**Generic ESS Instrument Commissioning Plan**

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This document outlines commissioning activities for an instrument at the ESS. The activities apply generally to all instruments. Instrument-specific activities are taken into account where needed. As conclusion, time required for Hot Commissioning and Early Science phases are estimated. The overall process is pictured below.



Cold Commissioning Initiation Criteria

Completed sub-system tests

Completed sub-system installation

Cold Commissioning Success Criteria

Instrument ready for Safety Readiness Review (SRR)

Instrument functions verified (without neutrons)

Hot Commissioning Initiation Criteria

Completion of TG5

Completion of Safety Readiness Review (SRR)

Transfer of the instrument into Operations

Hot Commissioning Success Criteria

Define Hot Commissioning completion criteria

Define conditions to start Early Science

Define conditions of start of User Program

List of acceptable incomplete / missing components at the start of commissioning. Resulting mitigations, deferrals.

General Considerations

* Below process describes a mostly successful commission. Large deviations from expected performance will lead to additional testing iterations and possible rework on the instrument as installed.

In order to estimate the safety margin, \*X, to be included with the time estimate,

Real commissioning time = 1st-attempt successful commissioning time\*X Commissioning experience from similar instruments at other facilities will be used.

* Expect iterative process.
* For measurements and requirements related to count rates / flux / neutron current, determine scaling relation with respect to accelerator power / proton current.
* The activities will be mapped onto the neutron production schedule. The durations needed indicate the numbers of beam days needed, unless otherwise noted.
* For larger deviations from expected performance, a Fault Study Plan may be needed.
* Resources needed for the activities [personnel + equipment], Roles and responsibilities.
* Some Hot Commissioning tasks can be done regardless of source properties, ex. If the standard ESS 3-ms pulse is not yet achieved. It is indicated which measurements are of this type.

For each Commissioning Stage / Activity, include some, or all:

* Prerequisites
* Equipment needed
* Manpower needed
* Responsible
* Outcomes
* Time needed
* Deferments

Equipment Needed

Equipment recommended for hot commissioning:

* **Gold foil**. Recommended in the Gold Foil Task Force report (Dec 2019). Capability to use gold foils to calibrate beam monitors 1) next to the first monitor 2) next to the normalization monitor. Include option of using Dy foils in in order to avoid the epithermal resonance in Au. Include gamma image plate reader to allow position-sensitive readout of foils.
* **RAF rig**. A special sample environment insert with a diffraction sample and a fixed-angle counter. Allows characterization of the spectrum. Requires short pulse virtual source and a timing reference from the instrument. (used successfully in ISIS)
* **N-GEM** **camera**. An integrated 100x100 mm2 GEM n monitor (available from Japan). Allows position-sensitive ToF-resolved beam characterization in the sample area. Requires a timing reference from the instrument. (used successfully in ISIS)
* **Neutron Camera**. Integrating, position-sensitive imaging, but lacking time resolution. Allows verification of beam profile, without spectral resolution.

Phase 4:

Cold Commissioning Stage 1: Sub-system Commissioning

**SAT of each sub-system**

Verify correctness of delivery

Verify functionality

Verify installation

Verify integration

**Verify Hazard Mitigating systems**

Test hazard mitigation systems

**Vacuum Systems**

Measure ultimate pressure / pump down rate in:

* Detector tank
* [DREAM] Sample environment vessel
* [CSPEC, gate valve closed] Sample environment pot
* [CSPEC] Gate Valve performance: detector tank pressure with GV open vs. closed. Time to close, time to pump down.
* Guide housing

Measure deformation where needed.

**Grounding Inspection**

Verify component grounding. Measure current between components?

**Motion Components Tests**

As applicable:

* Movable monitors
* [CSPEC] Oscillating collimator
* Jaws / slits
* Focusing nose changers
* [BIFROST] Detector tank rotation
* [LOKI] Detector motion
* [LOKI] Collimation selector
* [LOKI] Beam stop selector
* Thermal shutter
* [ODIN] WFM chopper motion

**[DREAM] Bi-spectral Switch**

Part of the BBG assembly, it requires the best possible alignment in Cold Commissioning stage. Alignment of the switch within the vacuum housing, alignment of the housing in the installation.

