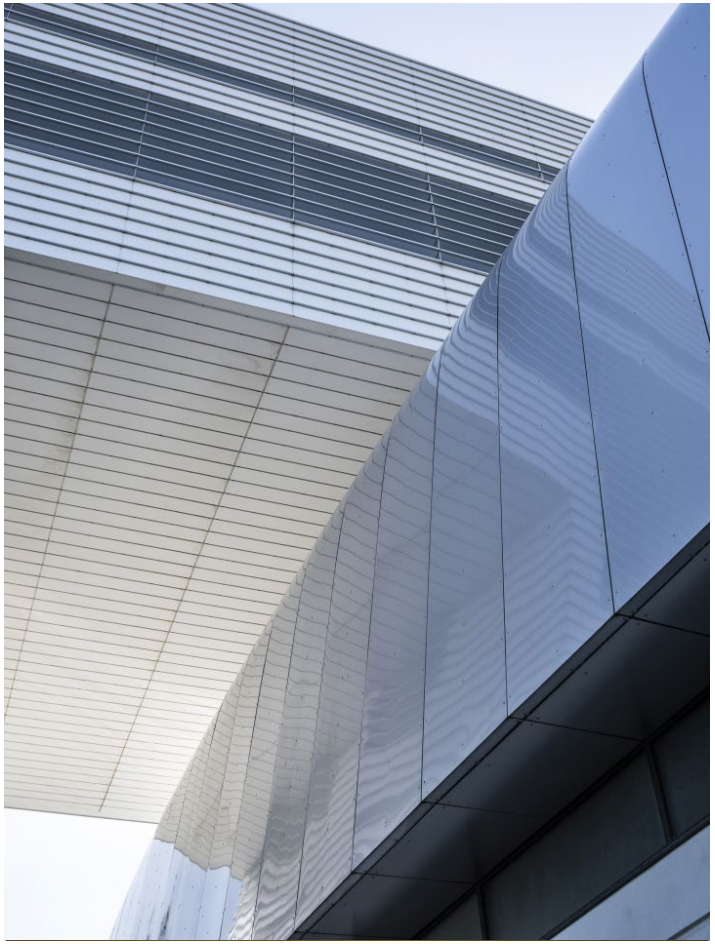
Planned maintenance of the MAX IV personnel safety system

A. Rosborg, J. Malmqvist, N. Jönsson, MAX IV

11th International Workshop on Radiation Safety at Synchrotron Radiation Sources, ESRF, Grenoble, France, 30 May – 2 June 2023

Outline

- Facility update
- PSS overview
- Planned maintenance
- Annual check
- Mission time

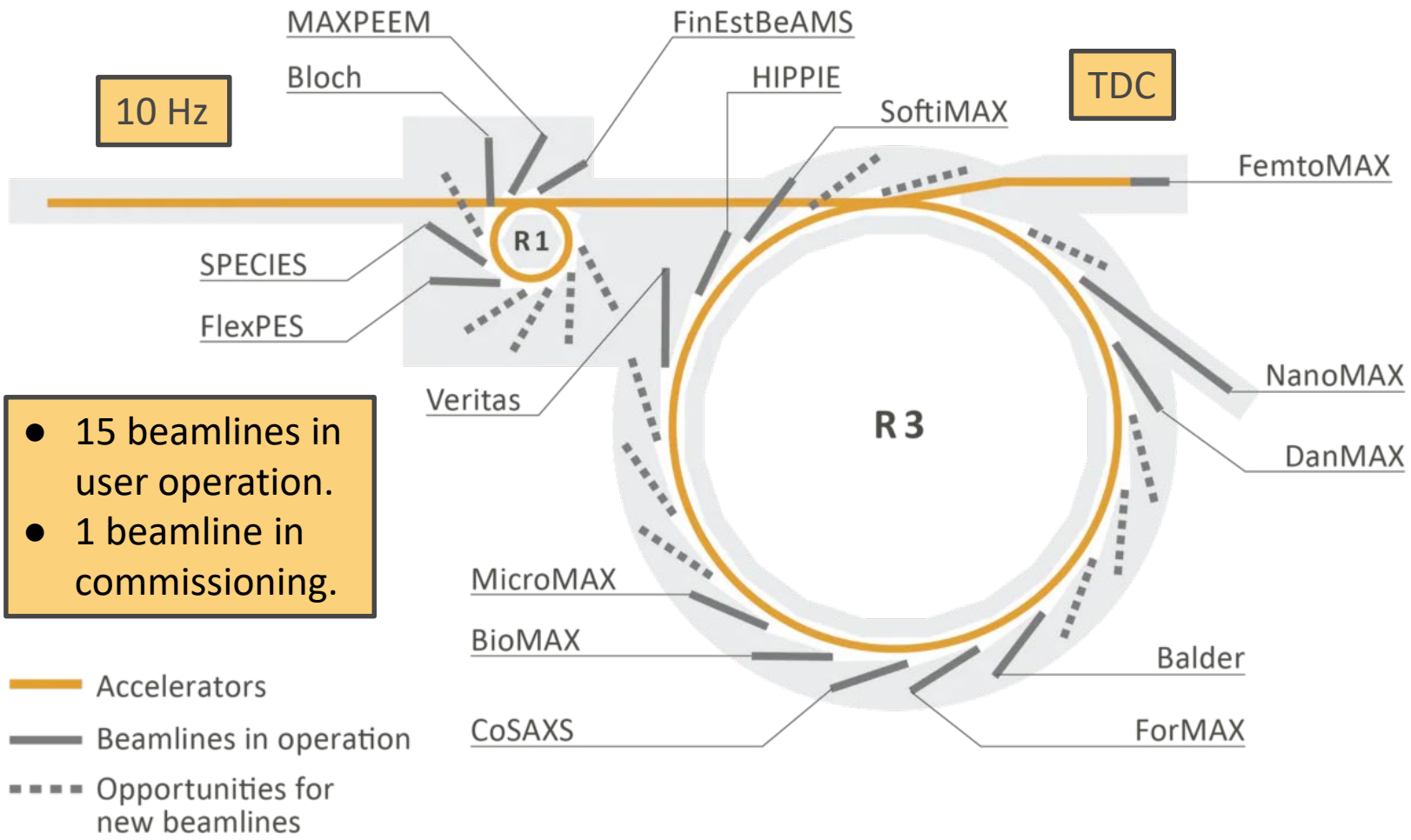


Facility update

Magnus Lundin (1970-2021)

