# TSS Concept Specification

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# 1. SCOPE

This document provides a concept specification for the Target Safety System (TSS) at ESS in Lund, Sweden. The document relates to lifecycle part 1 in IEC 61511 [1]. See Figure 1.

## 1.1. Objective and purpose

The objective and purpose of this document is to develop a level of understanding of the TSS and its environment sufficient to enable the other safety lifecycle activities of the system development to be satisfactorily carried out.

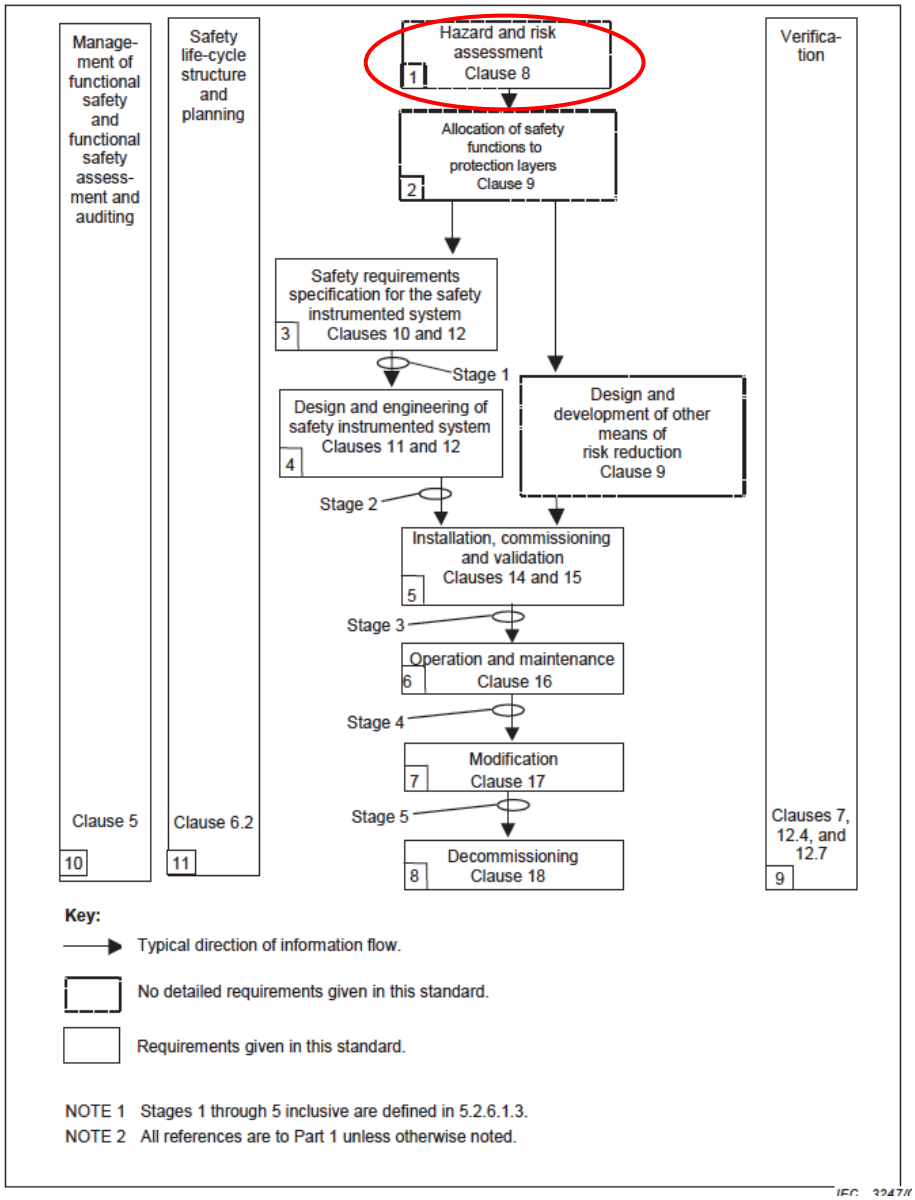


**Figure 1 IEC61511 life-cycle in [1], Part 1, development of overall safety requirement (concept, scope definition, hazard and risk assessment)**

# 2. ISSUING ORGANISATION

The issuing organisation of this document, and the development of the TSS, is the Target control group within WP7, Target division at ESS.

# 3. CONTEXT

ESS will be the world's most powerful neutron spallation source. This new facility will be around 30 times brighter than today's leading facilities, enabling new opportunities for researchers in the fields of life sciences, energy, environmental technology, cultural heritage and fundamental physics. The facility design and construction includes a linear proton accelerator, a heavy-metal target station and a large array of state-of-the- art neutron instruments. See [2] for more details.

