IntOps document (short)

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Early operations of the ESS Neutron Instruments and first scientific results

Preamble

This document defines a few notions and ideas that will be collectively owned and understood by all sectors of ESS to ensure its early scientific success. The recent delays and re-baselining that followed have forced a major reshuffling in the plans for initial operations and ramp-up of the major ESS actors, the neutron source and instruments. As a result of the reshuffle, the three major systems (Accelerator, Target and NSS) will ramp-up more or less in parallel. Since the initial success of ESS will be measured by the scientific output of the first instruments that will accept users, it is essential that the combined ramp-up programmes for Accelerator, Target and NSS are synchronised in order to maximise the capacities of ESS (neutron production and instruments) for scientific operations in the early months of the user programme. The interactions between systems need to be considered holistically and facility wide through an integrated ESS commissioning and ramp-up schedule driven by the overall ESS success criteria “of scientific output on instruments”. Therefore, it is important that NSS schedule shall be considered the central point for integration.

The plan below builds upon a previous document (ESS-0011768, referred to as ESS-OM and to be updated) that describes in detail the modes of operations of ESS during what was called the Initial Operations Phase and the Steady State Phase, back in 2015. Although the majority of these modes remain valid today, we focus here on what will be the highest priorities in the first five years after beam-on-target (2022-2027) in terms of neutron production. The years 2022-2027 are to be divided into three periods, defined by the new baseline schedule: from the present and Up to Beam on Target, ESS Initial Stages with neutron beams, and the Start Of the User Programme (SOUP). For each period, the document specifies key deliverables and the associated timing that must be captured in the detailed planning for concerned divisions and sub-projects within ESS. This plan reflects today’s understanding of the situation, as it is captured in the overall ESS new baseline (appendix 1) and in the NSS Master Schedule Version 4.0 (appendix 2). Nevertheless, the options described below will remain valid even if adjustments in parameters values are made in due time. The final transition period towards the Steady-State Operations will be discussed in an update of the 2015 document ESS-OM documented, together with a full documentation of the present document.

1 - Up to Beam on Target (-July 2022).

The calendar base of this document and the associated operational requirements described is the new ESS baseline schedule. The date for first beam on target (BOT) coincides with completion of the neutron guide bunker. According to the NSS Master Schedule V4.0, the bunker construction activities provide for installation of in-monolith components for all neutron instruments (15 user instruments + test beamline) and the in-bunker components for the test beamline and the first user instruments. Since the bunker

construction is on the critical path for (BOT), no accelerator pre-commissioning activities can be allowed to impede bunker construction. i.e. any early accelerator commissioning activities using beam dump must not produce radiation above permissible level at or around the monolith face that affects or delays the installation work.
The licensing applications and the anticipated received permits towards/from the Swedish Radiation Authority (SSM), are divided into three steps: Normal Conducting LINAC (beam on temporary dump), Super Conducting LINAC (beam on dump) and neutron production (BOT). For the last and most important step, all specific conditions given by SSM must be fulfilled. It can be noted that for the NSS instruments, safety assessments must be conducted before the actual installation can start, thus before the BOT application.

All ESS systems should have gone through the appropriate tollgates or milestones. All ESS sectors, in particular ICS and ES&H, will have been involved with the readiness for BOT.

2 - The ESS initial stages (July 2022-December 2023).

This 18-month period covers the critical period during which the first instruments are being hot commissioned, and when the performance of the ESS facility is tested by expert users. Scientifically significant experiments will be performed.