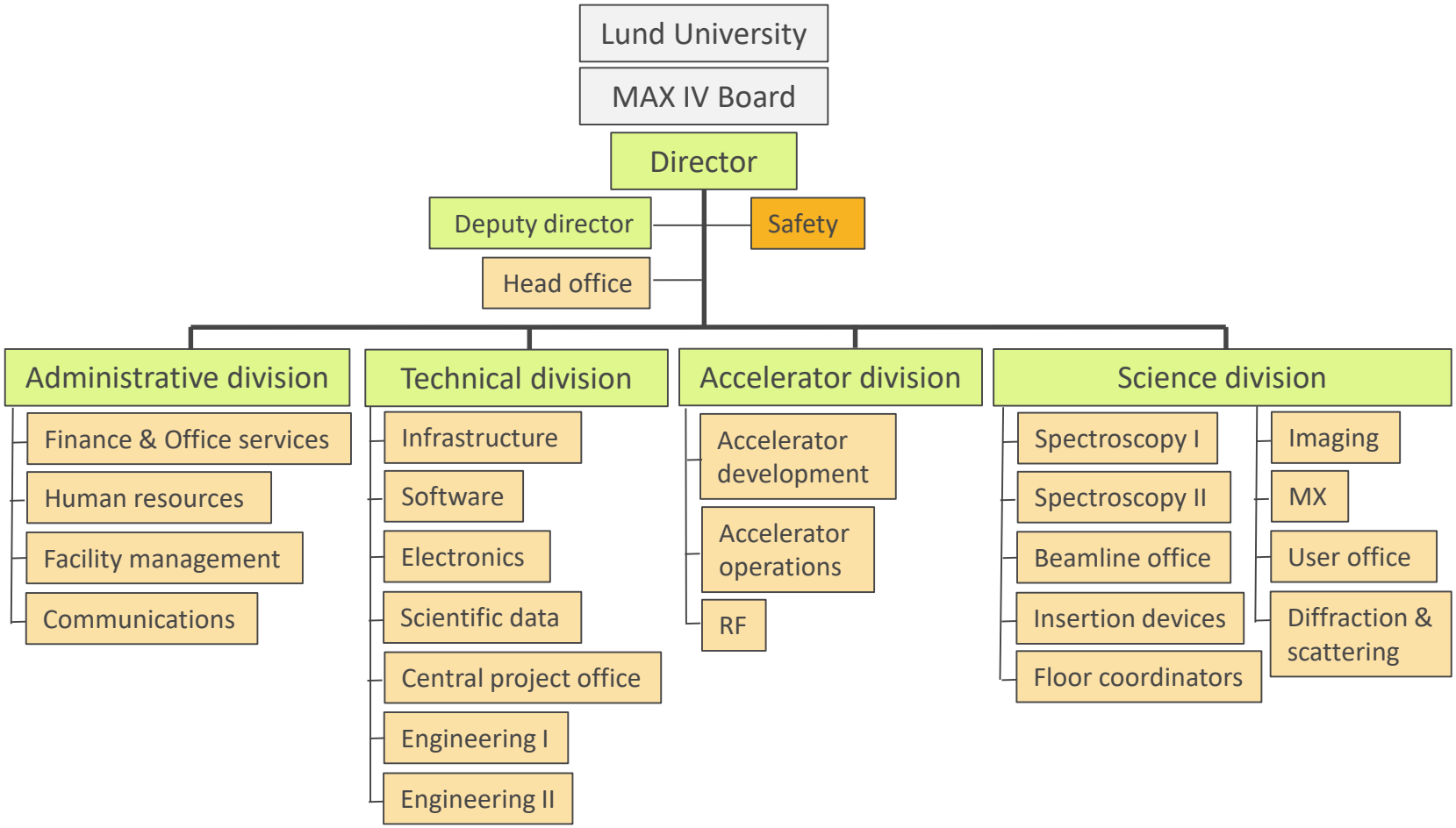
- Magnus Lundin led the radiation safety work at the MAX IV Laboratory for more than 15 years.
- Magnus is remembered as a dedicated and brilliant, friendly and helpful, quiet but determined colleague who played a key role in the MAX IV project. He is dearly missed.