A spallation process produces the neutrons where the accelerated protons collide with the tungsten wheel inside the target station. This process might under certain circumstances generate radiological releases above limits specified by Swedish Radiation Authority (SSM). Since permissions from SSM are required in order to operate the facility, several passive and active radiation safety systems are planned to meet SSM requirements, among them the TSS.

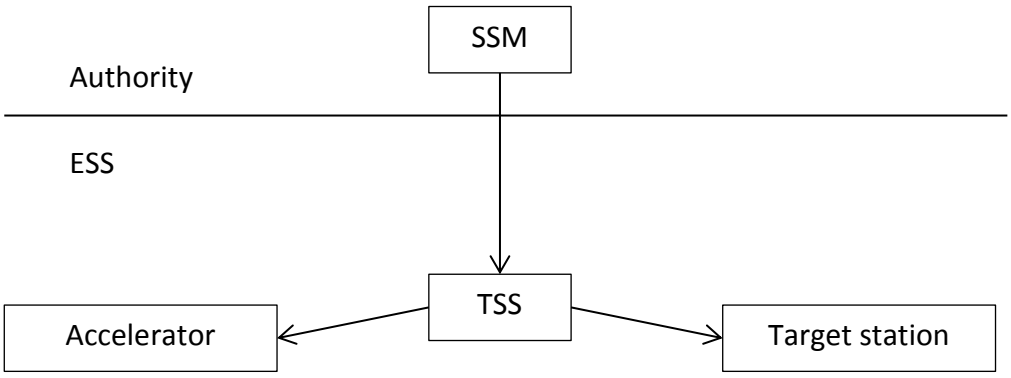


**Figure 2 Stakeholder hierarchies**

## 3.1. TSS goal

As part of the overall radiation safety plan for the Target Station, the goal for TSS is to protect the public from exposure to unsafe levels of radiation, and preventing the release of radioactive material beyond permissible limits and to bring the target station into a safe state in case of an abnormal event from nuclear radiation safety point of view. Since the safe state of the facility is defined as the spallation process shutdown the TSS main goal is to shut down the proton beam. Other contributors to the safe state are being defined and will be incorporated in the TSS as necessary.

This is further detailed as

- The Target Station shall operate safely, reliably, and with high availability [3].
- The Target Station shall protect workers and the public from radiation exposure beyond allowable limits [3].
- Prevent or minimize impacts of events and circumstances that lead to increased radiation levels [4].

# 4. NOTATION FOR DESCRIPTION

N/A.

# 5. DESCRIPTION

The radiation safety functions of the TSS will be based on results from quantitative analyses regarding radiation hazards within target station. The most critical hazard tends to be related to increased temperature of the target wheel tungsten, which, if accompanied by oxidation of the tungsten [5], might have consequences of radiological releases. There are different initiating events related to this hazard, see [6], for example:

- No or slow target wheel rotation
- Poor cooling efficiency of the target wheel
- Increased energy deposition by the proton beam due to changes in configuration or footprint on the target material

Since the energy in the proton beam is the root cause of the increased temperature the essential action of the TSS will be to prevent the proton beam from reaching the target wheel.

## 5.1. TSS architecture

The TSS will be an isolated standalone safety interlock system with no dependency to other communication or control systems. It will utilize its own dedicated sensors to evaluate potential hazards and its own dedicated actuators to bring the spallation processes in the target monolith to a safe state. Furthermore, the TSS will include physical separation, diversity and fail-safe criteria to such an extent that it can resist hazards that could impact reliability of the system in order to reach the required radiation safety level.

## 5.2. TSS interfaces

The TSS will have its dedicated sensors and actuators located in other systems to monitor parameters and perform actions to meet radiation safety requirements.