- **Early Days: BOT to (BOT + 3 months)** (July – September 2022).
  - **Main activities.** The first neutrons will be produced from the target at very low beam power, including ramp up and testing from Accelerator, Target and ICS systems. This is also an anticipated condition from SSM. The Test Beamline and up to 5 user instruments will be ready to accept neutron beams and will start their Hot Commissioning which requires the production of neutron beams at low power levels. Emphasis shall be on availability of beam over beam power. This corresponds to the Target Studies Operation Mode (OpM) in ESS-OM, providing confidence in safety systems and preliminary validation of shielding performance on the first instruments. Access into the bunker and other potentially activated areas will be needed for corrective work on beamline components.
  - **Overall objectives**: The establishment of the beam characteristics (long pulse 2.86ms with a stable current throughout the pulse, based on a time grid of 14Hz) that match the design of the neutron instruments is the highest priority along with the production of neutron beams to commission instruments. Within these parameters, the repetition rate can be adjusted to ramp up the accelerator power.
  - **Neutron pulse parameters**: Pulse length: 2.86 ms stable current throughout the pulse, based on a time grid of 14Hz.
  - **Proton Beam parameters** (indicative): Current ~6 mA and beam energy ~570 MeV.
  - **Operating cycle for NSS**: 1 x 8-hour shift at least once a week at minimum power (0.1MW). More shifts will be needed for the neutron source itself: their planning will be coordinated with NSS.
  - **Shutdowns**: This period will resemble Target Studies Mode (described in ESS- OM).
  - **Radiation Protection (RP) & Occupation Health Safety (OHS):** Control of Shielding (monitoring system) for the target, the neutron beamlines and the NSS instruments.

Control and support (trouble-shooting) for the NSS instruments in terms of RP and OHS.

- **Consolidation Days: The next 3 months: (BOT + 3 months) to (BOT + 6 months)** (October – December 2022).
  - **Main activities:** The key performance challenges of the neutron source (accelerator, target and moderators) should have been identified, in part with data provided by the test beamline, and will begin to be addressed. Meanwhile several more instruments will commence hot commissioning. Emphasis shall be on availability[1] and reliability of beam over beam power, when operating in neutron production mode. Access into the bunker and other irradiated areas will be needed for corrective work on beamline components. The repetition rate can be adjusted to ramp up the accelerator power
  - **Overall objectives:** An increase in the availability and reliability of neutron beams. Consolidation of hot commissioning process of the first 5 instruments, while installing more instruments in the experimental halls.
  - **Neutron pulse parameters**: Pulse length: 2.86 ms stable current throughout the pulse, based on a time grid of 14Hz.
  - **Proton Beam parameters** (indicative): Current ~6 mA and beam energy ~570 MeV.
  - **Operating cycle for NSS**: 2 consecutive days (6 shifts) per week at minimum power (0.1MW) with possible ramp-up at no expense to availability). More shifts might be needed for the neutron source itself: their planning will have to be properly coordinated with NSS.
  - **Shutdowns**: Weekly programmed shut downs of ~2days or 4-5days.
  - **Radiation Protection (RP) & Occupation Health Safety (OHS):** Control and support (trouble-shooting) for the NSS instruments in terms of RP and OHS.

- **Performance Assessment days: (BOT + 6 months) to (BOT + 9 months)** (January – March 2023).
  - **Main activities:** The teams for the first (up 5) instruments will assess the instrument performance against the high-level systems requirements; scientific calibrations and benchmarking will be performed. By this time all of the first eight instruments should have entered hot commissioning. By the end of this period, a selection will be made of the first three instruments ready for SOUP, which is currently scheduled for BOT + 18 months. Emphasis shall still be on availability and reliability of beam over beam power.
  - **Overall objectives:** An increase in the availability of neutron beams. Consolidation of hot commissioning process of the first 5 instruments, while installing more instruments in the experimental halls.
  - **Neutron pulse parameters**: Pulse length: 2.86 ms stable current throughout the pulse, based on a time grid of 14Hz.
  - **Proton Beam parameters** (indicative): Current ~6 mA and beam energy ~570 MeV.

[1] Here availability refers to the percentage of neutron production delivered relative to planned neutron production, whereas reliability refers to percentage of neutron production delivered on schedule.

