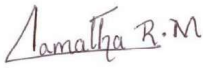


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Document Number:	S5-RS-RAL-UVNS-0002
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CHANGE RECORD

Issue	Date	Change
0.1	31/01/2018	First Draft
0.2	24/08/2018	Updated after internal review and revised window modelling
0.3	21/09/2018	Document updated prior to customer review
0.4	05/06/2019	Document sent as draft for customer review
0.5	13/06/2019	Document updated with comments from ADS
1.0	18/06/2019	Document released

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1 Scope

This document is the S5 UVNS C&C Test Facility Window and Flange Specification. This document summarises the requirements for the optical windows, alignment windows and flanges for the 5m diameter Thermal Vacuum Chamber, at RAL Space.

2 Applicable Documents

No.	Document Number	Title	Issue
AD1	BS ISO 10110	Optics and photonics - Preparation of drawings for optical elements and systems	
AD2	ISO-SPAP-MECH-007	Inspection Requirements	
AD3	ISO-SPAN-AIV-102	Cleaning Requirements	
AD4	BS EN ISO 20485:2018	Leak Testing: Tracer Gas Method	
AD5	GS5.RS.ASG.UVNS.00001	Sentinel 5 UVNS instrument Cleanliness Requirement Specification (CRS)	5.0
AD6	GS5-SP-ADSO-UVNS-1000113913	B21 - C&C TF - C&C Facility Requirements Specification	2.0

3 Reference Documents

No.	Document Number	Title	Issue
RD1	KE-0291-045	S5 WINDOWS OUTLINE	A
RD2	ECSS-Q-ST-70-01	Cleanliness and Contamination Control	C
RD3	ECSS-Q-ST-70-02	Thermal Vacuum Outgassing Test for the Screening of Space Materials	C
RD4	S5-LI-RAL-UVNS-0002	Acronyms and Abbreviations	2.0

4 List of Acronyms and Abbreviations

ARO	After Receipt of Order
BBAR	Broad Band Anti-Reflective
C&C	Calibration and Characterisation
DRB	Delivery Review Board
IF	Interface
IPA	Isopropyl Alcohol
ISO	International Organisation for Standardisation
KIP	Key Inspection Point
MIP	Mandatory Inspection Point
MRR	Manufacturing Readiness Review
RAL	Rutherford and Appleton Laboratory / RALSpace
RMS	Root Mean Square
S5	Sentinel 5
TV	Thermal Vacuum
TVAC	Thermal Vacuum Chamber
UVNS	Ultra-violet Visible Near-Infrared Shortwave

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Note:

Please note, drawings will be provided with all required dimensions. Dimensions which have not been specified are to be determined by the supplier and approved by RAL prior to manufacture.

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5 Introduction

RAL Space require custom window and flange assemblies for a 5m TV Chamber at RAL. These assemblies will interface in four locations on the TV Chamber.

A concept of one of the window assemblies is shown below in Figure 1. Figure 2 shows the four windows in a section view of the 5 m vacuum chamber.

