



Document Title:

# Loki Neutron Guide Specification

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### Revision History

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1	22/11/18	First Issue	All	W Halcrow	Issued

Table 1 – Revision History

### Approvals

This document has the following approvals

Name	Title	Date
Will Halcrow	Loki Lead Engineer	16/11/18
Andrew Jackson	Loki Lead Scientist	22/11/18

Table 2 - Approvals

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## 1 Attachments

SI-7613-019.pdf	Loki Guide Drawing
SI-7613-019.STP	Loki Guide CAD model
SI-7612-011.pdf	Pure Aluminium Wire Seal
SI-7612-041.pdf	Flange Assy, Al Seal
SI-7612-042.pdf	Flange, DN160 – Al Seal Test
SI-7612-043.pdf	Flange Sub-Assy, DN160 – Al Seal Test
SI-7612-044.pdf	Flange, DN160 – Al Seal Test
ESS-0147089 Rev 1	ESS GUIDELINES FOR ACCESSING AND PERFORMING WORK ON SITE
ESS-0147100 Rev 1	Safety Training Matrix for Installation Activities on Site

## 2 Definitions

UKRI	UK Research & Innovation (contract customer) – STFC Governing Body
STFC	Science Technology and Facilities Council
RAL	Rutherford Appleton Laboratory - The UKRI site where the customer staff are based, Oxford, UK
ISIS	The Neutron and Muon Source at RAL
ESS	European Spallation Source – (Lund, Sweden)
PDR	Preliminary Design Review
CDR	Critical Design Review
FDR	Final Design Review
TG3	Tollgate 3 ESS review process for approval for procurement and manufacturing
FAT	Factory Acceptance Testing
LIBS	Laser induced breakdown spectroscopy
TCS	ESS Target Co-ordinate System
ISCS	Instrument Source Co-ordinate System
NBOA	Neutron Beam Optical Assembly – Beamline Section 1
BBG	Bridge Beam Guide – Beamline Section 2
SMR	Spherical Mounted Retroreflector

### 2.1 Coordinate System

X, Y & Z are used in this document as per their definition on the ISCS, as defined in drawing SI-7613-019

X = Horizontal, collinear with neutron beam direction

Y = Horizontal, perpendicular to neutron beam direction

Z = Vertical

### 2.2 Nomenclature

Name	Description
Beamline section	Each section of the beamline is grouped. Within each grouping the base level support and alignment is common. With respect to other beamline sections, the base level support and alignment is independent.
Guide segment	Individual guide substrate sections
Vacuum vessel	Vacuum tubes and vessels that house the guides
B4C shroud	Boron carbide covering that surrounds the guide segments
Guide alignment device	Devices that allow the guide segments to be aligned
Vessel alignment device	Devices that allow the vacuum vessels to be aligned
Beamline section	Base support structure that allows each beamline section to be
Alignment base	independently aligned

See Figure 11 & Figure 19

## 3 Introduction

This document outlines the requirements for the supply of the Loki neutron guide. The guide will be installed at the ESS facility. The Loki instrument project is an ISIS in-kind project for the ESS facility involving ESS and UKRI. The guide must meet UKRI and ESS requirements.

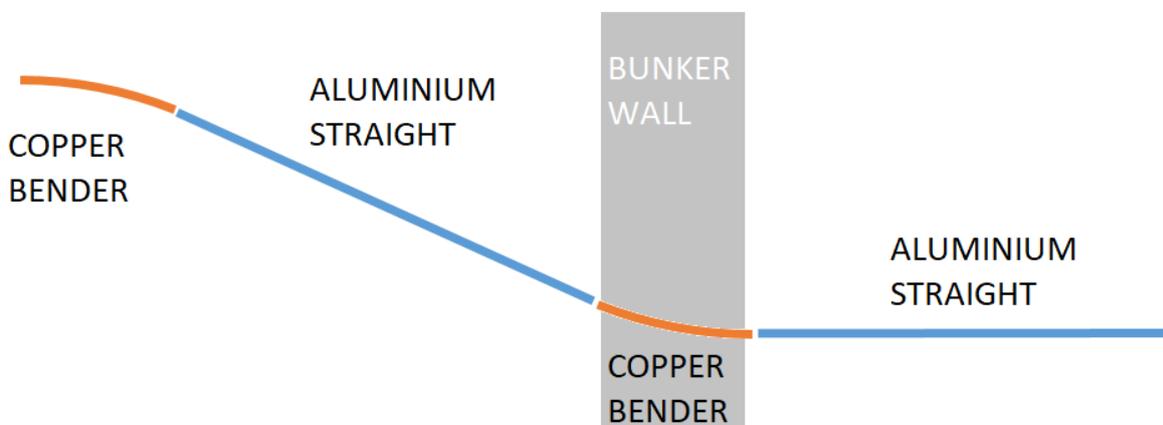
This document outlines the key requirements for the guide and sets boundaries for the scope of the project for the purposes of tender and contract definition. This document is intended to be read with the drawings SI-7613-019 and with respect to the CAD model SI-7613-019. Together they form the complete specification, outlining the critical requirements and highlighting the design intent.

### 3.1 System Overview

The Loki beamline consists of 9 primary sections (shown in *Figure 2*):

1. Beamline Section 1 - NBOA
2. Beamline Section 2 - Bridge Beam Guide (BBG)
3. Beamline Section 3 - Chopper 1
4. Beamline Section 4 - In-Bunker Straight
5. Beamline Section 5 - Heavy Shutter
6. Beamline Section 6 - Bunker Wall Feedthrough
7. Beamline Section 7 - Normalization Monitor
8. Beamline Section 8 - Collimation Selector
9. Beamline Section 9 - Snout

Each of these beamline sections is described in Section 5.1. The guide consists of a 3.5m long copper substrate multi-vane bender in the monolith insert, 6m of straight aluminium substrate guide, which runs through the in-bunker area; a 3.5m long copper substrate multi-vane bender, that runs through the bunker wall; followed by another 5.7m of straight aluminium substrate guide, which runs outside the bunker area surrounded by local shielding. The guide sections are contained within vacuum vessels.



*Figure 1 – Symbolic Representation*

## Beamline Sections

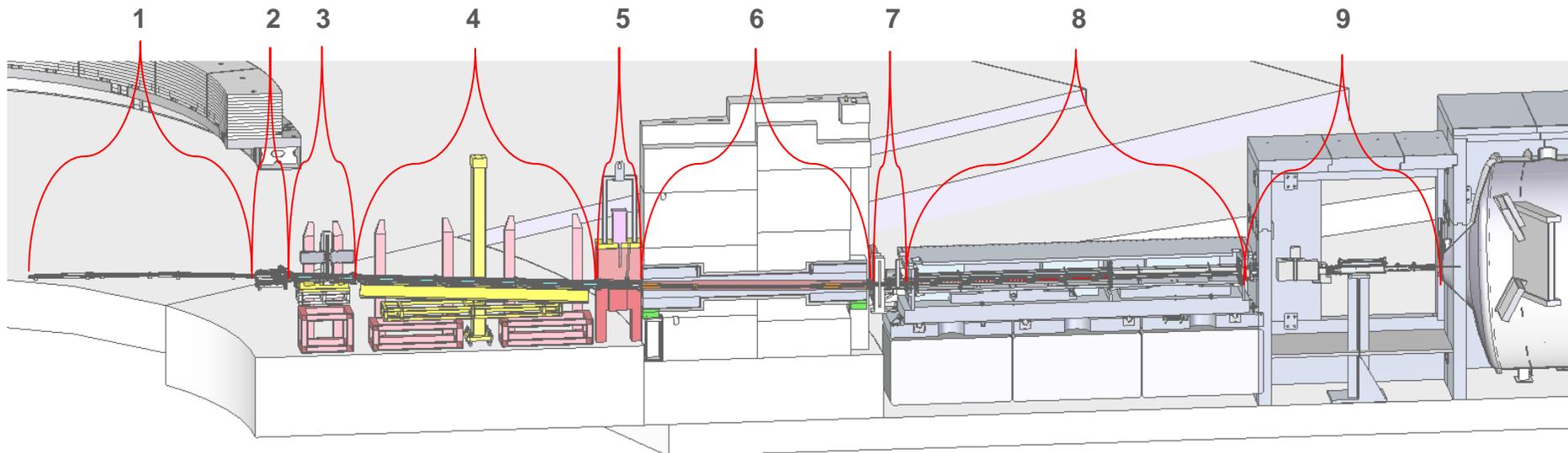


Figure 2 –Loki Beamline Sections

## 4 Scope

The Supplier will be responsible for designing, manufacturing and delivering the guide, vessels and associated alignment devices for the Loki instrument. The design must be optimized to the requirements outlined in this document and meet UKRI approval.

The Supplier will also be responsible for installing and aligning the guide segments and vacuum vessels at the ESS site in Lund. The alignment requirements are outlined within this document. As a part of this, the Supplier will be responsible for the design and delivery of suitable handling and lifting features and any specialised tooling that is required for alignment & installation. The Supplier will be responsible for providing suitable crate packaging to ensure safe transport and storage for the delivery plan outlined in Section 4.3.

The supplier will be responsible for defining, implementing, and documenting the results of, the quality control and assurance plan, in line with the requirements outlined in Section 6. As outlined in Section 4.1 vacuum windows are not included within the scope of work, however suitable blanking flanges will be required for testing, as per the Supplier quality plan. The design and delivery of these flanges are included within the scope of work.

The Supplier will be responsible for delivering the project documentation outlined in Section 4.2.

### 4.1 Scope of Beamline Sections

This section outlines which components within each Beamline Section are within the scope of work.

#### 4.1.1 B4C shrouds

All B4C resin shrouds will be free issued to the Supplier. An option will be given within the tender questions for inclusion of the supply of these shrouds into the scope, as an additional cost option (See PR18162 Pricing Schedule). The Supplier will be responsible for designing the interface and support for these shrouds, the Supplier will be responsible for installing the shrouds into the assemblies. The final design of the shrouds will be agreed mutually between the Supplier and UKRI.

#### 4.1.2 Beamline Section 1: NBOA

This section of the beamline is not included within this scope of work. The specification for this section of the beamline is ISIS-ESS-Loki-Sp-0003. This section of beamline is being delivered as a part of a separate contract.

#### 4.1.3 Beamline Section 2: Bridge Beam Guide

This section of beamline is included within the scope of work. Only the guide segment is included (highlighted in Figure 3)

(Excluded: vacuum vessel, windows and alignment devices, monitor detector)

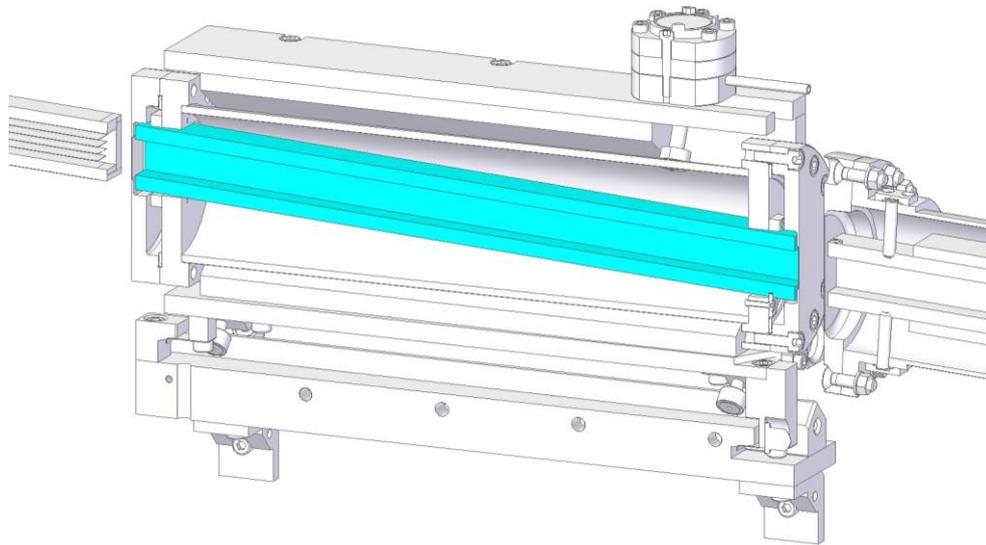


Figure 3 – Beamline Section 2 Scope

#### 4.1.4 Beamline Section 3, 4 & 5

These sections of beamline are included within the scope of work. Included in the scope of work is the guide, guide segment support struts, vacuum vessels, vessel-vessel interface seals and fasteners, guide alignment devices, vessel alignment devices, survey features, and B4C resin shroud (highlighted Figure 4, Figure 5 & Figure 6).

