CONCEPTS OF OPERATIONS FOR THE ACCELERATOR PERSONNEL SAFETY SYSTEM 1

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TABLE OF CONTENT PAGE

LIST OF FIGURES

1. SCOPE

This document specifies the Concepts of Operations (ConOps) for the Accelerator Personnel Safety System 1 (PSS1), under development for the ESS project in Lund, Sweden. The PSS1 ConOps document provides a high-level description of the PSS1 systems and their expected operations. The PSS1 systems and their operational procedures are described from a user's point of view, the stakeholders of the system and their needs are identified, and interfaces to existing and future systems are established.

2. ISSUING ORGANISATION

Protection Systems Group (PSG) in Integrated Control System division (ICS).

3. PSS1 CHARACTERISTICS

3.1. Environment

The NCL is installed in the first 60 meters of the accelerator tunnel and consists of an Ion Source (ISrc), a Low Energy Beam Transport (LEBT) section, a Radio-Frequency Quadrupole (RFQ), a Medium Energy Beam Transport (MEBT) section, and a Drift Tube Linac (DTL) [1]. It should be noted that commissioning of proton beam until the end of the DTL4 is planned for NCL trial operation [2].

3.2. PSS1 purpose

NCL stakeholders need to access NCL area for various reasons such as maintaining the RFQ, MEBT, DTL systems and their supporting electrical and mechanical infrastructure, etc. The purpose of PSS1 is primarily to restrict access to NCL area and to ensure that personnel are protected from being harmed by exposure to ionising radiation in the NCL, generated by the proton beam and high-power Radio Frequency (RF) systems. This is achieved by allowing access to the NCL area in the accelerator tunnel (hereafter referred to as "PSS1 controlled area") only during safe state of the area. The radiation and conventional hazards which are mitigated by PSS1 are described in Normal Conducting Linac Risk Assessment for Operation with Beam up to DTL4 document [3] and in Radiological Hazard Analysis Report for G area - prompt and residual radiation (Normal Conducting Linac Beam Commissioning) document [2].

3.3. PSS1 overview

PSS1 is the Personnel Safety System (PSS) for the NCL trial operation. It consists of two subsystems: The Safety Interlock System and the Access Control System. Figure 1 shows the layout of the NCL and the Front-End Building (FEB) with the PSS1 controlled area coloured in orange. It should be noted that controlling the access to the area coloured in green (in Figure 1) will be handled procedurally, should this area be a controlled area based on radiation measurements to be carried out in initial days of NCL trial operation.

There is one entry point for personnel and one entry point for materials into the PSS1 controlled area, which are located in the FEB, level 90. Furthermore, there are two emergency exits, which can be used to exit the PSS1 controlled area in case of emergency. One emergency exit door is located next to the Personnel Access Station (PAS) in the FEB, and the other one is located downstream the temporary shielding wall which is built after DTL4 in the accelerator tunnel.

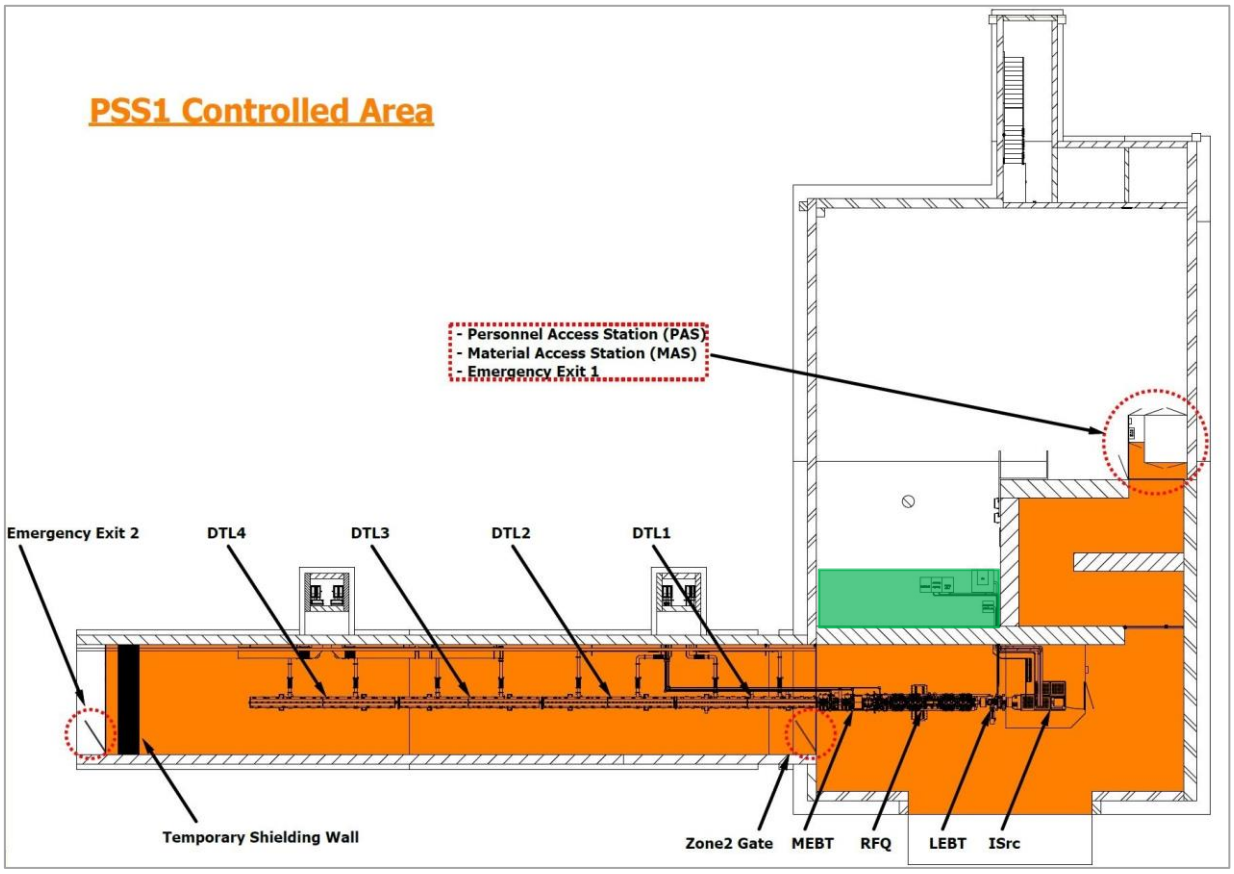

Figure 1: PSS1 controlled area marked in orange

Appendix 1 details a plan view of the accelerator tunnel and the klystron gallery, highlighting the areas where the Local Control Room (LCR), the PSS1 controlled area and the PSS1 cabinets are situated.

3.3.1. Safety interlock system

To ensure the safety for personnel working in the PSS1 controlled area, a number of safety interlocks are installed. The safety interlock system consists of sensors, logic solvers and actuators that remove the permits to power the proton beam and RF systems under conditions leading to ionising radiation hazards. The PSS1 safety interlocks are listed below:

1. If the PSS1 Main key in the key exchange system (Appendix 4) is removed, the proton beam is switched off by removing the power to the designated Stakeholder Associated Equipment (SAE), which are the ISrc High Voltage Power

Supply (HVPS) and the RFQ modulator. The RF power to the MEBT bunchers and DTLs is also switched off by removing power to the MEBT bunchers Solid State Amplifiers (SSA) and the DTL modulators respectively.

2. Lock access doors to PSS1 controlled area prior to enabling the power to the designated SAE as described in 3.3.1.1. This function is derived from Worker Radiation Safety Function (WRSF) 94 in [2].
3. If an intrusion into PSS1 controlled area is detected by the safety position monitoring switches at any access or emergency exit door of PSS1 controlled area, the proton beam is switched off by removing the power to the designated SAE, which are the ISrc magnetron Power Supply (PS), the ISrc HVPS and the RFQ modulator. The RF power to the MEBT bunchers and DTLs is also switched off by removing power to the MEBT bunchers SSA and the DTL modulators. This function is derived from WRSF 95 in [2].
4. The PSS1 controlled area is equipped with emergency switch-off pushbuttons. Pressing any of the emergency switch-off pushbuttons in the PSS1 controlled area immediately switches off the proton beam and the RF power by removing the power to the designated SAE as described in 3.3.1.3.
5. If PSS1 receives a high radiation alarm or a fault signal from any of the Area Mixed-Field Monitors (AMM), the proton beam and the RF power are immediately switched off by removing the power to the designated SAE, as described in 3.3.1.3, in order to protect personnel working in the vicinity of the PSS1 controlled area. This function is derived from WRSF 141 in [2]. Appendix 2 details the location of the AMM around the PSS1 controlled area.
6. The RF systems for RFQ and DTLs will need to be tested in the klystron gallery whilst access to PSS1 controlled area is allowed. Only if a dedicated removable part of the RF Distribution System (RFDS) is removed, the power to the RFQ and DTL modulators is enabled by PSS1. The PSS1 monitors the position of the removable RF waveguide and ensures this part is removed prior to enabling power to the respective RF system.
7. The RF systems for MEBT will need to be tested in the klystron gallery whilst access to the PSS1 controlled area is allowed. Only if the RF switch on the RF coaxial cable is closed, the power to the MEBT bunchers SSA is enabled by PSS1. The PSS1 monitors the position of the RF switch on the RF coaxial cable and ensures it is closed prior to enabling power to the respective RF system.

3.3.1.1. Stakeholder Associated Equipment for PSS1

Stakeholder Associated Equipment (SAE) are the equipment in NCL that PSS1 interlocks in order to mitigate their associated hazard(s) within PSS1 controlled area.
The PSS1 interfaces with SAE are realised as below:

- PSS1 interfaces with ISrc:
    - PSS1 interface with mains incoming power to ISrc magnetron PS;
    - PSS1 interfaces with mains incoming power to ISrc HVPS.
- PSS1 interfaces with RF switches after the Low-Level Radio Frequency (LLRF) systems;
- PSS1 interface with modulators:

- PSS1 interface with mains incoming power to the modulators;
- PSS1 interface with modulators through control system. PSS1 requests de-energisation of the modulators through EPICS shortly (500 milliseconds)[1] prior to disabling the mains incoming power to modulator by PSS1. The purpose of this interface is to prevent any potential damage to the modulators due to disabling the modulator mains incoming power by PSS1;

- PSS1 interfaces with Radio Frequency Local Protection Systems (RF LPS).
- PSS1 interface with mains incoming power to the MEBT bunchers SSA.

3.3.2. Access control system

The PSS1 access control system controls the access to the PSS1 controlled area. It consists of a Personnel Access Station (PAS) and a Material Access Station (MAS).

3.3.2.1. Personnel Access Station

The PAS in the FEB is a double-gated access system consisting of two doors and an enclosed area between them. The PAS is intended for personnel access to the PSS1 controlled area. Door 1 connects the PAS with the FEB, and Door 2 connects the PAS with the PSS1 controlled area. The PAS has the following functional specifications:

1. The PAS ensures single person entry and exit to the PSS1 controlled area.
2. Door 1 and Door 2 of PAS cannot be open at the same time.
3. Entry and exit to the PSS1 controlled area are granted by swiping the person's ESS Identification (ID) card with entering the Personal Identification Number (PIN) that is registered in the ESS Access Management System (AMS) database(s). Upon swiping the card and entering the PIN, the AMS verifies if the person is authorised to access the PSS1 controlled area. The verification includes, but is not limited to personal identification, safety training and person's annual effective dose level.
4. Inside the PAS, a key exchange system is used to limit the number of people allowed to enter PSS1 controlled area in specific access modes (as described in section 5). Furthermore, a pressure floor mat (with a marked area, which provides standing space to only one person) is installed to ensure that only one person is present inside the PAS at a time.
5. The person shall verify that they are carrying an Electronic Personal Dosimeter (EPD) to be able to proceed with access to PSS1 controlled area.
6. For communication between the PAS and LCR, intercom and video surveillance systems are installed inside and outside the PAS.
7. A message display system is installed on top of Door 1 of the PAS providing personnel with information such as the current state of PSS1, access mode to PSS1 controlled area, etc.