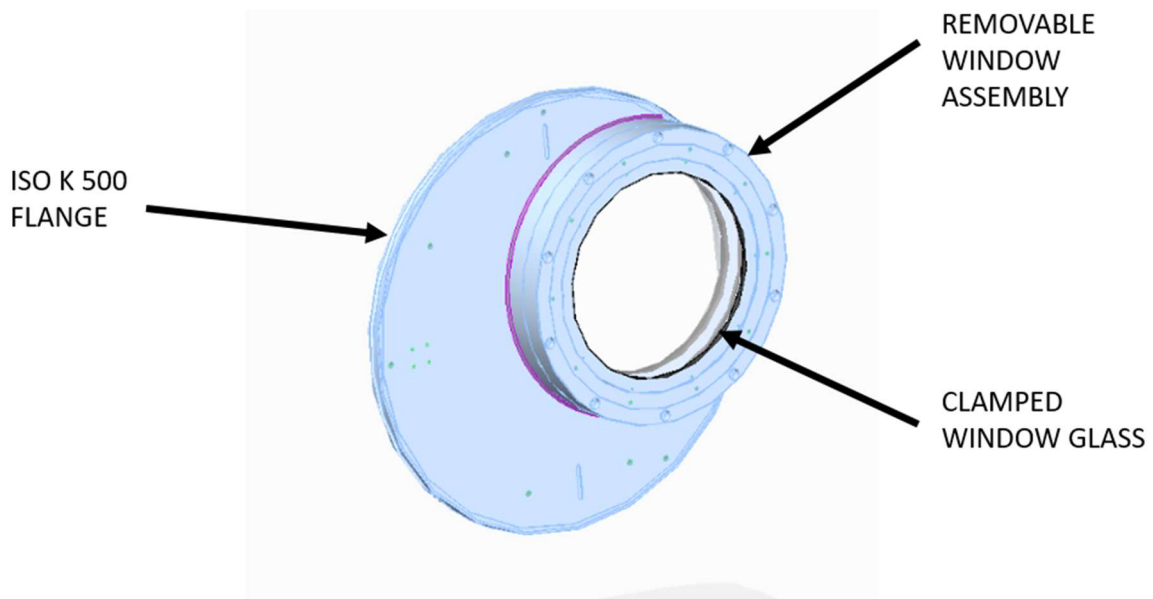


Figure 1 Concept Flange and Window Assembly

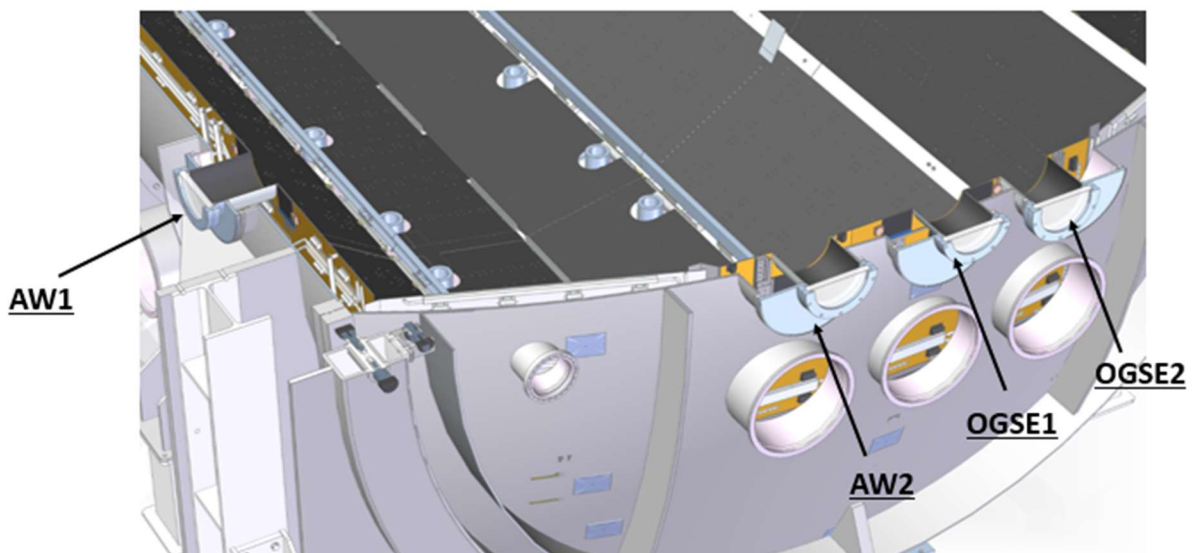


Figure 2: Location of Windows within Vacuum Chamber

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This tender requires the provision of 4-off ISO-K 500 flanges and 6 completed window assemblies. The windows are divided into two types: 3-off Alignment Windows and 3-off Optical Windows.

The flanges must interface with a 500mm TV chamber aperture (500 ISO-K) and a 320mm window in order to give a window clear aperture of at least 281 mm.

The overall diameter of the window glass of 300 – 320 mm is stated as a guide; the flange supplier shall define the exact dimension. The requirement is to have a visible aperture of at least 281 mm, and preferably larger. Therefore, the overall diameter of the window is dependent on the supplier clamping method and must also take into account all interface flanges as shown in Figure 3.