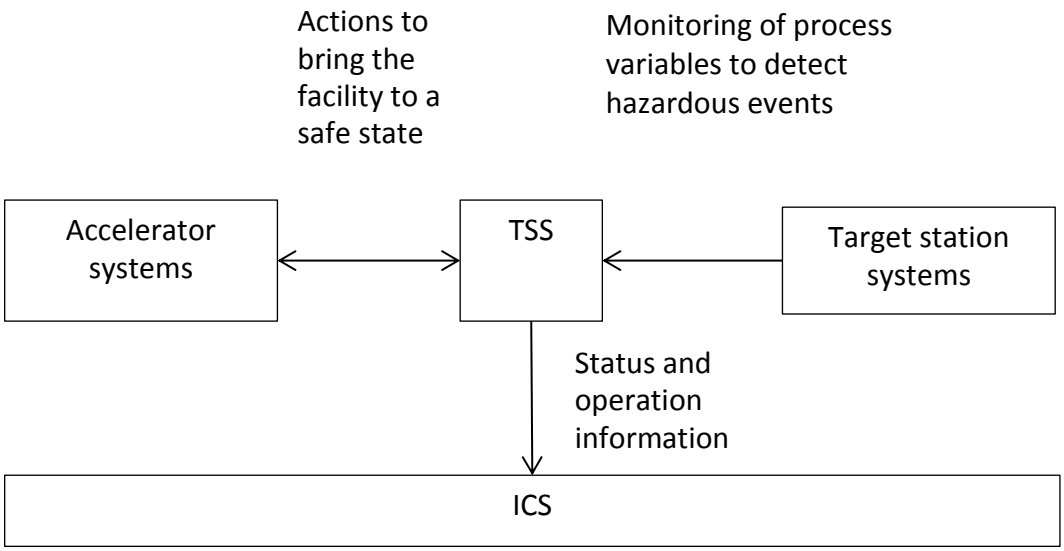


**Figure 3 TSS system interfaces**

From the target station systems, critical process values are monitored and evaluated continuously. Any sign of failure will cause the action to go to the safe state. The TSS will extract information from accelerator systems related to operational modes in order to meet operational requirements. The status of the TSS will be available for monitoring to the operator personnel in the main control room.

## 5.3. TSS development standard

Based on studies done in [7], the development of the TSS will follow the lifecycle of international standard IEC 61511 [1] in order to meet the required radiation safety level [4]. The TSS will apply IEC 61511, safety standard for the process sector, on the systems-of-systems level and, as required in this standard, will use IEC 61508 on the subsystem or components level.

IEC 61511 addresses safety-instrumented systems, which are based on the use of electrical/electronic/programmable electronic technology. Its complete lifecycle and pragmatic quantification of the risks and architecture provides a valuable framework for the safety engineering.

IEC 61511 covers all possible risks. Starting from a hazard and risk assessment with the necessary methods, measurements, system layout etc. this standard can be applied to achieve the required risk reduction for all risks. In addition, other international standards like IEC 61513 can, if adequate, be added as informative guidelines, or those parts that are sufficient to prove conformity with [4].

## 5.4. Swedish legislative body

ESS will obtain the license for operation from SSM, if requirements set by the SSM are met.

The Target Safety System is a critical part for the ESS project, which is subject to the SSM conditions [8], [9], [10] and legislations. The design of the TSS system will also meet the requirements described in Chapter 4 of [4] and Section 10 - Review of control systems [11].

The TSS group will consult the safety health and environment group (ES&H) for the ESS local rules concerning risk and hazard management.

# 6. SUMMARY

This document briefly describes the TSS as an active safety credited control system and its physical environment including interfaces to surrounding systems. Sources of critical events and the safety function to mitigate the hazard are explained briefly and legislation bodies applicable to the system are addressed.

This document serves as reference to the next level documents in the life cycle of the safety system, see [6] and [12].

# 7. GLOSSARY

| Term | Definition |
|---|---|
| ES&H | Environmental Safety and Health |
| ESS | European Spallation Source |
| ICS | Integrated Control System |
| SSM | Svenska strålskyddsmyndigheten (Swedish Radiation Authority) |
| TSS | Target Safety System |

# 8. REFERENCES

[1] IEC 61511, First edition, 2003 - Functional safety - Safety instrumented systems for the process industry sector
[2] http://europeanspallationsource.se
[3] ESS-0005857, Target Station System Requirement Document: Target Station, Rev 2
[4] ESS-0018828 Official permit from SSM regarding construction of ESS
[5] G.A. Greene, C.C. Finfrock, '*Vaporization of tungsten in flowing steam at high temperatures,*' Experimental Thermal and Fluid Science 25 (2001) 87-99
[6] ESS-0037525 Hazard Analysis - Target Wheel and Helium Cooling system
[7] ESS-0047208 Safety Standard Evaluation: Nuclear or process standards
[8] SSM2008-27 The Swedish Radiation Safety Authority Radiation safety regulations concerning activities with accelerators and sealed radiation sources.
[9] SSM2008-29 The Swedish Radiation Safety Authority General recommendations on the competence of radiation protection experts.
[10] SSM2008-51 The Swedish Radiation Safety Authority. Basic provision for the protection of workers and the general public in practices involving ionizing radiation.
[11] SSMFS2014-127 The Swedish Radiation Safety Authority Review of application for license for activity involving ionizing radiation. Section 10 – Review of control systems.
[12] ESS-0002776 TSS system requirements specifications

# DOCUMENT REVISION HISTORY

| Revision | Reason for and description of change | Author | Date |
|---|---|---|---|
| 1 | First issue | Atefeh Sadeghzadeh | 2016-02-4 |
| 2 | Updated for PSAR | Atefeh Sadeghzadeh | 2017-02-10 |