**Timing System Test**

? synchronous signal injection into sub-systems?

Hot commissioning tests provide many indirect tests of timing, but may not be highly sensitive.

**Sample positioning**

Verify sample position

**Remote handling**

Bunker remote handling – will this be tested as part of instrument commissioning, or is there an overall Bunker commissioning?

**General services and PSS**

Sprinklers (if installed)

Interlocks

Other safety features

Cold Commissioning Stage 2: Instrument functionality (non-beam)

**Data Acquisition**

Verify data collection using background radiation; n, gamma sources.

* ToF spectra available
* PHS spectra available
* 2D / 3D images available
* Gating in ToF / PHS / images available

Verify time stamp consistency for components

Verify Metadata consistent with settings

Stress-test file writing: set detectors below normal threshold and measure with strong gamma source.

**Instrument Control**

Verify controls enable selecting instrument settings, and monitoring the same:

* Chopper speeds, phases
* Motion components position
* Detector HV, thresholds
* Shutter
* [CSPEC] Gate valve
* Pumps, pressure
* [CSPEC] Gas Flow
* [LOKI] Collimation selector
* [BIFROST] Detector tank rotation
* Electronics temperature
* Interface with SE?

**Remote functions**

Access to instrument remotely

Access to data remotely

**Maintenance access to components**

Verify that components that have an access possibility, or possibility to be removed can indeed be accessed as planned. Verify no collisions occur.

**[CSPEC, DREAM] Verify detector stability / performance as a function of gas flow**

Use background and n-/gamma-sources to verify the expected flushing time and pressure are sufficient to reach a stable operation. (Can further be re-verified with beam, but this can be done as part of other measurements and possibly does not need its own test in HC).

Overall Output of Cold Commissioning

* Verification Report
* Verification Plan deferrals
* Validation Plan update

Phase 5:

Hot Commissioning Stage 1: Instrument Parameters // Sub-system Characterization // Calibration and System Integration

[[Validate integration of instrument sub-systems into the instrument control system, timing system. Verify beam delivery, sample exposure performance. Calibrate sub-system and instrument parameters. Verify low-level software functionality.]]

[[Characterization sample performance – Vanadium, powder, single crystal. Measure and validate Instrument E, Q, x, resolutions.]]

**Fulfil radio-protection requirements**

Measure dose rate (neutron, gamma combined) in locations along the instrument. Confirm compliance with the 3uSv/h requirement in green zones and with appropriate levels in other zones. Needs repeating when proton power steps up.

Note that in practice for each sufficiently new operational mode the shielding will be surveyed. H2 and other accident scenarios will not be deliberately recreated.

Following measurement list addresses measurements that allow confirmation of specific beam scenarios which drove shielding calculations.

* Along the guide shielding
	+ At locations with highest simulated dose rate
	+ At chopper pit [H2/H1 xxx AUB on closed chopper]
	+ At shutter pit [H2/H1 xxx AUB on closed shutter]
	+ At location with thickest total beam window (ex. 2x guide window + 2xmonitor windows)
	+ [BIFROST] At chopper pit with attenuators in beam
* Outside of the cave
	+ Jaws / collimators closed [H2 xxx AUB on closed jaws]
	+ MOB incident on Cd sample
	+ MOB incident on single crystal
	+ MOB incident on strong incoherent sample (water/plastic)
	+ MOB/AUB incident on beam stop
	+ [LOKI] Steel equipment in sample position
	+ [LOKI] Cd mask in front of detector, full beam
	+ Full beam on the back of the detector tank

Rough number of measurements:

* 10 beam settings. Assuming 5 operational modes, and 2 beam powers during HC.
* Maximum 1 day of survey per new setting of the instrument.
* These runs can potentially be combined with other tests.

Deferment:

Needs repeating in every future accelerator power increase.

In case of excessive dose rate, it may be possible to temporarily re-classify an area. Then return it to the intended classification after the fix / rework is finished.

Time needed:

5 beam days, 5 beam days combined with other measurements

**Test Attenuation**

Shutter attenuation

Measure beam monitor and detector rate with white beam with:

* Shutter closed
* Shutter open
* Shutter transitioning from closed to open [Determine shutter opening / closing time]

Chopper attenuation: this is a signal-to background measurement, combined with background characterization.