Accelerators & beamlines

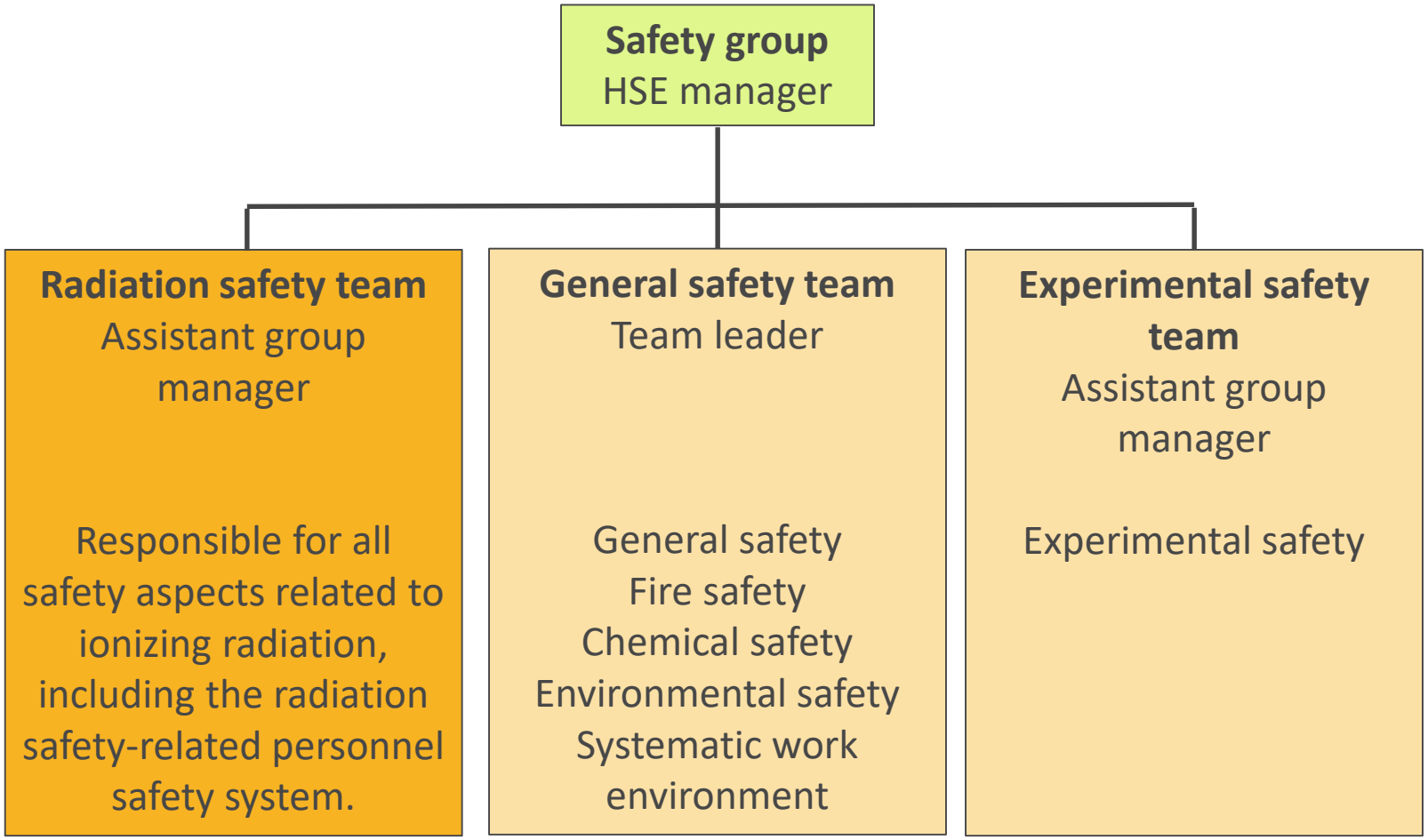


- 15 beamlines in user operation.
- 1 beamline in commissioning.

Organization: MAX IV Laboratory



Organization: Safety group



PSS overview

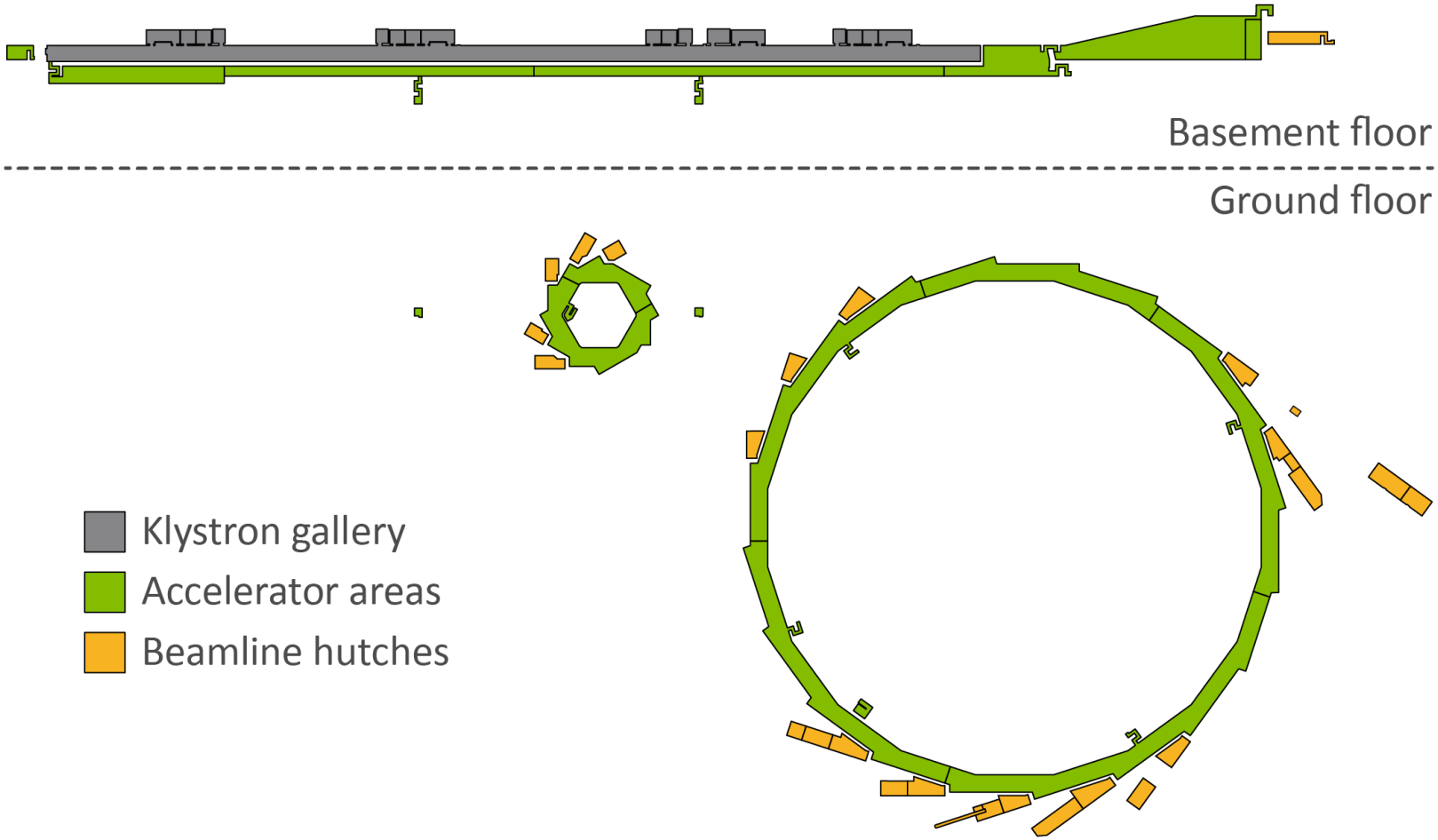
MAX IV personnel safety system

An overview of the design and functionality of the radiation safety-related personnel safety system (PSS) at MAX IV was given at RadSynch17 [1].