[1] This value will be justified during initial operations, when more data will become available.

3.3.2.2. Procedures for entry to the PSS1 controlled area through the PAS

In order to enter the PSS1 controlled area through the PAS, the steps mentioned below are followed:

1. The person obtains an EPD from the electronic dosimetry system in FEB prior to access to the PSS1 controlled area.
2. The person swipes the ESS ID card and enters PIN at Door 1. Upon approval from the AMS database and on the conditions that PSS1 allows access to the PSS1 controlled area and the PAS is not occupied, Door 1 opens.
3. The person enters the PAS, Door 1 closes and locks.
4. Inside the PAS, the following steps are carried out in order to proceed with access to the PSS1 controlled area:
    a. The person stands on the marked area on the pressure mat.
    b. The person shall verify they are carrying an activated EPD by inserting it in the EPD slot. The person shall remove the EPD from the slot in order to be able to proceed with access to the PSS1 controlled area.
    c. Depending on the mode of access, the person might need to take an Entry Key, which is used as a safety token in order to proceed with access to the PSS1 controlled area.
    d. The access procedure aborts in case the person presence in the PAS exceeds a certain amount of time (the time is to be defined) or the person is standing outside the marked area.
5. If all conditions in previous step are ok, Door 2 opens and the person enters the PSS1 controlled area.
6. The AMS logs the person's entry to the PSS1 controlled area.

3.3.2.3. Procedures for exiting the PSS1 controlled area through the PAS

In order to exit the PSS1 controlled area to the FEB through the PAS, the steps mentioned below are followed:

1. The personnel shall measure themselves for contamination on their hands and feet before leaving the PSS1 controlled area using the Site Hand and Foot Monitor (SHM) [4]. If the contamination measurement is positive, the person shall contact LCR via the intercom next to Door 2 of PAS in order to receive further instructions. Appendix 2 details the location of the SHM.
2. The person swipes the ESS ID card and enters PIN at Door 2. If the PAS is not occupied, Door 2 opens. The person enters the PAS, Door 2 closes and locks.
3. Depending on the mode of access, the person might need to return the Entry Key in order to proceed with exiting the PAS.
4. Door 1 opens, and the person exits the PAS.
5. The AMS logs the person's exit from the PSS1 controlled area.
6. The person returns the EPD to the electronic dosimetry system in FEB.

Notes:

- In case of emergency, personnel should exit the PSS1 controlled area through one of the two emergency exits.
- In case of power failure in PAS, Door 2 remains locked and Door 1 unlocks to ensure the person is not trapped inside the PAS. In this period, the emergency exit door 1 next to PAS should be used to exit PSS1 controlled area.

3.3.2.4. Material Access Station

The MAS in the FEB is a double-gated access system consisting of two doors and an enclosed area between them. Door 1 connects the MAS with the FEB, and Door 2 connects the MAS with the PSS1 controlled area. The MAS is intended for transporting large-sized equipment into/out of the PSS1 controlled area, and it is installed next to the PAS. The MAS is equipped with a motion detection system to ensure that no person uses it to enter or exit the PSS1 controlled area. For this purpose, motion detectors with high resolution capable of covering the whole MAS volume are used. Door 1 and Door 2 of MAS cannot be open at the same time.
It shall be noted that to transport equipment into PSS1 controlled area, the rules described in ESS Rules for Tracking of Radioactive Material document [5] shall be considered.

3.3.2.5. Procedures for transporting equipment into the PSS1 controlled area through the MAS

In order to transport large-sized equipment into the PSS1 controlled area through MAS, the steps mentioned below are followed:

1. The person presses the open-door pushbutton at Door 1 of the MAS. Door 1 opens, and the person leaves the equipment inside the MAS, ensuring the equipment stands still.
2. The person leaves the MAS through Door 1 and presses the close-door pushbutton at Door 1. Door 1 locks.
3. The motion detectors check that no person is inside the MAS. In case of any motion detection, Door 1 of the MAS opens and the equipment entry cycle shall be repeated.
4. The person enters PSS1 controlled area through the PAS as described in section 3.3.2.2.
5. The person presses the open-door pushbutton at Door 2 of the MAS. Door 2 opens.
6. The person removes the equipment from the MAS and presses the close-door pushbutton at Door 2. Door 2 locks.

3.3.2.6. Procedures for transporting equipment out of the PSS1 controlled area through the MAS

In order to transport large-size equipment out of the PSS1 controlled area through MAS, the steps below are followed:

1. The person presses the open-door pushbutton at Door 2 of the MAS. Door 2 opens, and the person leaves the equipment inside the MAS, ensuring the equipment stands still.
2. The person leaves the MAS through Door 2 and presses the close-door pushbutton at Door 2. Door 2 locks.
3. The motion detectors check that no person is inside the MAS. In case of any motion detection, Door 2 of the MAS opens and the equipment exit cycle shall be repeated.
4. The person exits the PSS1 controlled area through the PAS as described in section 3.3.2.3.
5. The person presses the open-door pushbutton at Door 1 of the MAS. Door 1 opens.
6. The person removes the equipment from the MAS and presses the close-door pushbutton at Door 1. Door 1 locks.

Notes:

- In case of power failure in the MAS, both Door 1 and Door 2 of MAS remain locked. Removing the equipment trapped inside the MAS shall be performed procedurally.

3.3.3. PSS1 architecture

PSS1 is built using fail-safe Programmable Logic Controllers (PLC) and distributed input and output (I/O) modules with redundant sensors and actuators. Redundancy is addressed in PSS1 by measures such as using redundant signals in safety position monitoring switches on the access doors to PSS1 controlled area, using redundant contacts on emergency switch-off buttons, and using redundant actuators in order to interlock the SAE.
Diversity is addressed by measures such as using diverse safety position monitoring switches (magnetic and mechanical switches) on the access doors to PSS1 controlled area, switching off the proton beam by de-energising three independent systems (ISrc plasma generation system, ISrc beam extraction system and RFQ) as three independent technical solutions, and switching off an RF system by de-energising two independent systems (designated modulator system and output signal of the designated LLRF system) as two independent technical solutions.
Appendix 3 details the layer architecture of PSS1, in which PSS1 field devices (sensors and actuators), PLC modules and PSS1 interfaces with Fast Beam Interlock System (FBIS) and Experimental Physics and Industrial Control System (EPICS) is represented.

3.3.4. PSS1 Supervision

3.3.4.1. PSS1 Operator Interface in LCR

The NCL is operated from the LCR. The PSS1 operator screens in the LCR consist of an Operator Interface (OPI) for PSS1 supervision and an OPI for surveillance cameras installed inside and outside the PAS.
The OPI for PSS1 supervision provides operators with information as below:

- The current mode of PSS1.
- The state of PSS1 permit to the Fast Beam Interlock System (FBIS).
- The state of PSS1 permits to SAE.

Notes:

- The PSS1 OPI in the LCR provides operators with read-only access to PSS1 Process Variables (PV) and there is no possibility to modify PVs or acknowledge PSS1 alarms from operator screens in the LCR.
- The PAS and MAS can grant or deny access to PSS1 controlled area according to pre-set configurations. The operator(s) in LCR cannot control PAS and MAS remotely, but can provide personnel, who might require assistance at PAS and MAS, with instructions. The PAS is equipped with intercoms and cameras (inside and outside the PAS), enabling the operator(s) in LCR to communicate with personnel at the PAS and MAS.

3.3.4.2. PSS1 Human Machine Interface

There is a Human Machine Interface (HMI) on the PSS1 cabinet in FEB level 90. The HMI provides PSS team members and NCL operators with the PSS1 information, such as modes, diagnostics signals, etc. The PSS1 alarms can be acknowledged through this HMI. The HMI is password protected, and can be accessed only by NCL operator(s) and PSS team members.

3.3.5. PSS1 data archiving

PSS1 is integrated into the EPICS in order to be able to archive the PSS1 information as mentioned below in the EPICS archiver:

- The alarm and warning notifications from PSS1.
- The PSS1 PLC diagnostics signals.

4. PSS1 PRINCIPLES OF OPERATION

PSS1 operates according to the principles mentioned below:

- Prior to energising the SAE (i.e. enabling beam operation and RF systems):
  - Trained operators shall carry out a formalised search in the PSS1 controlled area.
  - The access door and emergency exit doors of the PSS1 controlled area shall be locked (the emergency exit doors can be opened from inside the PSS1 controlled area).

- Prior to granting access to PSS1 controlled area:
  - The SAE shall be turned off through the control system.
  - The mains incoming power to the SAE shall be disconnected.
  - The mains incoming power to the SAE shall be secured against re-connection.

5. PSS1 MODES

To ensure safe access to the PSS1 controlled area and safe energisation of the SAE within the PSS1 controlled area by following required procedures, the PSS1 operates in eight modes. Figure 2 shows these modes and the interconnections between them. The green arrows indicate the direction towards Open Access mode, the blue arrows indicate the direction towards Beam ON mode, and the red arrows indicate the direction towards Alarm mode. This section provides a brief description of PSS1 modes.

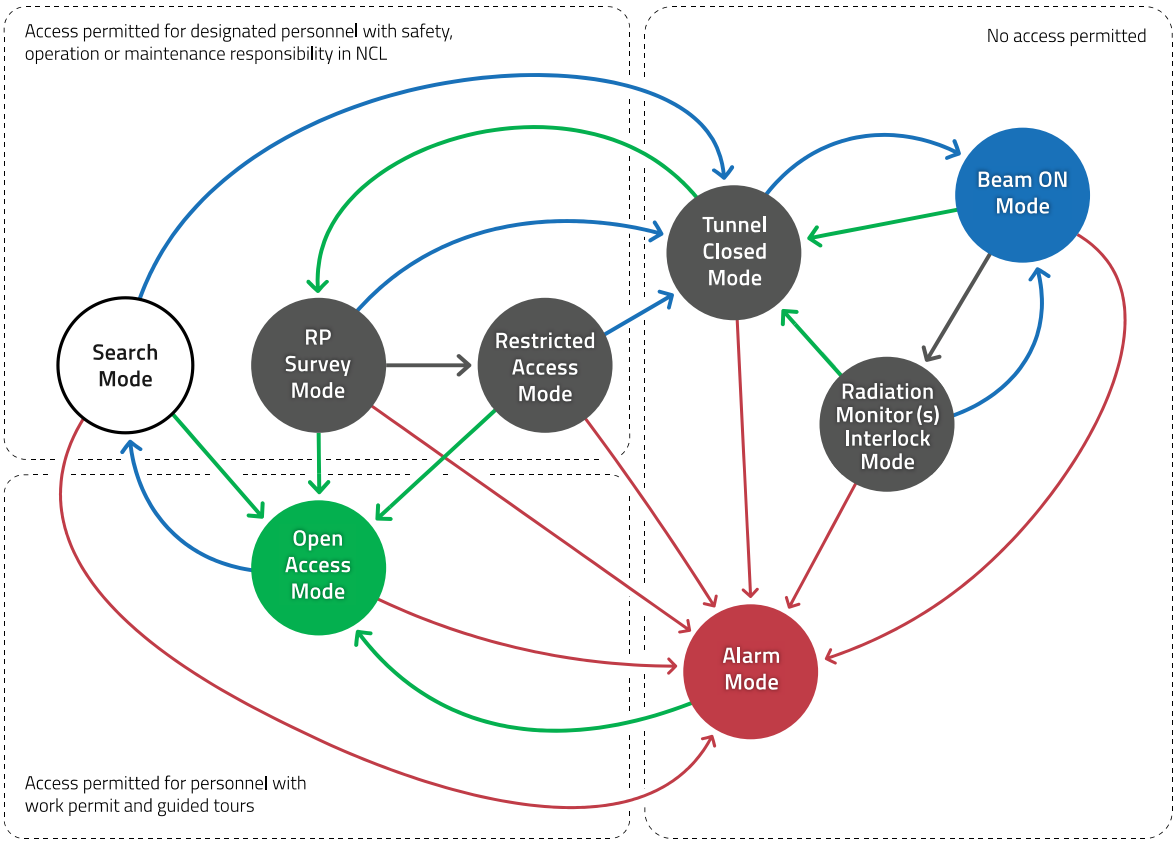

Figure 2: PSS1 modes

5.1.1. Open Access mode

During this mode, all the personnel who are authorised by the AMS can access the PSS1 controlled area through the PAS. However, the PSS1 software limits the number of people in the PSS1 controlled area to maximum 30 individuals at a time.
In this mode, the PSS1 state is as below:

1. The PSS1 controlled area search is broken upon first access. Since the personnel do not carry an Entry Key during access to the PSS1 controlled area in this mode, the area shall be searched before transition to the Tunnel Closed mode.
2. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
3. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA).