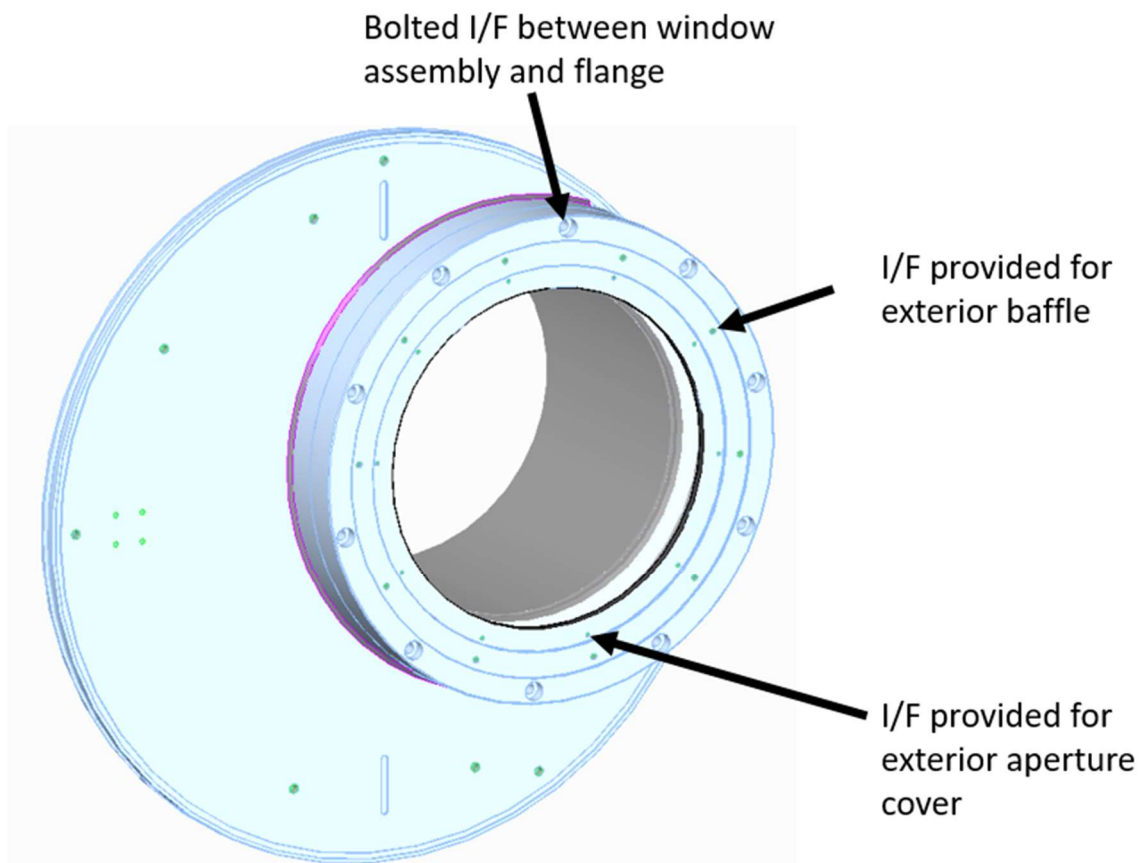


Figure 3: External Interfaces Required on Window Assembly

Figure 4 shows a window assembly with the airside baffle and aperture plate mounted. These two components are not part of the procurement but shown here to demonstrate the design intent for the interfaces.

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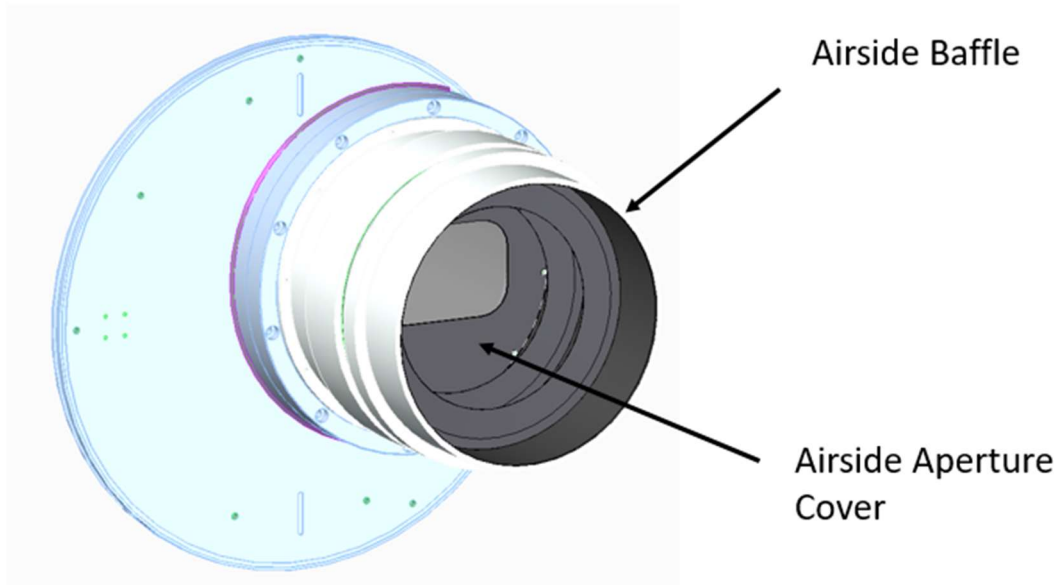


Figure 4: Window Assembly shown with additional airside components installed

This specification is for a total of six window assemblies to be manufactured and tested (four windows intended to be used for the test at RAL Space and two spares) and four ISO-K 500 flanges (no spares required). All flanges have a unique window position. The windows must be delivered to RAL Space, installed within the flange and fully tested as outlined within this specification. The spare assemblies must be fully assembled.

The product tree is shown in Figure 5.