(Excluded: windows, window seals, window fasteners, chopper interface seal, chopper interface fasteners)

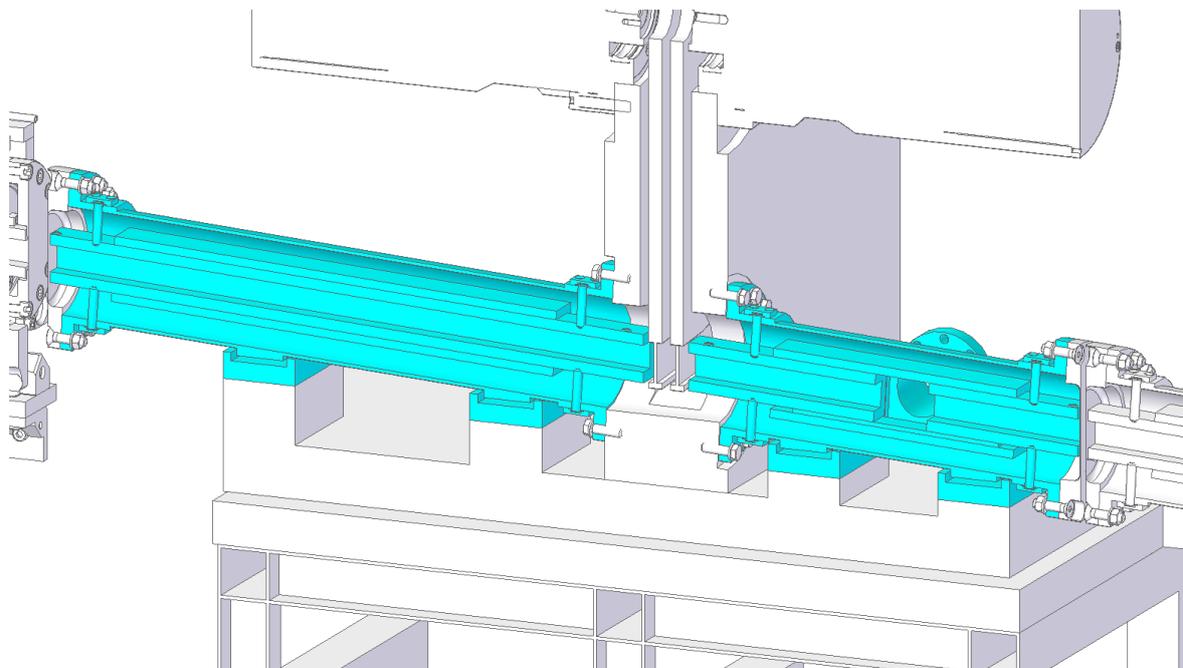


Figure 4 – Beamline Section 3 Scope

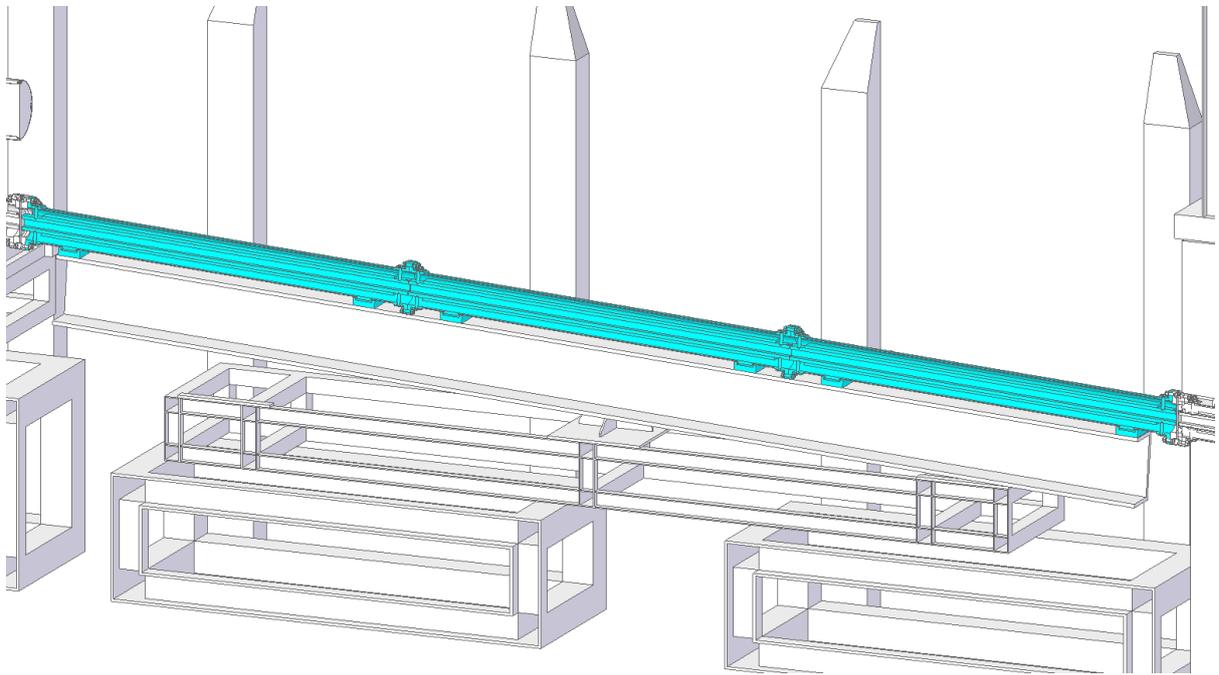


Figure 5 – Beamline Section 4 Scope

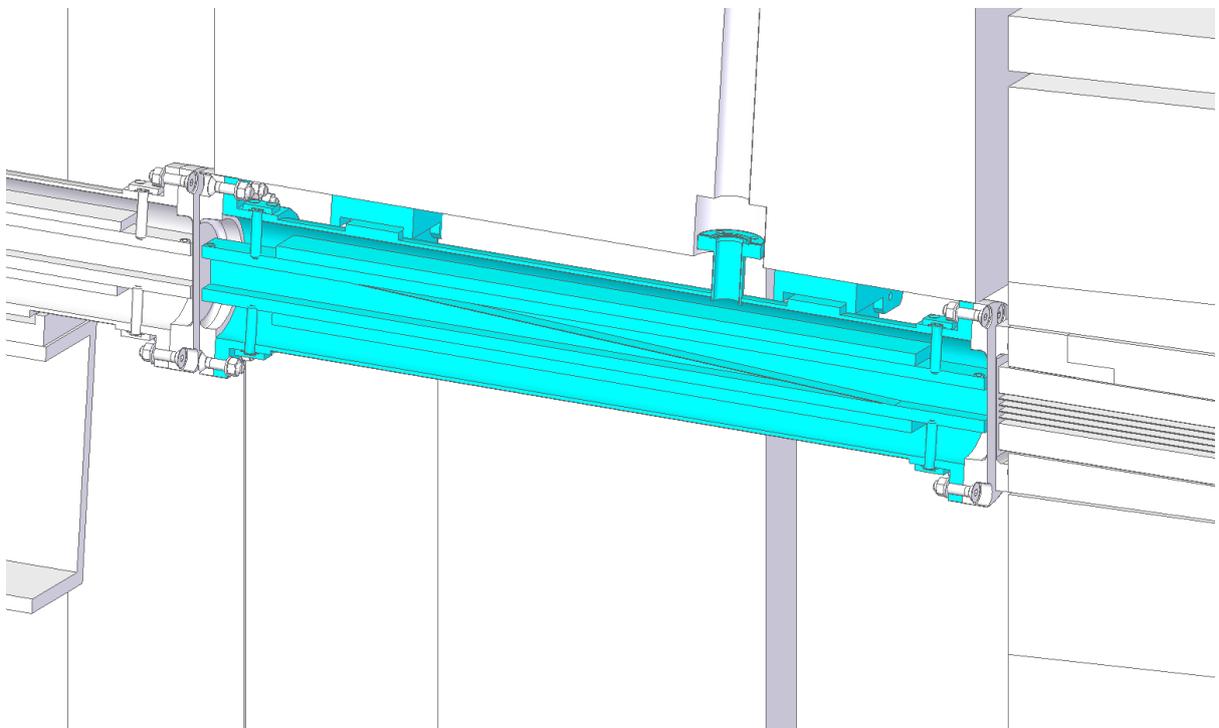


Figure 6 – Beamline Section 5 Scope

#### 4.1.5 Beamline Section 6: Bunker Wall Feedthrough

This section of beamline is included within the scope of work. It includes the guide, vessel, bellows, guide alignment devices and survey features (highlighted in Figure 7).

(Excluded: Windows, window seals, window fasteners, feedthrough plug and feedthrough plug alignment system)

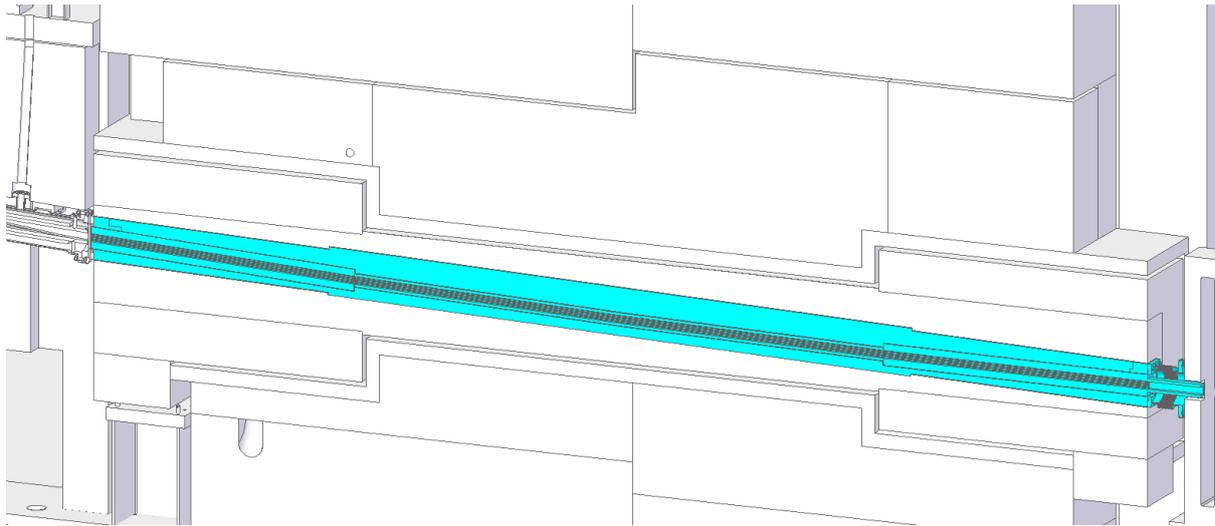


Figure 7 – Beamline Section 6 Scope

#### 4.1.6 Beamline Section 7

This section of beamline is included within the scope of work. It includes the guide, guide segment support strut, guide alignment devices, survey features, the vacuum vessel assembly with bellows, vessel alignment devices (highlighted in Figure 8).

