



Conventional Safety for HL-LHC

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Outline

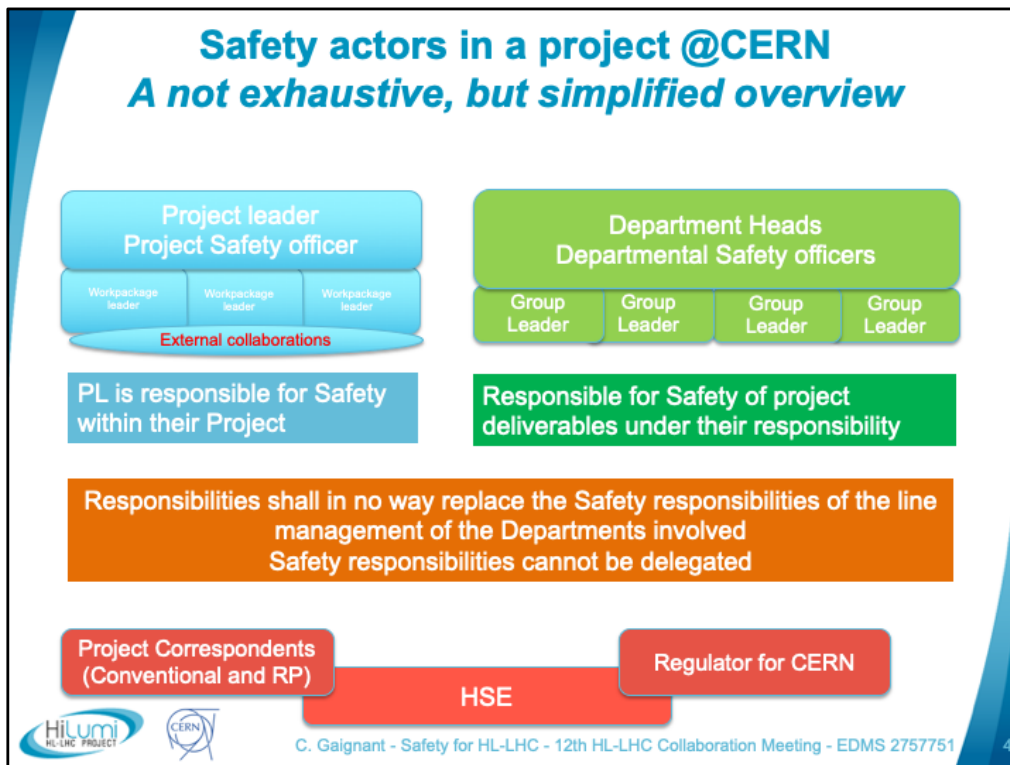
- HL-LHC Safety Organisation
- HL-LHC Safety Documentation and Challenges for the Collaborations
- Highlights on 3 deliverables
- Summary



HL-LHC Safety Organisation



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Responsibilities and organisational structure in matters of Safety at CERN

See: https://edms.cern.ch/ui/file/1389540/LAST_RELEASED/SR-SO_E.pdf and <https://hse.cern/content/safety-organisation-so>

Project Leader

The Safety organisation, including Safety responsibilities, of a Project shall be defined in writing, it being understood that such responsibilities shall in no way replace the Safety responsibilities of the line management of the Departments involved.

The Project Leader shall be responsible for Safety within his Project.

He shall in particular:

- keep himself informed regarding all aspects of Safety within his Project;
- take the necessary measures to ensure that Safety Files for his Project are established and updated;
- improve Safety within his Project;
- take the necessary measures to ensure that Safety clearance is obtained in accordance with the applicable CERN Safety Rules;
- appoint a Project Safety Officer if he so deems appropriate;
- collaborate with the HSE Unit and Safety Correspondents, as required.

Department Head (extract)

Each Department Head shall be responsible for Safety within his Department, including for the Safety of Installations, activities and projects under its responsibility, and in particular for the implementation within his Department of the CERN Safety Policy, the CERN Safety Rules, the CERN Safety Objectives and best practices.

Each Department Head shall take the necessary measures to ensure the safe interaction of the Installations, activities and projects under his responsibility with those under the responsibility of other Departments or of Large Experiments.

