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| --- | --- | --- | --- | --- | --- |
| **Confidentiality Level** | | *PU - Publish* | **TC ID / Revision** | | *00261222/F* |
| **Document Status** | | *Document Released* | **Document No.** | | *N/A* |
| **WBS code** | | *5.4 - RP5 – Laser plasma and high-energy-density physics* | | | |
| **PBS code** | | *E.E3.MOB.1* | | | |
| **Project branch** | | *Engineering & Scientific documents (E&S)* | | | |
| **Document Type** | | *Specification (SP)* | | | |
| ***[RSD Product Category C]***  ***MOB Vacuum Chamber***  ***For Beam Input into P3 Experimental Chamber***  ***TP20\_066***    *Keywords*  *Vacuum chamber, requirements, Beam Transport, Cleanliness* | | | | | |
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| --- | --- | --- | --- |
| ***RSS History*** | | | |
| RSS TC ID/revision | RSS - Date of Creation | RSS - Date of Last Modification | Systems Engineer |
| 020354/A.001 | 19.03.2020 | 19.03.2020 | Aleksei Kuzmenko |
| 020354/A.002 | 23.03.2020 | 23.03.2020 | Aleksei Kuzmenko |
| 020354/A.003 | 01.04.2020 | 01.04.2020 | Aleksei Kuzmenko |
| 020354/A.004 | 21.04.2020 | 21.04.2020 | Aleksei Kuzmenko |

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| --- | --- | --- | --- |
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| --- | --- | --- | --- | --- |
| ****Revision History**** | | | | |
| Revision Number | Revision Made by | Date of Revision | Revision description | TC Revision |
| 1. | M. Taylor | 06.03.2020 | RSD draft creation | A |
| 2. | M. Taylor,  A. Kuzmenko | 23.03.2020 | RSD update, version for internal review | B |
| 3. | A. Kuzmenko | 21.04.2020 | RSD update after 1st review process | C, D |
| 4. | M. Taylor,  A. Kuzmenko | 07.05.2020 | RSD update after 2nd review; final version for approval | E |

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# Introduction

## Purpose

This Requirements Specification Document (RSD) describes the requirements and constraints for the design, manufacturing and delivery of the MOB Vacuum Chamber (MOB-VC). This chamber will be delivered to the ELI Beamlines facility by the Supplier and then installed into the E3 experimental hall by ELI with support from the Supplier. The chamber is designed to enable beam manipulation for L3 and L4p lasers prior to their entry into the P3 experimental chamber. The current MOB-VC concept is approximately 4.2 x 3.3 x 3.2 meters. The primary sub-assemblies are the vacuum chamber assembly, the breadboard assembly and the support structure. The MOB-VC will house a variety of highly sensitive optical components including the following: turning mirrors, deformable mirrors, periscope mirrors, etc. One major feature is its utilization of a large number of removable panels. This is required for two reasons: 1. To provide regular access to the optical components; 2. To provide flexibility of beam input and output locations.

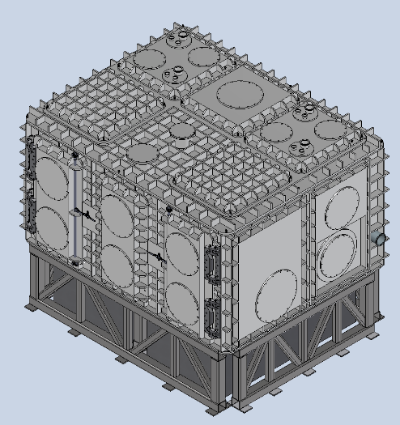
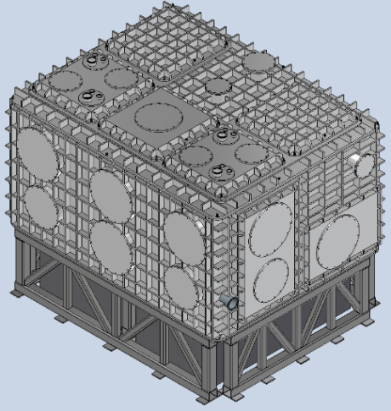
 

Figure 1: MOB Vacuum Chamber with all components. Note this represents an initial concept. Detailed design and analysis shall be carried out by the supplier.

The breadboard assembly shall consist of a first level and a second level. The breadboard assembly must have a low vibration response and thus high first Eigenfrequency. To enable this, it shall be mechanically decoupled from the vacuum chamber assembly and will have its own support legs which will pass decoupled through the bottom of the vacuum chamber. An edge welded bellows connection shall be used to make the vacuum seal between the vacuum chamber assembly and the breadboard legs.

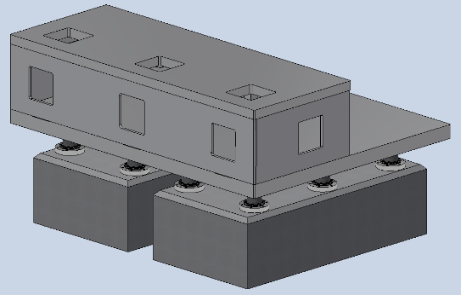
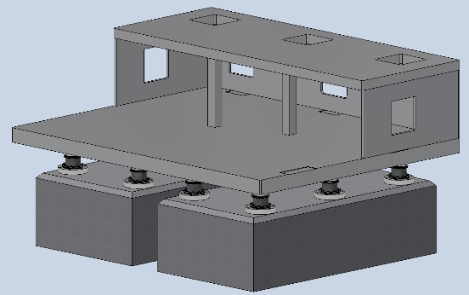
 

Figure 2: MOB-VC Breadboards and support structure. Note this represents an initial concept. Detailed design and analysis shall be carried out by the supplier.

This RSD also acts as the parent document for the technical requirements that need to be addressed in lower-level design description documents.

## Scope

This RSD contains all of the technical requirements for the following product: MOB Vacuum Chamber (Tender Code: TP20\_066). This includes: functional, design, performance, transportation, installation support, safety, quality and verification requirements.

The MOB-VC is an integral part of the beam transport to the P3 Experimental Chamber within the experimental hall, E3. This product is registered in the PBS software under the following PBS code: E.E3.MOB.1.