(Excluded: monitor detector, O-rings with centring ring, vessel support structure)

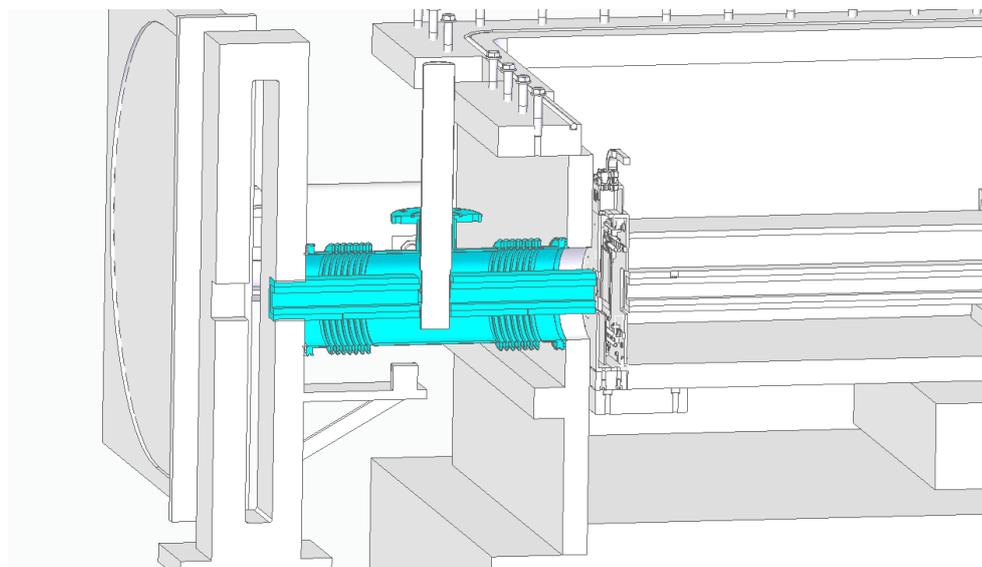


Figure 8 – Beamline Section 7 Scope

#### 4.1.7 Beamline Section 8: Collimation Selector

This section of beamline is included within the scope of work. It includes the guide, guide alignment devices and survey features (highlighted in Figure 9).

(Excluded: the sliding base plate and guide changer assembly and vacuum vessel)

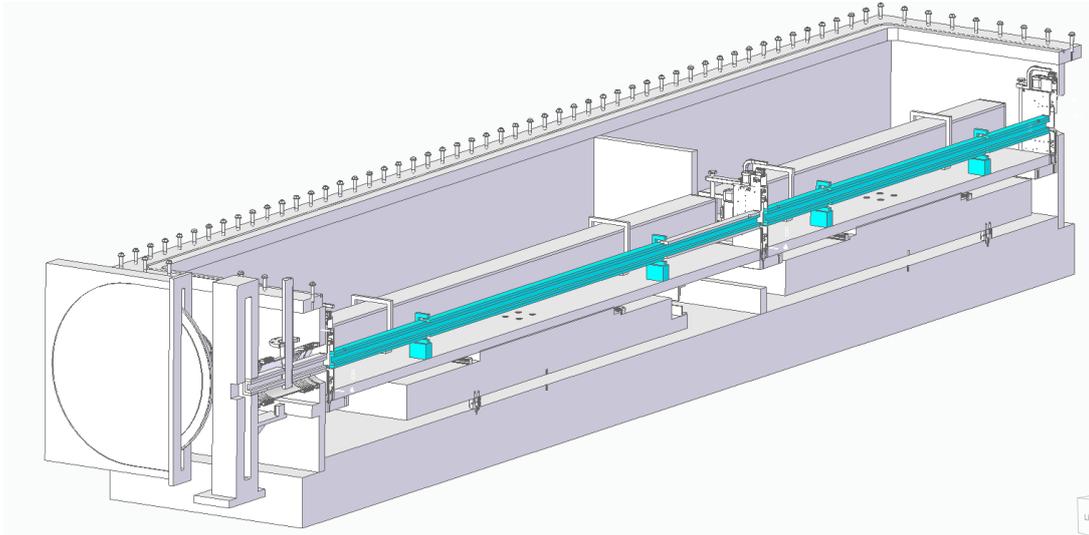


Figure 9 – Beamline Section 9 Scope

#### 4.1.8 Beamline Section 9: Snout

Not in scope. This section of the beamline is not included within this scope of work.

### 4.2 Documentation

As a part of the contract the Supplier must provide:

- Stress and deflection calculations for vacuum and lifting conditions.
- Detailed drawings of all parts supplied
- 3D as built models (STEP format)
- Documentation for all reviews as detailed in Section 8
- A maintenance manual, detailing frequencies and maintenance operations.
- Materials list – including quantities by mass and details of grade or composition
- Material grade / composition certificates for all components (to EN 10204:2004 type 3.1)
- Factory inspection and test reports, as detailed Section 6.7
- Documentation to support unload, installation & alignment
- Final alignment report – record of alignment as installed, as detailed Section 6.7.

All documentation must be provided prior to delivery to the ESS site, with the exception of the final alignment report – see Section 8.

## 4.3 Project Management

The detail needed for quotation regarding lead times is listed in the PR18162 Technical Questions AW6 document. The design freeze date and the delivery date will be agreed, based on tender return, and will be fixed as a part of the contract.

The contract will be with UKRI. The design approval and requirements management for the guide will be set by UKRI. UKRI will retain all approval authority. It will be necessary for the Supplier to submit documents and support a preliminary design review, critical design review, final design review (TG3), and factory acceptance & inspection report review for UKRI approval – the requirements for which are outlined in section 6.7 and section 8. Regular Skype updates and single page progress reports must also be supported.

Communication between the Supplier and ESS through UKRI is expected to be necessary during the delivery, installation and alignment. For all communications UKRI is expected to be kept informed and will remain the contract authority.

Some of the interfacing components referenced in the document have not yet been fully designed. Provisional interfaces are shown in the model and outlined in this specification. The detail of these interfaces will be finalized mutually in-line with the requirements outlined in the specification. The finalization of the monitor detector interface is expected to be delayed until Q3 2019 due to the maturity of monitor development.

### 4.3.1 Delivery Plan

The vacuum vessels and interfacing mechanical components must be delivered to the ISIS facility by the Supplier. These vacuum vessels and interfacing mechanical components will be assembled as a part of the ISIS pre-build. In the pre-builds ISIS will test the installation and remote handling processes and check fit with interfacing and neighbouring components. The guide segments will not be needed for the pre-builds and as such must be safely stored by the guide Supplier until delivery to the ESS. UKRI will be responsible transporting the vessels from ISIS to the ESS for installation, once the pre-builds have been completed. The transportation crates must be provided by the Supplier, these crates must be suitable for re-packaging of the vessels following pre-builds.

## 5 Technical Requirements

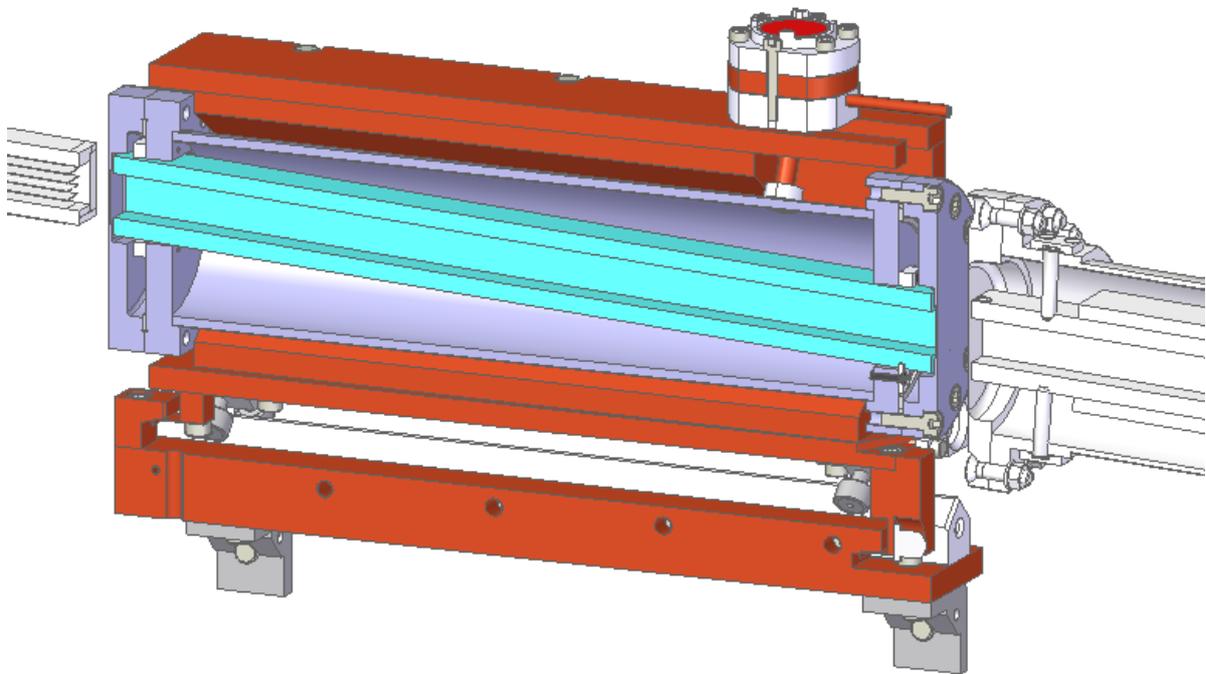
All materials used must comply with requirement outlined in Section 9.3.

### 5.1 Context: Beamline Section Component Parts Overview

This document section gives a brief description of each Beamline Section. Section 4.1 outlines which components within these Beamline Sections are included within the scope of work.

#### 5.1.1 Beamline Section 2

Figure 10 shows the primary elements of Beamline Section 2.



*Figure 10 – BBG Overview*

The guide is held in a fixed position by set screws and a locking washer that are mounted on the vessel. The complete vessel is then aligned within the BBG housing on a second set of set screws. The complete BBG assembly is mounted into the light shutter mechanism at ESS on a set of rails. These rails support installation and provide a repeatable position.

### 5.1.2 Beamline Section 3

Figure 11 shows the primary elements of Beamline Section 3.

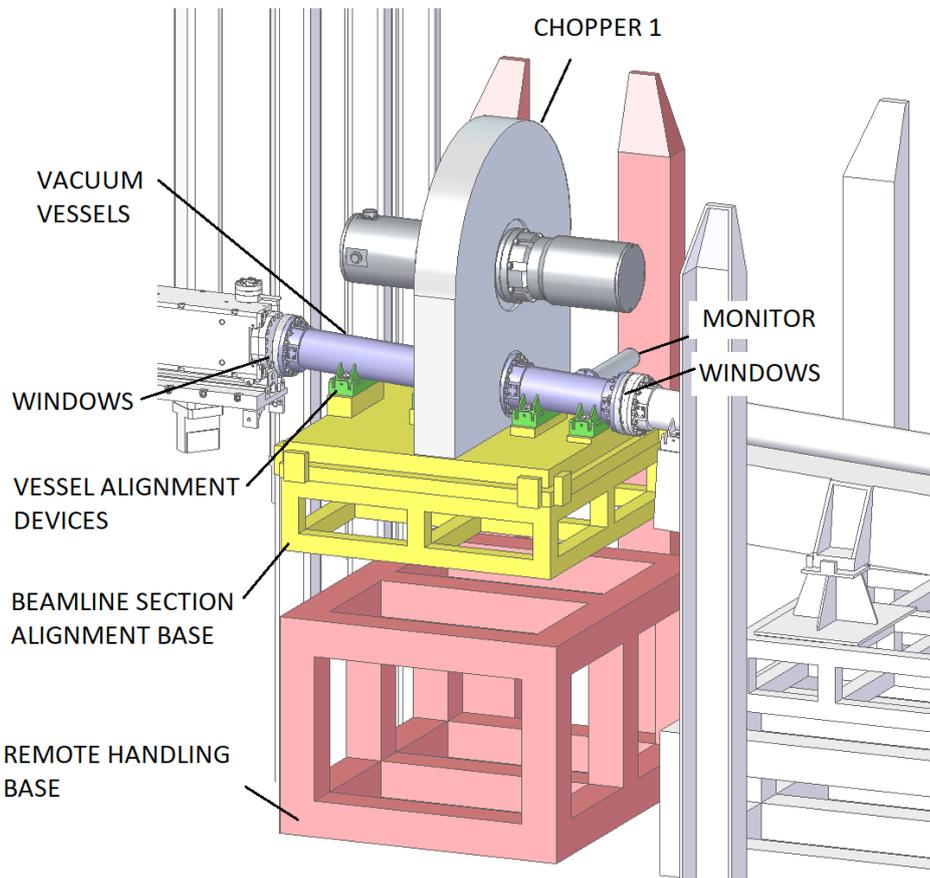


Figure 11 – Beamline Section 3 Overview

The complete Beamline Section is independent from the neighbouring Beamline Sections, separated by vacuum windows and a small clearance gap. This will allow it to be craned in and out of the bunker for maintenance. The Remote Handling Base will guide the Beamline Section during craning and thereby ensure it does not clash with neighbouring components. Kinematic mounts on the Remote Handling Base will ensure it can be re-installed into a repeatable position to ensure guide and beamline component alignment is maintained.