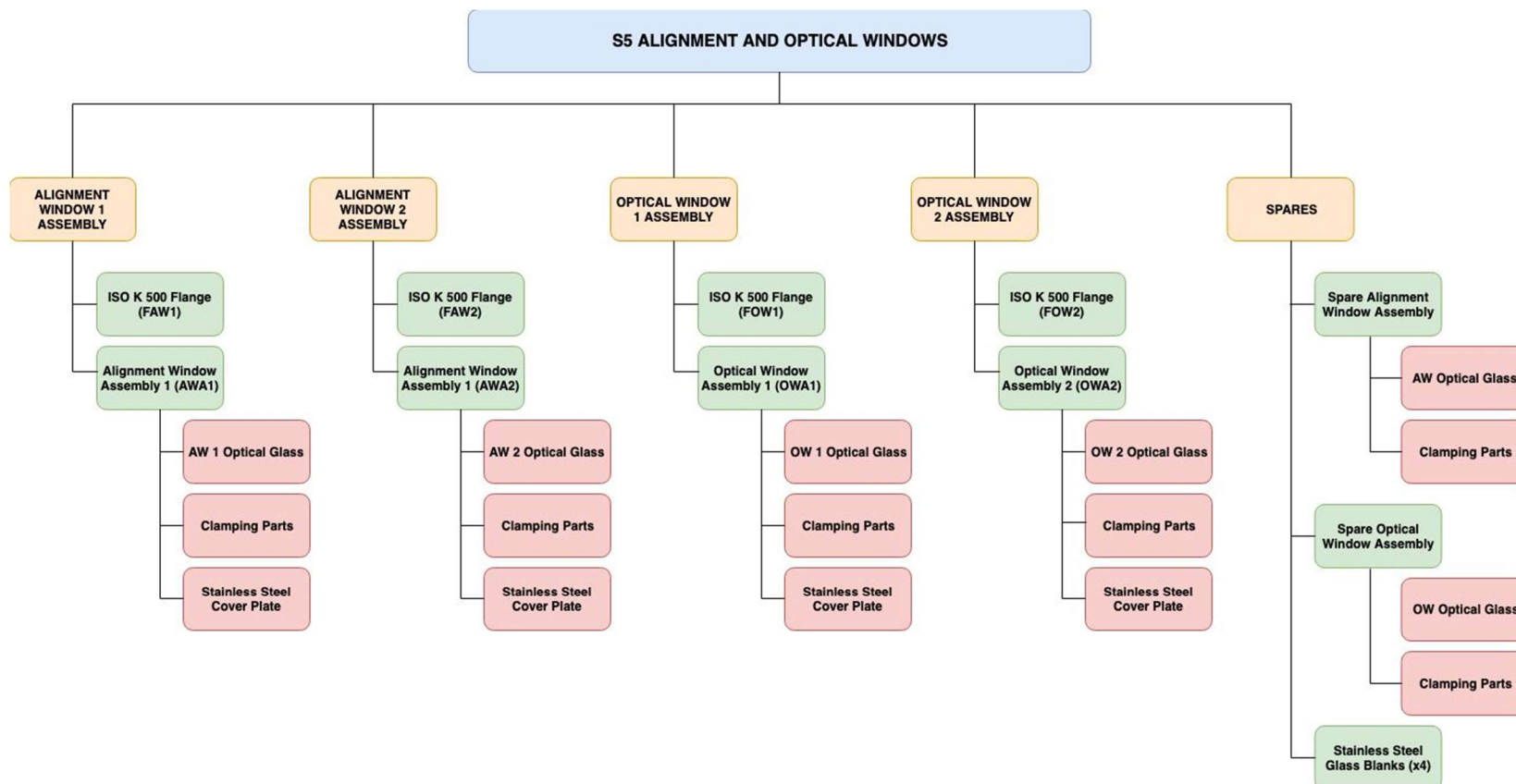


Figure 5: S5 Windows Product Tree

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6 Requirements

The following tables define the requirements for the flange and window assemblies. Table 1 defines the general requirements applicable to the flange/window assemblies. Table 2 defines the optical requirements applicable to all windows. Table 3 defines the specific additional requirements applicable to the OGSE windows only.

In each table, the required method of verification is defined with the following notation:

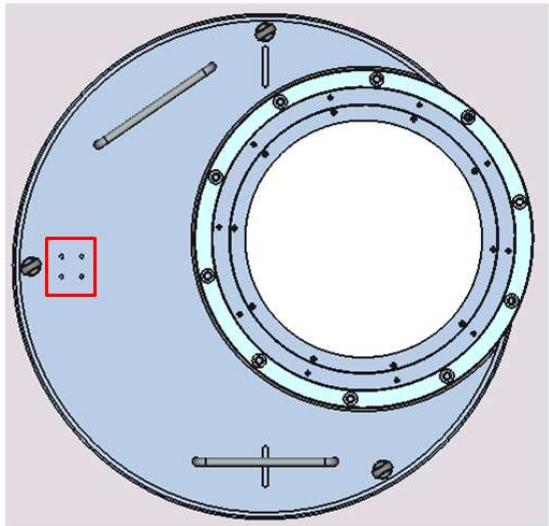
- I – Inspection
- R – Review of Design
- T – Test

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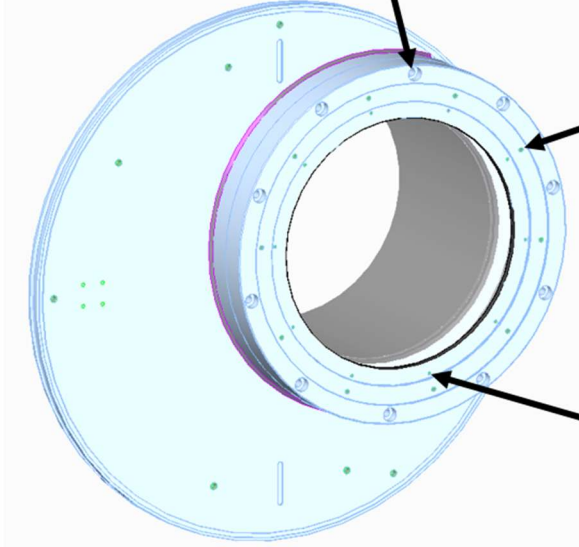
Table 1: General Requirements