However, if a removable piece of the RFDS is removed, the permit to the control system to energise RF system under testing remains enabled (see section 7.8).

4. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.1.3. However, if a removable piece of the RFDS is removed, the permit to power RF system under testing remains enabled (see section 7.8).
5. PSS1 disables the relay on the output signal of the LLRF of the RF systems (the RFQ LLRF, the MEBT bunchers LLRF, the DTLs LLRF). However, if a removable piece of the RFDS is removed, the permit to enable the relay on the output signal of the LLRF of the RF system under testing remains enabled (see section 7.8).

5.1.2. Search mode

This mode is used to control the formalised search procedure in order to ensure that no person is left inside the PSS1 controlled area prior to transitioning to Tunnel Closed mode from Open Access mode. The PSS1 controlled area is divided into two zones: zone 1 is the area between access stations in FEB and the zone 2 gate, zone 2 is the area between the zone 2 gate and the emergency exit 2. The main purpose of zoning in PSS1 controlled area is to optimise the time required to conduct formalised search. If zone 2 is not accessed during Open Access mode (i.e. zone 2 gate, whose position is monitored by PSS1 safety position monitoring switches, is not opened during Open Access mode), the search state of zone 2 is not broken, and formalised search shall be carried out only in zone 1. Two trained and authorised operators shall carry out the formalised search, and a third operator can join the search team for training. For this purpose, Entry Keys are available on the key exchange system unit #3 (see Appendix 4 for key exchange system details), which shall be used by the search team during formalised search. Carrying the Entry Keys ensures that PSS1 cannot transition to Tunnel Closed mode unless all Entry Keys are returned to the key exchange system unit #3, i.e. the search team has left the PSS1 controlled area.
In this mode, the PSS1 state is as below:

1. The PSS1 controlled area is being searched to ensure that nobody is left inside.
2. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
3. PSS1 enables the Public Address (PA) system to broadcast a message in the PSS1 controlled area informing personnel to leave the area.
4. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA). However, if a removable piece of the RFDS is removed, the permit to the control system to energise RF system under testing remains enabled (see section 7.8).
5. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.2.4. However, if a removable piece of the RFDS is removed, the permit to power RF system under testing remains enabled (see section 7.8).
6. PSS1 disables the relay on the output signal of the LLRF of the RF systems. However, if a removable piece of the RFDS is removed, the permit to enable the relay on the output signal of the LLRF of the RF system under testing remains enabled (see section 7.8).

5.1.3. Tunnel Closed mode

The Tunnel Closed mode is a transition mode, which is used during:

- PSS1 transition from Beam ON to RP Survey mode;
- PSS1 transition from any access mode to Beam ON mode.

In this mode, the PSS1 state is as below:

1. The PSS1 controlled area search is not broken.
2. The PAS and MAS are locked to ensure nobody can enter the PSS1 controlled area.
3. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
4. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA). However, if a removable piece of the RFDS is removed, the permit to the control system to energise RF system under testing remains enabled (see section 7.8).
5. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.3.4. However, if a removable piece of the RFDS is removed, the permit to power RF system under testing remains enabled (see section 7.8).
6. PSS1 disables the relay on the output signal of the LLRF of the RF systems. However, if a removable piece of the RFDS is removed, the permit to enable the relay on the output signal of the LLRF of the RF system under testing remains enabled (see section 7.8).

5.1.4. Beam ON mode

In this mode, PSS1 issues all permits necessary for the operator to be able to turn on the proton beam and RF-powered systems in the NCL.

In this mode, the PSS1 state is as below:

1. The PSS1 controlled area search is not broken.
2. The PAS and MAS are locked to ensure nobody can enter the PSS1 controlled area.
3. PSS1 enables the PA system to broadcast a message in the PSS1 controlled area that “proton beam is imminent”. This message is broadcasted for 120 seconds after PSS1 transitions into Beam ON mode.
4. PSS1 turns off normal white lights and turns on the blue lights in the PSS1 controlled area as a warning that “proton beam is imminent”.
5. PSS1 enables the relays on the output signal of the LLRF of the RF systems.
6. PSS1 permit to the SAE is enabled by connecting the mains incoming power to the SAE (ISrc magnetron PS, the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA).
7. PSS1 permit to the control system is enabled, in order to energise the SAE as listed in 5.1.4.6.
8. PSS1 permit to the FBIS is enabled.

5.1.5. RP Survey mode

The Radiation Protection (RP) Survey mode is used during:

- PSS1 transition from Beam ON to Open Access mode;
- PSS1 transition from Beam ON to Restricted Access mode.

The RP team shall carry out an RP Survey in the PSS1 controlled area prior to granting access to personnel. The RP survey ensures that personnel entering the PSS1 controlled area are protected against residual ionising radiation resulting from possible activation of parts exposed to the proton beam and air activation during operation of the NCL [6].
The RP Survey shall be carried out by two people, and a third person can join the RP team for training. For this purpose, Entry Keys are available on the key exchange system unit #3 inside the PAS, which shall be used by the RP team. Carrying the Entry Keys ensures that PSS1 cannot transition to the Tunnel Closed mode unless all Entry Keys are returned to the key exchange system unit #3, i.e. the RP team has left the PSS1 controlled area.
In this mode, PSS1 state is as below:

1. The PSS1 controlled area search is not broken, since PSS1 keeps track of the Entry Keys carried by the RP team members during the RP Survey.
2. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
3. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA). However, if a removable piece of the RFDS is removed, the permit to the control system to energise RF system under testing remains enabled (see section 7.8).
4. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.5.3. However, if a removable piece of the RFDS is removed, the permit to power RF system under testing remains enabled (see section 7.8).
5. PSS1 disables the relay on the output signal of the LLRF of the RF systems. However, if a removable piece of the RFDS is removed, the permit to enable the relay on the output signal of the LLRF of the RF system under testing remains enabled (see section 7.8).

5.1.6. Restricted Access mode

The Restricted Access mode is intended for short access to the PSS1 controlled area for a very limited number of personnel (up to 4 individuals at a time). For this purpose, four Entry Keys are available on the key exchange system unit #3, which shall be used by the personnel entering the PSS1 controlled area during Restricted Access mode. Carrying the Entry Keys ensure that PSS1 cannot transition to Tunnel Closed mode unless all Entry Keys are returned to the key exchange system unit #3, i.e. the personnel have left the PSS1 controlled area. The main difference between this mode and Open Access mode is that the PSS1 controlled area search is not broken during Restricted Access mode.
In this mode, the PSS1 state is as below:

1. The PSS1 controlled area search is not broken, since PSS1 keeps track of the Entry Keys carried by the personnel during Restricted Access mode.
2. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
3. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA). However, if a removable piece of the RFDS is removed, the permit to the control system to energise RF system under testing remains enabled (see section 7.8).

4. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.6.3. However, if a removable piece of the RFDS is removed, the permit to power RF system under testing remains enabled (see section 7.8).
5. PSS1 disables the relay on the output signal of the LLRF of the RF systems. However, if a removable piece of the RFDS is removed, the permit to enable the relay on the output signal of the LLRF of the RF system under testing remains enabled (see section 7.8).

5.1.7. Radiation Monitor(s) Interlock mode

AMM are provided and installed in several positions by the RP group outside the PSS1 controlled area [4]. They ensure that the radiation dose of a monitored area is within the legal limits of the area classification [7]. The alarm thresholds are defined by the RP group. If PSS1 receives a high radiation alarm or fault signal from any of the AMM, PSS1 transitions to Radiation Monitor(s) Interlock mode. Appendix 2 details the location of the AMM around the PSS1 controlled area.
In this mode, the PSS1 state is as below:

1. The PSS1 controlled area search is not broken.
2. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
3. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc magnetron PS, the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA). However, if a removable piece of the RFDS is removed, the permit to the control system to energise RF system under testing remains enabled (see section 7.8).
4. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.7.3. However, if a removable piece of the RFDS is removed, the permit to power RF system under testing remains enabled (see section 7.8).
5. PSS1 disables the relay on the output signal of the LLRF of the RF systems. However, if a removable piece of the RFDS is removed, the permit to enable the relay on the output signal of the LLRF of the RF system under testing remains enabled (see section 7.8).

5.1.8. Alarm mode

The Alarm mode is the fall-back mode of the PSS1. PSS1 transitions to Alarm mode if any of the events mentioned below occurs:

- Any of the emergency switch-off buttons inside PSS1 controlled area is pressed (during any mode of the safety interlock system);
- Intrusion into the PSS1 controlled area (during Beam ON, Tunnel Closed and Radiation Monitor(s) Interlock modes);
- Internal error in the PSS1 PLC (during any mode of the PSS1).

The first intervention into PSS1 controlled area after PSS1 transitions into Alarm mode shall be done by a trained person who is authorised by the shift leader. From the Alarm mode it is only possible to transition to the Open Access mode (see section 5.1.1) after the anomaly is addressed, all errors in PSS1 are removed and alarms are acknowledged.
In this mode, the PSS1 state is as below:

1. The PSS1 controlled area search is broken.
2. PSS1 permit to the FBIS is disabled, in order to stop the proton beam.
3. PSS1 permit to the control system is disabled, in order to de-energise the SAE (the ISrc magnetron PS, the ISrc HVPS, the RFQ modulator, the DTL modulators, and the MEBT bunchers SSA).
4. PSS1 permit to the SAE is disabled by removing the mains incoming power to the SAE as listed in 5.1.8.3.
5. PSS1 disables the relay on the output signal of the LLRF of the RF systems.

Notes:

- If PSS1 transitions to Alarm mode, the PSS1 permits for RF systems under test are disabled.

6. PSS1 KEY EXCHANGE SYSTEM

The PSS1 key exchange system is a mechanical trapped key interlock system, which is used to ensure PSS1 operating procedures are performed as a predetermined sequence of events, and cannot be circumvented. PSS1 uses modular key exchange units that are used to exchange a key for a number of other keys. The units will contain stainless steel mechanical lock modules with uniquely coded keys. Appendix 4 details PSS1 key exchange system units and their location. A brief description of the key exchange system units and keys is provided below:

- PSS1 main key exchange (unit #1): This unit is installed in the PSS1 cabinet in FEB level 90.
- PSS1 mode selection key exchange (unit #2): This unit is installed in the PSS1 cabinet in FEB level 90.
- Personnel access station key exchange (unit #3): This unit is installed inside the PAS.
- Main Key (MK): If the PSS1 Main key is removed, the proton beam and RF-powered equipment are switched off by removing the power to the designated SAE. The slots for MK are coloured in red.
- Mode Selection Key (MODEK): The MODEK is used to transition between various PSS1 modes. The slots for MODEK are coloured in red.
- Shielding Configuration Management Key (SCMK): The SCMK is used to control the mechanical key bolts interfacing the removable shielding blocks. In addition to the key bolt for the Temporary Shielding Wall (TSW), spare key bolts are foreseen for PSS1 interface with any other removable shielding block in PSS1 controlled area. The slots for the shielding configuration management keys are coloured in orange.
- Safety Veto Key: The safety team takes possession of the Safety Veto key. The safety team can forbid any access to the PSS1 controlled area by removing the Safety Veto key. The slot for Safety Veto key is coloured in brown.
- Entry Keys (EK): Entry Keys are used as safety token during Search, Restricted Access and RP Survey modes. The slots for EK are coloured in green.