The Beamline Section Alignment Base will allow the complete Beamline Section to be re-aligned in X Y and Z, independent of the neighbouring Beamline Sections. Z adjustment will be possible remotely. X and Y adjustment will require removal of the Beamline Section to an offline area, or bunker access.

The Chopper 1 design is not yet completed. The 2 vacuum vessels will seal against the chopper housing and they will share a common vacuum environment with the chopper. The pumping port for the vacuum environment will be situated on the chopper housing. The expected interface is represented in the model SI-7613-019, the final detail of which will be agreed mutually, and will be in accordance with the in-bunker vacuum requirements outlined in Section 5.4.

The monitor will be fixed to the second vacuum vessel on the monitor flange. A gap in the guide will be required for the monitor to project into the beam path. The design of the monitor is not yet complete. The expected guide gap is shown in drawing SI-7613-019. The expected flange interface is shown in model SI-7613-019.

The vacuum vessels are fixed to the Beamline Section Alignment Base via the vessel alignment devices. The guide segments are supported within the vacuum vessels on the guide alignment devices. Around each guide segment is a B4C resin composite shroud.

### 5.1.3 Beamline Section 4

Figure 12 shows the primary elements of Beamline Section 4.

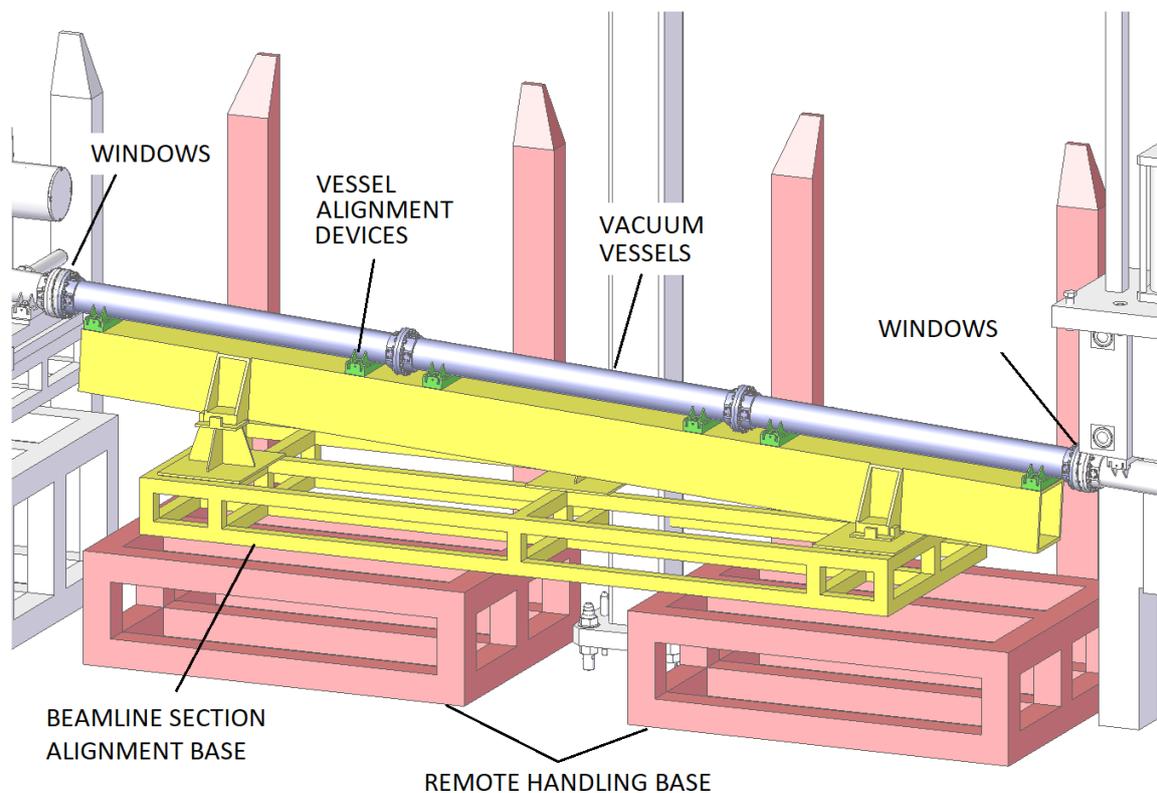


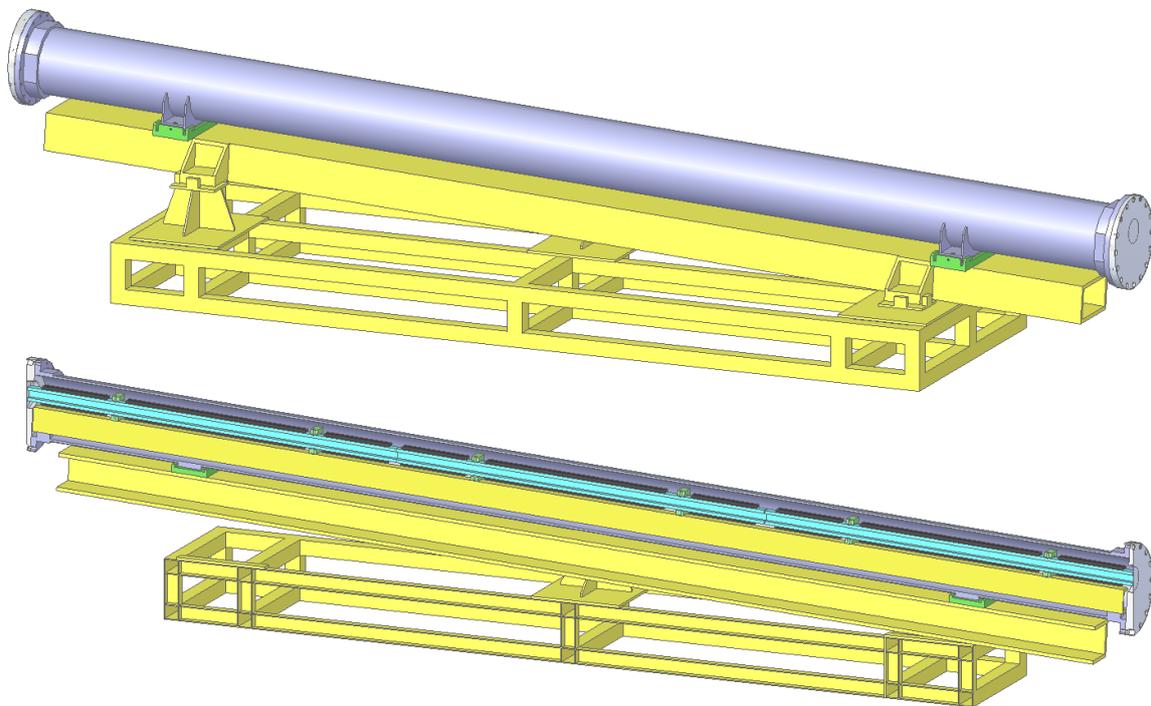
Figure 12 – Beamline Section 4 Overview

The complete Beamline Section is independent from the neighbouring Beamline Sections, separated by vacuum windows and a small clearance gap. This will allow it to be craned in and out of the bunker for maintenance. The Remote Handling Base will guide the Beamline Section during craning and thereby ensure it does not clash with neighbouring components. Kinematic mounts on the Remote Handling Base will ensure it can be re-installed into a repeatable position to ensure guide and beamline component alignment is maintained.

The Beamline Section Alignment Base will allow the complete Beamline Section to be re-aligned in X, Y and Z, independent of the neighbouring Beamline Sections. Z adjustment will be possible remotely. X and Y adjustment will require removal of the Beamline Section to an offline area, or bunker access.

The vacuum vessels are fixed to the Beamline Section Alignment Base via the vessel alignment devices. The guide segments are supported within the vacuum vessels on the guide alignment devices. Around each guide segment is a B4C resin composite shroud.

Beamline Section 4 is shown in drawing SI-7613-019 and model SI-7613-019, as an assembly of 3 vacuum vessels. An alternative configuration (single vacuum vessel) such as that shown in Figure 13, or an assembly of 2 vacuum vessel can be accepted and would be subject to approval as outline in section 5.9.



*Figure 13 – Beamline Section 4 Single Vessel Configuration*

### 5.1.4 Beamline Section 5

Figure 14 shows the primary elements of Beamline Section 5.

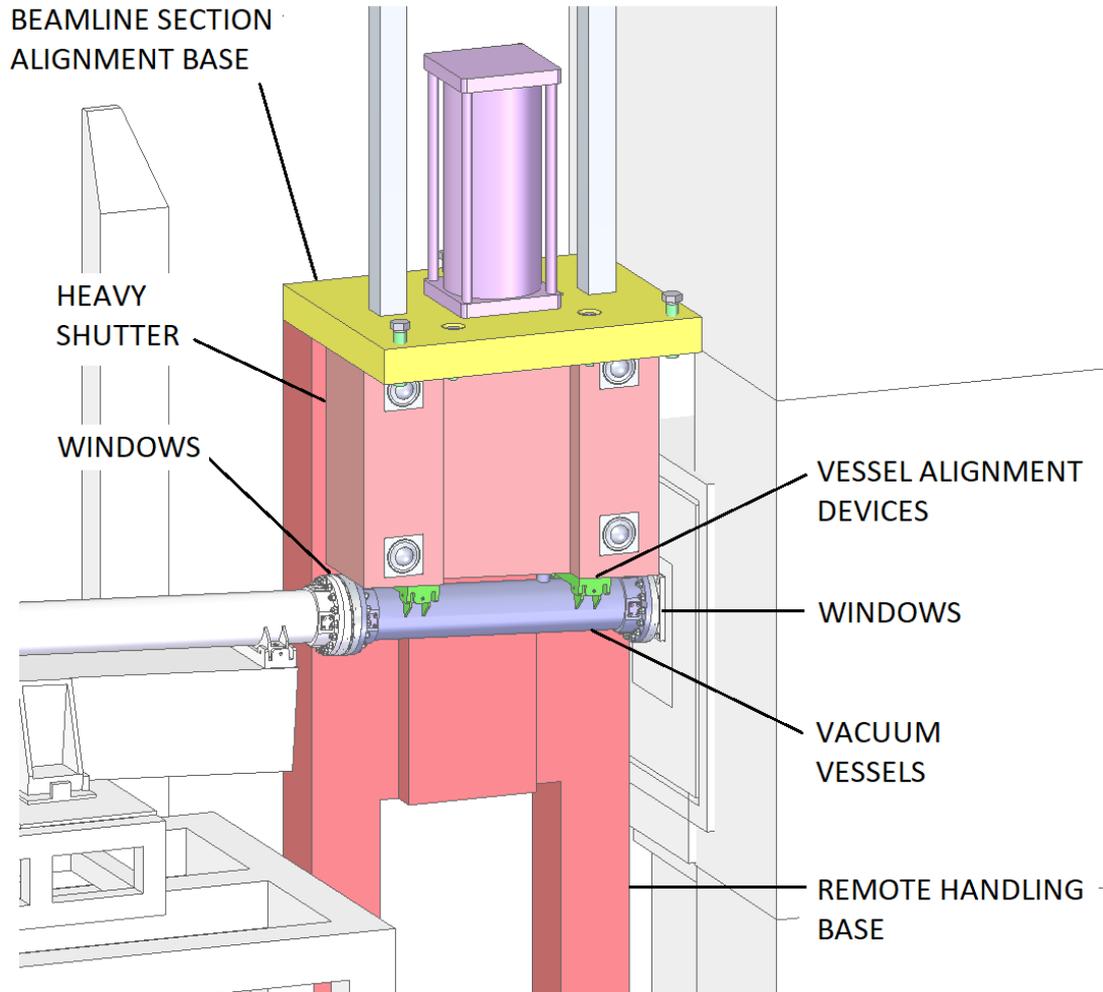


Figure 14 – Beamline Section 5 Overview

The complete Beamline Section is independent from the neighbouring Beamline Sections, separated by vacuum windows and a small clearance gap. This will allow it to be craned in and out of the bunker for maintenance. The Remote Handling Structure will guide the Beamline Section during craning and thereby ensure it does not clash with neighbouring components. Kinematic mounts on the Remote Handling Structure will ensure it can be re-installed into a repeatable position to ensure guide and beamline component alignment is maintained.