Req. No.	Customer Req. No.	Verification Method	Requirement Description
GW1	RAL-0001	I	The supplier shall provide 3 Optical Window Assemblies.
GW2	RAL-0002	I	The supplier shall provide 3 Alignment Window Assemblies.
GW3	RAL-0003	I	The supplier shall provide 4 ISO-K 500 mm flanges
GW4	RAL-0004	I	Each window assembly shall guarantee a minimum useful, unobscured optical diameter of 281 mm (when mounted on the ISO 500 flange).
GW5	RAL-0005	I	The window material thickness shall be at least 30 mm <i>This is to provide the required safety factor of 10 on withstanding the atmospheric/vacuum pressure differential</i>
<i>Comment</i>			The assumed glass diameter is 320 mm but should be selected by the supplier to facilitate their preferred clamping method.
GW6	RAL-0006	R	The window clamping method shall not allow direct metal to glass contact i.e. gaskets or intermediate material must be used
GW7	RAL-0007	R, I	Each window shall have a 45 ° chamfer on the edge of both sides. The width is to be proposed by the supplier.
GW8	RAL-0008	R	All materials shall be vacuum compatible and be able to be cleaned with IPA. The supplier shall submit a materials list for approval prior to manufacture.
GW9	RAL-0009	R	The preferred material for the Optical window is Infrasil 302. <i>Alternative materials can be proposed if they are compliant with the optical requirements defined in Table 2 and Table 3.</i>
GW10	RAL-0010	R	The preferred material for the Alignment window is BBAR Coated DUV Grade Fused Silica.

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			Alternative materials can be proposed if they are compliant with the optical requirements defined in Table 2.
GW11	RAL-0011	I	Vacuum side, non-optical surfaces of the flanges shall be black coated.
GW12	RAL-0012	R	The applied black coating shall have a reflectivity of less than 3% in the 260 – 2700 nm wavelength range.
GW13	RAL-0013	I	All ISO-K 500 flanges shall have 4-off tapped holes on the air side. This is to allow the mounting of a mirror cube on each flange. Interface holes shall be M4 x 0.7mm pitch, on a 20mm square pattern as indicated below:  Note: The location of mirror cube interface holes on the flange face is not critical. Thread depth shall be a minimum of 1.5 x thread diameter.
GW14	RAL-0014	R	The flange design must enable the window assembly to be easily removed and installed by one person working on a lab bench. Bolted interface holes are therefore preferred.

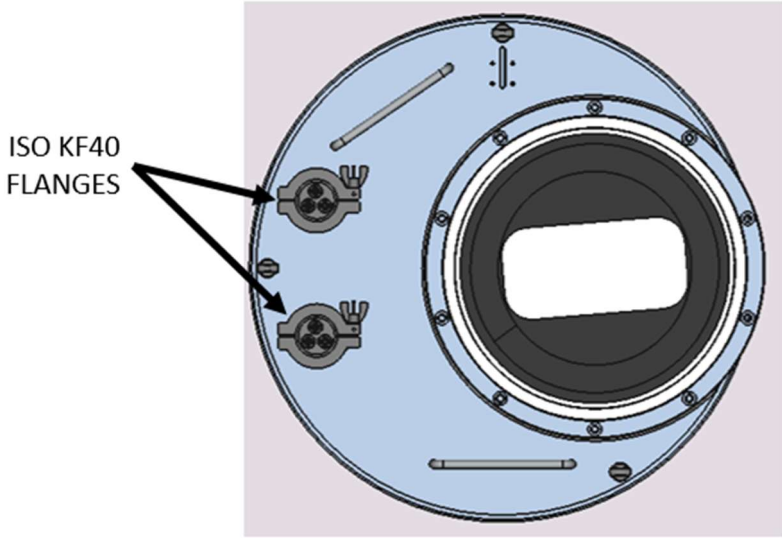
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GW15	RAL-0015	R	Each flange shall include lifting handles to aid lifting via hand and installation via crane hook (i.e. Eyebolt).
GW16	RAL-0016	R	Each window assembly shall include separate bolted interfaces on the airside for both a baffle and exchangeable aperture plate. Suggested sizes are: Aperture – 10 off M3x0.5 on 288 mm PCD External baffle – 10 off M5x0.8 on 316 mm PCD All holes to be tapped to a minimum of 1.5x thread diameter  Bolted I/F between window assembly and flange I/F provided for exterior baffle I/F provided for exterior aperture cover <i>Note: provision of the baffles/exchangeable aperture plates are not part of this procurement.</i>