A short recap is presented below.

[1] A. Rosborg, The MAX IV personnel safety system, Proceedings of the 9th International Workshop on Radiation Safety at Synchrotron Radiation Sources, NSRRC, Hsinchu, Taiwan, pp. 219--254 (2017).

PSS areas


Basement floor
Ground floor
Klystron gallery
Accelerator areas
Beamline hutches

PSS hardware

The PSS is based on Safety PLCs and components suitable for safety systems.

The critical safety functions are designed based on the general design principles of ISO 13849-1 to reach performance level e (PLe). The entire chain, from input devices to logic to output devices and feedbacks from these, belong to the PSS.

- **Contactors** control the three-phase power to the equipment that accelerate the electrons.
- **Electron beam dumps and photon beam shutters** control which areas of the facility the electron and photon beams can reach.

PSS keys

Keys are used by the PSS to enable the running of different parts of the facility and different modes of operation.

- **Accelerator control room**
  Keys that allow operation of the contactors, electron beam dumps and front-end beam shutters and enable different modes of operation (linac frequency, top-up, I/O tests etc.).
- **Individual beamlines**
  Keys that allow operation of the monochromatic beam shutters and enable different modes of operation (e.g. I/O tests).

Planned maintenance

Overview

The planned maintenance can be divided into two areas.

- **Annual check**
  All operational radiation safety-related personnel safety systems are checked each calendar year.
- **Mission time**
  Replacement of critical PSS equipment before the mission time of 20 years has passed.

Annual check

Introduction

As long as the safe part of the PLC code is locked and equipped with a safety signature no significant changes can be done to the functionality of the PSS.

- The annual check is limited to a check that all individual PSS components work as intended.
- Functional tests are only performed when a new or updated version of a PSS is deployed.

Annual check of all PSS components

The correct operation of each PSS component is checked each year.

- **I/O test**
  Verify the input and output signals.
- **Visual inspection**
  Check for signs of damage or signs of abuse or interference. Ensure, when relevant, that the component is accessible and that the associated signage is in place.

In total, the radiation safety-related PSS consists of about 2500 components. There are 7013 I/O signals, out of which 3923 are safe signals, distributed over 93 I/O nodes and 20 Safety PLCs.

I/O signals

PSS	I/O sum	Standard input	Safe input	Standard output	Safe output	Analogue safe input
IPSS	1622	24	642	867	63	26
R1PSS	740	2	413	296	24	5
R3PSS	1941	5	1034	837	56	9
GPSS	133	3	59	64	7	0
BSP02PSS	94	0	54	32	8	0
B107APSS	86	3	48	27	8	0
B108APSS	86	3	48	27	8	0
B110APSS	86	3	48	27	8	0
B111APSS	86	3	48	27	8	0
B112APSS	86	3	48	27	8	0
B303APSS	350	13	181	137	19	0
B304APSS	292	10	159	106	17	0
B308APSS	188	6	103	66	13	0
B309APSS	253	6	131	103	13	0
B310APSS	283	6	166	98	13	0
B311APSS	207	8	112	73	14	0
B312APSS	306	9	167	113	17	0
B316APSS	87	2	50	26	9	0
B317APSS	87	2	50	26	9	0
B318APSS	87	2	50	26	9	0
Sum	7013	111	3561	2979	322	40

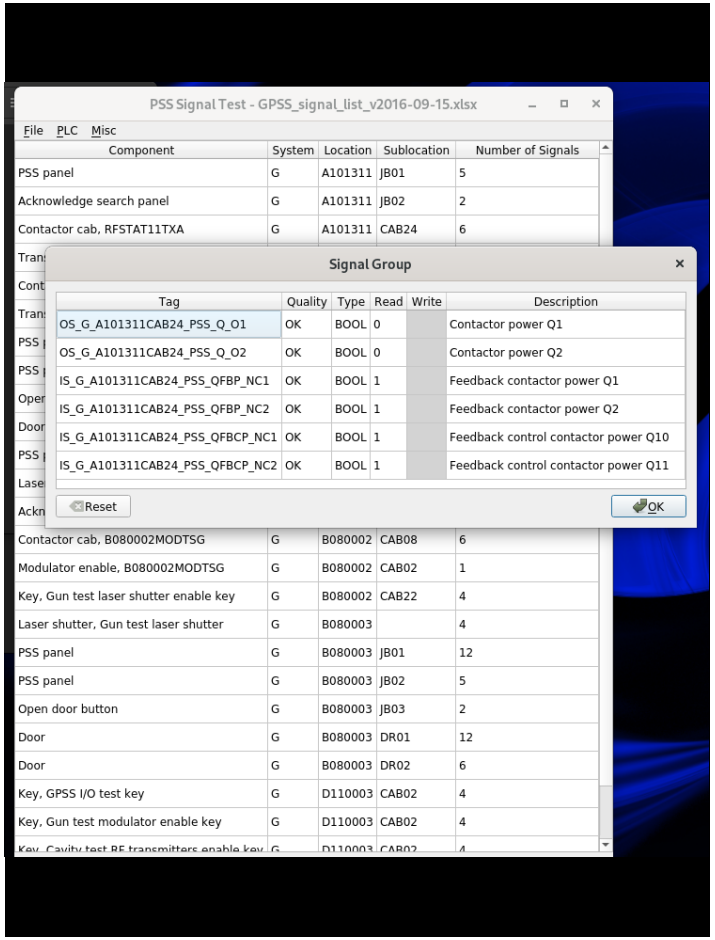
I/O test GUI

An I/O test GUI has been developed to assist in the testing.