Jaws attenuation

Test jaws in the closed (overlapping) position. Verify full closure. Determine position when transmission starts.

Rough number of measurements:

* 10 runs
* Shutter closed measurements are long, but can be combined with background measurements

Deferment:

Shutter attenuation must be verified as one of the first measurements, chopper and jaw attenuation are not as urgent (still done during HC).

Depending on background level and detector/monitor noise the measurement may only give an upper limit and need to be postponed.

Time needed:

5 beam days, can be partially combined with background measurements

**[DREAM] Bi-Spectral Switch**

The switch performance is to be evaluated early on, while its activation is low, in case access and adjustments are needed. Beam monitor ToF spectra are needed to evaluate alignment.

Rough number of measurements:

* Can be combined with RP requirements measurements.

Deferment:

None. High-priority verification.

Time needed:

Assuming is combined with other early measurements.

**Flux / Current measurements**

Measure beam monitor rates for

* MOB
* Monochromatic/wavelength band settings [xN settings]
* [BIFROST] 3x wavelength bands, 10 x PSC settings

Calibrate monitor efficiency using Au foil in monochromatic settings.

Calibrate neutron current: Select beam settings where a monitor is exposed to high integrated flux, low instantaneous flux (to stay in linear response of the monitor and maximize Au activation).

Rough number of measurements:

* 10 beam settings
* 1 monitor run per setting
* 1 Au foil run per setting
* Shielding removal / replacement (access to foil)

Deferment:

If Au-foil measurement cannot be schedule during Phase 5 (due to bunker / chopper pit accessibility), perform calibration for normalization monitor only. Defer remaining monitors.

Time needed:

2 days beam, 2 weeks non-beam if Bunker/pit accessed

**Beam on sample characterization**

Beam flux on sample:

* Au foil at sample position for each focusing nose

Beam divergence, dimensions, profile

* n-camera image at sample position, several positions upstream and downstream of sample.
* [equipment needed] mechanics to mount camera at sample position and up/down the beam
* Adjust the beam to be measured by Au foil using slits/jaws.

Repeat the above for N Ei. Assuming fully open collimation for each run [possible need to measure at >1 collimation setting?].

Rough number of measurements: [large number, can be reduced if results show to be predictable]:

* N [=10-20?] beam Ei settings
* 6 runs per setting (1x Au, 5x camera positions)
* 2 weeks

Deferment:

None for settings that must be available for Early Science. Testing of additional settings can be deferred.

Time needed:

2 weeks beam time

**Neutron Transport**

* Verify Chopper phasing
* Verify Ei / energy band / pulse structure settings
* [CSPEC] Verify dE/E

Measurement of ToF spectrum of:

* Each monitor
* Detectors (with V sample)

If measured ToF spectra do not correspond to expected spectra, search for errors in chopper phases [large number of runs]

Investigate Prompt Pulse (PP): PP from target, PP from sample [can be attained using a U-containing sample, or using strong gamma emitter, ex. B10, operating detectors with low threshold].

* Relation to ToF spectrum
* Pulse-to-background

[CSPEC] Confirm Ei settings

Start with a known diffraction sample in white beam. Select Ei to target specific diffraction features (powder rings or Bragg spots). Confirm that the primary spectrometer delivers the energy that is expected. Confirm Ei using Prompt[target]/Prompt[sample] signal.

For verified Ei settings / wavelength bands, high resolution / high flux measure

* Line width on normalization monitor
* Line width on detectors with V sample

Determine Chopper Phases as a function of Ei / wavelength band

[CSPEC] Determine Time Offsets

If necessary, determine time offsets for Ei/Ef reconstruction

Energy Spectrum at sample (also at beam monitor positions)

* Can be measured relative detector / monitor efficiency curve
* May not be measurable directly absolutely.

Rough number of measurements:

* 100+

Deferment:

None for settings that must be available for Early Science. Testing of additional settings can be deferred.

Time needed:

2-4 weeks. This has typically required significantly more time than expected on new instruments with large numbers of choppers (ie. Applies to all ESS instruments)

**Detector alignment**

Measure in diffraction mode: white beam with powder. Confirm alignment of powder rings throughout detector elements.

