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Justification for the implementation of Remote Handling solutions for NSS Instruments

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1. GENERAL REMARKS

1.1 Document objectives

This document provides the justification for the decision to deploy remote handling measures on the neutron instruments at the ESS. It goes through the legislative and operational constraints in a dose-centric perspective.

1.2 Document scope

This document describes the environment, service times and expected dose on personnel using traditional methods of service for neutron instrumentation.

Conventional hazards are not included in this document.

1.3 Stakeholders

All personnel engaged in the successful design, construction and maintenance of the ESS neutron instruments.

Table 1 - Stakeholder table

Group ID	Stakeholder group	Individual ID	Stakeholder	Surrogate
SH-4	Regulators			ESS ESH&Q
SH-5	Operators	SH-5.2	Maintenance staff line managers.	NSS project leader
				Instrument technologies group leaders

1.4 Applicability

The document focuses on neutron chopper maintenance and repairs since it is the field with the most up to date data and knowledge. The conclusions and information from the chopper area can easily be applied to other component areas as well.

2. ESTIMATION OF DOSE EXPOSURE ON CHOPPER MAINTENANCE STAFF

2.1 Legislation and ESS implementation

The environmental conditions expected in the instrument halls and regulations on staff exposure is defined in ESS-0000004 [1] and ESS-0001786 [2].

The maximum yearly dose is limited to an average of 2mSv per year per person for ESS workers. This value is used as the dose exposure limit in this document.

ESS has decided to implement the ALARA [3] principle to minimise dose exposure to personnel.

2.2 Bunker area overview

The bunker area's purpose is to create a common shielding volume in order to fulfil the legislative requirements on ESS [4] whilst still allowing ESS to operate and maintain neutron instruments. The front end of instrument up to 15 or 28 meters are situated within this area, depending on their respective beamport.

Within the two halves of the bunker, located in D01, D02 and D03, the initial 15 instruments plan for 64 chopper axis [5].

Each half of the bunker area can be split into two separate areas with respect to instrument installation. The front and back area. The front area is considered everything up to R11.5m. The back area is considered everything beyond the R11.5m. This distinction is made to be able to show the different working conditions in each of those areas and is based on the density of equipment. Out of the 64 chopper axis, only ten (10) are situated in the back area of the bunker.

The full scope of the ESS incudes 22 instruments. Extrapolating from 15 to 22 instruments gives an indicative number of 94 chopper axis that is located within the bunker area. For simplicity this is rounded to 100 axis.