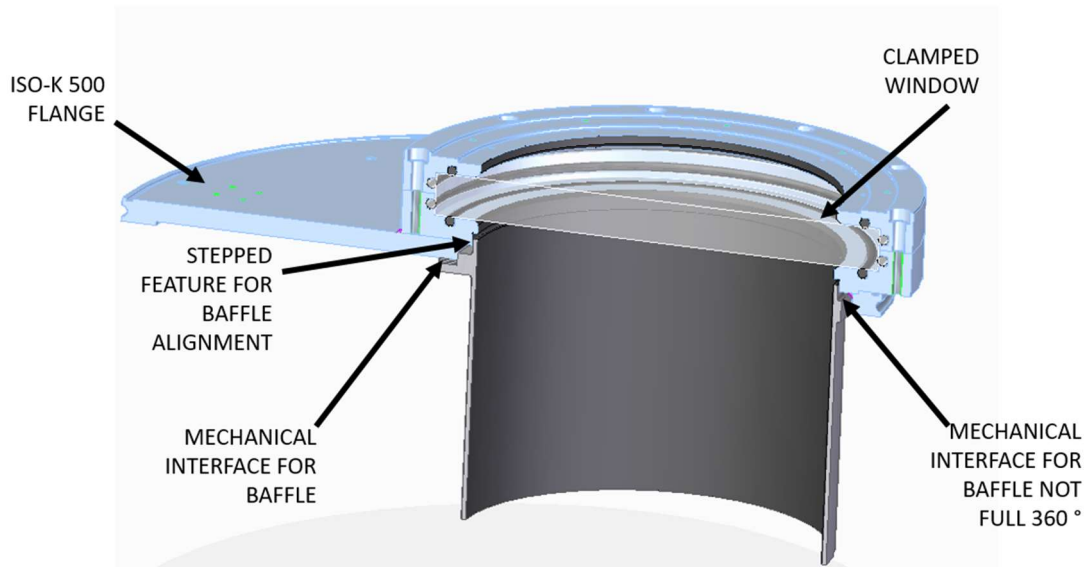
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GW17	RAL-0017	I	The location of window centres with respect to the ISO 500 flange centre shall be in accordance with drawing KE-0291-045 presented in Appendix A . This includes the maximum positional tolerance of the window position to be within a diameter of 1 mm. Note: This tolerance is a key performance requirement and shall be minimised as far as possible.
GW18	RAL-0018	R	Flanges will be clamped to TV Chamber with Double Claw Clamps. The flange shall therefore be compatible with double clamp claws.
GW19	RAL-0019	R	The supplier shall provide a procedure for removing and installing a spare window assembly. Alignment features shall be used to ensure the mirror assemblies can be repeatably located within the required tolerance.
GW20	RAL-0020	I	The 6 window assemblies (alignment and optical) shall be part marked to individually identify each window.
GW21	RAL-0021	R, I	The Flange for Alignment Window 2 (AW2) shall also include 2-off KF40 Interface Flanges. The location is to be proposed by supplier but shown below for indication.

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GW22	RAL-0022	R, I	Each flange shall include datum markings in 6 o'clock and 12 o'clock positions
GW23	RAL-0023	R,I	Each window assembly shall include a stainless steel cover plate that can be placed over the optical window (from the air side). This plate shall be able to be fixed in place. The cover shall be air/dust tight. The window facing side of this cover plate shall be black coated in accordance with GW12/RAL-0012. Note – this plate could use the same interface holes as the aperture plate interface.

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GW24	RAL-0024	I	Each flange assembly shall include a stainless steel “window” plate as a spare which can be installed instead of either the glass window, i.e. a 320mm diameter x 30mm thick plate, OR can replace the complete window assembly.
GW25	RAL-0025	R, I	The vacuum side of each ISO-500 K flange shall include a stepped feature and tapped interface holes around the optical diameter. This is to facilitate the installation and location of a vacuum-side baffle, as shown below.  Notes: - Provision of the baffle is NOT part of this procurement - M4x0.7 is the suggested hole size on 310 PCD - For some of the windows a full 360° step may not be possible due to the positioning near edge of the ISO-K 500 flange

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Table 2: Window Optical Requirements

Req. No.	Customer Req. No.	Verification Method	Requirement Description
AW1	CCFRS-1862	T	The transmission of the TV chamber windows shall be higher than 90% over the wavelength range [260 – 2700 nm]. <i>Note: In the wavelength range [260 - 275] nm, a reduced transmission down to 80% is acceptable.</i>
AW2	CCFRS-1864	T	The micro-roughness of the TV chamber window surfaces shall be smaller than 0.5 nm RMS.
AW3	CCFRS-1865	T	The OGSE and Alignment windows in the TV chamber shall have a wedge between both optical surfaces smaller than 40 arcsec.
AW4	CCFRS-1942	R	The orientation of the wedge of all TV chamber windows shall be known and marked better than 5 deg.
AW5	CCFRS-1943	T	The birefringence of the materials of all TV chamber windows shall be characterised and known with an accuracy of 1 nm / 10 mm.
AW6	CCFRS-1945	T	The bulk defects including bubbles of the materials of each TV chamber window shall be 1 / 5 x 0.1 or better. <i>The statement of the material bulk defects of all kind shall be in accordance with [AD1].</i>
AW7	CCFRS-1948	T	The homogeneity of the materials of each TV chamber window shall be 2/3, 3 or better. <i>The statement of the material homogeneity of all kind shall be in accordance with [AD1].</i>
AW8	CCFRS-1950	T	The maximum allowed number and maximum size of surface defects including digs and scratches of the optical surfaces of the TV chamber windows shall be less than 5 / 3 x 0.1. <i>The statement of the surface defects of all kind shall be in accordance with [AD1].</i>
AW9	CCFRS-1951	T	The induced wave front error of the TV chamber windows mounted on the TV chamber flange shall be less than 30nm RMS under ambient and air condition on both sides. The wave front error shall be measured on the clear aperture. Sub-aperture measurement is allowed.
AW10	CCFRS-1953	T	The induced wave front error of the TV chamber windows mounted on the TV chamber flange shall be less than 30nm RMS under thermal-vacuum condition. The wave front error shall be measured on the clear aperture. Sub-aperture measurement is allowed. The wave front error under thermal-vacuum condition shall contain all the Zernike up to 36 with exception of the Zernike Z4 term (defocus).

