Estia - Initial Operations and Staging Plan

Version 1.1

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1 Introduction

1.1 Purpose of the document

The initial operations and staging plan describes the preliminary plan for the validation of the instrument function and scientific performance using spallation neutrons. This 'hot commissioning' is beyond the scope of the instrument construction work unit. This document also describes the potential upgrades beyond the allocated budget.

1.2 Definitions, acronyms and abbreviations

Abbreviation	Explanation of abbreviation
BTCS	Beam transport and conditioning system
COM	Milestone: Commissioning
DES	Milestone: Design
INST	Milestone: Installation
NOSG	ESS neutron optics and shielding group
PBS	Product breakdown structure
PM	Project management
PNR	Polarized Neutron Reflectometry
SCS	Scattering characterization system
SES	Sample exposure system
SSM	Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority)
SP	Subproject
VS	Virtual Source
WBS	Work breakdown structure
WP	Work package

Specific to neutron guides:

Abbreviation	Explanation of abbreviation
segment	A single physical piece of a neutron guide as produced by the vendor.
mirror	A collection of segments that belong to the same geometrical shape or serve the same physical purpose. An example would be an elliptical mirror, which describes one reflector with elliptic shape that is implemented using several segments.
guide	One or more mirrors that share the same location on the beam axis and form one component of the beam delivery system. An example would be an elliptical guide that is a collection of four elliptical mirrors, two opposite mirrors for horizontal and vertical direction, each.
guide system	The collection of neutron guides that form the full beam delivery system from source to sample.

2 Hot Commissioning

The 'hot' commissioning of an instrument refers to the testing and validation of the instrument using spallation neutrons from the ESS target station. The main objective of the hot commissioning of the *Estia* reflectometer is to prepare the instrument for the user program in the operational phase of the ESS. In the spirit of the ESS Early Success Strategy, the hot commissioning phase will also aim to show how the instrument can deliver its full scientific performance with the challenging high intensity focusing mode and footprint control by the Virtual Source. In this preliminary plan general physical beam characteristics will be discussed separately from measurements being performed on standard samples, both necessary evaluation items for the instrument performance.

2.1 Validating instrument function

A neutron scattering instrument is a complex machine with many custom-built subsystems (e.g. optical system, detector system) that in turn consist of technical components (e.g. guides, choppers, detector units, electronic control units). The factory acceptance tests, installation and site acceptance tests of each individual component are included in the cold commissioning of the instrument, but their function together as system to perform scientific experiments can only be tested when neutrons are being produced by the target. The goal of the function validation of the individual systems is to establish the readiness of the instrument to produce reliable experimental data. The validation of the instrument function starts with the validation of the neutron beam characteristics, essentially verifying that the expected resolution and intensity is delivered by the guide and collimation system. The second part of instrument function validation is data collection from a known and well characterized sample, such as a smooth nickel film on silicon substrate.

2.1.1 Beam validation

The results of McStas simulations will be used to estimate the expected intensity and resolution at the sample position. Flux will be measured with gold foils during the hot commissioning to find unexpected losses. The wavelength resolution and calibration achieved by the time of flight technique can be evaluate by measuring Bragg-peaks from high quality single crystals like silicon.

2.1.2 Reflectivity measurement from a well characterized sample

The scientific performance of the instrument as well as the software capabilities can be tested by measuring well known standard samples. A set of Ni layers on silicon, Ni/Ti-supermirrors and similar samples will be prepared during the instrument construction and characterized with x-ray reflectivity and neutron reflectivity on a known instrument. The measured reflectivities in high intensity and almost conventional ToF mode can then be used to evaluate instrument resolution, alignment, calibration and background.

2.1.3 Validating virtual source imaging

Special standard samples will be prepared to be able to evaluate the imaging capability and stability of the *Selene* guide, projecting the VS onto the sample position. The desired quality of the system is described in the SR document.

2.2 Background evaluation and reduction

The maximum measurable q-range at a horizontal scattering reflectometer is mostly determined by the signal to background ratio. Although great care is taken to keep background as low as possible, there are many sources for instrument background and considerable effort during the hot commissioning phase will be necessary to reduce this background as much as possible.

2.3 Polarization analysis

Estia is a polarized reflectometer to measure magnetic thin films. The polarizer and analyzer performance needs to be validated by measuring magnetic standard samples (Fe/Si-supermirror) to characterize transmission and polarization parameters, to be compared to the expected values. With high probability a part of this evaluation process will be to optimize the magnetic guide fields, which lead to neutron depolarization if the field drops or changes direction too quickly.

