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Interface
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ID 25 – Risk Assessments
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SUMMARY

In this document the current status of risk assessment for the ESS accelerator is discussed, along with plausible risk mitigations.

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TABLE OF CONTENTS

1. SAFETY ANALYSIS

The work on a safety analysis for ESS was begun for the early design, but went into stasis along with the rest of the project. Now we should to continue that work parallel with the technical design update of the facility. The design update safety analysis, which is a continuation of what had already been started for the 2003 design [1], is comparable to SNS PSAR [2] which served as a frame. Two significant differences are, however, (i) stricter regulations in Europe compared to the US and (ii) ESS' location in a densely populated area. Both of these facts lower the limits on acceptable radiation levels. Furthermore, the higher beam power and energy of ESS will result in higher radiation. Consequently, the ESS safety analysis must be more rigorous than the SNS PSAR.

The main concern is with safety in the accelerator and klystron gallery. For these areas the accident scenarios are not considered high risk. Accidents should be infrequent and only a few scenarios could potentially lead to severe consequences.

In the Moorman *Status of Safety Analyses for the ESS Target* [3] it is noted that:
"The target is the only component in Spallation Sources, which requires detailed accident analyses: accidents, harming the public, are imaginable only for the target due to its substantial radiotoxic and chemical toxic inventory. Other components (accelerators etc.) need safety considerations for normal operation/- abnormal events only".

As most of the safety concerns for the accelerator is regarding radiation protection, the majority of the safety related work would be done in the radiation protection analysis, for which a first preliminary study has been performed [4]. To prevent undue hazards to public and personnel the safety measures concluded in that analysis must be adhered to. Technical and administrative controls both are required to reduce accident frequencies and their consequences.

A list of initiating events that need evaluation is given in Table 1. The worst imaginable scenario from a radiation point of view is a weakening or removal of the shielding around the collimators while the accelerator keeps running. Any sequence of events for that to happen is not obvious.

1.1 Construction phase

There are no radioactive or reactive chemical compounds or materials used neither in the accelerator nor for its installation, activation occurs first and only with operation. Hence, there are no specific hazards associated with the construction of the accelerator, only standard industrial construction work hazards.

Table 1: plausible initiating events

Initiating Event	Sources	Comment
Fire events		Could weaken shielding, and make particles airborne
Hydrogen explosion at the ion source/front end building	- Hydrogen bottles	Could weaken shielding in the low energy end of the linac
Beam misalignment	- Human error - Failed hardware - Bad installation	
Helium leak (eruptive)	- Cryogenic failure	Not likely
Oil leak	- Modulator oil - Compressor oil	Mostly fire hazards
Activated water leak	- Cooling water circuit inside the tunnel	Likely to happen to some extent. What activation levels ? What quantities ?
Natural disasters	- Seismic event - Flooding - Precipitation - Storm	
External accidents	- Plane crash - Ground vehicle crash	
Sabotage		

1.2 Operations

With the start-up of the accelerator, radiation and activated materials inevitably follow. Caution is needed.

1.2.1 Normal operations

During normal operation the accelerator will be a source of radiation, called prompt radiation, whenever it is running. The prompt radiation is due to small unavoidable losses of protons. When the accelerator is turned off the prompt radiation stops. Even with proton losses kept as low as technically achievable, the produced prompt radiation will be high. The design criterion is that losses should be <1 W/m of the accelerator, which is chosen to allow hands-on maintenance in the tunnel within 24 hours after shut down. Beam misalignment would increase the amount of radiation and the worst case would be a complete beam loss at full energy.

The prompt radiation will activate the interior of the accelerator tunnel and the shielding, so that a residual radiation will remain even when the accelerator is turned off. This poses a radiation threat to workers that need to do maintenance on the accelerator, both from being in the tunnel as well as from handling equipment from the tunnel, even if taken to an external work area. A first assessment of radiation levels and protection necessary has been performed [4], with some preliminary conclusions on the extent of shielding required and control measures needed for safe operations.

A sensitive matter is the activation of mobile substances, like air or liquids. Studies have begun on air activation and releases to atmosphere, but there is still work to do. There is not sufficient knowledge of the possible activation levels in the cooling water circuits, nor if there could be any radiation danger in the event of a leak. More studies are required, including an evaluation of potential impurities in the circulating media (water and helium).

The following incidents deserve a closer look:

- In the case of fire in the tunnel, could there be radioactive releases with the smoke, due to combustion of radioactive materials ?
- What would be the consequences of a hydrogen explosion at the ion source ?
- Could a helium leak - either slow or eruptive - pose a threat ? To whom (worker or general public) ?

Except for the obvious threat to a nearby worker in the case of fire or explosion, the above events are not considered to present any direct dangers to the public. They might, however, lead to new pathways for radiation to leach out of the facility, by fire smoke, or weakened radiation shielding.