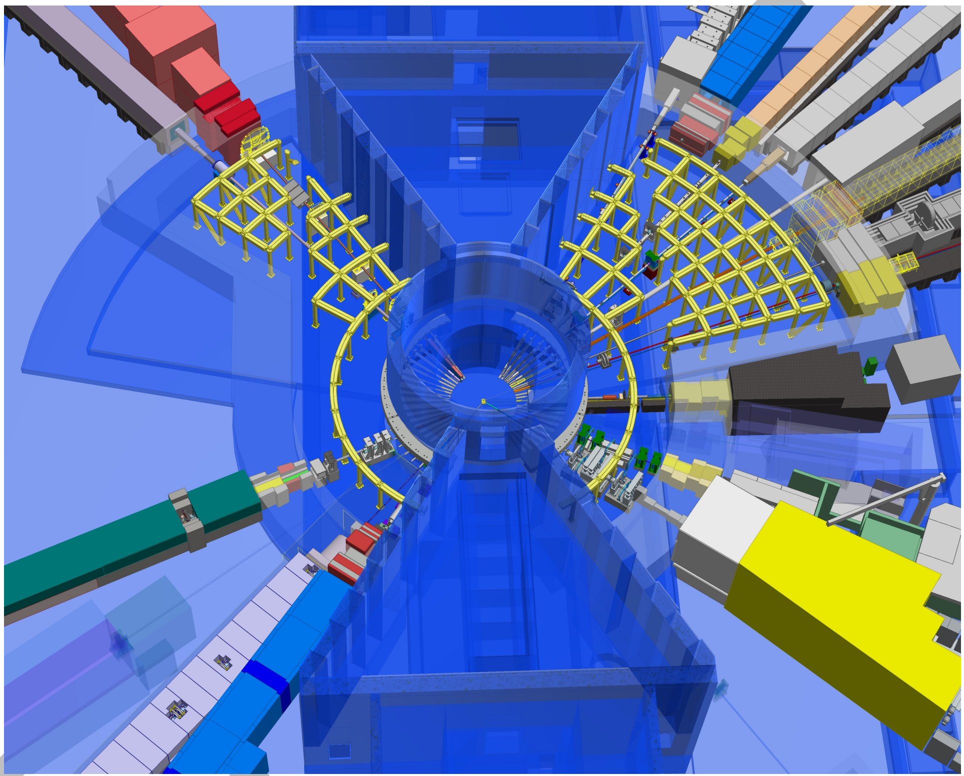

Figure 1 - Bunker overview

2.3 Expected operational conditions

2.3.1 Operational schedule

During steady-state operation the bunker is only considered to be accessible during the two long shutdowns specified in the ESS baseline schedule [6]. The shorter shutdowns are not sufficient to allow for sufficient cooldown and unstack and stack the shielding.

During the early years of operation, intermediate mid-length shutdowns might permit access to the bunker. These are however not part of the baseline schedule and not considered in this document.

2.3.2 Physical conditions

The physical working conditions in the bunker can be found in the bunker PDR report [7].

The bunker area is the most densely populated area of the instrument hall, with respect to instrument components. The area is covered with maintenance components such as choppers. Sections of neutron guides are installed roughly 120cm above the floor level directed away from the target monolith.

2.3.3 Component activation levels

Levels of activation was calculated for components within the bunker for the Bunker PDR in December 2016 [8]. The levels are calculated with 100 days of beam on target at full ESS specified power (5MW). It does not include the activation of the monolith or structural components of the Bunker. All calculations assume idealised configurations and ignore effects of material impurities. Given the assumptions the levels of activations should be considered as low estimates.

		Contact dose [µSv/h]				
Delay following beam shutdown	Material	1h	1 day	3 days	7 days	1 year
Guide upstream of the 1st chopper	Aluminium (5083)	1000	50	<3	<3	<3
Guide downstream	Aluminium ?	40	<3	<3	<0.5	<0.5
Collimator (streaming)	Copper	1000	200	<25	<25	<25
Chopper (no steel)	Aluminium housing / Alu rotor	15000	200	<25	<3	<3
Heavy shutter	Tungsten / no housing	20000	1000	500	<100	<100
T_0 chopper (Tungsten hammer)	Tungsten / steel housing	20000	1000	500	<100	<100
Inside rear bunker wall (with lead)	Lead /PolyConcrete/ Steel	<3	<3	<3	<3	<0.5
Note all calculations assume idealised configerations and ignore the effects of trace material impureties						
Exposition prior to shutdown is assumed to be 100days at full rated power (5MW)						

Figure 2 - Dose from components within the bunker at direct contact (Bunker PDR 12-2016)

		Whole body dose @ about 30 cm [µSv/h]				
Delay following beam shutdown	Material	1h	1 day	3 days	7 days	1 year
Guide upstream of the 1st chopper	Aluminium (5083)	200	<3	<0.5	<0.5	<0.5
Guide downstream	Aluminium ?	<25	<3	<0.5	<0.5	<0.5
Collimator (streaming)	Copper	<50	<25	<3	<3	<3
Chopper (no steel)	Aluminium housing / Alu rotor	300	<50	<3	<0.5	<0.5
Heavy shutter	Tungsten / no housing	1000	100	<50	<25	<25
T_0 chopper (Tungsten hammer)	Tungsten / steel housing	1000	100	<50	<25	<25
Inside rear bunker wall (with lead)	Lead /PolyConcrete/ Steel	<3	<3	<3	<3	<0.5
Note all calculations assume idealised configerations and ignore the effects of trace material impureties						
Exposition prior to shutdown is assumed to be 100days at full rated power (5MW)						

Figure 3 – Dose from components within the bunker at 30cm distance (Bunker PDR 12-2016)

2.4 Assumptions

The following dose exposure calculations are based on hands-on chopper maintenance and repairs.