The annual check is based on the signal lists of the PSS. In the I/O test GUI the signal list of a PSS can be loaded and a connection can be made to the corresponding PSS PLC.

- The state of each I/O signal is read and displayed.
- For standard output signals, it is possible to write to PLC tags that control the state of the outputs (if the PSS is in I/O test mode).

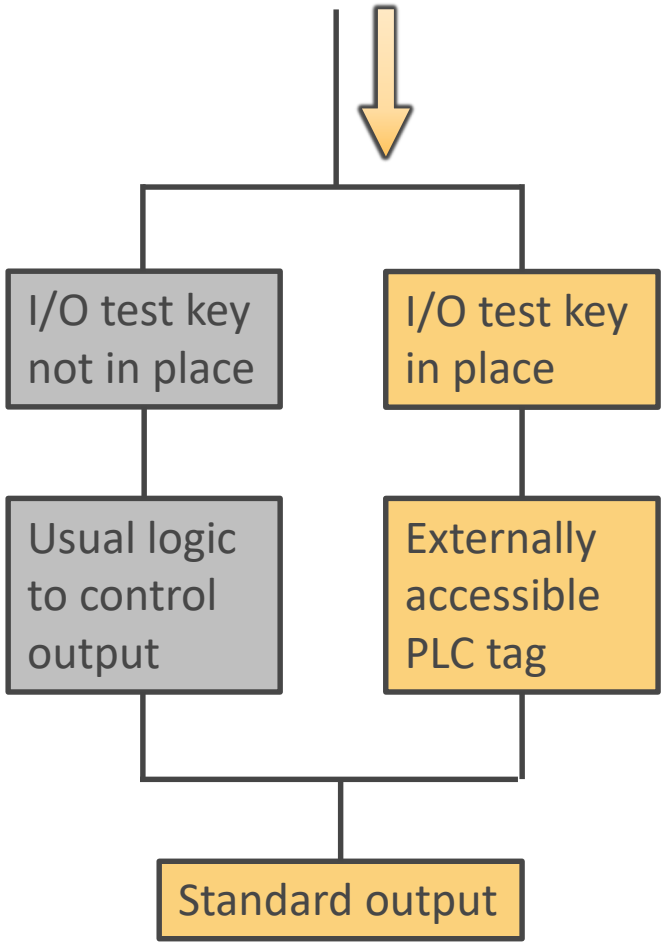
Tag	Quality	Type	Read	Write
O_G_B080003DR02_PSS_PIL01_P1	OK	BOOL	0	0



I/O test mode

Separate mode of operation enabled by turning an I/O test key.

- **External control of standard outputs**
  The standard output signals can be controlled by writing to externally accessible PLC tags. Each standard output has a unique PLC tag associated with it.
- **Sources of ionizing radiation disabled**
  All sources of ionizing radiation related to that part of the facility (accelerator/beamline) are shut down and it is not possible to search any of the associated PSS areas.



Example: Emergency stop

Press emergency stop button.

- _NC1 and _NC2 signals 1->0.

Tag	Quality	Type	Read	Write	Description
IS_B312A_A101230JB12_PSS_SES_NC1	OK	BOOL	1		Emergency stop NC1
IS_B312A_A101230JB12_PSS_SES_NC2	OK	BOOL	1		Emergency stop NC2
O_B312A_A101230JB12_PSS_SES_P	OK	BOOL	0	0	Emergency stop lamp

Tag	Quality	Type	Read	Write	Description
IS_B312A_A101230JB12_PSS_SES_NC1	OK	BOOL	0		Emergency stop NC1
IS_B312A_A101230JB12_PSS_SES_NC2	OK	BOOL	0		Emergency stop NC2
O_B312A_A101230JB12_PSS_SES_P	OK	BOOL	0	0	Emergency stop lamp

Example: Emergency stop

Restore emergency stop button.

- _NC1 and _NC2 signals 0->1.

Tag	Quality	Type	Read	Write	Description
IS_B312A_A101230JB12_PSS_SES_NC1	OK	BOOL	0		Emergency stop NC1
IS_B312A_A101230JB12_PSS_SES_NC2	OK	BOOL	0		Emergency stop NC2
O_B312A_A101230JB12_PSS_SES_P	OK	BOOL	0	0	Emergency stop lamp

Tag	Quality	Type	Read	Write	Description
IS_B312A_A101230JB12_PSS_SES_NC1	OK	BOOL	1		Emergency stop NC1
IS_B312A_A101230JB12_PSS_SES_NC2	OK	BOOL	1		Emergency stop NC2
O_B312A_A101230JB12_PSS_SES_P	OK	BOOL	0	0	Emergency stop lamp

Example: Emergency stop

Set signal _P to 1.

- Button light lit.

Tag	Quality	Type	Read	**Write**	Description
IS_B312A_A101230JB12_PSS_SES_NC1	OK	BOOL	1		Emergency stop NC1
IS_B312A_A101230JB12_PSS_SES_NC2	OK	BOOL	1		Emergency stop NC2
O_B312A_A101230JB12_PSS_SES_P	OK	BOOL	1	1	Emergency stop lamp

Example: Emergency stop

Set signal _P to 0.

- Button light off.