- The keys shown in black (RPK, RAK, and SMK) are released according to the chosen mode by the MODEK. The released key is inserted in unit #3 to obtain Entry Key(s) prior to access to PSS1 controlled area.

7. OPERATING SCENARIOS

The operating scenarios described below will be carried out by the NCL shift leader and the operator(s).

7.1. Beam ON to Open Access procedure

In order to transition from Beam ON to Open Access mode and enter the PSS1 controlled area, the steps mentioned below are followed:

1. The shift leader issues the permit to access the PSS1 controlled area in Open Access mode.
2. The operator switches off the PSS1 SAE via the control system.
3. The operator goes to the FEB and removes the MK from slot 1 of key exchange unit #1 and inserts it into slot 2. PSS1 transitions to Tunnel Closed mode (see section 5.1.3).
4. The operator obtains the MODEK from slot 3. The MK remains mechanically trapped in slot 2, unless the MODEK is returned to slot 3 again. The SCMK can also be removed from slot 4, if it is required to open any removable shielding block such as the TSW.
5. The operator inserts the MODEK into the RP Survey Mode (RPM) slot on key exchange unit #2 and removes the RP key (RPK) from slot 6. The MODEK remains mechanically trapped in the RPM slot, unless the RPK is returned to slot 6 again.
6. The PSS1 transitions to RP Survey mode.
7. The first member of the RP team enters the PAS (section 3.3.2.2), and inserts the RPK to slot 1 of the key exchange unit #3. This person obtains the first Entry Key (EK1), which is used as a safety token, and enters the PSS1 controlled area.
8. The other members of the RP team enter the PSS1 controlled area through the PAS one by one and each person obtains one EK. The RPK remains mechanically trapped in slot 1, unless all EKs are returned to key exchange unit #3.
9. The RP team carries out the RP survey in the PSS1 controlled area.
10. The members of the RP team exit the PSS1 controlled area through the PAS (section 3.3.2.3) one by one and return their Entry Keys to key exchange unit #3.
11. The last member of the RP team goes to the PAS, returns the Entry Key to key exchange unit #3, obtains the RPK, and exits the PAS to the FEB.
12. In case the RP team approves the access to the PSS1 controlled area, the operator returns the RPK to key exchange unit #2 and inserts the MODEK in the Open Access Mode (OAM) slot. (If the RP team does not approve access to the PSS1 controlled area, they return the RPK to key exchange unit #2, and remove the Safety Veto key. The issue shall be communicated to the shift leader.)
13. PSS1 transitions to OAM (section 5.1.1) and personnel can enter PSS1 controlled area through PAS (section 3.3.2.2).

7.2. Open Access to Beam ON procedure

In order to transition from Open Access to Beam ON mode, and enable proton beam operation and RF-powered systems in the NCL, the steps mentioned below are followed:

1. The shift leader issues the permit to prepare the PSS1 controlled area for proton beam operation and energising RF-powered systems using PSS1 procedures.
2. The operator removes the MODEK from the OAM slot, and inserts it in the Search Mode (SM) slot on key exchange unit #2 and obtains the Search Mode Key (SMK).
3. PSS1 transitions to Search mode. The PA system broadcasts a message in the PSS1 controlled area that formalised search is about to start and informs personnel to leave the area.
4. The search team waits for all personnel to leave the PSS1 controlled area. The search team receives a confirmation from the PSS1 HMI screen on the PSS1 cabinet in the FEB to enter the PSS1 controlled area and start the formalised search.
5. The first member of the search team enters the PAS (section 3.3.2.2) and inserts the SMK into slot 1 on key exchange unit #3. This person obtains the EK1, which is used as a safety token, and enters PSS1 controlled area.
6. The other members of the search team enter the PSS1 controlled area through the PAS one by one, each obtaining one EK (section 3.3.2.2). The SMK remains mechanically trapped in slot 1, unless all EKs are returned to key exchange unit #3 again.
7. The Search team carries out the formalised search in the PSS1 controlled area according to a prescribed procedure as described below.
    a. The search team shall start the formalised search from point 1 if both zones 1 and 2 were accessed during Open Access mode. (In this case, the search team shall ensure the emergency exit door 2 is closed and locked, and the TSW is closed by removing the TSWK from the key bolt).
    b. The search team shall start the formalised search from point 4 if only zone 1 was accessed during Open Access mode.
8. The search team shall carefully inspect all corners of the PSS1 controlled area to ensure no one is left inside the area. The search buttons shall be pressed according to the sequence of search buttons numbers shown in Appendix 5. (After pressing search button number 3, the search team shall ensure that zone 2 gate is closed before pressing search button number 4).
9. The members of the search team exit the PSS1 controlled area through the PAS (section 3.3.2.3) one by one and return their Entry Keys to key exchange unit #3.
10. The last person from the search team who exits the PSS1 controlled area through the PAS, returns the Entry Key to key exchange unit #3 and obtains the SMK.
11. The operator returns the SMK to key exchange unit #2 and obtains the MODEK. PSS1 transitions to Tunnel Closed mode.
12. The operator returns the MODEK to key exchange unit #1 in the FEB. The SCMK shall also be returned to key exchange unit #1.
13. The operator obtains the MK and inserts it into slot 1 in key exchange unit #1.

14. The normal white lights turn off, and the blue lights in the PSS1 controlled area turn on as a warning that the proton beam is imminent. The PA system also broadcasts a message in the PSS1 controlled area that the proton beam is imminent and the area shall be evacuated immediately.
15. PSS1 transitions to Beam ON mode after 120 seconds.

Appendix 5 details the location of the search buttons and the route for formalised search inside the PSS1 controlled area.

7.3. Beam ON to Restricted Access procedure

In order to transition from Beam ON to Restricted Access mode and enter the PSS1 controlled area, the steps mentioned below are followed:

1. The shift leader issues the permit for a limited number of personnel (up to 4 individuals at a time) to access the PSS1 controlled area in Restricted Access mode (RAM).
2. The operator switches off the PSS1 SAE via the control system.
3. The operator goes to the FEB and removes the MK from slot 1 of key exchange unit #1 and inserts it into slot 2. PSS1 transitions to Tunnel Closed mode (see section 5.1.3).
4. The operator obtains the MODEK from slot 3. The MK remains mechanically trapped in slot 2, unless the MODEK is returned to slot 3 again. The SCMK can also be removed from slot 4, if it is required to open any removable shielding block such as the TSW.
5. The operator inserts the MODEK into the RPM slot on key exchange unit #2 and removes the RP key (RPK) from slot 6. The MODEK remains mechanically trapped in the RPM slot, unless the RPK is returned to slot 6 again.
6. The PSS1 transitions to RP Survey mode.
7. The first member of the RP team enters the PAS (section 3.3.2.2) and inserts the RPK into slot 1 in key exchange unit #3. This person obtains the EK1, which is used as a safety token, and enters the PSS1 controlled area.
8. The other members of the RP team enter the PSS1 controlled area through the PAS (section 3.3.2.2) one by one and each person obtains one EK. The RPK remains mechanically trapped in slot 1, unless all EKs are returned to key exchange unit #3.
9. The RP team carries out the RP survey in the PSS1 controlled area.
10. The members of the RP team exit the PSS1 controlled area through the PAS (section 3.3.2.3) one by one and return their Entry Keys to key exchange unit #3.
11. The last member of the RP team goes to the PAS, returns the Entry Key to key exchange unit #3, obtains the RPK, and exits the PAS to the FEB.
12. In case the RP team approves personnel access to the PSS1 controlled area, the operator returns the RPK to key exchange unit #2 and inserts the MODEK in the RAM slot. (If the RP team does not approve access to the PSS1 controlled area, they return the RPK to key exchange unit #2, and remove the Safety Veto key. The issue shall be communicated to the shift leader.)

13. PSS1 transitions to RAM (section 5.1.6) and a limited number of personnel (up to 4 individuals at a time) can enter the PSS1 controlled area through the PAS.
14. The first person enters the PAS (section 3.3.2.2) and inserts the RAK into slot 1 of key exchange unit #3. This person obtains the EK1, which is used as a safety token, and enters PSS1 controlled area.
15. The other three persons can enter the PSS1 controlled area through the PAS (section 3.3.2.2) one by one and each person obtains one EK. The RAK remains mechanically trapped in slot 1, unless all EKs are returned to key exchange unit #3.
16. The person(s) carry out their work in the PSS1 controlled area in RAM.

7.4. Restricted Access to Beam ON procedure

In order to transition from Restricted Access to Beam ON mode and enable proton beam operation and RF-powered systems in the NCL, the steps mentioned below are followed:

1. The shift leader issues the permit to prepare the PSS1 controlled area for proton beam operation and energising RF-powered systems using PSS1 procedures.
2. The personnel exit the PSS1 controlled area through the PAS (section 3.3.2.3) one by one and return their Entry Keys to key exchange unit #3.
3. The last person goes to the PAS and returns the Entry Key to key exchange unit #3 and obtains the RAK. The person exits the PAS to the FEB.
4. The operator returns the RAK to key exchange unit #2 and obtains the MODEK.
5. PSS1 transitions to Tunnel Closed mode (section 5.1.3).
6. The operator returns the MODEK to key exchange unit #1 in the FEB. The SCMK shall also be returned to key exchange unit #1.
7. The operator obtains the MK and inserts it into slot 1 in key exchange unit #1.
8. The blue lights in the PSS1 controlled area turn on as a warning that the proton beam is imminent, and the normal white lights turn off. The PA system also broadcasts a message in the PSS1 controlled area that the proton beam is imminent and the area shall be evacuated immediately.
9. PSS1 transitions to Beam ON mode after 120 seconds.

7.5. Beam ON to Radiation Monitor(s) Interlock mode

PSS1 transitions from Beam ON to Radiation Monitor(s) Interlock mode as soon as it receives high radiation alarm or fault signal from any of the five Area Mixed-Field Monitors (AMM). It should be noted that in the Radiation Monitor(s) Interlock mode, the search state of the PSS1 controlled area remains intact i.e. search is not broken.

7.6. Radiation Monitor(s) Interlock to Beam ON mode

In order to transition from Radiation Monitor(s) Interlock to Beam ON mode, the steps mentioned below are followed:

1. PSS1 receives TRUE signals from all the radiation monitors.
2. The shift leader issues the permit to manually rearm the PSS1 permits to the SAE in order to enable beam operation and energise RF-powered systems in the NCL.
3. The operator presses the reset button on the PSS1 HMI screen in the FEB.

4. PSS1 transitions to Beam ON mode.

7.7. Radiation Monitor(s) Interlock to Access modes

In order to transition from Radiation Monitor(s) Interlock to Open Access mode or Restricted Access mode, the procedures detailed in section 7.1 and 7.3 shall be followed respectively.

7.8. RF systems test procedures

RF tests in the klystron gallery can be carried out in all PSS1 modes except Alarm mode. During any access mode to the PSS1 controlled area, PSS1 permits the testing of an RF system only on the condition that the transmission of the RF signal to the respective cavity in the PSS1 controlled area is blocked.

7.8.1. Isolate an RF system from the PSS1 controlled area

In order to isolate an RF system from the PSS1 controlled area and start an RF test in the klystron gallery, the steps mentioned below are followed:

1. The RF system owner and the shift leader agree on the RF system to be tested, and the shift leader issues the permit to isolate the RF system from the PSS1 controlled area.
2. The RF system owner prepares the RF system for isolation from the PSS1 controlled area.
3. *In case of RFQ and DTLs:*
   The RF system owner isolates the RF system from the PSS1 controlled area by removing the removable waveguide and installs the RF short circuit plate on the RFDS in the klystron gallery. PSS1 monitors the position of the removable waveguide and the RF short circuit plate on the RFDS and enables or disables the respective RF system accordingly.