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AW11	CCFRS-1954	T	When mounted the TV chamber windows shall not change the state of polarisation of the light going through by more than 0.05% for different incident beams from 0 deg. to 2 deg. over the wavelength range [270 – 2400 nm].
AW12	CCFRS-1941	T	The optical performance of all windows (including spares) shall be characterised to allow the best windows to be selected.
AW13	CCFRS-1955	R	The optical surfaces of the windows shall be cleanable when integrated in a window assembly. Cleaning refers to particulate and molecular contamination.
AW14	CCFRS-1956	R	The supplier shall provide a cleaning procedure for the window assemblies. After application of this procedure the particulate contamination of the cleanable optical surfaces shall be less than 100 ppm. The average particle size shall be smaller than 0.5 microns.
AW15	CCFRS-2203	T	The orientation of the wedge of all windows when installed in the flange shall be perpendicular to the gravity vector i.e. in the 3 o'clock position.

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Table 3: OGSE Specific Window Requirements

No.	Customer Requirement No.	Verification Method	Requirement Description
OW1	CCFRS-1863	T	The transmission of the TV chamber OGSE windows shall be characterised and known with an accuracy of 0.1% over the wavelength range [270 - 2400 nm].
OW2	CCFRS-2176	T	The transmission of the TV chamber OGSE windows shall be characterised and known with an accuracy of 5% over the wavelength range [260 – 270 nm].
OW3	CCFRS-2177	T	The transmission of the TV chamber OGSE windows shall be characterised and known with an accuracy of 5% over the wavelength range [2400 – 2700 nm].

7 Testing

Table 4 details the verification tests required on the window assemblies.

Table 4: Verification Tests Required

Test	Build Level	Description / Success Criteria
Optical verification	Component	Demonstrated compliance with all optical requirements.
Proof Pressure Testing	Flange assembly	1.52 barg N2, 20 minutes duration on outside face
Leak test (helium) (BS EN ISO 25485)	Flange assembly	Leak rate shall be less than 1x10-9mbar l/s at pressure lower than 1x10-6mbar
Geometric Inspection	Flange assembly	Verification of geometric compliance (CMM)

As part of the response to the tender the contractor shall supply a description of the test plan for all inspections and tests, indicating applicable test standards. The adequacy and detail of the test plan shall be a key part of the tender evaluation criteria. If suppliers are unable to perform these tests then this should be highlighted in the tender and they may be conducted by RAL.

The leak test shall be conducted before and after pressure testing. Any failure of the components to meet pressure and leak tests (either at the supplier or RAL) shall be rectified by the supplier.

All testing needs to be documented in a test report(s), providing evidence that the relevant requirement has been met.

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8 Certification and Inspection

All materials must be vacuum compatible, as well as any greases, lubricants etc. used on the subsystem. Advice and support can be provided by RAL on the suitability of materials. No lubricants, cutting fluids, polishing agents or packaging containing silicone shall be used.

At RAL's discretion, a RAL representative may visit the supplier's premises during test set-up or during test. This will be arranged between RAL and the supplier with reasonable notice provided by RAL.

Material and Product Certificate of Conformance and deliverable documentation with inspection and test results showing all requirements have been met must be provided. A review of documentation, visual inspection, sample testing will be undertaken upon delivery of the subsystems.

On delivery, the hardware will be subject to standard RAL Space inspection procedure [AD2] and the following additional tests:

- CMM inspection of optical diameter (size and location wrt flange centre)
- Helium leak test

A Mandatory Inspection Point (MIP) will be held at the Test Readiness Review to review the test set-up, procedures and success criteria. Dates to be discussed and agreed with supplier.

9 Storage and Transport

Window and flanges shall be double bagged (under dry nitrogen purge) to minimise contamination. Desiccant shall be included in the outer bag.

A cleanroom compatible storage/transport container shall be provided for window and flange assembly. Options are to be proposed to RAL by the supplier. Wooden storage containers are not acceptable, unless all wooden surfaces are varnished/painted. Hard Peli-type cases are preferred.

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10 Cleanliness Requirements

10.1 Materials

The materials used for the optical windows and flanges shall be compatible with the outgassing requirements defined in Table 5 when tested in accordance with Thermal Vacuum Outgassing Test for the Screening of Space Materials [AD5,RD3].

Table 5 Outgassing Requirements

Mass Of Material Concerned (g)	CVCM (%)	RML (%)
>100	<0,01	<1
10-100	<0,05	<1
<10	<0,1	<1

No cadmium, zinc, oil or silicone based products, Polyvinyl chloride (PVC) plastic and potential hazardous materials such as beryllium shall be used.

A declared material list for the panels will have to be approved by the customer before the manufacturing readiness review.

Any stainless steel parts of the optical windows and flanges shall be electro-polished, unless exception can be justified.

All aluminium components of the optical windows and flanges must have a protective surface finish applied to ensure no oxide layer is able to form.

The contractor's proposed surface treatment shall be agreed in advance with RAL Space.

10.2 Cleanliness Level

As per CCFRS-1956 [AD6], the optical windows and flanges shall be delivered to cleanliness level as specified below:

- The molecular contamination shall be less than 0.5×10^{-7} g/cm².
- The particulate contamination of the optical surfaces shall be less than 100 ppm and the particle size smaller than 0.5 µm.
For the non-optical parts, this shall be less than 200 ppm.