Tag	Quality	Type	Read	**Write**	Description
IS_B312A_A101230JB12_PSS_SES_NC1	OK	BOOL	1		Emergency stop NC1
IS_B312A_A101230JB12_PSS_SES_NC2	OK	BOOL	1		Emergency stop NC2
O_B312A_A101230JB12_PSS_SES_P	OK	BOOL	0	0	Emergency stop lamp

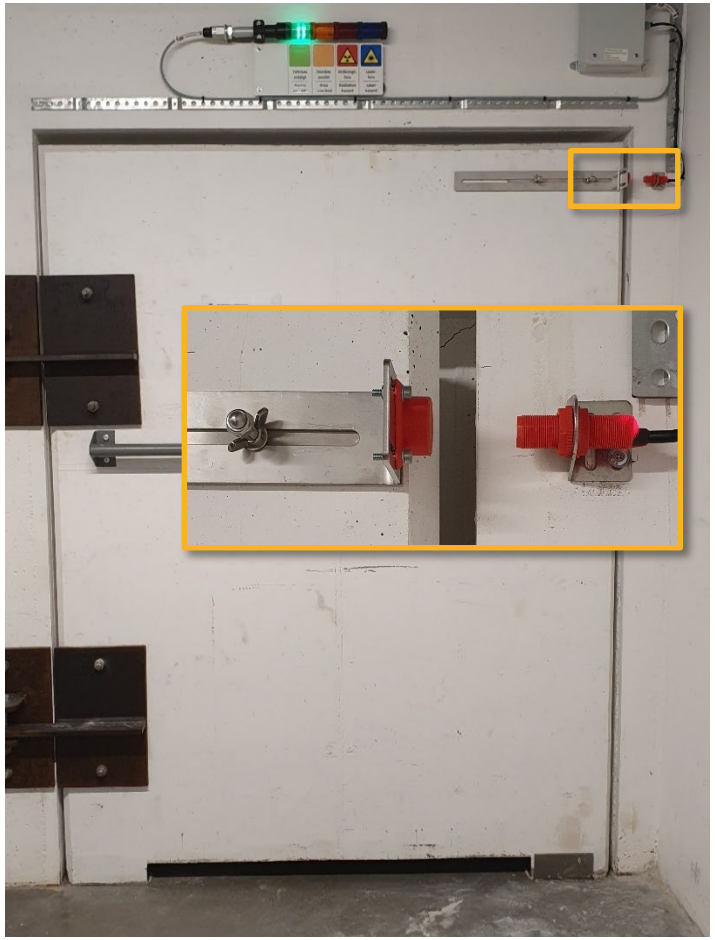
Example: Door switch

Open door switch.

- _NO1 and _NO2 signals 1->0.

Tag	Quality	Type	Read	Write	Description
IS_G_B080003DR02_PSS_BSIC01_NO1	OK	BOOL	1		Inductive circular switch NO1
IS_G_B080003DR02_PSS_BSIC01_NO2	OK	BOOL	1		Inductive circular switch NO2

Tag	Quality	Type	Read	Write	Description
IS_G_B080003DR02_PSS_BSIC01_NO1	OK	BOOL	0		Inductive circular switch NO1
IS_G_B080003DR02_PSS_BSIC01_NO2	OK	BOOL	0		Inductive circular switch NO2



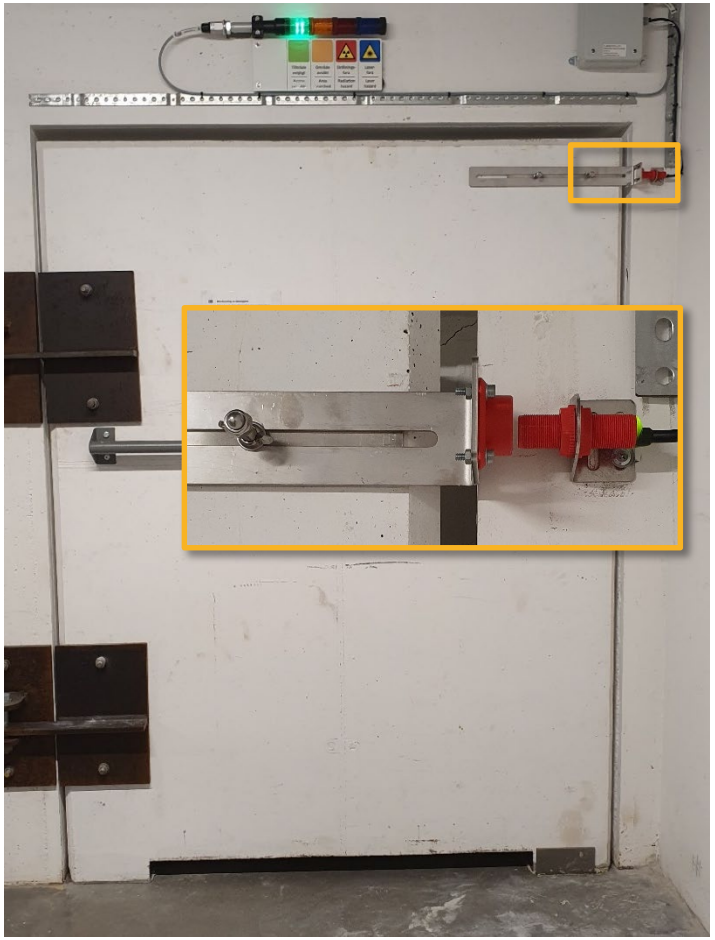
Example: Door switch

Close door switch.

- _NO1 and _NO2 signals 0->1.

Tag	Quality	Type	Read	Write	Description
IS_G_B080003DR02_PSS_BSIC01_NO1	OK	BOOL	0		Inductive circular switch NO1
IS_G_B080003DR02_PSS_BSIC01_NO2	OK	BOOL	0		Inductive circular switch NO2

Tag	Quality	Type	Read	Write	Description
IS_G_B080003DR02_PSS_BSIC01_NO1	OK	BOOL	1		Inductive circular switch NO1
IS_G_B080003DR02_PSS_BSIC01_NO2	OK	BOOL	1		Inductive circular switch NO2



Test outline

- Most of the components are tested with the I/O test key is in place.
- Some components require that PSS areas are searched (e.g. contactors, beam dumps and beam shutters).
- A small number of components can only be tested while the accelerators are running (e.g. the linac trigger rate monitors and the current monitors for the stored electron beam in the rings).

Detailed instructions for how the annual check is performed and the required action and test result for each type of PSS component and I/O signal are available in a manual.