Detector Pixel Distance Calibration. Using information from Ei reconstruction.

[LOKI] Detector position distance calibration

[DREAM] Verify detectors are aligned that the images (Bragg peak positions) as a function of detector depth are constant. Verify that there is no unexpected shadowing of detector pixels. Done by comparing pixel intensities to expectation.

[BIFROST] Detector tank alignment

[BIFROST] Calibrate detector tank position using scattering from a known sample

Rough number of measurements:

* 10 runs/settings/powders in order to cover most of the detector pixels

Deferment:

Measurement to be repeated when additional detectors are added.

Time needed:

2 days beam time, possible with imperfect beam

**Detector / Monitor Threshold Setting**

Measure ToF Pulse-Height Spectra (PHS) with:

* Neutrons
* Gammas (can be produced by Cd sample). (Monitors: existing gamma flux)
* Shutter closed / source off.

Repeat measurements throughout HC, in order to access stability.

Determine pixel efficiency correction (uniformity map)

Can be measured already in CC with lab n, gamma sources, however, should be retested in HC with beam (Beam represents a much cleaner n flux than a lab source (AmBe/252Cd) could provide).

Rough number of measurements:

* 10 runs
* time (depends on the number of detector channels and software available)

Deferment:

None, but needs to be periodically repeated.

Time needed:

1 week beam time, extra verification time during other tests. Possible with imperfect beam. Can be combined with other measurements where the beam is fully propagated.

**Background Characterization**

Minimum background requirements have to be fulfilled prior to Early Science start.

Compare detector and monitor rates with:

* Beam on, V sample
* Beam on, no sample
* Shutter closed
* Source off
* Source off (has been off for a longer period)
* Beam on with various SA [can be combined with other tests]
* Test effectiveness of radial collimator / vanes / cross talk shielding??? How???

Rough number of measurements:

* 10+ runs
* Source on and off required
* All measurements here benefit from large statistics.

Deferment:

Background measurements and optimizations are expected to continue throughout Early Science and early stages of the User Program.

Auxiliary detection systems may be needed.

This is expected to be an iterative process.

Time needed:

2 weeks beam, 2 weeks non-beam, 2 days of shutter closed. Can be combined with other activities in the same beam conditions.

**Detector pixel crosstalk**

Test of the efficiency of:

* [BIFROST] Crosstalk shielding
* [CSPEC] Vanes

Use a Bragg reflection into a given detector angle. Observe signal in neighbor pixels, comparing to:

* Background with beam off
* Background with beam on (Bragg reflection far away)
* Signal in pixels that have a line of sight to the Bragg spot detection location

Rough number of measurements:

* 10 runs
* Source on and off required

Deferment:

To be tested during HC. Data containing this information likely to be available from some of the regular experiments. It can be used to periodically verify crosstalk.

Time needed:

3 days beam

**Detector rate capability**

While this is tested in the development stage of the detector, it should be verified in the final configuration.

Measure a beam at fixed beam transport settings with several different known attenuators.

Using:

* Single crystal reflection
* Powder rings
* V elastic line
* [SANS, Reflectometers] Direct beam

Study:

* Count rate vs. incoming flux
* ToF distribution as function of incoming flux
* Position resolution as function of incoming flux

Time needed:

2 days beam. Likely extra iterations in case DAQ behaves poorly in high rate situations and fixes are necessary. 10 non-beam.

Hot Commissioning Stage 2: Instrument Operation // Instrument Characterization // Validation Experiments

+ Early Science

[[Test basic operating modes with standard samples. Test and tune calibration, data reduction and analysis]]

[[Experiments demonstrating performance gains and new science potential. Confirm the ability to enter the user program.]]

**Test Samples**

[DREAM] Calibration measurements of diamond, empty container and solid vanadium rod could be taken.

[DREAM] The pulse length at various wavelengths will be measured using an inorganic crystal of known mosaicity.

[DREAM] Calibration standards in powder diffraction (Si, Ni, diamond and LaB6).

[CSPEC] H2O for quasielastic line shape characterization.