HL-LHC Safety Officers

- Since January 2022, the Project Safety Office is composed of two employed staff members who hold the functions of **Project Safety Officer (PSO) and Deputy (DPSO)**.
- For the closed, independent worksites, i.e. HL-LHC Point 1 and 5 worksites, safety is coordinated by an independent **Safety coordinator**.
- The Safety Organisation for HL-LHC is detailed in a specific document (EDMS 1313247).



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Project Safety Officer : https://edms.cern.ch/ui/file/1410233/LAST_RELEASED/GSI-SO-7_E.pdf

Worksites Category 1 : https://edms.cern.ch/ui/file/1440243/LAST_RELEASED/SR-WS_EN.pdf

Category 1 operation:

all the works and services executed towards the same objective:

- of a total volume greater than 4000 hours; and
- on a single, cordoned-off worksite; and
- involving several operating entities and not interfering with CERN's operations.

Safety coordination

Every operation requires Safety coordination, which falls under the responsibility of:

- the Project Leader in the case of Category 1 operations;
- the person in charge of the operation in the case of Category 2 operations;
- the organic unit responsible for technical coordination in the case of Technical Stops.

In the case of Category 1 operations, the **Project Leader shall be assisted by a Safety Coordinator** and shall take into account any Safety requirements issued by the latter.

SAFETY COORDINATOR FOR CATEGORY 1 OPERATIONS :

https://edms.cern.ch/ui/file/1440246/LAST_RELEASED/SSI-WS-1-1_EN.pdf

The Safety Coordinator shall act as an advisor to the organic unit responsible for the operation.

HL-LHC Safety Documentation and Challenges for the Collaborations



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HL-LHC Safety documentation

- **System Safety Assessment (SSA):**
 - **Description** of the system or equipment, its functions, characteristics and final location.
 - **Hazard inventory** and mitigations measure to control the hazards with standard best practises (SBP),
 - **Risk assessments** when mitigation measures are not fully covered by SBP
 - Based on the hazard list, a decision by the HSE unit if the system or equipment has **major safety implications (mSi)**.
- Other documents such as **Master SSA** for complex assemblies of equipment, **Safety Report** for complex risk assessment for assemblies of equipment.



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Safety Organisation for the HL-LHC project: <https://edms.cern.ch/document/1313247>

In HL-LHC, the following safety document types are used:

System Safety Assessment (SSA): this schematic document, based on a template describes the hazards and their control by SBP. It contains:

- A brief description of the system or equipment, its functions, characteristics and final location.
- An editable hazard list. The hazard list of project deliverables is edited jointly between PSO and work package engineers.
- Based on the hazard list, a decision by the HSE unit if the system or equipment has major safety implications (mSi).
- SBP solutions to control a specific hazard are entered next to it in the hazard list. SBP is found in *LSA Safety Requirements for HL-LHC hardware systems (Conventional Aspects)*, [EDMS 1827925](#) and beyond that in international standards, guidelines by industrial associations, and return of experience.
- short risk assessments with mitigation measures for risks not fully covered by SBP can be described in a dedicated chapter. Safety Reports document complex risk assessments, and their conclusions are reported here.

Master SSA: for complex assemblies of equipment (for example, the inner triplet magnet string, assembled from several distinct superconducting magnets, cryogenics, power converters and protection and controls equipment) and for families of equipment having very similar hazards (for example, the different power converters), a Master SSA can be edited. The Master SSA serves as a guideline or table of contents for the equipment-specific SSAs. It groups the common hazards and their SBP or risk assessment at a common place, thus avoiding repetition in the equipment SSAs.

The **Safety Report** is the right format for describing the complex risk assessment for assemblies of equipment, and for hazards for which no SBP exists. An example are the hazards and risks from powering of cryogenically cooled superconducting magnets. In Safety Reports, standard methods of hazard- and risk identification and assessment are used, for example Failure Mode and Effects Analysis (FMEA) or Probabilistic safety Assessment (PSA). The results of such a detailed safety assessment are reported in the corresponding SSA or Master SSA.

Challenges for Collaboration Conformity with EU standards

CE

CERN Safety regulations generally request that equipment operated at CERN meets the Essential Health and Safety (ESH) Requirements laid down in **European Directives** on Consumer Products.