1.2.2 External risks

External risks are events external to the ESS facility which affect the facility in such a way that there occurs an additional or enhanced threat to the public or the environment. Among those are natural disasters such as flooding and earthquakes, technical hazards such as coming from heavy industries or airplane crashes, and terrorist attacks. A study performed in the run-up to the site decision showed that the risk from natural phenomena is almost negligible at the Lund site and that the technical and political threats are low [5].

1.3 Decommissioning

A decommissioning plan should be formed along with further studies of safe procedures. More detail about decommissioning is available in ID22.

2. MITIGATION OF RISKS

Even though a detailed accident analysis is only needed for the target, mitigating the effects of operational and accidental hazards of the accelerator is equally of importance. It is deemed possible to safely operate the accelerator with fairly straightforward safety measures. A summary of the actions that could be taken to mitigate the risks from the initiating events of Table 1 is given in Table 2.

Table 2: mitigating actions for initiating events

Initiating event	Mitigating action
Fire Event	Fire zones, sprinklers (?)
Hydrogen explosion at the ion source/front end building	Enclosure of hydrogen bottles,
Beam misalignment	Shielding, MPS, PPS
Helium leak (eruptive)	Safety release valves
Oil leak	Collection vats, adapted building floors
Activated water leak	Special drains, manual surveys and pre-emptive maintenance
Natural disasters	Stable buildings
External accidents	Stable buildings, limited access
Sabotage	Good PR, limited access

2.1 Mitigation of accidental risks

The main accidental risk with the accelerator during operation is beam misalignment, with high radiation doses to both public and personnel as plausible consequences. The radiation protection should be designed such that, with a fast responding beam shutdown, the radiation dose received by an individual outside the radiation shielding would not exceed the acceptable limits. Mitigating measures would be redundant fast beam shutdown systems including e.g. choking the hydrogen flow to the source, inserting a beam stop immediately after the source before the beam is accelerated, a bend magnet that turns off - sending the beam into a beam dump instead of the accelerator and switching off RF power. It seems from first studies that a shutdown between two pulses would be sufficient for radiation protection and that faster systems would not be needed (unless required for machine protection). As a rule, the shut down should be fast enough so that the radiation shielding for normal conditions also suffice to keep the accidental dose to anyone just outside the shield below the limits. Along with technical and administrative safety controls, the accelerator should not pose any threat to people either on or off site, or to the environment.

2.2 Mitigation of threats and sabotage

The support for ESS is quite broad among both politicians and the population in Sweden and there is no history of sabotage or terrorism. Probably the best defence against threats is to maintain good public relations and to be open and inform about what is going on at the facility and what potential dangers it constitutes. A fence should be put up around the site, or certain areas where appropriate, to keep the public away from zones where control of occupancy is required. This could also intimidate would-be saboteurs or reversely attract their attention. In the least, entrance to the facility should be controlled.

The accelerator does not contain any fissile material or other dangerous compounds that could be used for e.g. weapons construction, so there is no big threat from theft of equipment. Nevertheless, activated materials from the accelerator should not be spread outside the facility.

A threat with mostly smaller consequence, but that could easily be overlooked, is weakening of the radiation shield. The earth berm could be eroded over time, perforated by rabbit holes or sabotaged. A survey of the earth berm now and then, along with radiation monitoring at points outside the shielding and at the facility borders, could be good practice. The surface could be treated, e.g. with hardened clay, to prevent water from penetrating into the berm. This would also serve to decrease the above-mentioned degradations of the berm.

2.3 Mitigation of normal risks during operation

Radiation will be emitted during normal operation, and materials in the accelerator will be activated. So will the air in the tunnel, the water in the cooling circuits and the soil surrounding the accelerator. This radiation constitutes the greater threat of the accelerator, since it is constant and unavoidable. However, radiation doses can be kept low and controlled by radiation protection and a thorough set of technical and administrative controls. Examples of administrative arrangements could include limited access to the accelerator and klystron gallery, dose control by TLDs and active immediate detectors, work permits that need to be filled out before any work is conducted and followed up afterwards. Technical controls are interlocks that shut the accelerator down if anomalies are detected. This could be someone accessing the accelerator while running, too high radiation levels at measured locations, failure to detect beam on target etc.

3. REFERENCES

[1] Bauer et al (editors), *The ESS Project Volume III Update,* 2003

[2] SNS, *SNS PSAR,* 2000

[3] Moorman, *Status of Safety Analyses for the ESS Target,* presentation SAFERIB I, 2002

[4] Ene, *Radioprotection studies for the ESS superconducting linear accelerator Preliminary estimates,* 2010

[5] ESSS, The ESS Scandinavia Submission to the ESFRI Working Group on ESS Siting, 2008