The Beamline Section Alignment Base will allow the complete Beamline Section to be re-aligned in X Y and Z, independent of the neighbouring Beamline Sections. Z adjustment will be possible remotely. X and Y adjustment will require removal of the Beamline Section to an offline area, or bunker access.

The Heavy shutter mechanism design is not yet complete. The vacuum vessels will mount to the heavy shutter via vacuum vessel alignment devices. The guide segments are supported within the vacuum vessels on the guide alignment devices. Around each guide segment is a B4C resin composite shroud.

### 5.1.5 Beamline Section 6

Figure 15 shows the primary elements of Beamline Section 6.

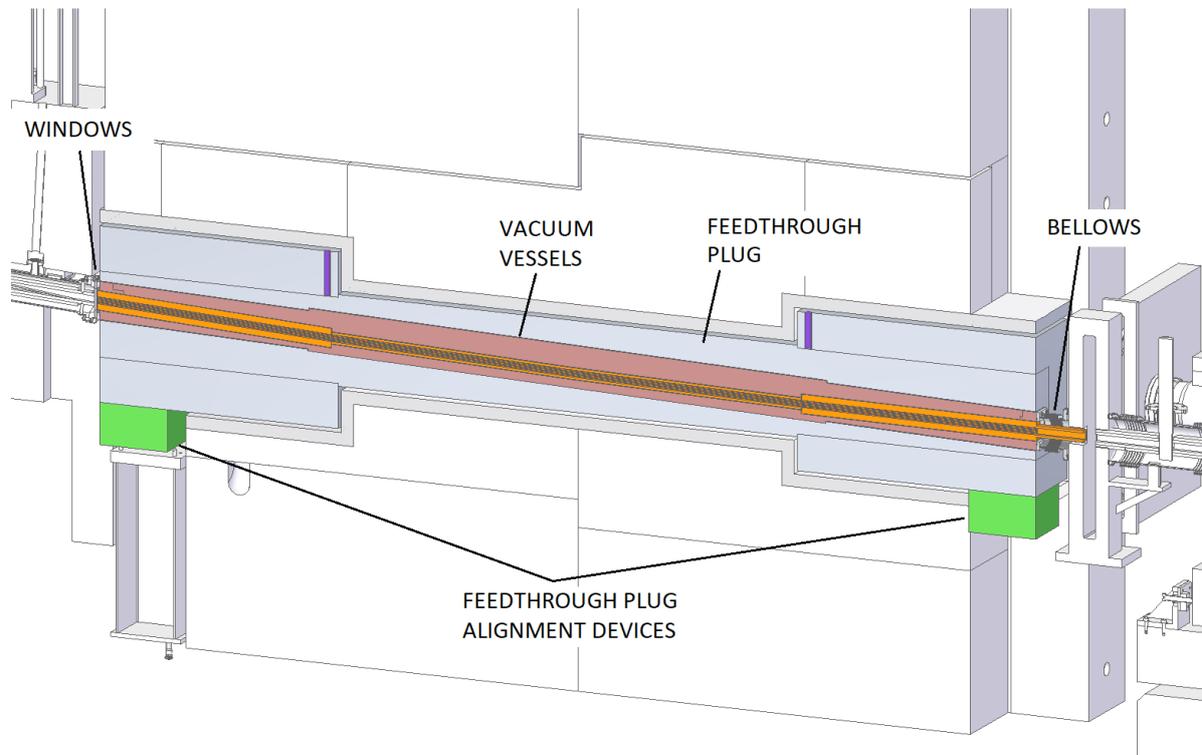


Figure 15 – Beamline Section 6 Overview

The Beamline Section will be supported on 2 pillars via the Feedthrough Plug Alignment Devices. These alignment devices will allow the complete Beamline Section assembly to be positioned as a single unit.

The Feedthrough Plug is a steel assembly that will support the guide vacuum vessel. It will form a large step that will prevent radiation shine down the clearance gap between the feedthrough and the bunker wall. The guide segments will be supported inside the vacuum vessel on the guide alignment devices.

The complete Beamline Section is independent from Beamline Section 5 but connected to Beamline Section 7 via a set of bellows. The bellows will connect to the Chopper 2 housing.

### 5.1.6 Beamline Section 7

Figure 16 shows the primary elements of Beamline Section 7

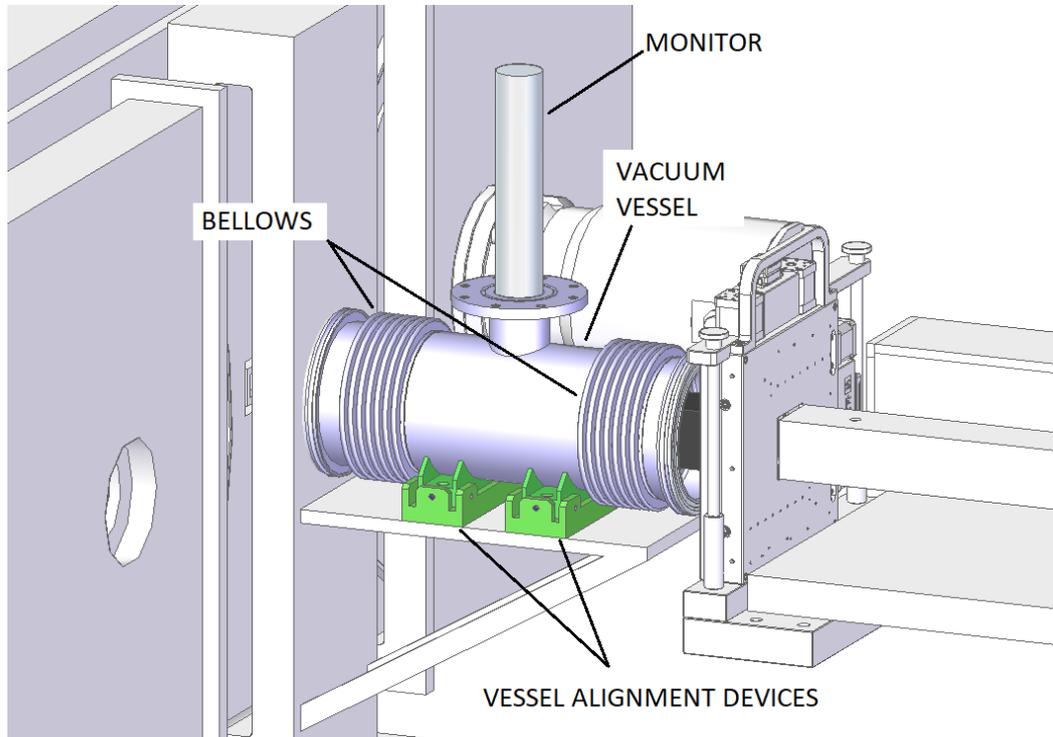


Figure 16 – Beamline Section 7 Overview

The guide vacuum vessel will seal against the chopper fixed post on one side, and a large vacuum vessel that contains the collimation selector (not shown in the above diagram) on the other side. Bellows will provide the interface between beamline assemblies. The guide vacuum vessel will be supported on the vessel alignment devices, which will locate onto a rigid support structure, supplied by UKRI. The vessel alignment devices will allow the complete Beamline Section to be aligned in X Y and Z, independent of the neighbouring Beamline Sections.

The guide section will share a common vacuum environment with the chopper and the collimation selector vacuum vessel. The main pumping port for the vacuum environment will be situated on the collimation selector vacuum vessel, with an additional pumping port on the chopper housing.

The guide will have to be installed through the wall of large vacuum vessel, from the upstream direction. Alignment features within the guide vessel will ensure the guide can be surveyed into position. Around each guide segment is a B4C resin composite shroud.

The monitor will be installed from directly above. The monitor will be fixed to the second vacuum vessel on the monitor flange. A gap in the guide will be required for the monitor to project into the beam path. The design of the monitor is not yet complete. The expected guide gap is shown in Drawing SI-7613-019. The expected vessel flange interface is shown in model SI-7613-019.

### 5.1.7 Beamline Section 8

Figure 17 shows the primary elements of Beamline Section 7

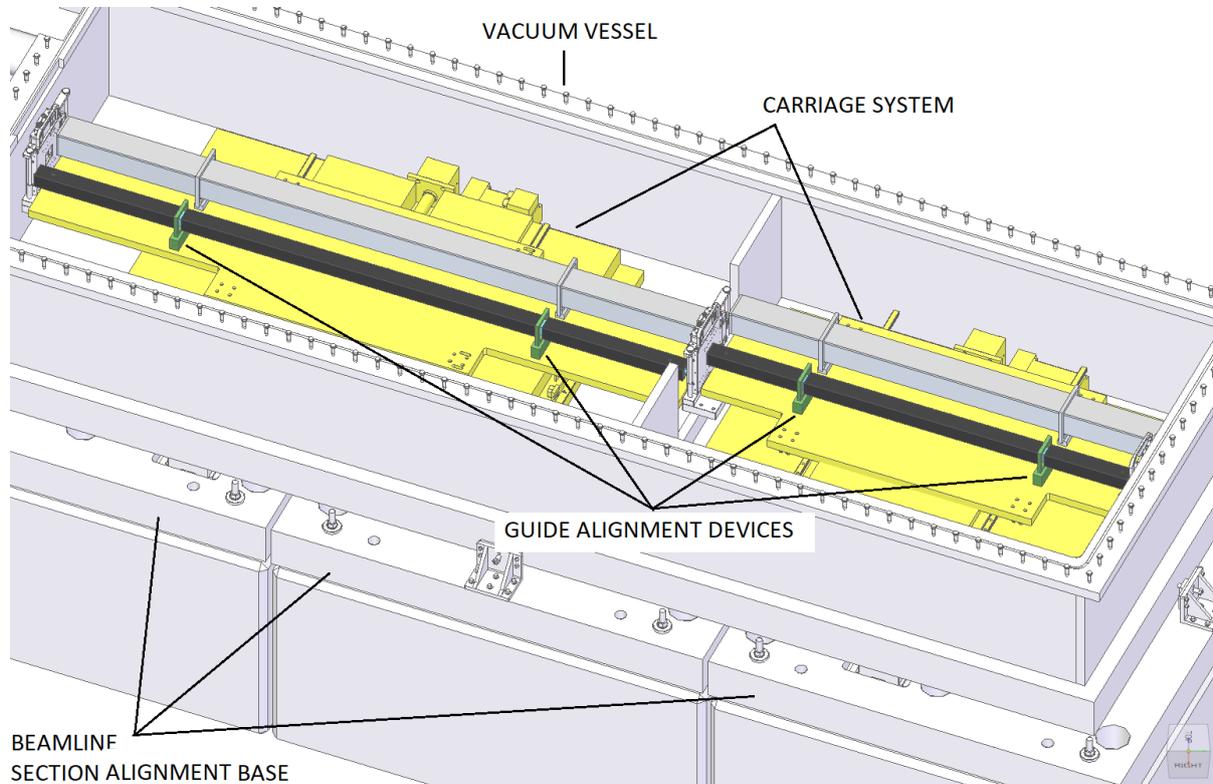


Figure 17 – Beamline Section 8 Overview

The complete Beamline Section contains two guide sections that are independent from each other and from the neighbouring Beamline Sections. The guides are separated from a jaw set at each end by a small clearance gap. These sections are contained in a large vacuum vessel, and each will be fixed to a carriage system to allow alternative apertures to be used in the beam. These assemblies will be supported on stationary plates with lifting points and heavy duty kinematic mounts, to allow them to be craned in and out of the vacuum vessel for maintenance. Guide segments will be mounted to these carriages via guide segment alignment devices.

The lifting structure will guide the Beamline Sections during craning and thereby ensure they do not clash with neighbouring components. Kinematic mounts on the base plates will ensure they can be re-installed into repeatable positions to ensure guide and beamline component alignment is maintained.

The vacuum tank has an alignment system for the base plate, which will allow the complete Beamline Section to be re-aligned in X, Y and Z, independent of the neighbouring Beamline Sections to within 0.5mm of the theoretically exact position.

## 5.2 Super Mirror Guide

The required guide geometry is shown in drawing SI-7613-019.