Within this procurement the following scope of work is required:

* Finalization of the MOB-VC design
  + Complete optimization of the design
  + Complete FEA stress analysis of the Vacuum Chamber
  + Complete FEA modal analysis of the Vacuum Chamber
  + Complete FEA modal analysis of Breadboard assembly
  + Complete detailed design of MOB-VC components
* Manufacturing
  + Manufacture all components
  + Cleaning of all components
  + Preparation of all components for delivery
  + Factory Acceptance Testing
* Delivery
* Installation Support

## Terms, Definitions and Abbreviations

For the purpose of this document, the following abbreviated terms apply:

| **Abbreviation** | **Meaning** |
| --- | --- |
| A | Analysis (as a Verification method) |
| A-R | Analysis Report |
| CA | Contracting Authority (Institute of Physics AV CR, v. v. i.) |
| CDR | Critical Design Review |
| CDR-R | CDR Report |
| E3 | Experimental Hall 3 |
| ELI | Extreme Light Infrastructure |
| ESD | Electrostatic Discharge |
| EUV | Extreme Ultraviolet |
| FEA | Finite Element Analysis |
| FEM | Finite Element Method |
| FFKM | Perfluoroelastomer |
| FKM | Fluoroelastomer polymer |
| FOS | Factor of Safety |
| I | Inspection (as a Verification method) |
| MOB-VC | MOB Vacuum Chamber |
| NCR | Nonconformity Report |
| NDT | Non-Destructive Testing |
| NVR | Non-Volatile Residue |
| R | Review of design or documentation (as a Verification method) |
| RSD | Requirements Specification Document |
| T | Test (as a Verification method) |
| T-R | Test Report |
| ULO | Ultra-Low Outgassing |
| VCD | Verification Control Document |

## Reference documents

|  |  |
| --- | --- |
| **Number of document** | **Title of document** |
| RD-01 | 00265316-00\_RD-01\_3D Model and Drawings\_01042020\_01 |
| RD-02 | 00211646-D\_Cleanlines and Contamination Control in Vacuum system |
| RD-03 | 00142371-B\_Design Safety Engineering Standards/Guidelines |
| RD-04 | 00261917-A\_VCD\_MOB Vacuum Chamber\_TP20\_066 |
| RD-05 | 00115311-C\_Alignment Marks System |

## References to standards

If this document includes references to standards or standardized/standardizing technical documents the CA permits equal solutions to be offered by the Supplier. The CA will not reject a Supplier’s bid, upon the Supplier proves that the supplies, services or works offered meet the requirements described, including references to standards or technical documents.

# System Overview

The MOB-VC is a critical component within the beam transport infrastructure at ELI Beamlines and is integral in transporting the high powered lasers into the P3 Experimental vacuum chamber. It will replace the current vacuum chamber which houses only one 45° turning mirror. The MOB-VC will be designed for modularity allowing users to employ a wide variety of optical layouts depending on the needs of each individual experiment. In order to provide access into and modularity of the chamber, it will be outfitted with a range of panels and doors. The MOB-VC will be connected to one beamline (L3) via a ISO-F DN500 pipe and another beamline (L4p) via a ISO-F DN630 pipe. Each beam will have the possibility to exit from the chamber on any side. However, the primary exit points will be the P3 facing side from the top three ports and lower center port. As a result, the MOB-VC requires a 2 level breadboard. Additionally, the chamber must be prepared to be outfitted with turbomolecular vacuum pumps, have a connection to the E3 roughing vacuum system, and several ports which will act as cable feedthroughs or diagnostic ports, though all of these additional components are out‑of-scope for this project.

The rest of this document outlines all of the requirements to be met by the Supplier in the completion of the MOB-VC.

## Summary of Cleanliness Requirements

A critical requirement for the MOB-VC is its cleanliness. The MOB-VC will be connected with the beam transport infrastructure, thus it needs to maintain a similar cleanliness level. The non-vacuum surfaces of all components of the MOB-VC shall minimally be cleanable to the requirements of class 7 cleanrooms according to ČSN EN ISO 14644 (equivalent to EN ISO 14644) or equivalent. All vacuum surfaces of the MOB-VC shall meet the following cleanliness levels per MIL–STD-1246C and superseded by IEST-STD-CC1246D (or equivalent):

* Particle level: 130 or better;
* The non-volatile residue (NVR): A/10 = 0.1 or better.

One method to achieving this level of cleanliness is to use electropolishing on stainless steel vacuum surfaces as well as proper cleanliness procedures both during manufacturing and installation. More detailed information is described in Sections 5 and 6.

## Required Certifications and Experience needed for contract realization

* ISO 1609:1986 – Vacuum Technology – flange dimensions (or equivalent);
* ISO 2861:2013 – Vacuum Technology – Dimensions of clamped type, quick-release couplings (or equivalent);
* All conductive parts must be designed according to the following Czech applicable standards:
  + ČSN 33 2000-4-41 (or equivalent);
  + ČSN 33 2000-5-54 (or equivalent);
* ČSN EN ISO 3834 (equivalent to EN ISO 3834) – Quality requirements for fusion welding of metallic materials (certification for welding) (or equivalent);
* ČSN EN ISO 9712 (equivalent to EN ISO 9712), Non-destructive testing – qualification and certification of NDT personnel (for non-destructive testing certification or equivalent for personnel performing leak tests) (or equivalent);
* ČSN EN 1779 (equivalent to EN ISO 1779), Non-destructive testing – Leak testing – Criteria for the method and technique selection (or equivalent);
* Experience and ability to fabricate vacuum vessels according to “AD 2000 Regelwerk” (or equivalent);
* Full system and safety responsibility for the completion of the design, fabrication, delivery and installation of the MOB-VC shall be a part of this tender/contract;
* The Supplier shall have ČSN EN 1090-1 and ČSN EN 1090-2 (equivalent to EN 1090-1 and EN 1090-2) and at least EXC 3, but preferably EXC 4, certification (or equivalent).

If the Supplier has no such certification, its certified subcontractor or certified authority shall perform a full system safety assessment and shall provide a certification of the safety compliance of the entire MOB-VC, including compliance of the support structures to the requirements described in the ČSN EN 1090-1 and ČSN EN 1090-2 (equivalent to EN 1090-1 and EN 1090-2) (or equivalent).