- **Operating cycle for NSS**: 3-4 days per week, or 9-12 shifts (currently assumed to be consecutive days and an average of 7 days per fortnight at minimum power (0.1MW) with possible ramp-up (at no expense to availability). More shifts might be needed for the neutron source itself: their planning will have to be properly coordinated with NSS.
- **Shutdowns**: Weekly programmed shutdowns of ~2 days or 4-5 days.
- **Radiation Protection (RP) & Occupation Health Safety (OHS):** Control and support (trouble-shooting) for the NSS instruments in terms of RP and OHS. Start of the safety approval process of the NSS instrument experiments.

- **First Performance Demonstration Days: (BOT + 9 months) to (BOT + 12 months)** (April – June 2023).
  - **Main activities:** For the selected 3 instruments, teams will begin to systematically demonstrate the instrument performance for intended scope of science after the SOUP milestone. This period could also provide early scientific results from selected instruments. The corresponding operation modes would be close to the USM mode (refer to ESS-OM) with several Optional Study Days to allow for maintenance/changes of instrument components. Dedicated shutdowns may be needed, in order to intervene to resolve specific issues on these instruments in hot-commissioning
  - **Overall objectives:** Since expert users will be present availability will be a key factor of early success, and consequently emphasis shall be on availability of neutron beam over beam power. A total of 50 days of good neutron beam will be made available during that period, with programmed shutdowns to perform corrective work on beamline components.
  - **Neutron pulse parameters**: Pulse length: 2.86 ms and frequency of 14 Hz, stable current throughout the pulse.
  - **Proton Beam parameters**(indicative): Current ~12mA and beamenergy ~570 MeV.
  - **Operating cycle**: 11 days per fortnight (33 shifts) at 0.3MW with possible ramp-up (at no expense to availability).
  - **Shutdowns**: Monthly programmed shutdowns of ~2 days and/or 4-5 days. Additional shutdowns may be needed for interventions to resolve specific issues on the instruments.
  - **Radiation Protection (RP) & Occupation Health Safety (OHS):** Control and support (trouble-shooting) for the NSS instruments in terms of RP and OHS.

- **Ramp up and Early Science for six months: (BOT + 12 months) to (BOT + 18 months)** (July – December 2023).
  - **Main activities:** For the selected 3 instruments, teams complete systematic demonstrations of the instrument performance for intended scope of science after SOUP. A total number of 100 days of neutron production is expected. This period will also include integrated testing of sample environment equipment[2], and initial experiments from expert users which will provide the first scientific results of ESS.

[2] Selected sample env. equipment must be commissioned on each instrument before it enters operation.

Further hot commissioning will continue in parallel and dedicated shutdowns may be needed, in order to intervene to resolve specific issues on these instruments in hot-commissioning. The neutron source will deliver high flux neutron beams to allow for more and more demanding experiments.

- **Overall objectives**: Completion of hot commissioning of three instruments and first experiments on other instruments.
- **Neutron pulse parameters**: Pulse length: 2.86 ms and frequency of 14 Hz, stable current throughout the pulse.
- **Proton Beam parameters** (indicative): Current ~12mA and beamenergy ~570 MeV.
- **Operating cycle**: 11days (33shifts) per fortnight at power higher than 0.3MW with availability up to 80%. Possible ramp-up to higher power (0.5 MW) at no expense to availability or reliability.
- **Shutdowns**: Monthly programmed shutdowns of ~2 days and/or 4-5 days. Additional shutdowns may be needed for interventions to resolve specific issues on the instruments.
- **Radiation Protection (RP) & Occupation Health Safety (OHS):** Control and support (trouble-shooting) for the NSS instruments in terms of RP and OHS. First approval of the of the NSS instrument experiments.

3 - The start of the ESS User programme SOUP (2024-2027)

At the SOUP milestone, the source power must be close to 0.5 MW with a beam availability above 80%. Again, availability and reliability will have priority over operating power. Gradually, the source power and availability, and the number of operating instruments will increase as shown in the table below.