All internal surfaces of the guide, that are exposed to the neutron beam, and both the convex and concave surfaces of the vanes of the bender, are to be coated with “m = 3” Ni/Ti supermirror. A minimum reflectivity of 99% must be achieved up to  $M=1$ . A minimum reflectivity of 85% must be achieved up to  $M=3$ . The guide cross section must be 30 (w) x 25 (h) mm, along its complete length. The bender in Beamline Section 6 must bend at a radius of 61m, from 3.25° to horizontal, with 5 channels (4 silicon vanes). The vanes must be no thicker than 0.5mm.

To allow for alignment and thermal expansion, small gaps between guide segments are permitted. These gaps are shown in the provisional design - drawing SI-7613-019. These gaps should be as small and few as practicable, the optimization of which, is included within the design scope. The solutions delivered by the supplier will be subject to approval as outline in section 5.9.

### 5.2.1 Frame Overlap Mirror

Beamline Section 5 must include a frame overlap mirror. This is shown in SI-7613-019 and illustrated in Figure 18. The mirror must be made from a silicon wafer, be inclined at 3.117°, and be coated with an  $M=1$  Ni/Ti mirror surface. A minimum reflectivity of 99% must be achieved up to  $M=1$ . The mirror can be located anywhere along the length of the Beamline Section 5 Guide Segment.

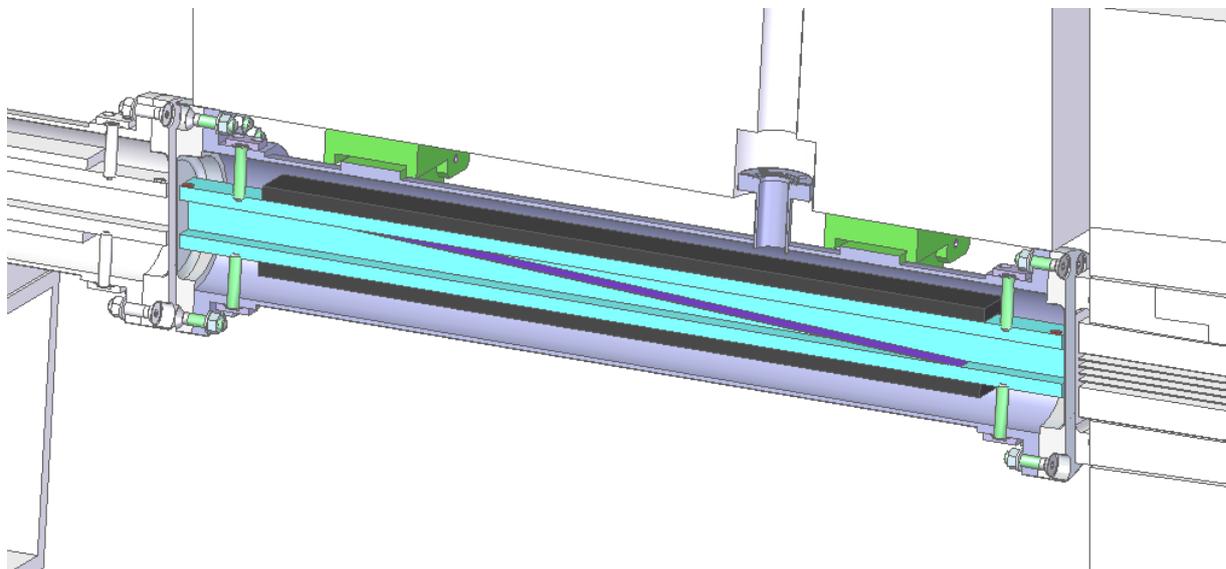


Figure 18 – Frame Overlap Mirror

## 5.3 Substrate

The guide substrate in Beamline Sections 2 – 5 must be made from aluminium (approved alloy grades shown in Section 9.3). The guide substrate of the bender in Beamline Section 6 must be made from high purity copper to the composition outlined in Section 9.3. Intended substrate thicknesses and lengths are shown in drawing SI-7613-019. Adjustments to these dimensions can be accepted, but will be subject to approval as outline in section 5.9.

Within the bender, the thicker section is required to block a potential shine path between substrate and the vacuum housing. The size of the step between thin and thick sections must not be decreased. Cut outs around radii and corner relief must be kept to a minimum and backfilled where possible.

The precise construction of the substrate (numbers of pieces, how they interface and are joined) will be the responsibility of the Supplier to design, and will be similarly subject to approval as outline in section 5.9. The thicker sections, required to block shine paths between bender and the vacuum vessel, can be formed as a part of the substrate, or by the addition of material to the outside of the substrate. If additional material is added it must be in gapless contact with the substrate - Contact shall be maintained over >90% of adjacent surfaces.

## 5.4 Vacuum Vessels

The vacuum vessels must be designed and delivered to the critical dimensions shown in drawing SI-7613-019.

The vacuum vessels for Beamline Sections 3 - 5 must be made from aluminium (see allowed materials specification in Section 9.3). The vacuum vessels for Beamline Sections 3 – 5 & 7 can be either rectangular or circular in the profile. The vacuum vessel for Beamline Sections 6 (see Figure 20) must be made from nickel plated steel. See materials specification in Section 9.3. The means of construction of the vacuum vessels (machined from solid vs. welded assemblies) is to be defined by the Supplier but will be subject to approval as outlined in section 5.9.

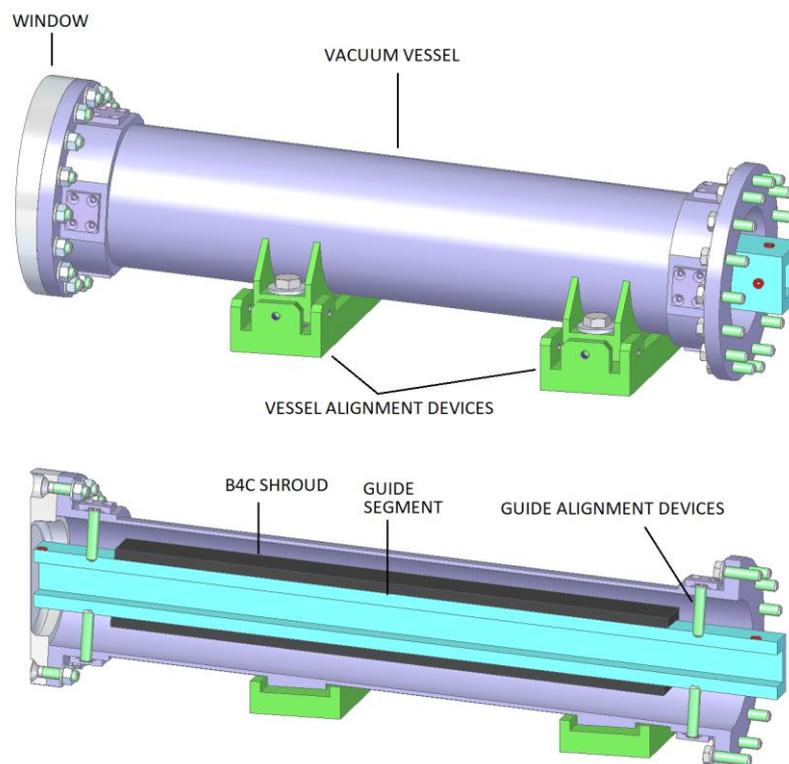


Figure 19 – Beamline Section Vessel

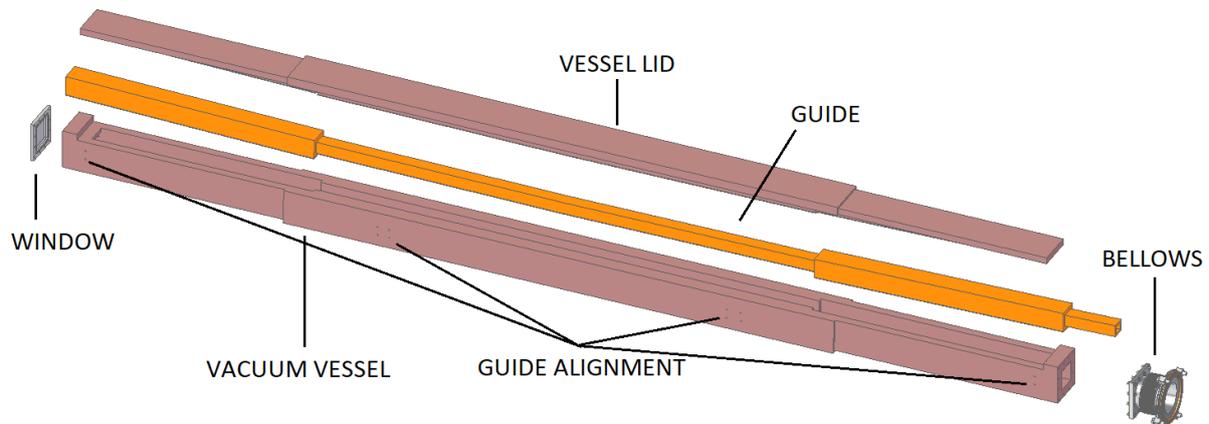


Figure 20 – Beamline Section 6 Vessel

In the bunker area, neither polymer seals, nor stainless steel are permitted. For these reasons ESS have defined a specification for aluminium seals on aluminium flanges. This is summarized in Section 9.2. This specification should be followed for all vacuum joints with aluminium sealing faces (Beamline Sections 3 - 5). Alternative vacuum seal/joint designs will be subject to UKRI approval and will be dependent on the Supplier demonstrating the suitability of the change as outlined in section 5.9. Vacuum joints in Beamline Section 6 will be formed between nickel plated steel faces and must be made using metallic seals - The design of which will be the responsibility of the supplier and should follow standard best practice.

Outside the bunker joints should be made using standard ISO K interface with centre ring and fluorocarbon seal.

The number of ports, holes and joints in the vacuum vessels should be kept to a minimum, to minimise the number of possible leak paths. As such the addition of any such feature, as compared to the provisional design, will require UKRI approval and justification as outlined in section 5.9. There is a desire to reduce the number of joints and seals where possible. Section 9.4 shows concepts that remove the requirement for penetrations through the vacuum vessel for the alignment devices. Where viable such concepts should be applied.

Positions and specifications of pumping ports are shown in drawing SI-7613-019. The port should have a Vacom AluVac CF DN 25 flange. Changes to these should be kept to a minimum, any changes required will be subject approval and justification as outlined in section 5.9.

Vacuum vessels must support vacuum load and must be designed to sound engineering practice. The vacuum vessels must be tested, as outlined in Section 6.7. All parts within vacuum must be suitably designed, manufactured and cleaned for the vacuum environment. As stated in Section 4 vacuum windows are not included within the scope of work, however suitable blanking flanges will be required for testing and are included within the scope of work.

The Vacuum vessel for section 8 is outside the scope of this work.

## 5.5 Mounting & Alignment

Drawing SI-7613-019 shows the guide geometry relative to the ESS ISCS. Mounting and alignment device bulk material should be made from aluminium see allowed material specifications in Section 9.3. Fasteners and fittings must be made from the materials listed in Table 3.

### 5.5.1 Beamline Section Alignment

Each Beamline Section will include an alignment base structure (Beamline Section Alignment Base). This will allow each complete Beamline Section to be aligned relative to the ISCS independently. Guide Segments, Vessels and other Beamline components must be precisely aligned relative to each other within each Beamline Section. The Beamline Section Alignment Base will have an adjustment range of  $\pm 10\text{mm}$ . In this way Beamline components could be aligned offline relative to their Beamline Section Alignment Base and then aligned to the ISCS as a complete Beamline Section. Conversely it will be possible to align all beamline elements to the ISCS in-situ. Beamline Section Alignment Bases will include an array of SMR nests. This configuration is shown in Figure 21.