Deliverables from countries where other safety standards are legally applied, and where achieving conformity with EU regulations represents a **cost and schedule risk**.

Deliverables manufactured in universities or research institutes, including CERN, where **no internal structure** exists to attest formally the conformity with EU directives.

Deliverables with **advanced technologies** for which there are no provisions in the regulations.



Strategy to meet Essential Health and Safety requirements for equipment with no CE Marking

The HSE Unit will classify the equipment as
“major Safety implication” (mSI)

The HSE and the WP elaborates in collaboration a **list of safety checks** which must be met before the equipment can be used at CERN.

In-situ verifications

Documentation checks

Safety Authorisation Form

Gives authorisation to operate the equipment/system



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HSE Unit:

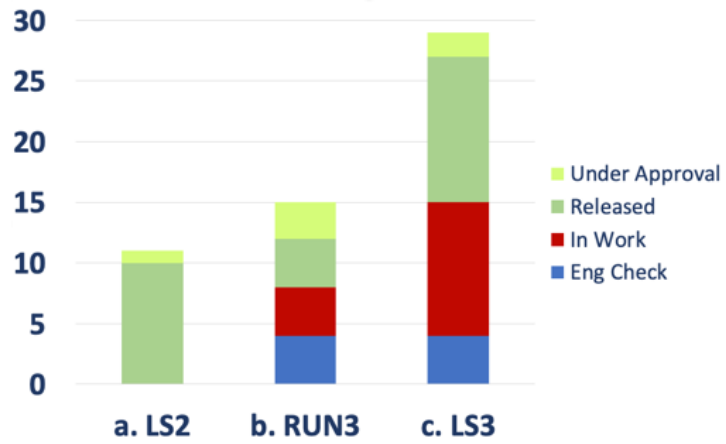
Safety clearance

- grant Safety clearance for Installations, including special equipment, activities, projects and CERN Experiments with major Safety implications prior to design, operation or dismantling.

The head of the HSE Unit may decide to refer Safety clearance decisions to the discretion of the Director-General.

Achievements

- All System Safety Assessments and Safety Reports for deliverables installed up to LS2 completed.



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Highlights on 3 deliverables



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WP6a: Cold Powering

Courtesy: T. Otto

- HTS cables in SC Link transport current from HL-LHC to tunnel
- Cooled by 15 K gaseous He

- **Failure modes in the electrical circuits** focussing on QDS / QPS - Working group chaired by P. Cruikshank
 - **Most credible incident** (Probability $\approx 3 \cdot 10^{-6}$ /year): electrical arc after a single QDS/QPS failure leading to helium release by the flap valves. Only local hazard, not enough He for ODH.
 - **Worst critical incident:** total failure of QDS+QPS. The electrical arc is powerful enough to pierce the outer cryostat and expose persons.
 - In SC Link, probability $< 3 \cdot 10^{-7}$ /year: protect SC link mechanically
 - In other components, only after total failure of QDS/QPS, prob. $< 10^{-11}$ /year. « Broadly acceptable risk »

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Mitigation of Adverse Outcomes of Electrical Failure Modes of the HL-LHC Cold Powering System (WP 6a) (<https://edms.cern.ch/document/2610846/1.0>)

Question to be answered: Is there an ODH issue in the HL-LHC galleries?

MCI: The emergency release of helium with a high mass flow following an internal electrical arc or a loss of insulation vacuum is classified as the Most Credible Incident (MCI). The gaseous helium inventory of the DSH and the DFH would be released abruptly (“champagne bottle effect”), creating a **local cryogenic hazard for personnel directly at the release point**. These persons could be exposed to a jet of cold, gaseous helium, and in general the event will generate noise and a cloud of condensed air around the release location. Due to the limited amount of helium released there will be **no persistent ODH condition in the UR or the UA**. The larger, liquid helium inventory in the DFX or DFM is thermally insulated and the small ratio of opening to length of the DSH assures a small heat leakage through the DSH. Release of the liquid helium inventory in the DFX would be slow, probably over many minutes or hours. To protect personnel from the consequences of a cryogenic MCI, the following recommendations are made:

- The passage zone for personnel shall be protected against standard helium release scenarios by **orienting all safety devices in the direction of the gallery wall**, or by equipping them with **deflectors** shielding the passage zone.
- The area between the DFH and the gallery wall shall be **forbidden for access during operation at full current**, unless a dedicated risk assessment for specific interventions shows that they are innocuous.
- The area in the passage zone in front of the DFH shall be marked as **no-stay zone for personnel**.