# Operational Conditions

REQ-028873/A

All components shall work in the following operational conditions:

* Temperature (standard during operation): 21 °C. In the case of climate control system failure, the MOB-VC needs to remain safe at 21 ± 10 °C;
* Relative humidity: 40 – 80 %;
* Internal pressure: 10e-7 mbar;
* External pressure: 1 atm (1.01325 bar);
* ISO 7 cleanroom compatibility according to ČSN EN ISO 14644 (equivalent to ISO 14644) is mandatory for all surfaces outside of the vacuum surfaces.

*NOTE: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R – review, T - test

# Design requirements

The general requirements specified herein in section 4.1 refer to all components of the MOB-VC and the next sub-sections 4.2-4.4 of the design requirements provide requirements of each of the main assemblies which make up the MOB-VC. These sub-assemblies are:

* Vacuum Chamber;
* Breadboard Assembly;
* Support Structure.

## General requirements

REQ-028874/A

The final design of the MOB-VC shall be developed by the Supplier using the ELI Beamlines conceptual design and 3D model as a starting point (see RD-01; section 1.4).

Verification method: R - review

REQ-028875/A

As part of the design finalization, the Supplier shall perform FEA analysis of the MOB-VC.

*NOTE: Load cases, which shall be MINIMALLY addressed are:*

* *FEA Stress analysis of Vacuum load*
* *FEA Stress analysis of Vacuum load and temperature control failure, i.e. thermal expansion and contraction caused by ±10°C temperature swing.*
* *FEA Stress analysis of Vacuum load and 5X 150kg loads on the top plate*
* *FEA Stress analysis during TMP crash or burst. (see REQ‑028919/A)*
* *FEA Modal analysis of MOB-VC*
* *FEA Modal analysis of Breadboard Assembly*

Verification method: R – review, A – analysis

REQ-028876/A

All components exposed to vacuum shall be high vacuum (i.e. 10e‑7 mbar) compatible and shall be manufactured using materials and procedures that will guarantee low outgassing rate (including seal and weld integrity).

Verification method: R – review

REQ-028877/A

Precautions shall be taken to avoid trapped volumes in vacuum spaces which result in virtual leaks. These spaces shall be suitably vented.

*NOTE: This includes utilizing vented screws which are designed for ultra-high-vacuum and venting of volumes trapped by the O-rings.*

Verification method: R – review

REQ-028878/A

The MOB-VC shall include pin holes for mounting alignment points which will be used for alignment and levelling of the MOB-VC. These alignment points shall be designed using the requirements outlined by RD-05. The positions of the alignment points shall be placed such that they are accessible when the MOB is fully assembled and spaced adequately to provide the leveling precision described in REQ-028885/A. The minimum number of points:

* Vacuum Chamber Main Body – 8;
* Vacuum Chamber Top Plate – 4;
* Breadboard Assembly – 4 / breadboard;
* Granite Foundations – 4 / part.

*NOTE: The alignment points shall be included on both the Vacuum Chamber and the breadboard assembly.*

Verification method: R – review, I - inspection

REQ-028879/A

All conductive/metal parts shall have grounding points so that they can be protected against Electrostatic Discharge (ESD).

Verification method: R – review, I - inspection

REQ-028881/A

Screws shall be compatible with the material of the corresponding threaded hole.

Verification method: R – review

REQ-028882/A

All vacuum surfaces shall be finished according to general UHV guidelines and stainless steel parts will subsequently be electropolished (or similar) to a surface roughness Ra ≤ 0.8 µm.

Verification method: R – review

REQ-028883/A

The outer (non-vacuum) surface finish of components shall comply with the requirements of cleanrooms of class 7 according to ČSN EN ISO 14644 (equivalent to ISO 14644).

*NOTE: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R – review, T - test

REQ-028884/A

Outer surface finish of vacuum components (chambers, blank flanges, etc.) shall be blasted with uniform glass beads or have any other clean room ISO 7 compliant adequate surface finish with low optical reflectivity.

Verification method: R – review, I - inspection

REQ-028885/A

The design of the breadboard assembly and vacuum chamber shall provide a means to perform fine adjustment in order to level and align the MOB-VC. The precision for each assembly shall be:

* The Vacuum Chamber: less than ±1.0 mm along each axis;
* The Breadboard Assembly: Less than ±0.5 mm along each axis for each individual breadboard.

*NOTE: This can be obtained by properly adjusting and installing granite foundations with proper tolerances applied to the breadboard legs, breadboard connecting elements and the breadboard itself.*

Verification method: R – review, T - test

REQ-028886/A

Tolerances of all parts shall be, at minimum, according to ČSN ISO 2768-mK (equivalent to ISO 2768-mK) (or equivalent).

*NOTE: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R – review

REQ-028887/A

The maximum size of any part shall fit through the entrance door of the E3 hall sized: 3.1 (width) x 2.4 (height) meters.

Verification method: R – review

REQ-028888/A

The maximum lifting capacities of the ELI lift are:

* 12.5 tons when traveling downward
* 10.0 tons when traveling upwards

Thus, the maximum weight of any single part shall be < 10 tons.

Verification method: R – review

REQ-028889/A

The MOB-VC shall accommodate the current connection to the L3 beam transport and ensure that there is free movement around the chamber.

*NOTE: Free movement means that the minimum pinch point within E3 as a result of the MOB-VC is 1.1m.*

Verification method: R – review, T - test

## Vacuum Chamber

REQ-028890/A

The minimum inner dimensions of the vacuum chamber shall not be less than 3.6 (width) x 2.8 (depth) meters.

Verification method: R – review, T - test

REQ-028891/A

The Supplier shall adhere to the following standard with regards to the design of the vacuum chamber: “AD 2000 Regelwerk”, EN 13445 or equivalent.

Verification method: R – review, A – analysis

REQ-028892/A

Deformation of all surfaces which are maintaining a vacuum seal shall not reduce the compression of the O-ring to < 10%. The maximum allowable sliding of sealing surfaces shall be limited to 10% of the nominal O-ring diameter. Otherwise, the maximum allowable deflection for any part of the vacuum chamber shall be < 3 mm.

Verification method: R – review, T - test

REQ-028893/A

The Supplier shall perform modal analysis of the vacuum chamber. Fundamental frequencies which shall be avoided include 50 Hz (±5 Hz), 100 Hz and 110 Hz.