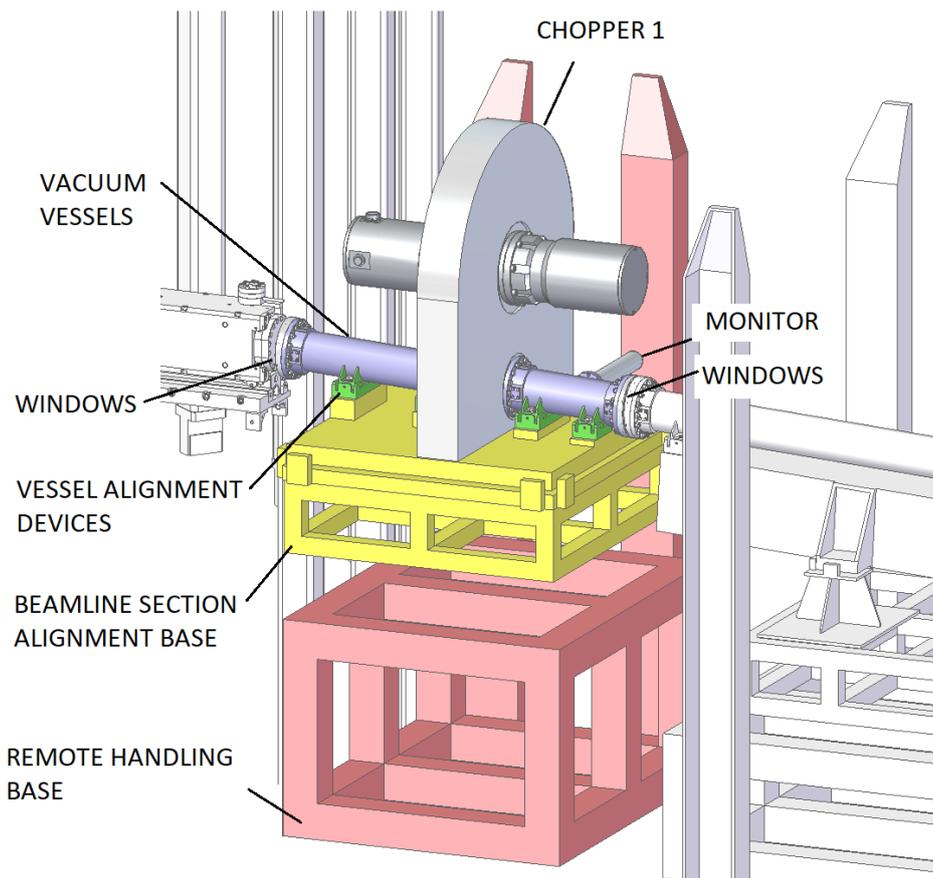


Figure 21 – Beamline Section Alignment

### 5.5.2 Guide and Vessel Alignment

Within each Beamline Section, Guide Segments must be aligned relative to each other, to the tolerances outlined in Section 6. Guide segments must be restrained to ensure they cannot move down the beamline collinearly with the beam trajectory (x axis).

The position of the Vacuum Vessel end flanges of each Beamline Section must be manufactured and installed to within a positional tolerance of 0.4mm, relative to the Guide Segments actual centre line and end faces. In Beamline Section 3 the vessel positions will, in part, be driven by their interface with the chopper housing. The detail of this interface will be developed in partnership between UKRI and the guide Supplier. As a general provision the chopper interfacing faces will be made by UKRI to a positional tolerance of 0.1mm to enable the top level requirement for Vacuum Vessel end flange positions to be met.

The design of the alignment devices for Beamline Sections 3 - 8 will be the responsibility of the Supplier. Alignment devices for the guides and vessels will be required. The alignment devices must maintain their accuracy for the life time of operation, in the operating conditions outlined in Section 5.8. It will be the responsibility of the supplier to design and define the installation, survey and alignment methodology and features of the components included within the scope of work. As indicated in Section 8 these methodologies and solutions must be presented at the reviews and will form a part of the approval assessment. As a part of this the Supplier will be responsible for demonstrating how the survey and alignment methodology enables and ensures the requirements outlined in Section 6. Where survey nests are used, they should be sized for a 1½" or ½" SMR.

### 5.5.3 Beamline Section 2: BBG

The interface with the BBG vessel is shown in drawing ESS-0318227. Changes to this interface due to optimizations in the substrate thickness can be supported but will be similarly subject to approval as above.

### 5.5.4 Beamline Section 6: Bunker Wall Feedthrough

The complete vacuum vessel guide assembly will be mounted within the feedthrough plug in a fixed position. The mounting of the guide vacuum vessel into the Feedthrough Plug is shown in the preliminary design as a face to face interface (highlighted in Figure 22). Alternative interface configurations can be accepted but will be subject to approval by UKRI as outlined in Section 5.9. As stated in Section 5.1.5 the plug, vessel, guide assembly will be aligned within the bunker wall cut out on the feedthrough plug alignment devices positioned at each end of the assembly.

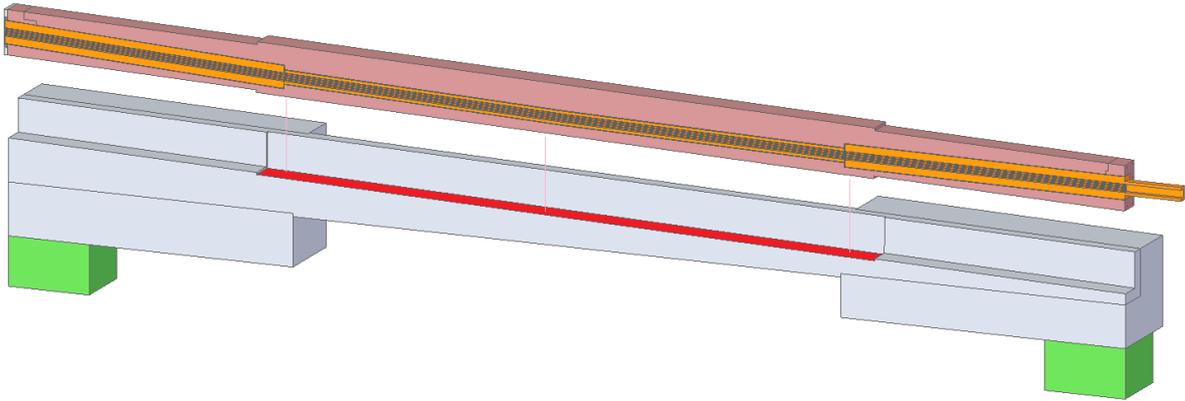


Figure 22 – Feedthrough plug interface

## 5.6 Boron Shroud

Sections 3, 4, 5, 7 & 8 will include a B4C resin composite shroud. The responsibility and scope for this element of the work is outlined in Section 4.1.1. A minimum coverage of 90% of the guide external surface is required. The coverage must be maximized, cut outs are permitted to allow good access around alignment and survey features and devices. It is acceptable for the shroud to cover the internal surface of the vacuum vessel rather than the outside surface of the guide substrate. The decision to change the design in this way will be by mutual agreement only, and may be dependent on manufacturing limitations at UKRI.

Included within the tender will be an 'optional extra' for the Supplier to provide the shrouds (see PR18162 Pricing Schedule). The B4C shrouds must fulfil one of the specification options listed below:

- 7mm thick and  $\geq 95\%$  B4C by weight
- 8mm thick and  $\geq 80\%$  B4C by weight
- 9mm thick and  $\geq 70\%$  B4C by weight
- 11mm thick and  $\geq 60\%$  B4C by weight

The remainder of the composite material should be epoxy resin or equivalent, verified rad hard polymer. As outlined in the PR18162 Technical Questions AW6, the material specification to be used must be given as a part of the cost option, if provided.

## 5.7 Maintenance

### 5.7.1 In-Bunker Maintenance

Access for maintenance inside the bunker will be extremely limited. Each Beamline Section is independent of the next and will be mounted on 3 point kinematic mounts. In this way it will be possible, once services are disconnected, to crane out individual Beamline Sections for maintenance. Nevertheless this is expected to be difficult due to activation inside the bunker and difficulties in accessing the bunker. In addition to this it is expected that Beamline Components will be extremely radioactive, and as such will require long cool down periods and limited 'contact' if maintenance is required. For this reason all parts within the scope of work should be designed and validated for no maintenance for the life time of the instrument – detailed in Section 5.8. Possible failure modes must be identified and, where necessary, mitigated to reduce the likelihood of unplanned maintenance.

### 5.7.2 Out of Bunker Maintenance

Access for maintenance outside the bunker will be somewhat limited. It will be possible to carry out limited maintenance however this is expected to be difficult due to activation of beamline components and difficulties in accessing the equipment. As such, it is anticipated some sections will require moderate cool down periods and limited 'contact' if maintenance is required. For this reason all parts within the scope of work should be designed and validated for minimal maintenance for the life time of the instrument – detailed in Section 5.8. Possible failure modes must be identified and, where necessary, mitigated to reduce the likelihood of unplanned maintenance.

## 5.8 Operating Conditions

### 5.8.1 In-Bunker Environment

Beamline sections 2 – 6 will be exposed to the in-bunker environment. The guide and vacuum vessels will be exposed to very high levels of radiation. The neutron flux down the guide is expected to be in the order of  $1 \times 10^{10}$  n/s. The general in bunker radiation is expected to be in the order of  $1 \times 10^6$   $\mu$ Sv/hr during cycle runs. The in-bunker area will operate at a maximum temperature of 35°C during cycle runs and during shutdowns will drop to 20°C.

The vacuum sections will be pumped down to  $1 \times 10^{-3}$  mbar. Maintenance requiring let up to atmosphere is expected no more than once per year.

The bridge beam guide vessel will contain the guide in an argon environment at 1.1bar for the life time of the instrument.

### 5.8.2 Out-Bunker Environment

Beamline sections 7 – 8 will be exposed to the out of bunker environment. The guide and vacuum vessels will be exposed to moderate levels of radiation. The out of bunker area will operate at  $22 \pm 2$  °C.

The vacuum sections will be pumped down to  $1 \times 10^{-3}$  mbar. Maintenance requiring let up to atmosphere is expected no more than once per year.

## 5.9 Optimizations

As outlined in this document, the detailed design of the guide, as well as certain optimizations will be the responsibility of the supplier. Such optimizations will be subject to UKRI approval at the reviews, and will be dependent on the Supplier demonstrating that the changes better assure performance, quality and reliability.

# 6 Quality

## 6.1 Alignment Accuracy

The guide reflective surfaces must be manufactured and aligned to within a profile tolerance of 0.04mm, relative to the theoretically exact geometry. The actual centre line must be aligned to a positional tolerance of 0.02mm relative to the theoretically exact centre line.

## 6.2 Segment length error

Segment length error is defined as the deviation of the length of the assembled guide unit as measured between the entry and exit faces along the guide axis. The maximum permissible deviation from the nominal values is  $\pm 0.2\text{mm}$

## 6.3 Step alignment error

Step alignment error is defined as lateral positioning error between subsequent individual guide elements, substrates or surfaces within an assembled unit. The step alignment error shall be  $< 0.02\text{mm}$ .

## 6.4 Waviness

Waviness is defined as: the angular deviation from a perfectly flat surface. On all reflective surfaces the angle between any two surface normals must remain within a cone of semi-angle  $< 1.5 \times 10^{-4}$  radian RMS (Root Mean Square deviation). The maximum peak value of acceptance of any point is  $< 3.5 \times 10^{-4}$  radian.

## 6.5 Local Defects

On all coated surfaces, the cumulative surface of all scratches, greyness, open bubbles, scuff marks, or other defect shall remain  $< 0.02\%$  of the total useful area of the component.

## 6.6 Internal Stress

To avoid degradation of the super mirror, internal stresses are to be minimised by a suitable manufacturing or annealing process.

## 6.7 Quality Control and Assurance

The guide system components and completed assembly must be inspected and validated to verify compliance to the specification. As stated in section 4 the supplier will be responsible for defining, implementing, and documenting the results of, the quality control and assurance plan. The Supplier must provide a detailed quality control and assurance plan at the CDR. The completeness of which shall form part of the review approval criteria. The plan submitted at CDR must demonstrate how the quality control and quality assurance steps planned and taken will ensure compliance to each specification clause.

Mandatory quality control measures include:

- Material grade / composition certification for all components (to EN 10204:2004 type 3.1)
- Reflectivity tests – must be completed on a statistically representative sample size (min 10%)
- Vacuum tests – Complete assemblies must be tested to  $1 \times 10^{-7}$  mbar achieving a maximum leak rate of  $1 \times 10^{-7}$  mbar·l/s
- Externally interfacing geometry must be measured for compliance with final approved drawings – as a part of the factory inspections
- Final alignment survey – following installation at ESS

In addition to the Supplier defined quality control steps and the above mandatory steps, the Supplier will also be required to support ESS LIBS materials testing. This may require material samples to be issued to ESS, and or, an ESS visit where parts will be tested. If the materials are found not to match that specified, the parts will be rejected, all work required to replace rejected part will be at the Suppliers cost.