3 Staging

The baseline scope of the *Estia* Instrument Construction Work Unit, together with an early operations upgrade of the magnet, will deliver a functional instrument with world-leading performance within the agreed budget. A 10% explicit budget contingency is included. The performance and throughput of the instrument could be significantly increased by the guide upgrade described below.

3.1 Adding a magnet

During the initial hot commissioning phase it is foreseen to purchase a room temperature bore cryomagnet so that a sample specific, optimized solution to generate a moderate magnetic field is present at the instrument. For most experiments this sample environment equipment will be sufficient and allow routine operation without unnecessary interruption. Cost estimate for a suitable solution is 300 k€.

3.2 Staging from the baseline to the full two beam instrument

By upgrading the *Selene* guide to transport two beams as described in the SR and PSD documents, the beam intensity can be doubled and the possibility of measuring with two different incident beam polarizations at once is added. This option will allow the simultaneous measurement of all four spin channels, which can be used for time dependent studies with single pulse resolution.

Upgrading the guides on existing granite carriers after initial neutron operations will be very challenging and expensive. Not only will it lead to an instrument down time of about 6 months, it will also need to be done on activated components and with the risk of damaging a fully operational instrument. Therefore two new granite carriers with full guide segments and positioning will be build to be installed in place of the existing guides. The estimated cost for such an upgrade is between 1.5 and 3.5 M€.

3.3 Staging of additional upgrades

Several optional instrument components usable for specific experiments have been taken out of the initial installation plan. These can mostly be installed independent from each other and each add new scientific possibilities to the instrument.

3.3.1 Sample changer

For higher throughput when measuring at ambient conditions, a sample changer will be developed. This upgrade will cost approximately 20 k€.

3.3.2 SRR Flipper

A spatial-spin-resonance flipper is a device that can be used to selectively flip the neutron polarization of only specific wavelength. When the coils creating the necessary guide field are supplied with a current that changes in phase with the source frequency, this can be used together with a polarization analyzer to increase the instrumental wavelength resolution. Such a device was successfully tested at SNS and will be added to *Estia* for 70 k€.

3.3.3 Space-time collimator

A set of four fast moving absorbers after the second *Selene* guide will be installed to allowed an encoding of incident beam angle coupled to the neutron wavelength. This option can be used to measure almost conventional ToF mode with increased q-range and at the same time to define a constant resolution better then the natural pulse resolution. The cost cannot be estimated very well now, but is expected to not exceed 250 k€.

3.3.4 Re-focusing for GISANS and background reduction

A special shaped mirror after the second *Selene* guide can be used to change the vertical beam focus from the sample position to the detector. This allows to achieve GISANS resolution with now intensity loss for large enough samples (25mm height) and can also be used to improve the signal to background ratio if the background is spread over the detector area. Cost will be governed by the mirror size and coating and is expected to be in the order of 350 k€.

3.3.5 Additional cryostats

The *Estia* sample stage is designed to allow fast, reproducible changes of the cryostat. For low temperature measurements on sets of samples this can be used to cool down a new sample outside the experimental cave while the previous sample is still measured and than just exchange the cryostats, which can be done in a few minutes. Having more then one cryostat is also a big advantage if the primary system fails, as many magnetic reflectivity experiments require low temperature measurements. Cost for each cryostat is around 25 k€.

3.3.6 Kerr-effect add-on

For a simultaneous measurement of the macroscopic magnetic moment of a sample it is possible to employ the magneto-optical Kerr effect. This can be added to the instrument as an expansion of the laser-alignment system by using a different laser and optical polarizers together with the suitable detectors. The upgrade is expected to be possible with approximately 60 k€.

3.3.7 Ultra-focus option + imaging detector

Estia is worldwide unique when it comes to the achievable flux with a very small focus. With small enough VS settings and additional optics it will be possible to achieve focus sizes <25 μm. This will allow experiments with magnification imaging of high resolution. Upgrading the optics and procuring a suitable image detector will cost around 450k€.

3.3.8 Laser for pump-probe experiments

Using the high flux of the ESS, faster time scales will be accessible. There are several experiments that could be performed at *Estia* where a pump laser is synchronized to the ESS source and changes physical properties within the sample by e.g. triggering photo-magnetism.

3.3.9 Pressure cell

The thin film community is recently expanding scientific effort by employing multiple physical parameter changes within a single experiment. The science case of *Estia* may therefore need to be expanded, too, to fulfill such future requirements. A pressure cell would need to be developed from scratch to be usable for thin film samples and within the *Estia* cryostat. Such development is expected to cost about 150 k€.