   In case of MEBT bunchers:
   The RF system owner isolates the RF system from the PSS1 controlled area by closing the RF switch on the RF coaxial cable in the klystron gallery. PSS1 monitors the position of the RF switch on the coaxial cable and enables or disables the respective RF system accordingly.
4. The RF system is isolated from the PSS1 controlled area, and the RF system test can start in the klystron gallery.

7.8.2. Reconnect an RF system to the PSS1 controlled area

In order to reconnect an RF system to the PSS1 controlled area, the steps mentioned below are followed:

1. The RF system owner and the shift leader agree on the RF system to be reconnected to the PSS1 controlled area, and the shift leader issues the permit to reconnect the RF system.
2. The RF system owner prepares the RF system for reconnection to the PSS1 controlled area.

3. *In case of RFQ and DTLs:*
   The RF system owner reconnects the RF system to the PSS1 controlled area by removing the RF short circuit plate and installing the removable waveguide on the RFDS in the klystron gallery.

   In case of MEBT bunchers:
   The RF system owner reconnects the RF system to the PSS1 controlled area by unlocking and opening the RF switch on the RF coaxial cable in the klystron gallery.
4. The RF system is reconnected to PSS1 controlled area.

Appendix 6 details the two situations of removable waveguide on the RFDS.

7.9. Modulators test procedures

Modulator(s) test in the klystron gallery can be carried out in all PSS1 modes except Alarm mode. During any access mode to PSS1 controlled area, PSS1 permits the testing of a modulator only on the condition that the transmission of the RF signal to the respective cavity in PSS1 controlled area is blocked. For this purpose, the procedures detailed in section 7.8 shall be followed.

7.10. Procedures to reset PSS1 in Alarm mode

In certain conditions (as described in section 5.1.8), PSS1 transitions to Alarm mode. PSS1 can transition from Alarm mode only to the Open Access mode by following the steps mentioned below:

1. Upon intervention by the safety team, the emergency situation in PSS1 controlled area has been resolved.
2. The RP team approves open access to the PSS1 controlled area.
3. The shift leader issues a permit to the PSS team to prepare PSS1 to transition into Open Access mode. The PSS team ensures that:
   a. Emergency exit doors of PSS1 controlled area are closed and locked.
   b. The PAS is ready for entry and exit of personnel to PSS1 controlled area.
   c. The MAS is ready for entry and exit of material to PSS1 controlled area.
   d. The list of personnel logged as present inside PSS1 controlled area is cleared (this is applicable only if the PSS1 transitioned to Alarm mode from an access mode).
4. Upon declaration by the PSS team that PSS1 is ready, the shift leader issues permit to the operator in order to reset PSS1 via the PSS1 HMI screen in the FEB.
5. The operator presses the reset button on the PSS1 HMI screen in the FEB.
6. PSS1 transitions to Open Access mode.

7.11. Procedures for visitors access to PSS1 controlled area

The visitors shall undergo a safety training prior to access PSS1 controlled area. The safety training is defined and conducted by ES&H.

The visitors can access the PSS1 controlled area only during Open Access mode (section 5.1.1). Visitors follow the same procedures as personnel to access PSS1 controlled area. If the number of visitors is more than 30 individuals (e.g. during open days), the access to PSS1 controlled area is handled procedurally, i.e. The PAS doors remain open or the emergency exit door 1 is used for access to PSS1 controlled area. ESS authorised person(s) shall accompany visitor(s) during access to PSS1 controlled area.

7.12. PSS1 maintenance and proof tests

According to Safety Plan for Personnel Safety Systems document [9], the proof test interval for PSS1 will be defined in the PSS1 Safety Requirements Specifications document. A maintenance manual will be developed which provides the maintenance personnel with the information and guidelines necessary to carry out the proof tests, preventive and corrective maintenance for PSS1. Any maintenance or repair for PSS1 safety interlock system will be carried out by PSS team during NCL shutdown. The NCL operation is not permitted during PSS1 maintenance.

8. INTERFACING SYSTEMS

PSS1 has interfaces with several systems as mentioned below:

- SAE (ISrc, MEBT, RFQ, DTLs) in NCL;
- The Area Mixed-Field Radiation Monitors;
- The Fast Beam Interlock System (FBIS);
- Control system for NCL;
- Normal white lighting system within PSS1 controlled area;
- Access Management System;
- Temporary Shieling Wall (TSW) built after DTL4. PSS1 interfaces with the TSW with a mechanical key bolt which is part of PSS1 key exchange system. This is to ensure that TSW can be opened only during Access modes, and also to ensure that it is closed prior to transitioning to Beam ON mode.

Notes:

- Appendix 7 details PSS1 interfaces with ISrc.
- Appendix 8 details PSS1 interfaces with MEBT bunchers.
- Appendix 9 details PSS1 interfaces with RFQ and DTL1.
- Appendix 10 details PSS1 interfaces with DTL2 and DTL3.
- Appendix 11 details PSS1 interfaces with DTL4.

9. GLOSSARY

Term	Definition
AD	Accelerator Division
AMM	Area Mixed-Field Monitor
AMS	Access Management System
ConOps	Concepts of Operations
DTL	Drift Tube Linac
DTL4	Drift Tube Linac 4
EPD	Electronic Personal Dosimeter
EK	Entry Key
ES&H	Environment, Safety & Health
FBIS	Fast Beam Interlock System
FEB	Front-End Building
ICS	Integrated Control Systems division
ISrc	Ion Source
LCR	Local Control Room
LEBT	Low Energy Beam Transport
Linac	Linear Accelerator
LLRF	Low-Level Radio Frequency
MAS	Material Access Station
MK	Main Key
MEBT	Medium Energy Beam Transport
MODEK	Mode Selection Key
NCL	Normal Conducting Linac
OAM	Open Access Mode
OPI	Operator Interface
PA	Public Address
PAS	Personnel Access Station
PIN	Personal Identification Number
PSG	Protection Systems Group
PSS	Personnel Safety System
PSS1	Personnel Safety System for Normal Conducting Linac trial operation
PV	Process Variable
RF	Radio Frequency
RFDS	Radio Frequency Distribution System
RFQ	Radio Frequency Quadrupole
RAK	Restricted Access Key
RAM	Restricted Access Mode
RP	Radiation Protection

RPK	RP Survey Key
RPM	RP Survey Mode
SAE	Stakeholder Associated Equipment
SCMK	Shielding Configuration Management Key
SHM	Site Hand and Foot Monitor
SM	Search Mode
SMK	Search Mode Key
TSW	Temporary Shielding Wall
TSWK	Temporary Shielding Wall Key
WRSF	Worker Radiation Safety Function

10. REFERENCES

[1] Technical Description of the ESS Normal Conducting Front End (ESS-0159957)
[2] Radiological Hazard Analysis Report for G area - prompt and residual radiation (Normal Conducting Linac Beam Commissioning) (ESS-0118232)
[3] Normal Conducting Linac Risk Assessment for Operation with Beam up to DTL4 (ESS-0512890)
[4] Radiation Monitoring for Normal-Conducting Linac (ESS-0503474)
[5] ESS Rules for Tracking of Radioactive Material (ESS-1066546)
[6] ESS Procedure for RP Survey before Access to PSS1 Controlled Area of the Accelerator Tunnel (ESS-0225865)
[7] ESS Handbook for Radiation Protection (ESS-0131289)
[8] Equipment Handover and Release (ESS-0372700)
[9] Safety Plan for Personnel Safety Systems (ESS-0469185)