Vanadium for uniformity, efficiency normalization. Energy resolution on spectrometers

[SPECTROMETERS] Sample size vs. energy resolution

Collimation vs. q resolution

Compare scattering rate for known sample to expectation

Test Frame-frame crosstalk [source in pulse skipping mode {does pulse skipping achieve 100% pulse suppression?}]

Characterize inelastic scattering. Confirm Ef reconstruction. Confirm Ef resolution.

Performance of SE in context of [instrument].

Use case of WFM / RRM

Demonstration of data processing

Overall Output of Hot Commissioning

* Verification Report update
* Validation Report
* Define list of systems to be deferred, that cannot be commissioned (due to missing equipment, or inaccessibility of operating modes)
* Define list of operating modes that will be deferred
* Plan for deferred commissioning
* Update of Risk Register
* Operation Manual
* Change requests

Total Time Requirement

Assumptions:

* **Hot Commissioning Time** estimated conservatively but based on generally successful process.
* **Beam tests that may be possible to perform simultaneously** are treated separately. This is a potential time saving, but is not guaranteed, it can only be leveraged if additional staff is available simultaneously.
* **Hot Commissioning Rework Time.** Iterations, issues and additional work is expected. It is expected that most of this can be done while the source is off, however, assuming that at least 2 issues will take at least 2 weeks each and require beam for resolution or confirmation. Issues not requiring beam are primarily limited by installation and procurement/manufacturing time – assuming that at least one item will have a 2-month delivery time and significantly impacts schedule – this time is added as non-beam time.
* **Neutron Production** is assumed to be with a sufficient percentage of time with a stable beam with the correct pulse characteristics. It is assumed that low-quality beam (if relevant) can be utilized for test that require neutrons in any time structure (mainly detector calibration and DAQ tests).
* **Early Science Time** needed for validation samples and new science samples is estimated as a typical (long) beam time for each sample in order to account for measurements with multiple sample environments and beam settings. Minimum 5 experiments, 1 week each.
* **Early Science Rework Time** is estimated as repeat of half the experiments. Assuming at least one technical issue that requires a procurement/manufacturing that delays other activities – 2 months.
* **Deferred Hot Commissioning** 30% of hot commissioning is assumed to be deferred to Early Science phase. Note, this 30% is not removed from HC time, these are activities that were performed in HC and in HC rework and nevertheless failed and have to be fully redone. This also includes repeated activities, such as calibration of additional detectors.
* **Accelerator/Target Commissioning** is not included. Any such commissioning that significantly disrupts neutron production must be added separately.
* **ESS Services Availability.** Technology, technical support, rigging, survey, vacuum, radioprotection teams and administration are assumed to be available whenever needed.

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| --- | --- | --- |
| **Hot Commissioning Time** | Beam days  | Non-beam days  |
| Radio-protection | 10 |  |
| Attenuation Tests | 5 |  |
| Flux Tests | 2 | 10 |
| Beam on Sample Characterization | 14 |  |
| Neutron Transport | 25 |  |
| Detector Alignment | 2 |  |
| Detector/Monitor Thresholds | 5 |  |
| Background Characterization | 14 | 14 |
| Detector Pixel Crosstalk | 3 |  |
| Rate Capability | 2 | 10 |
| ***Total***  | ***82*** | ***34*** |
| **Hot Commissioning Rework** | 28 | 60 |
| ***HC Total*** | ***110*** | ***94*** |

|  |  |  |
| --- | --- | --- |
| **Early Science Time** | Beam days  | Non-beam days  |
| Validation Samples | 35 |  |
| Validation Samples Rework | 17 | 60 |
| Deferred Hot Commissioning | 110\*30% = 33 | 94\*30% = 28 |
| ***Early Science Total*** | ***85*** | ***88*** |

**Estimate total = 377 days, or 12.5 months.**

* Mapping of the accelerator schedule onto the HC and Early Science schedules will not be perfect. Further, beam day losses will occur during accelerator ramp-up and commissioning.
* ESS services will be required simultaneously by multiple instruments and may not be available at request.
* Significant facility-wide operations, such as bunker access will stop HC of all instruments.

**Considering the above points, it is prudent to add at least 50% extra time, resulting in 18 months to complete both Hot Commissioning and Early Science Phases.**