Verification method: R – review, A – analysis

REQ-028894/A

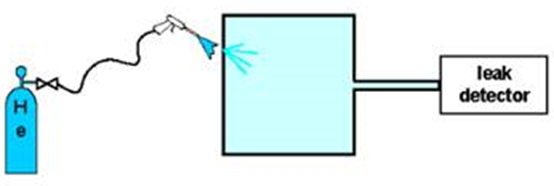
The assembly shall be designed for operation at vacuum level pressure differential equal to 1 atm (e.g. approximately 10e-7 mbar vacuum level).

Verification method: R – review, T - test

REQ-028895/A

The measured single leak rate using He detector shall be less than 1.0E-9 mbar·l/sec. The single (local) vacuum leak test (He spray test) shall be performed according to ČSN EN 1779 (equivalent to EN 1779); method A.3, local test with high enough detection limit/resolution to verify that the single He leaks rates are   
≤ 1 x 10-9 mbar·l/sec.

Schematics for the test:



*NOTE: The CA consider the UHV type vacuum welds to have   
≤* 1 x 10-11 mbar·l/sec *leak rate.*

Verification method: T - test

REQ-028896/A

The total leakage rate shall be less than 1.0E-6 mbar·l/sec.

Verification method: T - test

REQ-028897/A

The materials used for the vacuum chamber manufacture shall be one or a combination of:

* EN 1.4307 (AISI 304L);
* EN 1.4404 (AISI 316L).

*NOTE: The use of other materials which provide the same level of vacuum compatibility and structural integrity can be used, but shall be approved with the CA.*

Verification method: R – review

REQ-028898/A

O-ring groove designs shall be a dove-tail cross-section. The final groove geometry shall be approved by the CA.

*NOTE: If feasible, a feature shall be included which allows O-rings to be removed without being damaged.*

Verification method: R – review, I - inspection

REQ-029692/A

O-ring seals shall be heat treated at 100 °C while exposed to ~1E-5 mbar vacuum to reduce outgassing to ≤ 4 x 10-9 mbar\*l/s/cm² after ≤ 8 hours of pumping.

*NOTE 1: The O-rings are considered to meet the outgassing requirements and will be accepted if the measured RGA meets the following:*

* *43 AMU Peak amplitude shall be ≤ 1/10 of the 44 AMU peak*
* *The amplitude of all peaks > 44 AMU peak shall be no higher 1/100 of the 44 AMU peak with 1.1% of the 44 AMU peak of isotope 13C in CO2 subtracted from the 45 AMU peak.*
* *There are no significantly high AMU components above the background or instrument noise floor up to 200 AMU*

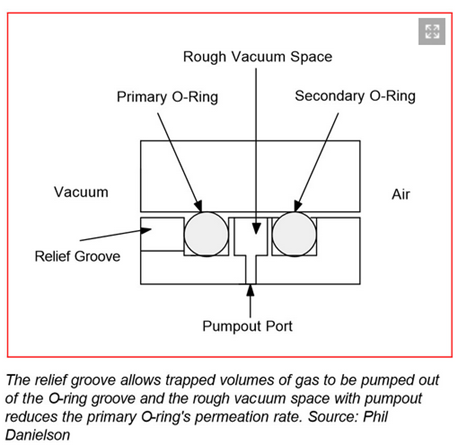
*NOTE 2: The documented validation of the outgassing or all O-rings shall be part of the order.*

*NOTE 3: The CA has the capability to RGA test the O-rings.*

Verification method: R – review, I - inspection

REQ-028899/A

All vacuum sealing faces shall be designed to perform without the use of vacuum grease. One implication of this shall be the implementation of differential pumping. Differential pumping shall be used on all removable panels and doors as well as the Main Top Plate (see RD‑01 for details). The schematics of differential pumping with a double O-ring design and a relief groove is shown below:



Verification method: R – review, I - inspection

REQ-028900/A

The vacuum chamber will require users to do work from the top, thus, the Supplier shall include in the design features which provide the adequate level of safety for this type of work. (This is currently not included in RD‑01).

*NOTE:* *Examples of such safety features include:*

* *A railing around the edges (bolted not welded);*
* *Hook points for attaching a harness;*
* *Means to get on top of the chamber safely.*

Verification method: R – review, I - inspection

REQ-028902/A

Lifting eyes shall be supplied to aid safe manipulation of the chambers removable panels.

Verification method: R – review, I - inspection

REQ-028903/A

The vacuum chamber shall include a large number of removable plates and doors to increase the modularity of the chamber. The number of panels/doors and their locations are documented in RD-01.

Verification method: R – review, I – inspection

REQ-029195/A

The vacuum chamber shall be designed to match the bolt hole pattern and orientation of existing equipment within the E3 hall. This information shall be provided to the supplier by the CA (see RD-01).

Verification method: R – review, I - inspection

REQ-029196/A

The vacuum chamber doors shall provide a means to maintain safety of workers while working inside the chamber, such as features for implementing a lock-out/tag-out system.Verification method: R – review, I - inspection

REQ-029500/A

The vacuum chamber Top Plate shall have several M12 holes as specified within RD-01.Verification method: R – review, I - inspection

## Breadboard Assembly

REQ-028904/A

The materials used for the breadboard assembly shall be optimized to meet the stability and cleanliness requirements of the chamber.

*NOTE 1: Recommended materials include:*

* *Aluminum (e.g.* EN AW-5083, EN AW-6082 or EN AW-6061;
* *Stainless Steel (e.g. EN 1.4307 (AISI 304L) or EN 1.4404 (AISI 316L).*

*NOTE 2: The use of other materials is possible, but must be agreed with CA. The CA shall agree on such other materials, if these show the same or better qualities for the intended purpose than the ones suggested above.*

Verification method: R – review

REQ-028905/A

The upper breadboard shall support up to 600 kg of optical equipment. This represents ~3x 200kg mirror mounts.

Verification method: R – review, A – analysis

REQ-028906/A

The lower breadboard shall support up to 2.0 tons of optical equipment. This represents ~10x 200kg mirror mounts.

Verification method: R – review, A – analysis

REQ-028907/A

The structure connecting the lower and upper breadboards shall be designed such that it provides the maximum amount of free space for optics and minimizes interference with laser beam paths.

*NOTE: Information anticipated optical layouts can be found in RD-01 drawings.*

Verification method: R – review

REQ-028908/A

The breadboard assembly shall be designed to have fundamental frequency > 120 Hz best effort while loaded the optical masses described in REQ-028905/A and REQ-028906/A. If 120 Hz is not feasible, the measured fundamental frequencies shall not be any multiple of 50 Hz (±2 Hz) or 110 Hz (±2 Hz). The breadboard design shall be approved by the CA prior to commencement of manufacture.