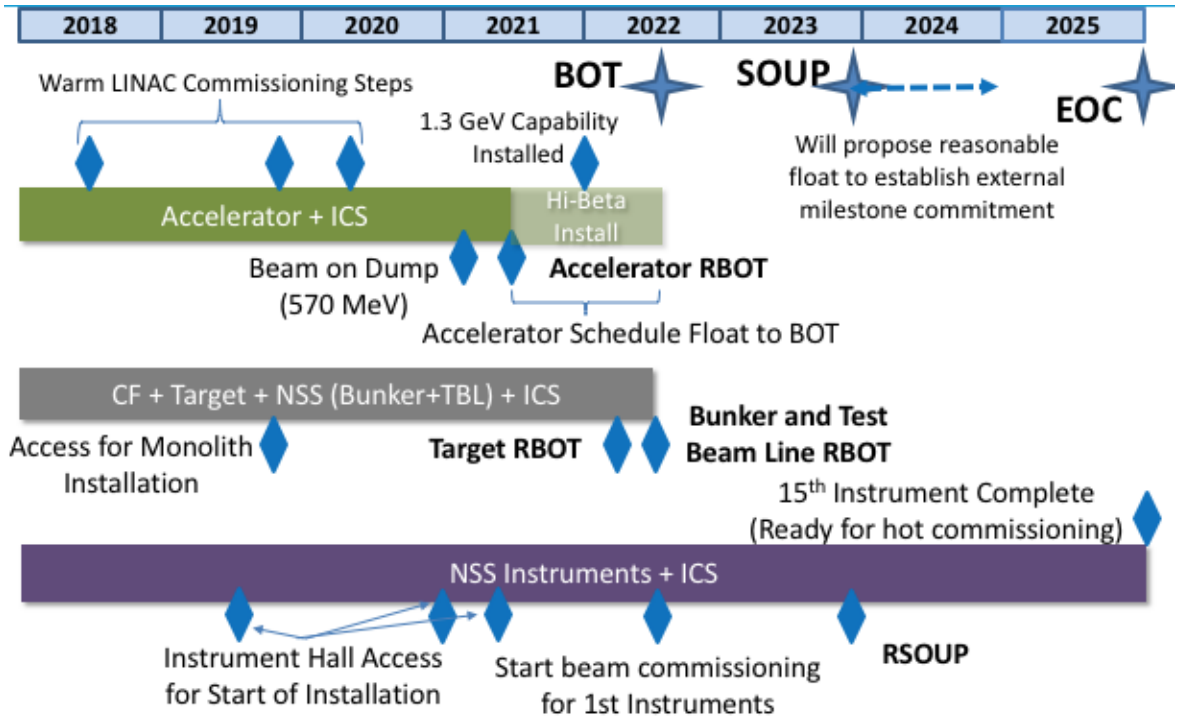
	January 2024	January 2025	January 2026	January 2027
Source operating power (MW)	> 0.57	1.25	2	2
Source Availability	80%	85%	90%	95%
Source installed capacity (MW)	1	2	3	
Instruments in operation [3]	3	8	12	15

Table 1: Target values for ESS ramp up of accelerator and instruments in first years of operation[3] in accordance with Appendix 2.