11. APPENDIX 1

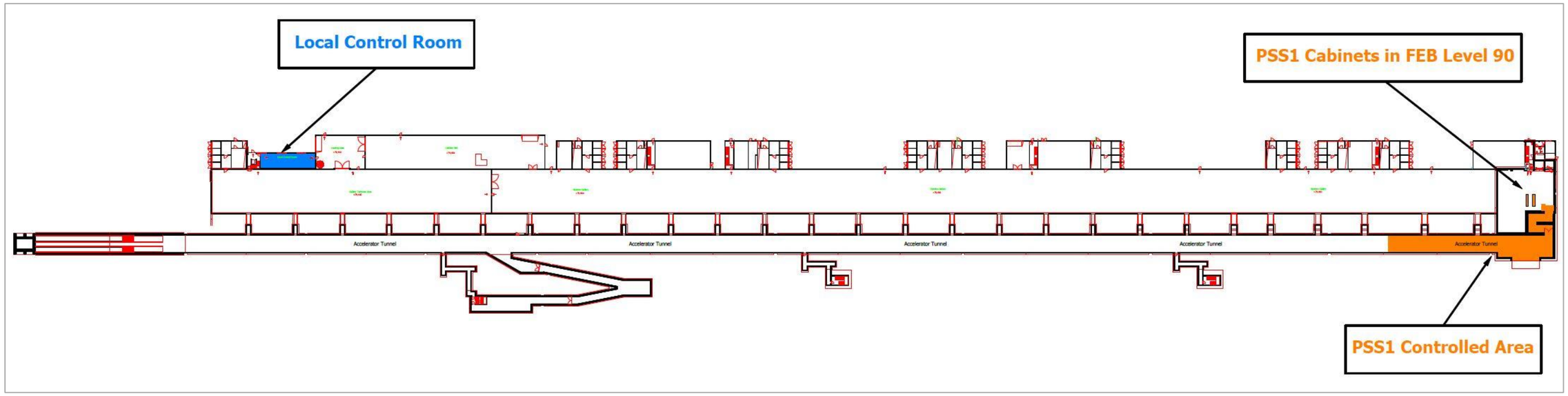

Figure 3: PSS1 controlled area and LCR location in accelerator buildings

12. APPENDIX 2

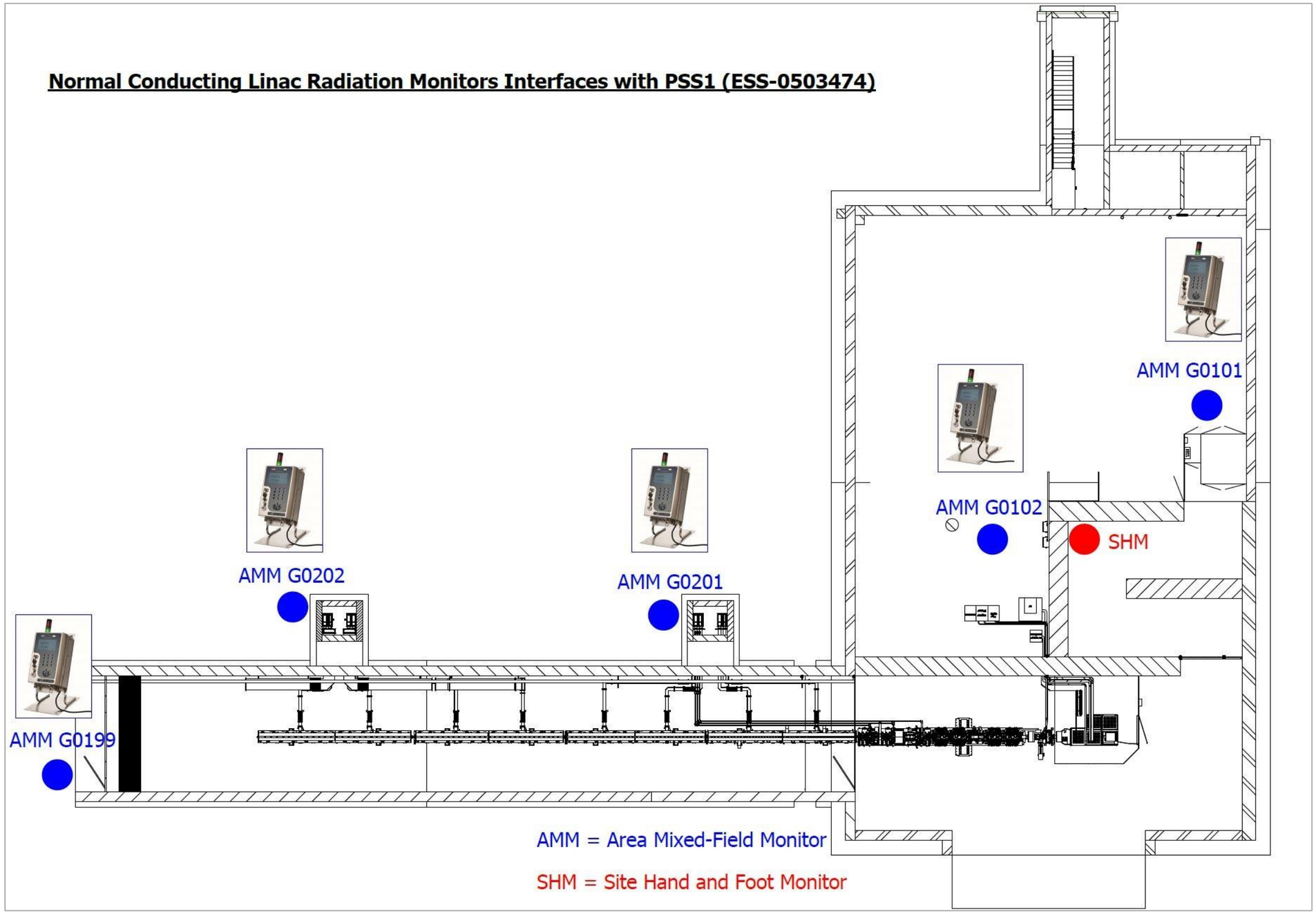

Figure 4: Radiation Monitors and SHM location

13.APPENDIX 3

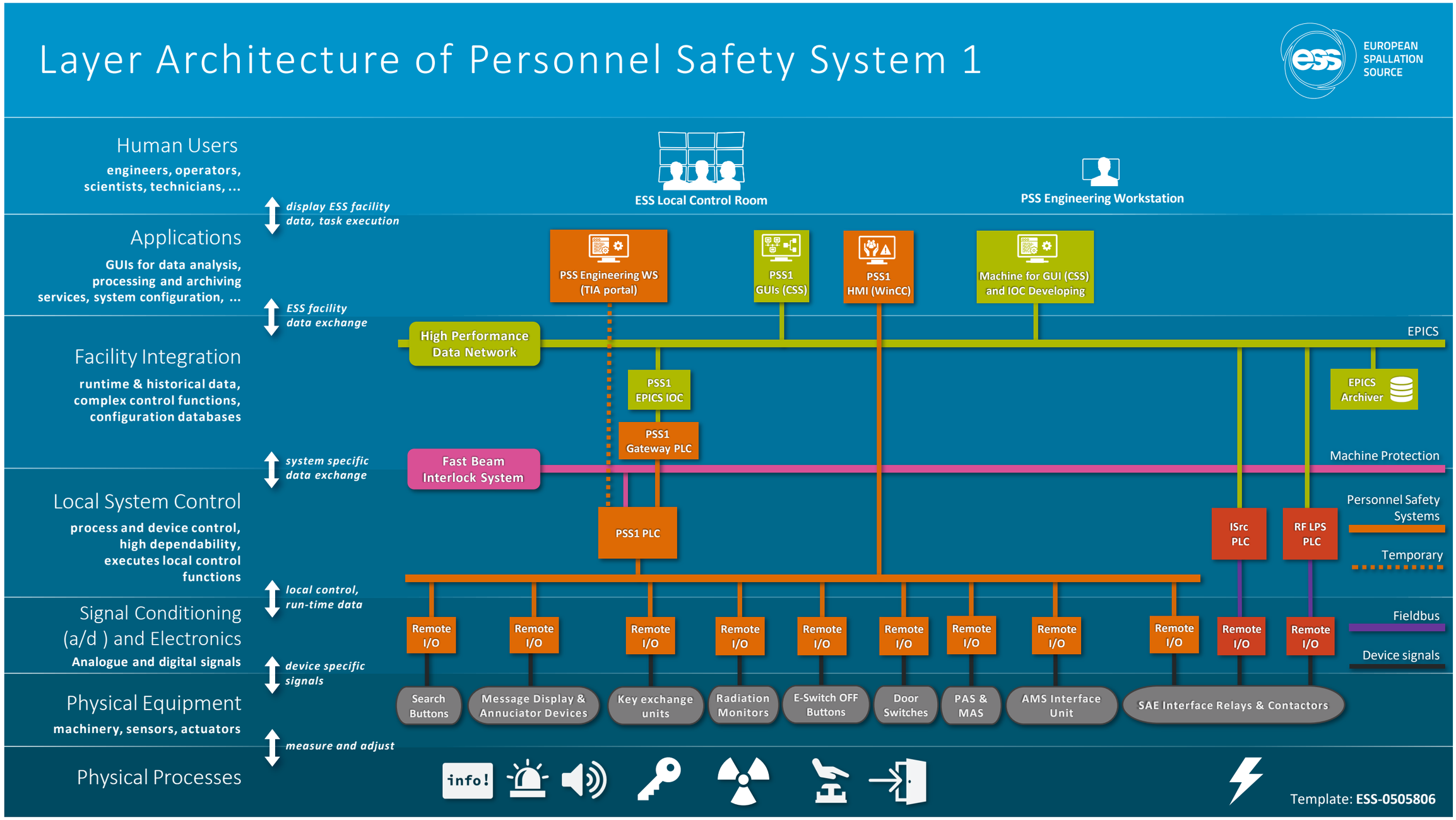

Figure 5: PSS1 layer architecture

14.APPENDIX 4

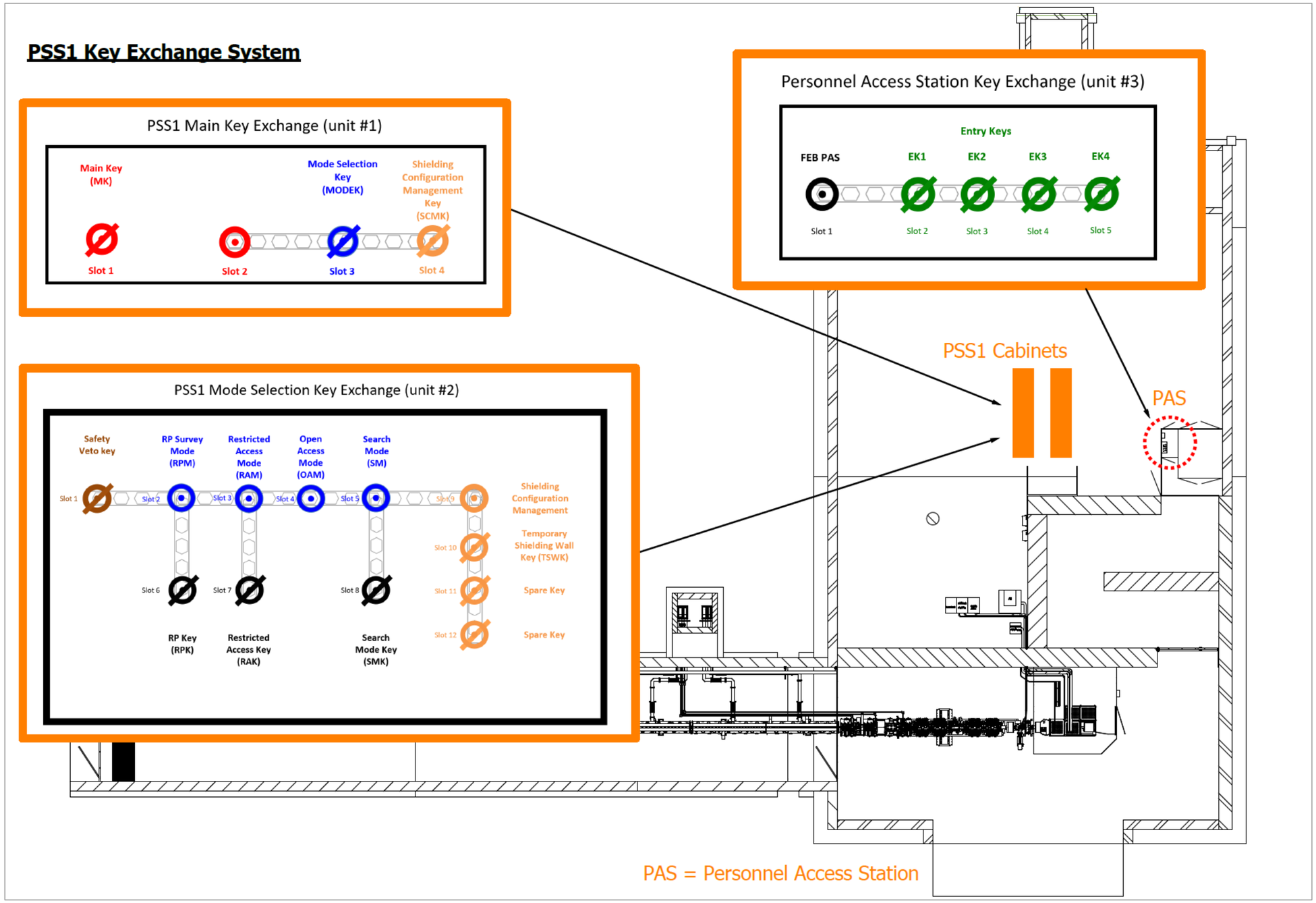

Figure 6: PSS1 key exchange system units and their location

15.APPENDIX 5

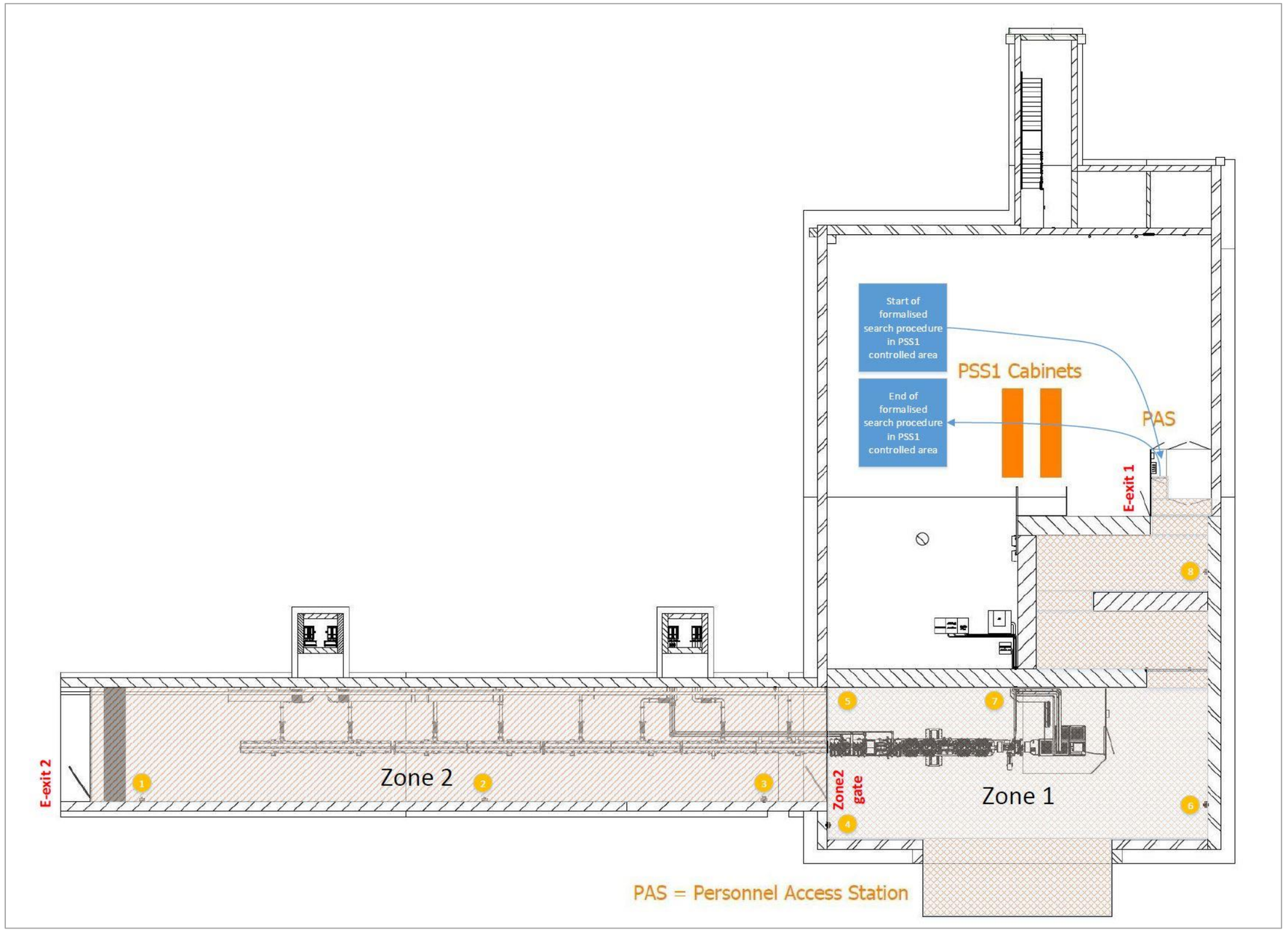

Figure 7: PSS1 formalised search

The yellow dots, numbered 1 to 8, indicate the locations of the search buttons.