*NOTE: For this analysis the upper breadboard shall be assumed to have 3x 200 kg mirror mounts and the lower breadboard shall be assumed to have 10x 200 kg mirror mounts. The mounts shall be equally spaced, they have a surface area 740mm x 300mm (w x d). The height of the COG for the mounts is 150mm.*

Verification method: R – review, A – analysis, T – Test

REQ-028909/A

Vibration decoupling bellows for vacuum sealing shall be utilized and shall be edge welded bellows.

Verification method: R – review, I - inspection

REQ-028910/A

The breadboards shall have M6 tapped holes with a depth   
30 – 35 mm. Though not fully tapped, the holes shall be through-holes to reduce the effort required for cleaning.

Verification method: R – review, I - inspection

REQ-028911/A

The breadboard hole spacing shall be 50 mm on a Cartesian grid.

Verification method: R – review

REQ-028912/A

The breadboards tapped holes shall not be pressed but rather cut to allow the cleaning to a non-volatile residue (NVR) level of A/10, i.e. 0.1 µg/cm2.

Verification method: R - review

REQ-028913/A

Each breadboard mounting surface shall have a surface flatness of 0.1 mm / 1 m2 or better for both the lower and upper breadboards.

Verification method: R – review, T - test

## Support Structure

REQ-028915/A

The support structure shall include granite foundations which the breadboard assembly shall be mounted to.

*NOTE: The vacuum chamber may be mounted directly to the granite or may have a separate steel structure which anchors directly into the concrete floor in the E3 hall. The floor of the E3 hall may not be drilled at any location due to the reinforcement bars and the water pressure of the ground below the floor. The CA shall provide scans of the E3 floor to ensure acceptable placements for all anchors.*

Verification method: R – review, I - inspection

REQ-028917/A

The Supplier shall perform an analysis validating that the support structure design is capable to support all vacuum forces, thermal loads and bending moments. It shall maintain a FOS > 2.0.

*NOTE: Analysis should be completed assuming the vacuum chamber is connected to the other vacuum systems via and “un-bridged” (i.e. freely movable) bellows.*

Verification method: R – review, A – analysis

REQ-028944/A

The fixation of the support structure shall be designed so that it can be performed using screws/anchors and cleanroom class 7 ultra-low-outgassing epoxy to the monolithic floor.

*NOTE: Non-class 7 certified epoxies may be utilized if approved by the CA beforehand.*

Verification method: R – review, I - inspection

## Interfaces

REQ-028918/A

The Supplier will design interfaces for all of the connections given in the RD-01(see section 1.4).

*NOTE 1:   All interfaces shall be in accordance with the ISO 1609:1986 and ISO 2861:2013 standards (or equivalent).*

*NOTE 2: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R – review

REQ-028919/A

Assessment of the safety aspects of the turbopump connections shall be performed by the Supplier (see section 1.4). There are two sizes of turbopumps which should be considered in this assessment.

*NOTE 1: 1x ISO320F TMP. Ex: Edwards STP-iXA3306C-ISO320F; Requirements from the manual state:*

* *Destructive Torque (kNm) = 71.2;*
* *12x M12 Bolts;*
* *Bolt Material: Carbon-Alloyed Steel;*
* *Bolt Class: 12.9 or more.*

*NOTE 2: 2x ISO250F TMP. Ex: Edwards STP-iXA3306C-ISO250F. Requirements from the manual state:*

* *Destructive Torque (kNm) = 48.1;*
* *12x M10 Bolts;*
* *Bolt Material: Carbon-Alloyed Steel;*
* *Bolt Class 12.9 or more.*

*NOTE 3: Further information about the turbopumps can be provided by the CA upon request.*

Verification method: R – review, A – analysis

REQ-028920/A

All sealing O-rings used for the MOB-VC shall be made of FKM or FFKM materials or equivalent.

Verification method: R – review, I - inspection

# Manufacturing Requirements

REQ-028921/A

A material certificate according to ČSN EN 10204-2.2/3.1 (equivalent to EN 10204-2.2/3.10) shall be provided for all vacuum materials and parts. These certifications shall be made available to the CA.

*NOTE: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R – review

REQ-028922/A

Any oxidation of vacuum surfaces, especially in the range of weld joints, shall be removed such that the cleanliness requirements are met (see section 5.1).

Verification method: T – test, I - inspection

REQ-028923/A

Sealing surfaces shall be free of scratches or dents.

Verification method: I - inspection

REQ-028924/A

The surface finish of all vacuum surfaces shall be better than Ra 0.8. The surface finish on all other surfaces shall be uniform. It is preferred that electro-polishing be utilized on stainless steel vacuum surfaces in order to achieve the required cleanliness levels.

*NOTE: Other finishing technologies which yield an acceptable level of cleanliness may be used if agreed with the CA.*

Verification method: R – review, I - inspection

REQ-028925/A

Continuous vacuum sealing welds shall be completed on the vacuum side of the vessel. If tack/stabilizing welding is required, it may be used on the non-vacuum side of the chamber only.

Verification method: R – review, I - inspection

REQ-029694/A

The Supplier shall use the following tolerable welding procedures: inert-gas tungsten-arc welding (TIG), inert-gas metal-arc welding (MIG, MAG), plasma, electron beam, or laser welding.

Verification method: R – review, I – inspection

REQ-028928/A

The Supplier shall supply the CA with an extra set of O-rings for each custom O-ring.

Verification method: I - inspection

## Cleaning requirements

All vacuum surfaces and vacuum components require cleaning compatible with high-energy laser e-beam coated optics. Failure to do this will cause catastrophic damage to the highly sensitive optics housed by the MOB-VC. Specifically, hydrocarbons are known to degrade the laser damage threshold of high-power laser optics. The cleanliness requirements detailed below are similar to ultra-high vacuum systems and the standards of EUV lithography/semiconductor industry. Only a monolayer of molecules on the surfaces inside of the vacuum is tolerable.