The exposure calculation assumes the following,

- Removal and reinstallation is carried out hands-on in the bunker area.
- Chopper designs are traditional chopper designs and not optimised for short intervention time or remote handling.
- 22 instruments, at 5MW ESS power.
- 100 chopper axis in the two bunker areas.
- ESS baseline operational schedule

The calculations assume three different reasons for accessing the equipment in the bunker,

- Routine service and maintenance
- Repairs and other short interventions
- Irregular operations

The operation durations are estimated from experience from other neutron facilities [9].

2.4.1 Routine service and maintenance

Routine service and maintenance is defined as all pre-planned service and maintenance. The chopper assembly specification requires a specified minimum service interval in order to ensure the availability of the neutron instrument suite. The calculation assumes the following numbers,

- 5-year maintenance interval (as specified in chopper system requirements).
- 20 units serviced per year (20%).
- 4 hours of removal time per unit.
- 8 hours of reinstallation and alignment.

This adds up to **240** hours per year of routine service and maintenance.

2.4.2 Repairs and other short interventions

This category of work includes all non-foreseen repairs and other short interventions. The numbers of incidents are extrapolated from the chopper availability report (ESS-0114102). The calculation assumes the following numbers,

- 3 incidents per year (Extrapolated from ESS-0114102).
- 4 hours of removal time per unit.
- 8 hours of reinstallation and alignment.

This adds up to **36** hours per year of repairs and other short interventions.

2.4.3 Irregular operations

During steady state operation, one major special operation is expected each year. This is initially the construction and installation of instrument 16 to 22 and later on replacement of the first generation of instruments. Assuming a 20 year lifetime of an instrument, one major operation is performed each year. Major upgrades of instrument would also fall into this category but is excluded in the calculation due to the uncertainty of how much equipment is affected.

An irregular operation assumes the need to remove all components within the first part of the bunker area to allow for access. On average this assumes,

- 4 choppers
- 2 choppers on each neighbour
- Each chopper removal assumes the removal down to the level of base plates.

Choppers are assumed for simplicity in this case. Similar removal times apply for other types of instrument components. For each operation, the following numbers are assumed,

- 8 hours for each disassembly (full system removal).
- 12 hours for each reinstallation (full system reinstallation).

This adds up to **160** hours per year of irregular operations.

2.4.4 Operational access

In order to achieve the number of operations specified above during the two long shut downs only three days of cooldown can be allowed. This forms the basis of the estimation of ambient dose below.

As work continues throughout the maintenance period the levels of activation will gradually drop, according to section 2.3.3. This is not taken into account in the dose estimations and can be considered a safety factor for uncertainties regarding material impurities or other uncontrolled environmental changes.

2.5 Estimation of ambient dose during maintenance scenarios

In this section, four typical chopper maintenance scenarios are used as examples for ambient dose calculations. Each scenario lists the sources and sizes of the received dose on staff.

2.5.1 Dose when working on front area T0 chopper

The following calculations assume work on a T0 chopper situated in the front-end area of the bunker.