As stated in section 4.2 the supplier will be responsible for compiling and providing:

- The factory inspection and test report: must include, results from all quality assurance steps undertaken - geometric measurements must be listed in a table with actual sizes and positions (measured values), deviations from nominal, specified engineering tolerance, and positions of key derived features (e.g. guide centreline)
- The final alignment report: must include a table of measured points with positions listed relative to 3 externally visible SMR positions on the Beamline Section. Measured points on guide segments and vessels must be identified on drawings and referenced in the factory inspection and test report.

The plan must be followed and the factory inspection and test report made available for review as detailed in Section 8. The final alignment report must be supplied within 5days of completion of the installation, and the raw data must be made available to UKRI & ESS within 24hrs.

## 6.8 Product Marking

Each subassembly shall be permanently marked on an exposed housing surface with the Seller's name and the appropriate subassembly part number. Guide segments must be marked with an ESS assigned number. The marking shall be machine engraved, chemical etched or stencil blast. Character height shall be approximately 6mm.

## 7 Installation at ESS

Risk assessments and method statements must be submitted by the Supplier prior to, delivery, installation and alignment. These must cover all unload, installation and alignment processes. Installation personnel will be required to undergo ESS training as a part of their induction to work on site (as outlined in ESS-0147100 Rev 1) and must conform to site rules (as outlined in ESS-0147089 Rev 1). Installation activities must be completed in accordance with Swedish regulatory requirements. The Supplier will bear the costs associated with fulfilling these regulatory responsibilities (training, certification or alike). Lifting features and equipment must comply with relevant Swedish and European regulations.

All contractors operating on site must be in possession of a valid ID06 card See Section 6.3 of ESS-0147089 Rev 1. – More information is available at <https://www.nexusid06.se/en>

## 8 Approvals & Reviews

Below are details for the required content of the design and documentation reviews. Any outcome of the design reviews shall not relieve the Supplier from the responsibility of delivering to the specification or the contracted delivery date.

All reviews can be held at the Supplier site, UKRI or ESS – to be decided by mutual agreement. All reviews must include an UKRI engineer and key members of the Supplier engineering and design team. It may also include an ESS representative.

UKRI or ESS staff may, at points during the contract, require access to visit the Supplier manufacturing site and carry out inspections and progress checks. Such visits must be accommodated by the Supplier.

### 8.1 Preliminary Design Review (PDR)

To be held within the first 3 weeks of the contract commencing. At the PDR the Supplier must present:

- Summary of the requirements
- Concepts for the alignment mechanism
- Concepts for the guide construction
- Concepts for the vessel construction
- Concepts for the installation, survey and alignment process
- Project schedule
- Primary project risks and mitigation measures

Design details will be reviewed and agreed. It may be necessary for further work to be carried out to clarify certain elements before the PDR is passed. As such 2 weeks must be allowed in the project schedule for the complete PDR process.

### 8.2 Critical Design Review (CDR)

To be held once the engineering design work is completed, but before detailed drawings are created. At the CDR the Supplier must present:

- Summary of how the key points within the specification have been met
- Description of any changes that are required to the interfacing components
- Stress and deflection calculations for vacuum and lifting conditions
- Technical risk assessment and mitigation measures
- Summary of engineering validation work undertaken
- Detailed inspection and validation plan (as outlined in Section 6.7)
- Draft maintenance plan
- Project schedule
- Outstanding project risks and mitigation measures

This review will act as a project gate to verify that the design does align with the customer expectation. It may be necessary for further work to be carried out before the CDR is passed. As such 2 weeks must be allowed in the project schedule for the complete CDR process.

### 8.3 Final Design Review (FDR)

This review will be carried out as a part of the ESS Sub-Tollgate 3 Process. To be held once all design work is completed and the design can be frozen, including all tolerances. At the FDR the Supplier must present:

- Any changes to the design since the CDR
- Detailed drawings of the guide system
- Complete bill of materials for all parts to be supplied (including masses)
- The quality plan
- Detailed installation and alignment plan
- The maintenance plan
- Project schedule
- Outstanding project risks and mitigation measures

The Supplier must submit the detailed drawings of the guide system. This review will act as a project gate to verify that the design aligns with the customer expectation and will freeze the design. It may be necessary for further work to be carried out before the FDR is passed. As such 2weeks must be allowed in the project schedule for the complete FDR process.

### 8.4 Factory Acceptance & Inspection Report Review

This review will be held at the supplier site and will be held after completion of the manufacturing and validation, prior to delivery to ISIS & ESS. At this review the Supplier must present:

- Factory inspection and test report
- Project schedule
- RAMS for installation and alignment
- Outstanding project risks and mitigation measures
- All further project documentation as outlined in Section 6.7

In addition to this the FAT test plan will be conducted in the presence of ESS & UKRI representatives in line with the agreed validation plan. This review should be a formality, with no further work required.

## 9 Technical Definitions & Information

### 9.1 M value

The M value describes the minimum critical angle of reflectivity, with respect to the critical angle of a natural Ni coating ( $m \times 1.73$  mradian/Å).

### 9.2 Aluminium Seals on Aluminium Flanges

The ESS specification dictates seal and flange characteristics. An example of the application of the specification is shown in drawing SI-7612-011, SI-7612-04 (1-4).

#### **Seal specification:**

Pure aluminium (99.99%), circular cross-section, 2mm diameter wire, TIG welded into complete ring.

#### **Flange Specification:**

One flange should have a shallow flat bottom groove 0.8mm deep, with a minimum width of 5mm. The bottom of the groove must meet a flatness tolerance of 0.1mm with a roughness of Ra 0.5, circular lay. The mating flange face should be flat with a roughness of Ra 0.5, circular lay. The mating faces of the flanges must meet a flatness tolerance of 0.1mm. Surfaces should be machined to the required roughness, polishing processes should be avoided.

### 9.3 Material Compositions

ESS Licencing rules require strict control over the materials used in the in-bunker area. Table 3 list the acceptable materials and application. The use of other materials will only be permitted in exceptional circumstances, justification will be required and will be subject to discretional approval by UKRI (must be agreed prior to CDR approval).

Name	Grades/Compositions	Application
High Purity OF Copper	UNS C10100; CW008A; DIN 2.0040-Cu OF	Bender Substrate
Silicon	Si	Vanes & Mirror Wafer
Aluminium alloy	AA 5083; ISO 3.3547; DIN AlMg4.5Mn	Any
Aluminium alloy	AA 5754; ISO 3.3535; DIN AlMg3	Any
Aluminium alloy	AA 6081; ISO 3.2315; DIN AlMgSi1	Any
Aluminium alloy	AA 2014; ISO 3.1255; DIN AlCu4SiMg	Any
Pure aluminium	ENAW-Al99.99	Aluminium Seals
Low alloy steel	S355JR, EN 1.0045	Fasteners & fittings, Beamline Section 6 Vessel
Low alloy steel	S275JR; EN 1.0044	Fasteners & fittings, Beamline Section 6 Vessel
Low carbon steel	Table 2 ISO 898-1:2013	Fasteners & fittings
Titanium Grade 2	Ti, 3.7035, R50400	Fasteners & fittings
Titanium Grade 5	Ti6Al4V, 3.7165, R56400	Fasteners & fittings
Phosphor Bronze	C51000	Fasteners & fittings
Nickel	Various – minimum purity 98% (see cobalt limit in Table 4)	Coating only
Titanium Nitride	TiN	Coating only
Boron Carbide Composite	B4C – Epoxy Resin	Boron Carbide Shrouds

Table 3 - Approved In-Bunker materials

### 9.3.1 Controlled substances

The substances listed in Table 4 are known to present issues with regards to activation. As such their use is prohibited. Impurity levels of these substances must be controlled:

Substance	Comment
Antimony	Additive in lead
Cobalt	Impurity in nickel and so stainless steels
Europium	Present in some concrete aggregates
Gold	
Molybdenum	Additive in stainless steels
Silver	Impurity in lead and other heavy metals
Tungsten	
Uranium	
Zinc	Used in brasses

Table 4 – Controlled Substances

## 9.4 Alignment Devices Concepts

### Fixed Guide Segment Position

For some beamline sections it should be possible to install the guide segments in a fixed position and align the vessel and guide as one, using the vessel alignment devices only

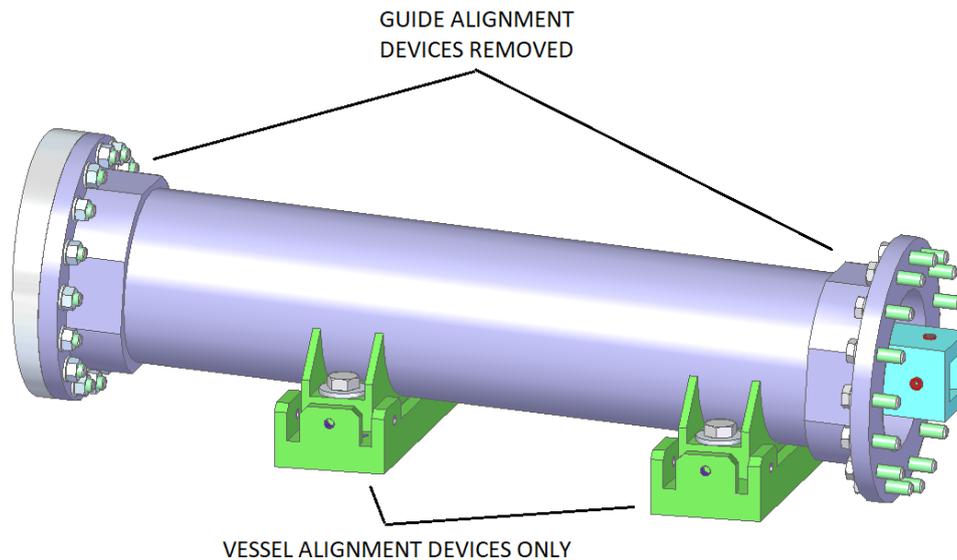


Figure 23 – Fixed Guide Segment Position

### Guide Adjustment on Flange End

For some beamline sections it should be possible to locate the guide alignment devices inside the vessel, with access from the end when the window (or alike) is removed.

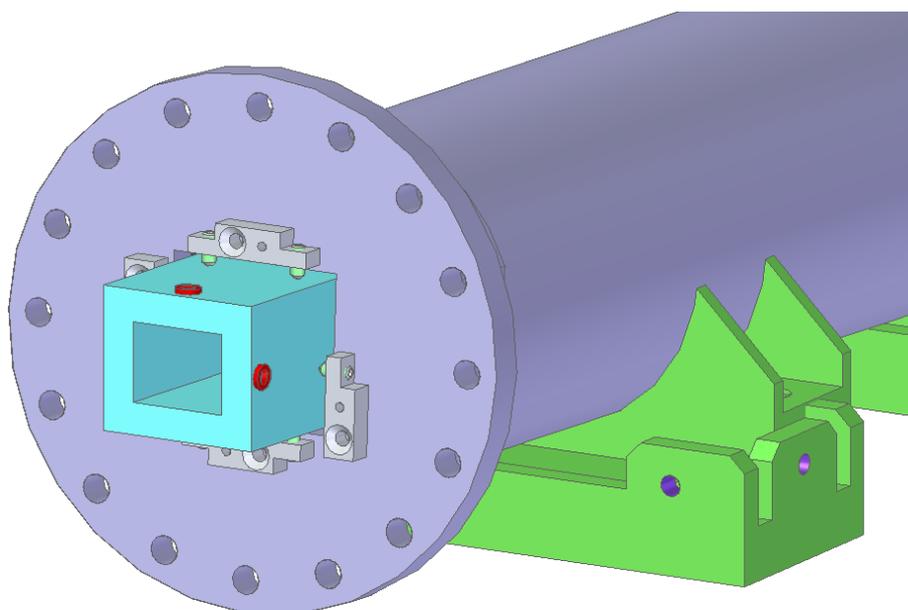


Figure 24 – Guide Adjustment on Flange End