REQ-028929/A

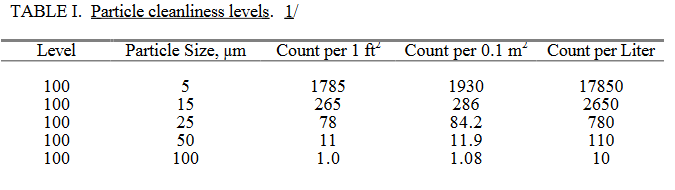
The Supplier shall provide the CA with the description of the cleaning procedure for vacuum components which will be reviewed and requires approval from the CA.

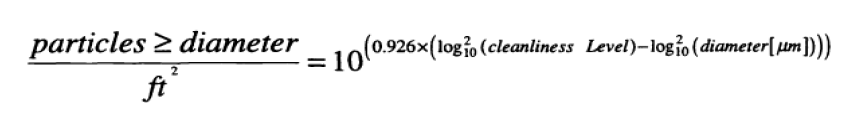
Verification method: R – review

REQ-028930/A

All parts shall be cleaned to meet a particle cleanliness level of 130 guaranteed per MIL–STD-1246C (or equivalent standard) superseded by IEST-STD-CC1246E for particles with size > 5 μm.

*NOTE 1: The table below shows the particle cleanliness level 100.*





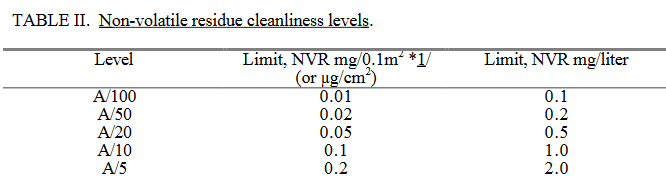
*NOTE 2: The CA reserves the right to perform this test instead of the Supplier. In such a case the CA shall inform the Supplier at least 2 weeks in advance. The Supplier will still be responsible to meet the requirement based upon the test result. The procedure that would be used is described in RD-02.*

Verification method: R – review, T - test

REQ-028931/A

The total non-volatile residue (NVR) testing shall be performed for all parts of the MOB-VC. The NVR level shall be A/10 per MIL-STD1246C (or equivalent standard) superseded by IEST-STD-CC1246E, i.e. < 0.1 μg/cm2.

*NOTE 1: The table below shows the non-volatile residue cleanliness levels of the MIL-STD1246C.*



*NOTE 2: The CA reserves the right to perform this test instead of the Supplier. In such a case the CA shall inform the Supplier at least 2 weeks in advance. The Supplier will still be responsible to meet the requirement based upon the test result. The procedure that would be used is described in RD-02*

Verification method: R – review, T - test

REQ-029197/A

Where validating directly the NVR is not feasible, and when agreed by the CA, the Supplier may utilize instead a Residual Gas Analysis (RGA) Test. RGA tests for the MOB-VC shall meet the same requirements as the L3 beam transport vessel as described in Table 4 of RD-02 (see section 1.4).

*NOTE 1: Minimally the RGA meets the following requirements*

* *The amplitude of all peaks > 44 AMU are no higher than 1/100 of the 44 AMU peak*
* *The peak at 43 AMU is < 1/10 of the 44 AMU peak with 1.1% of 44 AMU peak of isotope 13C in CO2 subtracted from 45 AMU peak.*
* *Check that there are no “significant” high AMU components above the background or instrument noise floor up to 200 AMU.*

*NOTE 2: The CA reserves the right to perform this test instead of the Supplier. In such a case the CA shall inform the Supplier at least 2 weeks in advance. The Supplier will still be responsible to meet the requirement based upon the test result. The procedure that would be used is described in RD-02.*

Verification method: R – review, T - test

REQ-028932/A

The Supplier shall provide procedures for the particle, the NVR, and RGA cleanliness levels verification to the CA. The CA shall approve of these procedures prior to test completion and acceptance.

*NOTE: See RD-02 and RD-03 for the CA’s approved methods for clean procedures and procedures for verifying cleanliness.*

Verification method: R – review

## Factory Acceptance Testing (FAT)

REQ-029995/A

The Supplier shall perform factory acceptance testing after cleaning and prior to delivery:

* Particle level testing (see REQ-028930/A);
* RGA testing (see REQ-029197 /A);
* Leak testing (see REQ-028895/A and REQ-028896/A).
* Dimensional check based upon RSD and RD-01 requirements
* General Over view based upon RSD and RD-01 requirements (e.g. ensuring all proper flanges and connections)

*NOTE 1: Procedures for all tests shall be approved by the CA, if all requirements stipulated in this RSD regarding the procedures are observed.*

*NOTE 2: The Supplier shall allow the representatives of the CA (up to 6 persons, unless parties agree otherwise) to be present during the testing so that the necessary cooperation with the Supplier (if any is necessary) is secured.*

Verification method: R – review, T - test

# Transportation requirements

## General requirements

REQ-028941/A

The Supplier will complete packaging and delivery in the presence of the CA.

Verification method: R – review

REQ-028933/A

The transportation to the ELI Beamlines facility in Dolní Břežany of the MOB-VC shall be conducted by the Supplier.

Verification method: I - inspection

REQ-028934/A

The crates shall be labelled with the contents of the crate, i.e. with all part numbers of the contained components.

Verification method: I - inspection

REQ-028935/A

All parts of the MOB-VC shall be inspected after arrival at the CA facility to ensure no damage occurred during transport.

Verification method: I - inspection

## Packaging for transport – Ensuring Cleanliness

List of Terms for this Section:

1. **ULO Polyethylene ("ULO")**: Ultra-Low Outgassing polyethylene bag or sheet ≥150 µm thick, with a certified NVR level of ≤ 0.14 µg/cm2 (certified ULO polyethylene or equivalent).
2. **Part Specific Label**: A cleanroom label identifying product information in accordance with contract documents.
3. **Intimate Layer**: The innermost layer of ULO and which is in direct contact with the MOB-VC.
4. **Outer Layer**: The outermost layer of ULO used in packaging of the MOB-VC.
5. **Label of Cleaner**: Cleanroom label with the following information: Cleaner name and location, cleaning process (es) used and date of cleaning.
6. **Cleaned Components/Assemblies:** Components/Assemblies that clean enough to satisfy cleaning requirements (i.e. components and surfaces which will be exposed to vacuum).

REQ-028937/A

Cleaned components/assemblies shall be double packaged in ULO foil and sealed.

Verification method: R – review, I - inspection

REQ-028938/A

All cleaned components/assemblies shall be dry prior to packaging.