Table 2.2 (continued): *Overview of the annual function check.*

Type	Test key	Action overview	Result overview	Also see Section
SBA	Yes	• Press button • Release button • Set signal _P to 1 • Set signal _P to 0	_NO signal 0→1 _NO signal 1→0 Button light lit Button light off	7.6.5
SBAW	Yes	• Press button • Release button • Set signal _P to 1 • Set signal _P to 0	_NO signal 0→1 _NO signal 1→0 Button light lit Button light off	7.7.5
SBL	Yes	• Press button • Release button • Set signal _P to 1 • Set signal _P to 0	_NO signal 0→1 _NO signal 1→0 Button light lit Button light off	7.8.5
SBK	Yes	• Press button • Release button	_NC signal 1→0 _NC signal 0→1	7.9.5
SES (button)	Yes	• Press emergency stop button • Restore emergency stop button • Set signal _P to 1 • Set signal _P to 0	_NC1 and _NC2 signals 1→0 _NC1 and _NC2 signals 0→1 Button light lit Button light off	7.10.5
SES (pull rope)	Yes	• Pull emergency stop rope • Restore emergency stop pull rope switch	_NC1 and _NC2 signals 1→0 _NC1 and _NC2 signals 0→1	7.10.5
SMS (ring)	Yes	• Set corresponding magnetic lock (RL) signal _O to 1 • Press machine stop button on one side • Restore machine stop button and reset alarm • Press machine stop button on other side • Restore machine stop button and reset alarm	Electromagnet active, door on metal gate locked _NC signal 1→0, door not locked _NC signal 0→1, door locked _NC signal 1→0, door not locked _NC signal 0→1, door locked	7.11.5

Continued on next page

Resource and time consumption

The annual check is performed by two persons.

- **Person A**
  Walks around the facility, inspects components, presses buttons, opens doors, verifies that lights are lit etc.
- **Person B**
  Sits with the I/O test GUI, reads the states of the I/O signals and writes to the PLC tags that controls the standard outputs.

The radiation safety team sets aside one week for the annual check each summer shutdown. With two experienced testers the check is completed in about 30 h.

Observations from the annual checks

- **2019:** 2 broken LED lights, 1 non-working lighting control.
- **2020:** 4 broken LED lights.
- **2021:** 1 faulty magnetic lock, 7 broken LED lights.
- **2022:** 1 faulty emergency stop, 22 broken LED lights, 1 non-working lighting control.

In addition, we have had issues with emergency stop buttons that are somewhat hard to press and reset.

Mission time

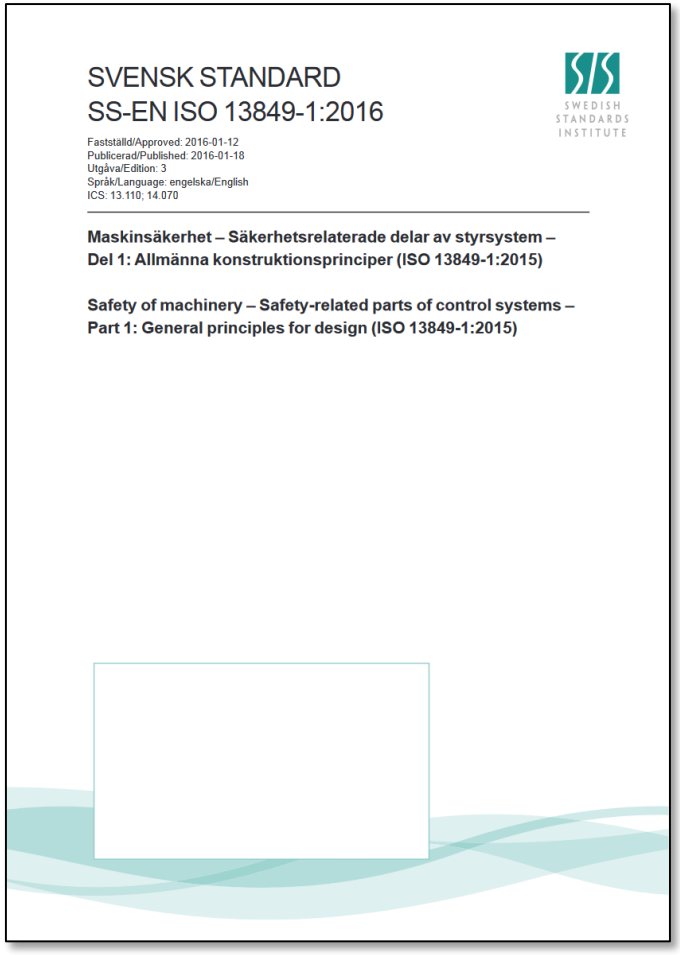
Mission time

When using ISO 13849-1, a mission time of 20 years is typically assumed. Within the mission time the components are assumed to have a constant failure rate.

If components are used beyond the stated mission time, the safety parameters in the product data sheets are no longer valid. It is thus necessary to replace the components before the mission time has been reached.

At MAX IV

A mission time of 20 years was used for the performance level calculations for the critical safety functions.