The supplier shall define a cleaning and inspection procedures which can achieve these levels and agree this procedure beforehand with the customer.

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10.3 Manufacturing, Assembly and Integration

Personnel involved in the manufacturing, assembly and integration of sensitive items shall be trained with respect to the cleanliness control requirements.

Note: Optical units are examples of sensitive items.

All elements manufactured in non-controlled areas or under non-clean conditions shall be the object of a cleaning process until the cleanliness requirements are met, before they are packaged for delivery.

Cleaning and packaging operations for all elements shall be processed according to procedures approved by the customer.

10.4 Vacuum Bake-out

Prior to delivery, the optical windows and flanges shall be vacuum baked for a minimum of 72 hours. The pressure shall be $\leq 1\text{E-}06$ mbar and the temperature shall be the maximum compatible with the function of the item (and justified by the supplier) until the outgassing rate as measured by a Thermoelectric Quartz Crystal Microbalance (TQCM) (set at a temperature of 253 K (or -20 °C)) reaches a significantly reduced and almost steady state.

In order to evaluate this:

- Record frequency rate at 0.5 hourly intervals minimum frequency

$$= \frac{(f(t - 0.5\text{hr}) - f(t))}{0.5}$$

- Record rate of change over five hourly intervals (for each data point captured), Rate, R is equal to

$$\frac{\left(\frac{df(t - 5\text{hr})}{dt} - \frac{df(t)}{dt} \right)}{\frac{df(t - 5\text{hr})}{dt}}$$

- Bake-out is complete when rate of change (R) < 0.05 continuously for a period of more than 3 hours.

Note: This shall be achieved after vacuum bake-out is completed for a minimum of 72 hours.

The minimum sensitivity level required for TQCMs in this application is 1.56 ng/cm²/Hz. To achieve this sensitivity and long-term stability, thermally matched 15MHz crystals are required.

The whole sensor head shall be mounted on a temperature-controlled heat-sink. This will enable the required sensitivity and long term stability required for mass deposition rate monitoring.

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Whenever the TQCM rate exceeds a specified frequency, the crystal needs to be heated while at high vacuum to drive contaminants from the crystal. The manufacturer's requirements for maximum temperature difference between the TQCM Crystal and TQCM heat-sink (typically 60 °C) shall be observed during this activity and all TQCM operations.

10.5 Particulates

Ideally, the design of the optical windows and flanges shall be such that no material is capable of producing particulates.

During installation of the optical windows and flanges in the Thermal Vacuum Chamber, particulate debris must be minimised, or any particulates produced must be easily removed.

During operation, the optical windows and flanges shall not generate particles.

10.6 Packaging, Containerisation and Transportation

The storage and transportation requirements for the cleanliness and contamination control shall be as specified above in Section 9.

Care shall be taken for packaging, containerisation and transportation and storage in order to maintain the cleanliness levels achieved [RD2].

Cleanliness protection shall be applied prior to leaving the controlled areas.

11 Schedule and Milestones

Whilst an earlier date is preferred, delivery of all units must be completed by 19th March 2020.

A schedule shall be provided by the supplier, including the design, procurement, manufacture and testing activities of the windows and flanges.

Table 6 details the proposed project milestones.

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Table 6 Proposed Project Milestones

Milestone	Purpose	Meeting Type	Date (months)
Project Kick Off	Initiate Project	Telecon	0
Design Review	Review concept design	Telecon	To be proposed by supplier
Manufacturing Readiness Review	To review final design, drawings and material selection prior to manufacture	Telecon	To be proposed by supplier
Test Readiness Review – Mandatory Inspection Point	To review test and verification plans	Face to face meeting at contractors premises	To be proposed by supplier
Post Test Review	To review results of verification tests	Telecon	To be proposed by supplier
Delivery Review Board	Provide consent to ship	Telecon	To be proposed by supplier

RAL reserves the right to request, with reasonable notice, to attend any of these milestone meetings in person. This may also include representatives from RAL's customer organisation.

In addition to these formal reviews, progress telecons shall take place at least monthly.

12 Deliverable Items

The hardware items required as part of this tender are defined in the product tree shown in Figure 5 and listed in Table 7. It consists of 4 completed flange/window assemblies and a selection of spare items.

Table 7 Hardware Deliverable Items

Item	Designation	Quantity
ISO-K 500 Flange: Alignment Window 1	FAW1	1
ISO-K 500 Flange: Alignment Window 2	FAW2	1
ISO-K 500 Flange: Optical Window 1	FOW1	1
ISO-K 500 Flange: Optical Window 2	FOW2	1
Alignment Window Assembly	AWA	3
Optical Window Assembly	OWA	3
Window external covers	COV	6
Window stainless steel blanks	BLNK	4

The documentation required as part of this procurement is defined in Table 8 along with the expected delivery milestone.

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Table 8 Documentation Required

Document	Delivery Stage
Test and Verification Plan	Tender (draft), TRR
Verification Matrix	Tender (draft), DRB
Mechanical drawings	MRR
Declared Materials List	Design review (draft), MRR
Test Reports	DRB
Window assembly removal and installation instructions	Delivery
Window cleaning and inspection procedure	Design review (draft), DRB
Certificate of Conformance	Delivery

Appendix A KE-0291-045 Window Offset Positions