Verification method: R – review, I - inspection

REQ-028939/A

When possible, the cleaner shall ensure that part number and, if applicable, serial numbers on the Part Specific Label match with that of the components/assemblies in that bag. Such label shall be at the inner and outer packaging ULO foil.

Verification method: R – review, I - inspection

REQ-028940/A

The cleaned components/assemblies shall be fully covered by ULO and then sealed.

Verification method: R – review, I - inspection

REQ-028941/A

Assembly and packing of the MOB-VC shall take place under controlled conditions in a cleanroom class 7 environment or better according to ČSN EN ISO 14644 (equivalent to EN ISO 14644).

*NOTE 1: The ISO 14644 certification of the Supplier’s cleanrooms is not required in lieu of an inspection by the CA.*

*NOTE 2: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R – review, I - inspection

# Installation Support

REQ-028941/A

The Supplier will review and provide input to the MOB installation procedures produced by the CA.

Verification method: R – review

REQ-028941/A

The Supplier will provide 1-2 individuals to assist in the installation of the MOB chamber.

Verification method: R – review

# Safety requirements

REQ-028947/A

The Supplier shall perform hazard identification and risk assessment of the MOB-VC as a part of the design process.

Verification method: R – review, A – analysis

REQ-028948/A

The Supplier shall be compliant with all regulations described in the Design Safety Engineering Standards/Guidelines (see RD-03 of reference documents).

Verification method: R – review

# Quality requirements

## General Quality Requirements

REQ-028950/A

The Supplier shall identify a Quality manager, which will be responsible for implementing and performing management and other Quality disciplines and functions to ensure fulfilment of all the requirements described in this RSD.

Verification method: R - review

REQ-028951/A

The Supplier shall define and document the responsibilities and the interfaces of the quality functions, either external or internal, involved in the contract.

Verification method: R - review

REQ-028952/A

The Supplier's personnel shall be certificated according to ČSN EN ISO 9712: 2013 (equivalent to EN ISO 9712:2012), Non-destructive testing - Qualification and certification of NDT personnel.

*NOTE: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R - review

REQ-028953/A

If the Supplier’s Quality organization delegates quality assurance tasks to any another organization it shall be done in a documented and controlled way monitored by the Supplier.

Verification method: Not To Be Tracked within VCD

REQ-028954/A

The Supplier shall prepare, implement and maintain a quality plan which shall be approved by the CA.

*NOTE: The CA can assist with the quality plan definition.*

Verification method: R - review

REQ-028955/A

The Supplier shall report quality plan progress to the CA as part of product assurance activities.

Verification method: Not To Be Tracked within VCD

## Documentation and data control

REQ-028956/A

The Supplier shall provide the following relevant manufacturing documents:

* Full technical documentation (including final 3D model and manufacturing drawings, see REQ-028874/A, REQ-028960/A and REQ-028961/A);
* Breakdown list as-built or/and material list (see REQ-028897/A, REQ-028904/A, REQ-028920/A, REQ-028921/A);
* All approved “requests for deviation/wavier” (see REQ-028964/A).

Verification method: I – inspection

REQ-028957/A

The Supplier shall provide to the CA the Product User Manual as part of the delivered MOB-VC. The Manual shall include the instructions and descriptions regarding the following procedures:

* transport, handling, storage;
* installation, alignment and cleaning;
* safe operation and maintenance procedures.

Verification method: R - review

REQ-028958/A

All tests shall be performed by the measuring instruments with the valid metrological confirmation.

*NOTE: The CA can request the Supplier to provide the valid Calibration Certificates.*

Verification method: R - review

REQ-028959/A

All documentation shall be supplied in the English language.

Verification method: R - review

REQ-028960/A

The Supplier shall prepare and supply the detailed manufacturing drawings for the MOB-VC in \*.pdf format and in one (two preferred) of the following file formats:

* \*.dwg;
* Native data
  + Drawing files for Autodesk Inventor version 2020,
  + Drawing files for Siemens NX.

Verification method: R – review, I - inspection

REQ-028961/A

The Supplier shall prepare and supply the updated 3D model of the MOB-VC in one (two preferred) of the following formats:

* Universal format: step \*.STP;
* Native data
  + Part/Assembly files for Autodesk Inventor version 2020,
  + Part/Assembly files for Siemens NX.

Verification method: R – review, I - inspection

REQ-028962/A

The Supplier shall use also the following data formats:

* \*.JPG, \*.PNG, \*.PDF, \*.HTML;
* text processors \*.doc, \*.docx; OpenDocument Format;
* spreadsheet processors \*.xls, \*.xlsx; OpenDocument Format;
* presentations \*.ppt, \*.pptx; OpenDocument Format.

Verification method: Not To Be Tracked within VCD

REQ-028963/A

The MOB-VC shall be marked on the outside with the following information:

* Manufacturer;
* Date of manufacture;
* Manufacturer reference (e.g. serial number).

Verification method: I - inspection

## Nonconformity Control System

REQ-028964/A

The Supplier shall establish and maintain a nonconformity control system compatible with ČSN EN ISO 9001 (equivalent to EN ISO 9001).

*NOTE: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: Not To Be Tracked within VCD

# Verification requirements for the Supplier

## General requirements

REQ-028966/A

The verification process shall be performed by the Supplier to demonstrate that the delivered MOB-VC meets the specified requirements of the CA. The verification process consists of:

1. **Verification planning** (via VCD, see section 10.3);
2. **Verification execution and reporting** (see sections 10.3 and 10.4);
3. **Verification control and close-out** (see section 10.5).

Verification method: Not To Be Tracked within VCD

REQ-028967/A

The Supplier shall assign clear responsibility for the implementation of the verification process including all activities defined in REQ-028966/A.

Verification method: R - review

## Verification Documentation

REQ-028968/A

The Supplier shall establish and maintain the system of verification process documentation.

Verification method: Not To Be Tracked within VCD

REQ-028969/A

Verification documentation shall consist of following basic types of documents:

* **Verification Reports**, including CDR Report, Tests and Analyses reports (see section 10.4);
* **VCD, Verification Control Document** (see section 10.3).

Verification method: Not To Be Tracked within VCD

REQ-028970/A

The verification reports shall be submitted to the CA for the review as agreed with the CA after corresponding verification activity completion, within the time frame agreed with the CA in the **VCD**.