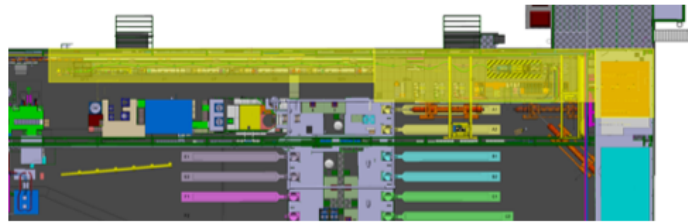
Worst Critical Incident: enough energy to damage the cryostat, more likely to happen within the SC Link because it is the weakest mechanical part. Electrical arc can be visible outside, same He quantity released. Initial risk assessment shows that a protected open arc (WCI) in the DSH falls in the broadly acceptable risk region. Nevertheless inherent technical design features and a simple operational measure provide additional risk reduction:

The following risk reduction measures are available:

- Technical: in the accessible portion of its length, the DSH is installed in a trench with a **heavy cover**, absorbing the radiative energy of a protected open arc
- Technical: in the short open section of the DSH, where it joins the DFHX/DFHM, a **safety distance** to the potential location of an arc can be defined and realised by distancing elements (e.g. a mesh, a tube) around the DSH.
- Organisational: during a first ramp-up of magnet current of the HL-LHC magnets after installation or after modification of the circuits, the HL-LHC areas in the vicinity of the DSH remain **inaccessible until the nominal current has been reached** and the protection systems have been commissioned. This can be realised for example by mobile fencing of the DFH and the corresponding DSH or by access control measures.

WP16: IT String

Courtesy: T. Otto



In Test hall SM18
(surface building)

- Probabilistic Safety assessment building upon WP6a
- MCI helium release flow estimated as $q \approx 2.3 \text{ kg/s}$:
 - In the large SM18 hall this rate is considered safe:
 - Safety distance given by fence around IT String.
 - He inventory too low to cause ODH.
 - Protect SC link by a safety distance (50 cm) for electrical arcs.
 - Commission all circuits, including QDS/QPS, at low energy.



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Same analysis as before, including the magnets.

Not exposed directly to the He release, fenced area + protection against direct release.

Major Critical Incident (MCI) likelihood = $10^{-6}/\text{y}$

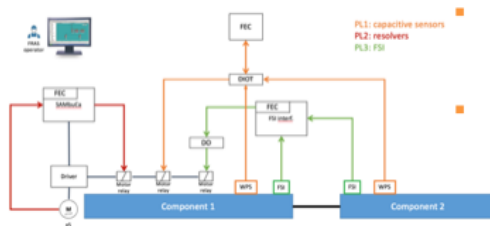
SM18 : He will be locally very cold, rapidly migrate to the ceiling and get dispersed. No ODH.

Major Critical Incident: interconnect between 2 magnets.

WP15.4: FRAS

Courtesy: M. Sosin, B. Adiego

- The **FRAS** will:
 - align simultaneously and remotely from the CERN Control Centre all the components from Q1 to Q5 on both sides of the Interaction Point within ± 2.5 mm,
 - move independently the components within the stroke of the corresponding bellows.
- **Risk analysis performed using FMEA:**
 - For personnel, Calibrated Risk graph from IEC 61511
 - For machine protection, risk matrix provided by TE-MPE
 - Risk reduction achieved by multiple protection layers according to IEC 61511



- Mechanical bellow protection: 3 layers of protection (position sensors and interlock on motor)
- Beam injection interlock in case of misalignment



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Machine protection:

- Based on experience of the MPE group at CERN – risk matrices for the LHC ([EDMS2647876](#))

Summary



End notes

- Safety assessments are on good track.

- Conformity / Standards
 - May be additional work to prove compliance.
 - We do our best to accommodate the requirements.
 - In case collaborations have questions or concerns, please let the WPL and Project Safety Officers know.





Thanks for you attention