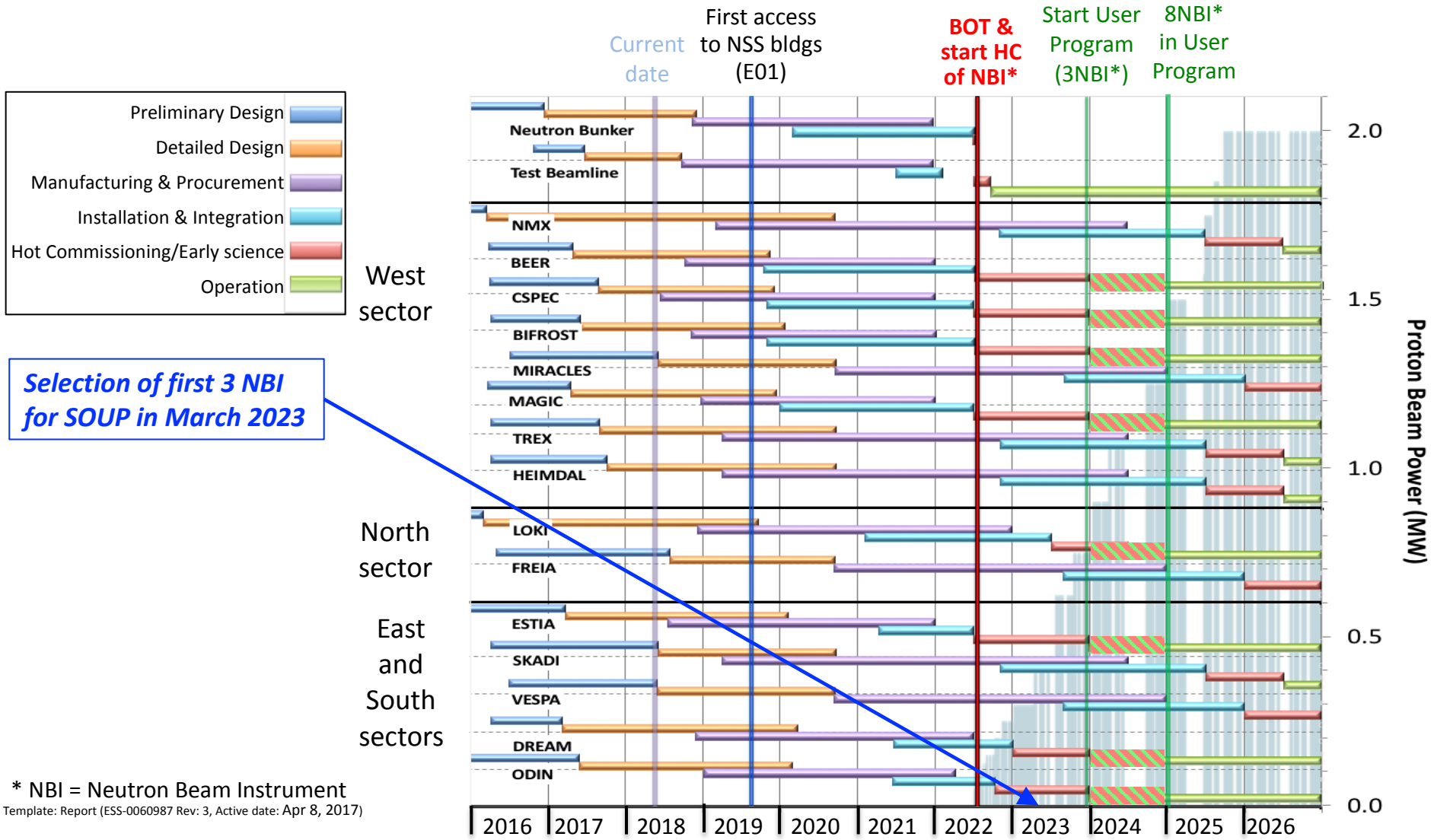
The scheduling of beam delivery and shutdowns is discussed in the updated ESS-OM document.

[3] Addition of instruments 9-12 into operation in January 2026 requires a long shutdown (~ 3 months) in 2024. Likewise addition of instruments 13-15 in January 2027 requires a long shutdown (~ 3 months) in 2025. (notional 3 month long shutdowns are included in Appendix 2)

Appendix 1: ESS overall Schedule after re-baselining (presented at ESS Schedule Review 22-24 May 2018).



Appendix 2: NSS Master Schedule for Neutron Beam Instrument Construction (V4.0, 11th May 2018). Eight instruments are scheduled to begin hot commissioning between Beam on Target (BOT) and December 2023, but only three are to be selected for start of user program (SOUP).



* NBI = Neutron Beam Instrument