16.APPENDIX 6

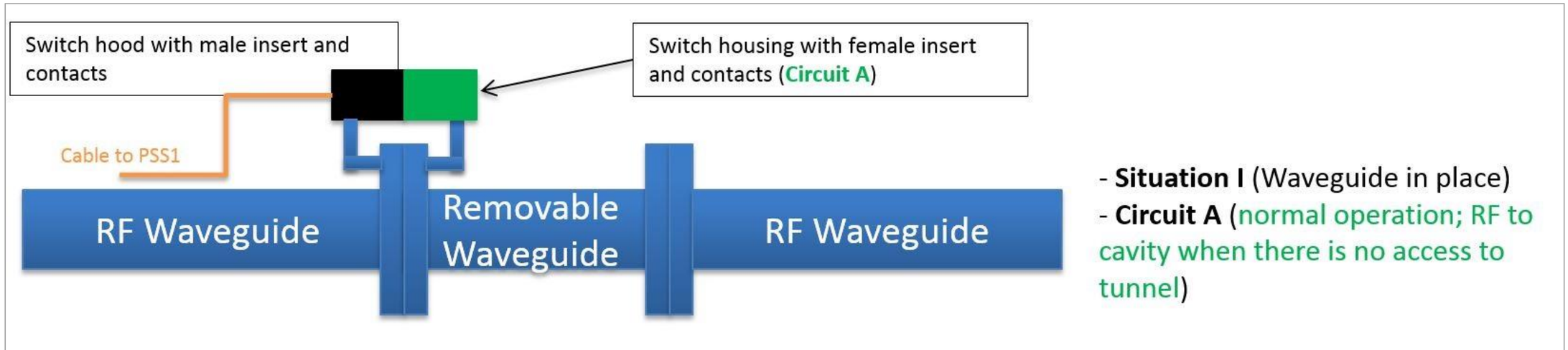

Figure 8: PSS1 interface with removable waveguide on the RFDS

17. APPENDIX 7

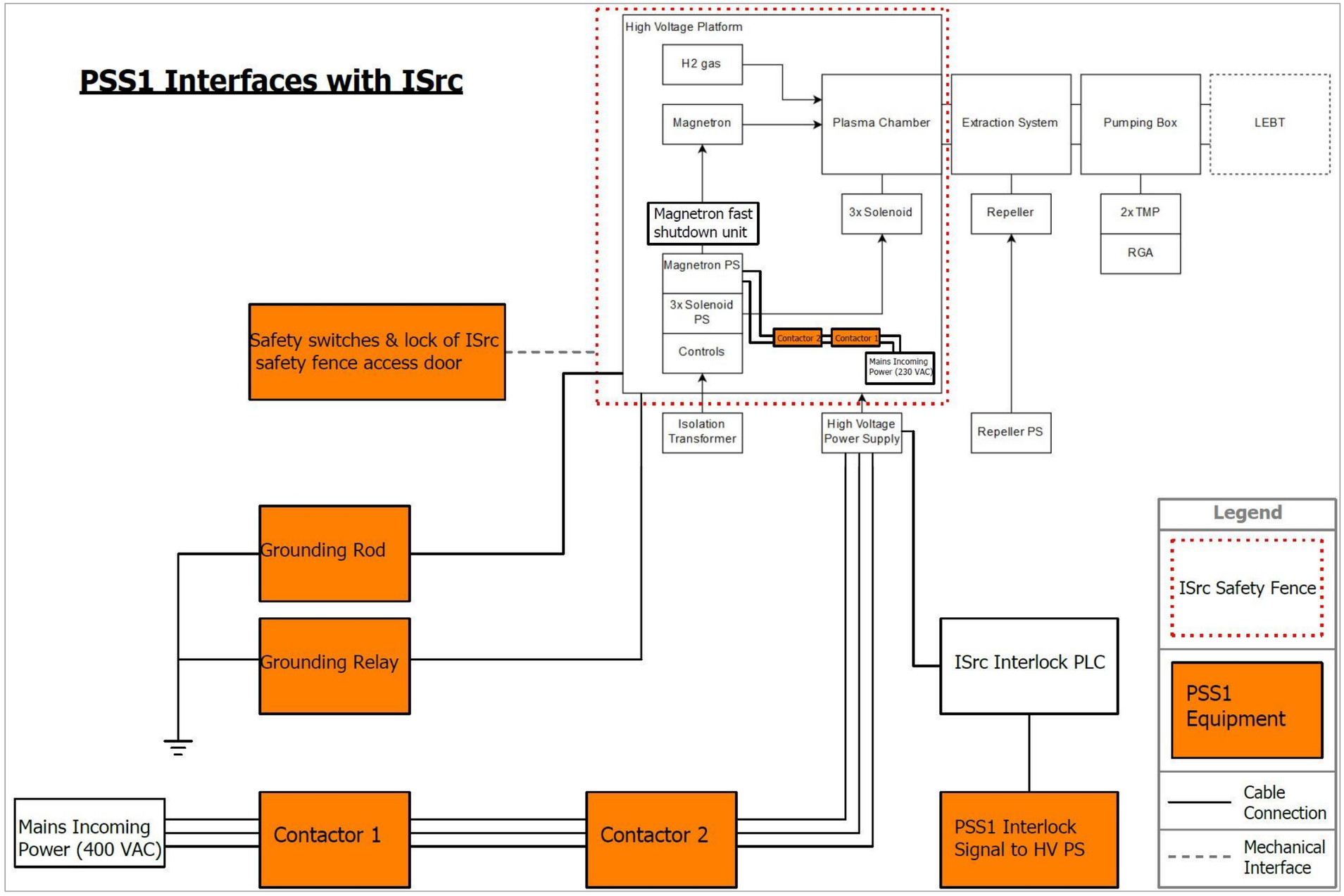

Figure 9: PSS1 interfaces with ISrc

18. APPENDIX 8

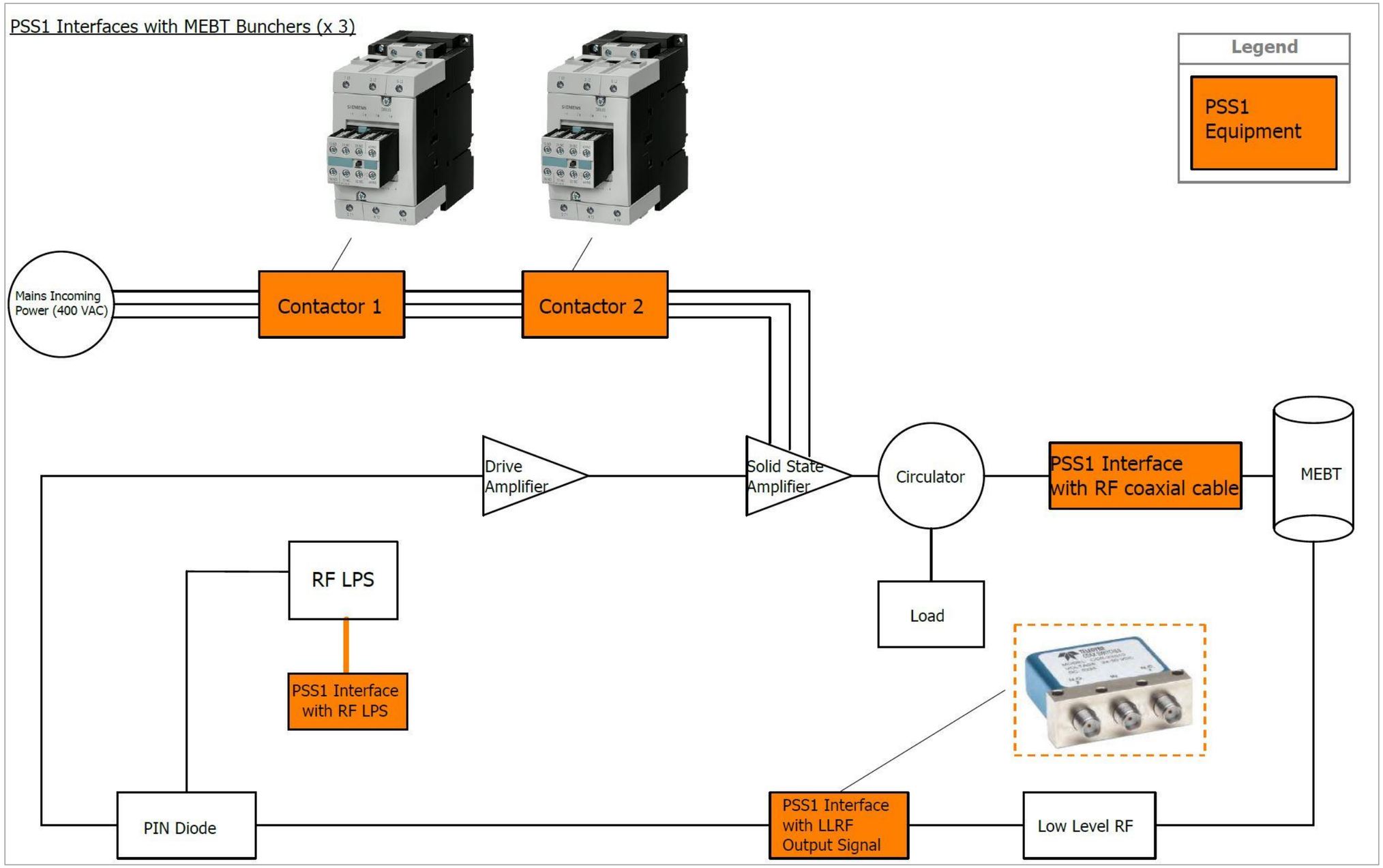

Figure 10: PSS1 interfaces with MEBT

19. APPENDIX 9

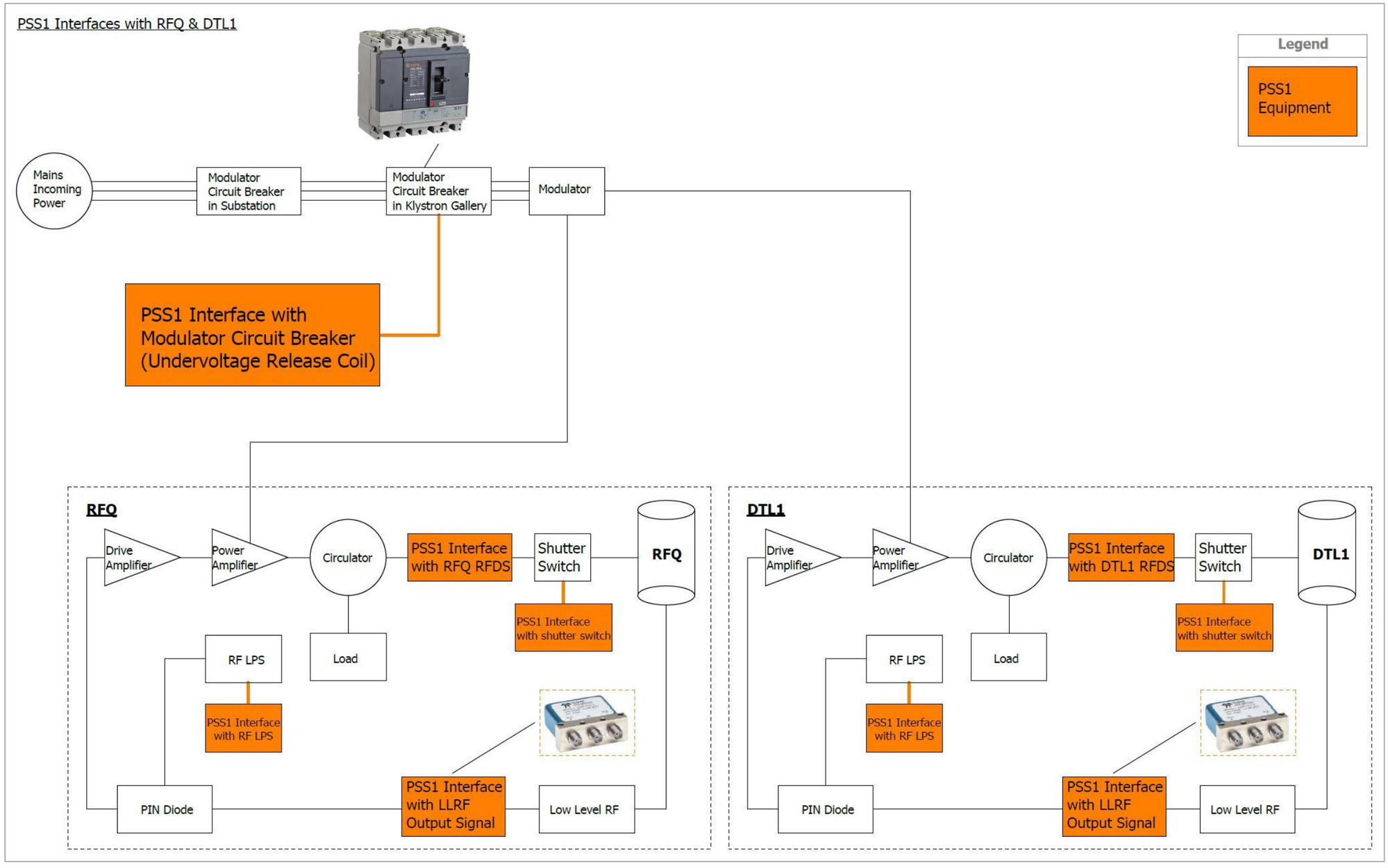

Figure 11: PSS1 interfaces with RFQ & DTL1

20.APPENDIX 10

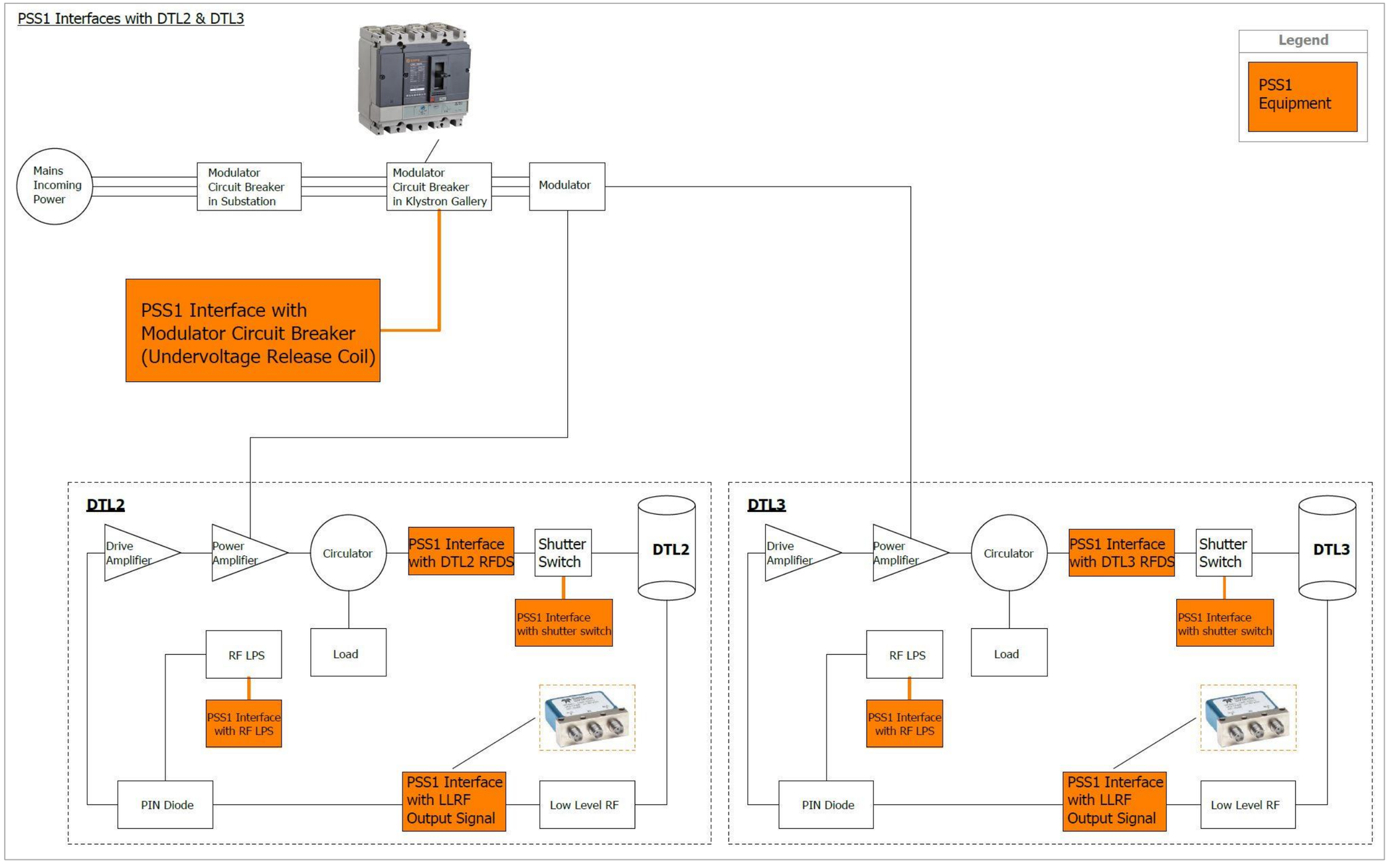

Figure 12: PSS1 interfaces with DTL2 & DTL3

21.APPENDIX 11

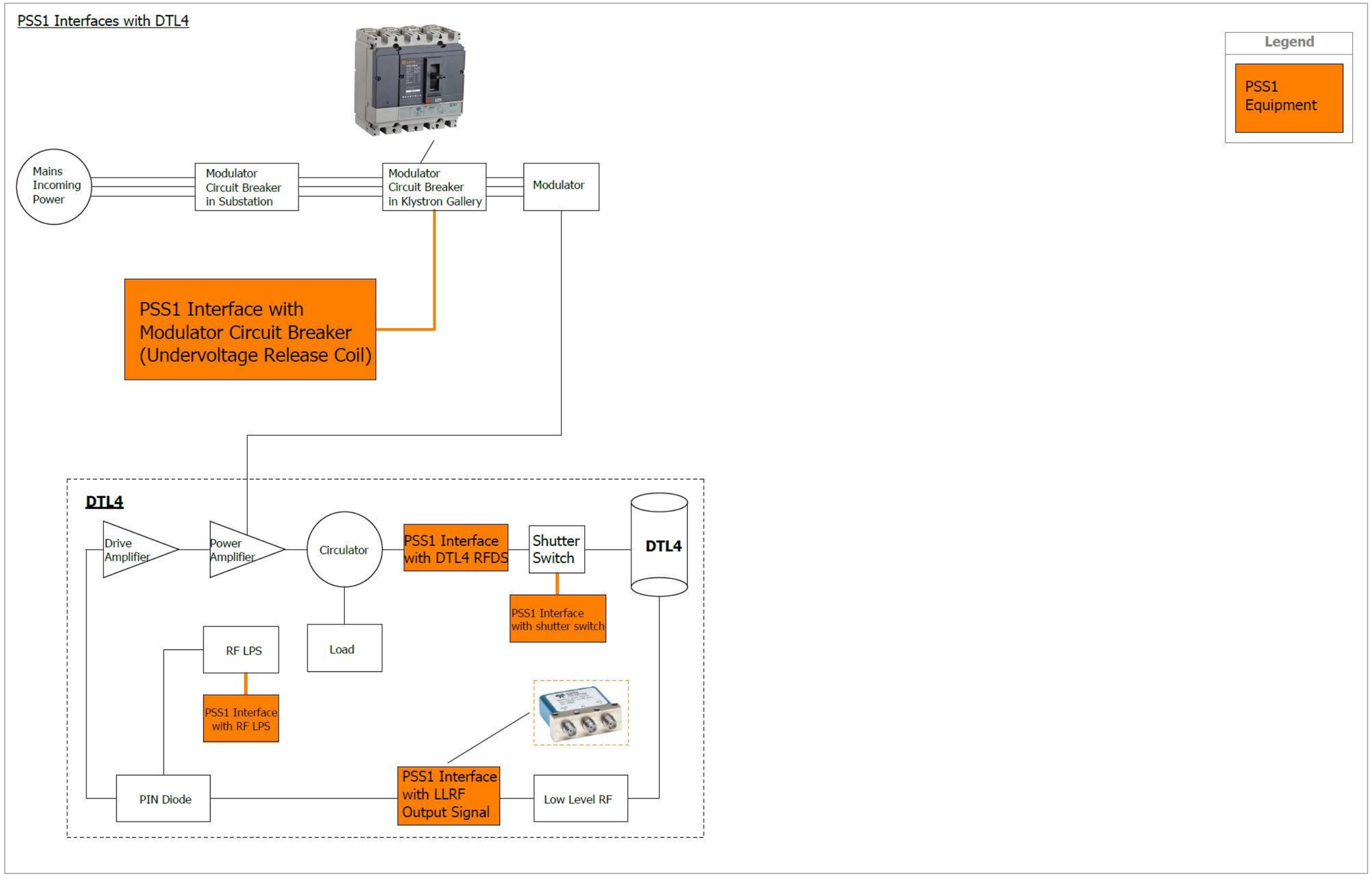

Figure 13: PSS1 interfaces with DTL4

22. DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue of PSS1 concepts of operations	Morteza Mansouri, Meike Rönn	2018-06-29
2	Re-structured the document, implemented comments from reviewers and approvers in the first revision, updated the PSS1 modes, added modulator testing procedure, and updated the appendices.	Morteza Mansouri, Meike Rönn	2019-01-15
3	Added description of PSS1 zones, Updated SAE states during different PSS1 modes, updated PSS1 architecture, added description of PSS1 data archiving, added Radiation Monitor(s) Interlock mode, updated operating scenarios, updated modulator testing procedure, added PSS1 interface with TSW, updated the appendices, harmonised the text to use the terms “person” and “personnel”, removed cool-down time between Tunnel Closed and RP Survey modes, and updated the reviewers list.	Morteza Mansouri	2019-03-11
4	Updated the key exchange system (increased entry keys to 4; added shielding configuration management key, added safety veto key); Added a section to describe PSS1 SAE; Updated number of search buttons; Added reference to ESS-0131289; Added reference to ESS-0118232 and tracing PSS1 functions up to WRSF 94, WRSF 95 and WRSF 141; Updated the reviewers list.	Morteza Mansouri	2019-07-03