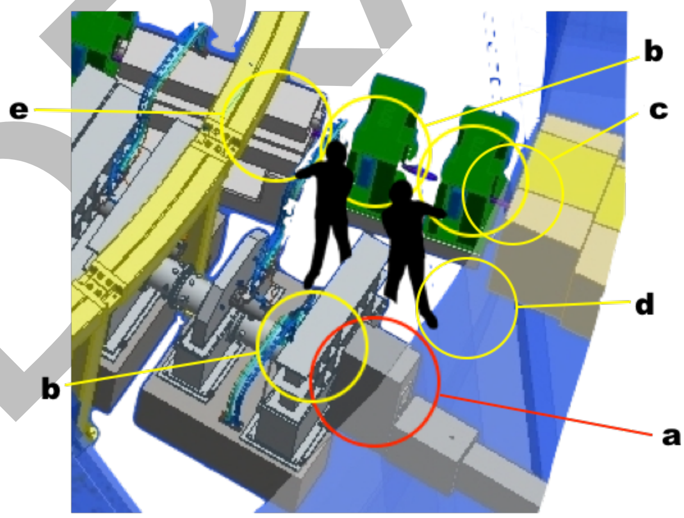

Figure 4 - Front end work

The workers receive the following dose,

a) Contact dose from T0 Chopper – 500μSv/h
a) Contact dose from two sections of guide – 6μSv/h (3μSv/h each)
b) Proximity dose (30cm) from three choppers – 9μSv/h (3μSv/h each)
c) Proximity dose (30cm) from one heavy shutter – 50μSv/h
d) Proximity dose (30cm) from bunker rear wall – 3μSv/h
e) Proximity dose (30cm) from copper collimator – 3μSv/h

Total dose adds up to 571μSv/h.

2.5.2 Dose when working on front area chopper

The following calculations assume work on a chopper situated in the front-end area of the bunker.

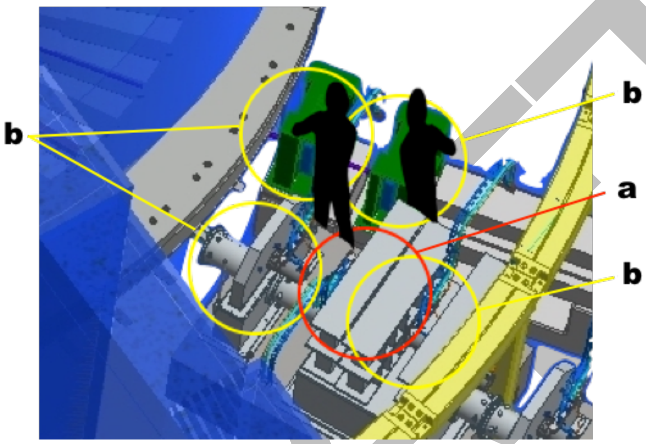

Figure 5 - Front end chopper maintenance

The workers receive the following dose,

a) Contact dose from two choppers – 50μSv/h (25μSv/h each)
a) Contact dose from two sections of guide – 6μSv/h (3μSv/h each)
b) Proximity dose (30cm) from four choppers – 12μSv/h (3μSv/h each)

Total dose adds up to 68μSv/h.

2.5.3 Dose when working on back area T0 chopper

The following calculations assume work on a T0 chopper situated in the back-end area of the bunker.

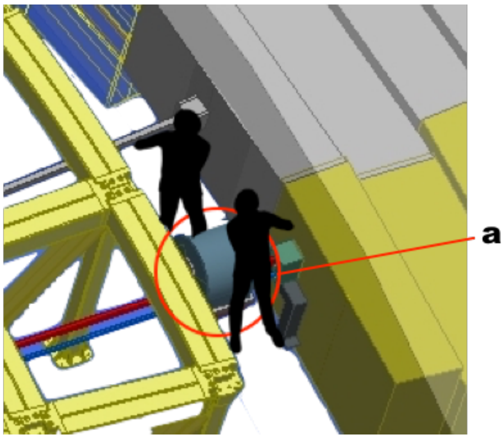

Figure 6 - Back area T0 maintenance

The workers receive the following dose,

a) Contact dose from T0 Chopper – 500μSv/h
a) Contact dose from two sections of guide – 6μSv/h (3μSv/h each)

Total dose adds up to 506μSv/h.

2.5.4 Dose when working on back area chopper

The following calculations assume work on a chopper situated in the back-end area of the bunker.

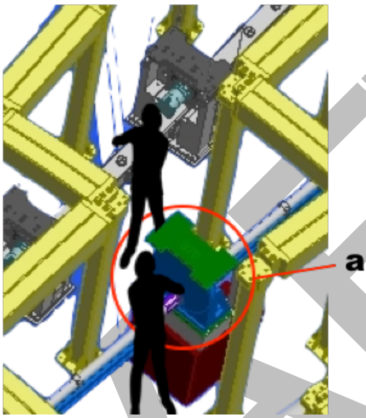

Figure 7 - Back area chopper maintenance.