*NOTE: Verification activity can be design review, test, analysis or inspection of the MOB-VC (see REQ-028977/A).*

Verification method: Not To Be Tracked within VCD

## Verification planning and reporting

**The** **Verification Control Document (VCD)** shall list the selected method(s) of verification, overall verification result (pass/fail) and reference to the relevant report, where necessary for each requirement. The VCD is a living (versioned) document and provides an overview of the mutually agreed Verification methods during the contract execution and overview of the verification results at the contract end to support the acceptance of the MOB-VC. The **VCD** represents a formal tool of communication between the Supplier and the CA (formal record, reporting tool). The **VCD** will be provided by the CA and it can be accommodated to the Supplier’s needs.

REQ-028971/A

The Supplier shall provide a Verification Control Document (**VCD**) in coordination with and having approval from the CA.

*NOTE 1: Guidelines for VCD preparation will be provided by the CA (see RD-04; section 1.4).*

*NOTE 2: The form of VCD will be agreed between the CA and the Supplier based on the best commercial praxis used by the Supplier.*

Verification method: R - review

REQ-028973/A

The verification approach shall be defined by the Supplier in the **VCD** prior to its implementation.

Verification method: R - review

REQ-028974/A

In the **VCD**, the Supplier shall describe **HOW** and **WHEN** each of the technical requirements is to be verified.

*NOTE: Since some requirements are to be verified through a review of design the VCD shall be prepared by the Supplier and agreed with the CA before starting of the Design Review.*

Verification method: R – review

REQ-028975/A

The Supplier will provide regular progress reports to the CA in the form of the VCD execution and, if required by the CA, a PowerPoint presentation. The frequency for these shall be no less than 1 per month.

Verification method: R - review

## Verification execution

REQ-028976/A

The verification execution process shall consist of following stages according to the phasing of the contract execution:

* **Critical design review** (CDR);
* **Verification of all components of the MOB-VC** (testing and inspection at Supplier’s site);
* **Acceptance by the CA at** **Supplier site**.

*NOTE 1: The CDR is intended to verify that the design meets corresponding requirements (could be accepted) and/or identify required corrective actions needed to accept the design and start manufacturing phase of the contract.*

*NOTE 2: Verification of all elements of the* *MOB-VC is executed at the end of each corresponding manufacturing phase by inspection and tests. The purpose of this verification is checking the product readiness for shipment to the ELI Beamlines.*

*NOTE 3: In the final acceptance stage the verification shall demonstrate that the* *MOB-VC is free of fabrication* *defects and is ready for the intended operational use.*

Verification method: Not To Be Tracked within VCD

REQ-028977/A

Verification shall be accomplished by the Supplier through one or more of the following verification methods:

1. **Review of design**; Verification by Review (**R**) shall consist of using approved records (examples of such approved records are design documents and reports, technical descriptions, and engineering drawings, manuals and accompanying operation documentation) or evidence that unambiguously shows that the requirement is met.
2. **Inspection**; Verification by Inspection (**I**) shall consist of visual determination of physical characteristics.
3. **Test** (including **functional demonstration**); Verification by Test (**T**) shall consist of measuring product performance and functions under the defined operating conditions.
4. **Analysis**; Verification by Analysis (**A**) shall consist of performing theoretical or empirical evaluations using methods defined in the VCD.

Verification method: Not To Be Tracked within VCD

REQ-028978/A

The results of the analysis shall be documented by the corresponding Analysis Report (**A-R**) and tracked in the VCD (see section 10.3).

Verification method: R – review

REQ-028979/A

The results of a review of design shall be documented in the Critical Design Review Report (**CDR-R**) and tracked in the VCD (see section 10.3).

*NOTE: The CA can provide to the Supplier the template of the CDR-R.*

Verification method: R - review

REQ-028980/A

Any dimensional or design modifications that may arise after the CDR shall be consulted with and approved by the CA.

Verification method: R - review

REQ-028981/A

The final manufacturing drawings and the parts of the VCD related to the Design of the MOB-VC shall be accepted by the CA before the commencement of manufacturing.

Verification method: R - review

REQ-028982/A

The results of the inspection shall be tracked in the VCD.

Verification method: R - review

REQ-028983/A

The results of the test shall be documented in the appropriate Test Report (**T-R**) and tracked in the VCD (see section 10.3).

Verification method: R - review

REQ-028984/A

The Supplier shall perform the verification leak testing of the MOB-VC in the presence of the CA representative.

*NOTE 1: Single leak test (spray test) shall be performed according to ČSN EN 1779, method A.3 (equivalent to EN 1779).*

*NOTE 2: Total leak test shall be according to ČSN EN 1779, method D.2 (equivalent to EN 1779). If this is not possible due to the size of the chamber, other methods may be proposed by the Supplier.*

*NOTE 3: Regarding the referred to standard/s the CA allows/permits also another equal solution to be offered.*

Verification method: R - review

REQ-028985/A

The Supplier shall provide reports with results of vacuum and cleanliness test of the MOB-VC.

Verification method: R - review

REQ-028986/A

With the support of the CA, the Supplier shall carry out the final verification of requirements according to the VCD and record the results in the final VCD issue (see section 10.5).

Verification method: R - review

## Verification close out (Acceptance)

Acceptance shall be carried out by the CA in three phases in the presence of the CA:

* Critical Design Review (CDR) and acceptance of all manufacturing drawings before manufacturing;
* Manufacturing completion culminating in the FAT;
* Delivery without incident carried out in the presence of the CA (Final Acceptance);

Upon the success of each acceptance phase, the CA will provide to the Supplier a signed acceptance protocol. In case of unsuccessful acceptance, the CA will provide to the Supplier a Nonconformity Report (NCR) and the Supplier will be obliged to address the nonconformance.

REQ-028987/A

The Final Acceptance phase shall demonstrate the following:

* The MOB-VC has been successfully verified by the Supplier and the results of this process have been documented in an appropriate way through verification reports (see section 10.4) and VCD (see section 10.3);
* All detected nonconformities have been solved in accordance with REQ-028964/A;
* Final MOB-VC is free of fabrication errors and is ready for the intended operational use.

*NOTE 1: The cleanliness is an important acceptance requirement.*

*NOTE 2: Supplier’s outgoing check shall be carried out prior to delivery and in the presence of the CA.*

Verification method: Not To Be Tracked within VCD