SVENSK STANDARD
SS-EN ISO 13849-1:2016

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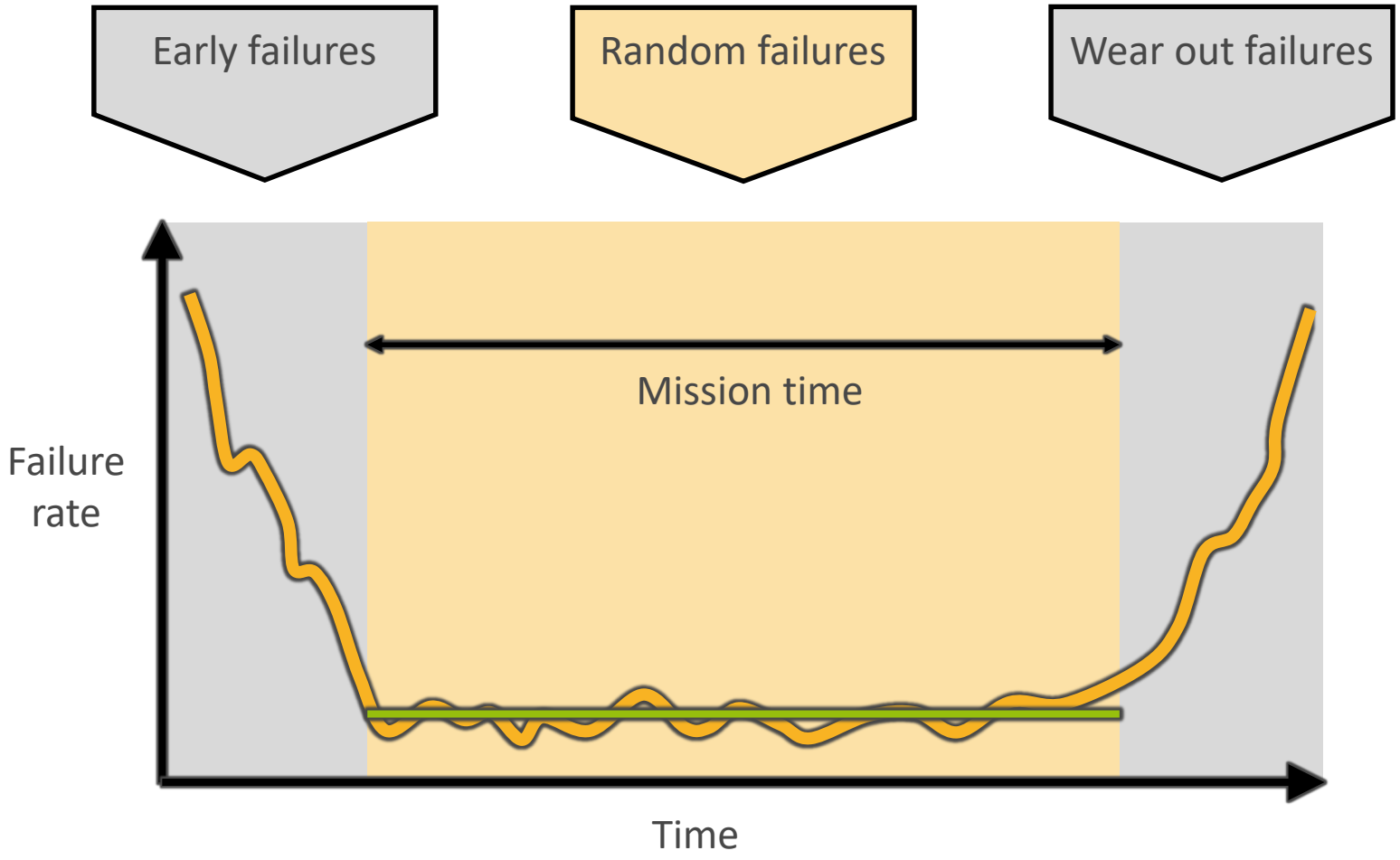
ICS: 13.110; 14.070

Maskinsäkerhet – Säkerhetsrelaterade delar av styrsystem – Del 1: Allmänna konstruktionsprinciper (ISO 13849-1:2015)

Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design (ISO 13849-1:2015)

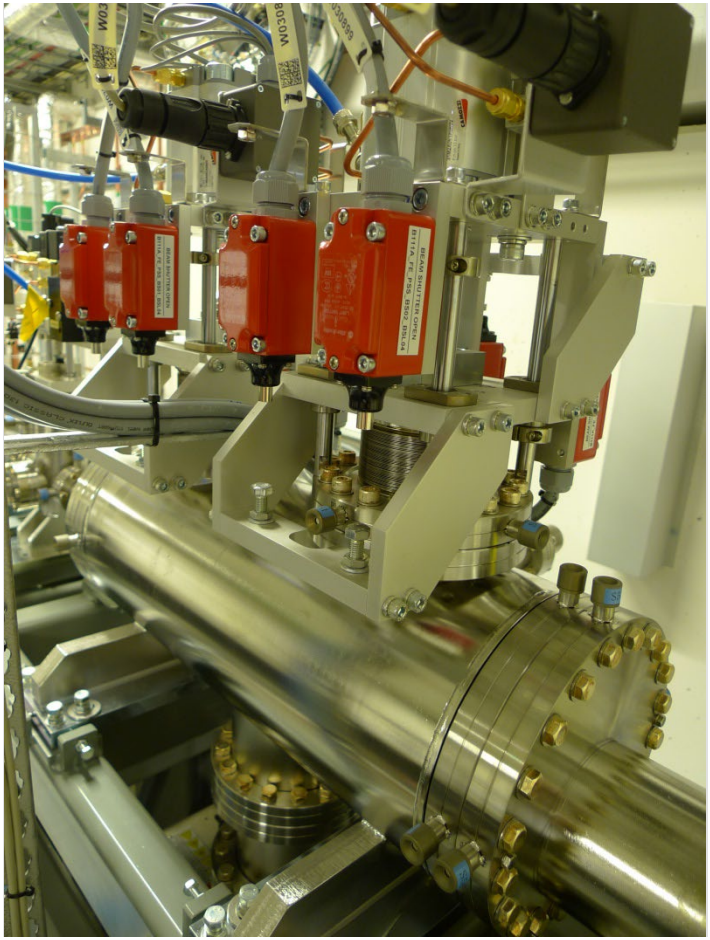
Bathtub curve



Replacement

The equipment that should be replaced is the equipment that is included in the performance level calculations, such as

- input devices (limit switches, door switches, emergency stops etc.),
- I/O nodes and I/O cards,
- PLC controllers and
- output devices (contactors etc.).



Example: Emergency stop

- **Replace**
  Contact blocks
- **Optional**
  Plastic enclosure
  LED light
  Cabling

Example: Door switch cabled to I/O card

- **Replace**
  Door switch
  I/O card
- **Optional**
  Cable to cabinet
  Internal cabling in cabinet
  Terminals by I/O card

Outlook

The oldest part of the MAX IV PSS was deployed almost 10 years ago.

The initial work to prepare for the equipment replacement has recently started. In particular, we will look into the question if and to what extent the validation of the PSS should be redone.

In summer 2024, we plan to upgrade the Safety PLC controllers for the PSS for the large accelerator areas with the newest version of the hardware.