The workers receive the following dose,

a) Contact dose from one chopper – 25µSv/h
a) Contact dose from two sections of guide – 6µSv/h (3µSv/h each)

Total dose adds up to 31µSv/h.

2.5.5 Resulting ambient dose

As seen in the estimations above, the hourly dose varies depending on the type of operation performed and the location of that operation.

The quota of T0 choppers with respect to regular disc choppers is at least 1 to 10 at this stage of the project. An even distribution of operations can be assumed between the different types of choppers, resulting in an 90-10% split of operations between T0 and regular type choppers. This distribution can be considered low since it is known from other facilities that T0 type choppers require more frequent maintenance than other types [10].

The results in an average ambient dose in the front area of **118µSv/h** (571*0,1+68*0,9) and in the back area of **78.5µSv/h** (506*0,1+31*0,9).

2.6 Estimated exposure on staff

The total time spent in the bunker area for maintenance, repairs and other operations is summarized to 436 hours per year. It can be broken down into the different types of operations. Details are described in sections 2.4.1 to 2.4.3.

All operations assume a crew of three people present in the work area. It is distributed as follows,

- 1.0 Mechanical technician.
- 0.75 Electrical technician.
- 0.25 Crane operator.

This results in the total number of man-hours spent in the work area is **872 hours per year** (436*1+436*0,75+436*0,25).

Out of the 64 chopper axis, only ten (10) are situated in the back area of the bunkers. Due to this distribution, the distribution of operations is assumed to be 80% to 20% between the front and rear section of the bunker.

The ambient dose at the time of exposure is 118μSv/h in the front area and 78,5μSv/h in the back area as described in section 2.5.5. The integrated dose in the work area, adds up to **96mSv per year** (118*872*0.8+78.5*872*0.2). The chopper group requires a staffing level of at least **48 people** to keep the dose exposure on staff to acceptable levels (as per ESS-0000004).

In an attempt to reduce dose on staff remote handling operations for T0 choppers can be assumed. Removing the T0 part of the calculation the integrated dose on staff (following all other assumptions) is 52,8mSv per year. Under these circumstances the chopper group would require a staffing level of at least 26 people to keep the dose exposure on staff to acceptable levels (as per ESS-0000004).

3. CONCLUSION

The calculated estimated dose on staff and the required number of staff within the chopper group does not comply with the current level of staffing for ESS operations [5].

The principle of exposing staff for these levels of dose does not comply with the ALARA principle.

Conventional hazards are not included in this document but would probably further reduce the suitability of the bunker area as a working environment.

Only access from the roof can be achieved within the current bunker concept. Access along the floor will cause issues due to many intervening neutron guide assemblies.

Introduction of remote handling strategies and solutions for instrument components within the bunker area is proposed.

4. REFERENCES

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[3] ESS, Javier, *ALARA Procedure*, ESS-0037524, February 2016

[4] ESS, Sångberg, Neutronics Design of the Bunker, ESS-0052649, Rev 3, March 2017

[5] ESS, Mérida, *Reliability and availability of neutron choppers in the NSS instrument suite at the ESS,* ESS-0114109. June 2017

[6] ESS, Haines, *Updated Report on Operations,* ESS-0011768, Rev 4, 24-26. April 2016

[7] ESS, Davidge, *PDR – Mechanical – 2016-12-15_Benjamin.pdf.* December 2016

[8] ESS, Sutton, *Bunker Operations Bunker PDR.* December 2016

[9] Sutton, Iain; NSS Senior Engineer and Tsapatsaris Nikolaos; Chopper group Development Engineer. Meeting 2017-10-03

[10] ESS, Nilsson, *SNS Chopper Group Organisation, Responsibility and Maintenance,* ESS-0063519. August 2016

5. LIST OF ABBREVIATIONS

Abbreviation	Explanation of abbreviation
ESS	European Spallation Source
NSS	Neutron Scattering Systems
ALARA	As Low As Reasonable Achievable
PDR	Preliminary Design Review

DOCUMENT REVISION HISTORY

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0.1	Draft release	2017-10-20