VERT-X Design of Vertical X-Ray Test Facility for ATHENA

TN16 DEVELOPMENT PLAN

Doc: VTX-OAB-IPM-PLN-001

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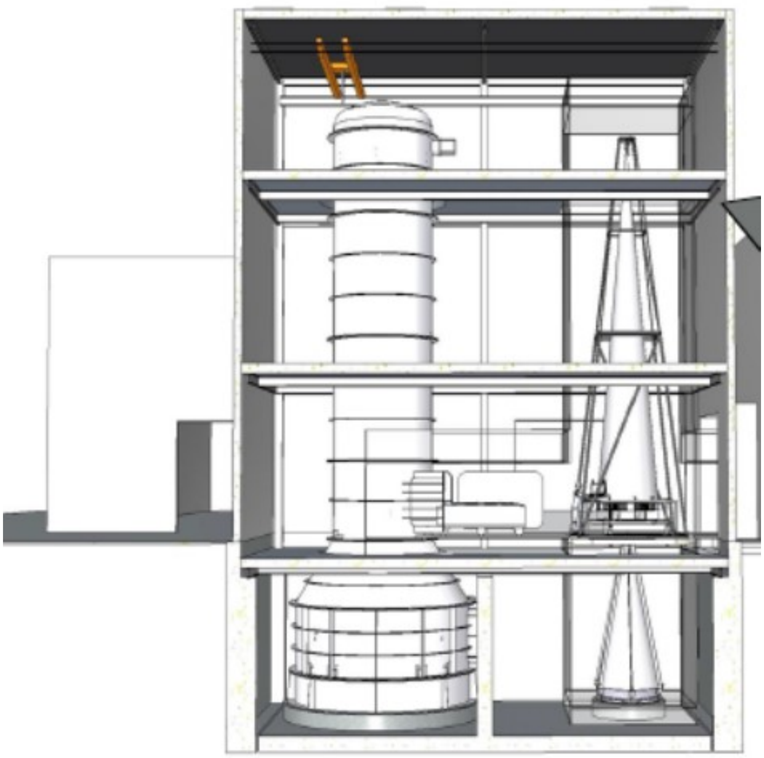

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1. INTRODUCTION

1.1. SCOPE

The scope of the present document is the illustration of VERT-X development plan, following the outcomes of the Detailed Design Review (DDR) and the study activities up to the Final Review (FR).

1.2. APPLICABILITY

The present document is one of the deliverables related to the FR milestone. It is intended to outline the main aspects of VERT-X facility development planning, providing a reference for the future studies and activities about it.

It may be a useful reference for the future Change Contract Notice (CCN) activities involving a de-risk demonstration study for some of the VERT-X facility key components.

1.3. ROADMAP

Document section	Content description
Section 2 (Applicable and reference documents)	List of applicable documents and reference documents.
Section 3 (VERT-X facility development plan)	Details of development plan for VERT-X facility.
Section 4 (Work breakdown structure)	Details of work breakdown structure (WBS).
Section 5 (Work package description)	Details of work packages.
Section **Error! Reference source not found.** (Workflow)	Description of workflow for development and testing activities..
Section **Error! Reference source not found.** (Work schedule)	Description of work schedule for development and testing activities.

Table 1-1: Roadmap of the document

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1. APPLICABLE DOCUMENTS

AD1	AO/1-9549/18/NL/AR - SOW	X-ray Raster Scan Facility for the ATHENA Mirror Assembly SOW
AD2	VERT-INAFOAB-001	VERTICAL X-Ray (VERT-X) Technical Proposal
AD3	ESA-TECMMO-RS-014713	Updated Requirements for the ATHENA VERT-X following the System Requirements Review

2.2. REFERENCE DOCUMENTS

RD1	VTX-OAB-ISE-REP-003	D5 Detailed Design Document
RD2	VTX-INAF-OAB-002	Proposal submitted in response to RFQ/3-16555/20/NL/IB/gg, *Demonstration of critical items for x-ray scanning facility*

2.3. GENERAL SPECIFICATIONS AND STANDARD DOCUMENTS

SD1	ECSS-M-40A	Configuration management
SD2	ECSS-M-50A	Information/documentation management

2.4. LIST OF ACRONYMS

AD	Applicable Document
AIT	Assembly, Integration and Testing
DDR	Detailed Design Review
DRW	Drawing
EIE	European Industrial Engineering
ESA	European Space Agency
FR	Final Review
GPAP	GP Advanced Projects
I/F	Interface
IASF	Istituto di AstroFisica Spaziale (INAF, Milano)
INAF	Istituto Nazionale di AstroFisica
ITT	Invitation To Tender
MA	Mirror Assembly
MLS	Media Lario S.r.l.
MM	Mirror Module
OAB	Osservatorio Astronomico di Brera (INAF, Milano)
PDR	Preliminary Design Review
RD	Reference Document
RS	Raster Scan
SD	Standard Document
SOW	Statement of Work
SRR	System Requirements Review
TBA	To Be Assessed
TBC	To Be Controlled
TBD	To Be Defined
TEC	Technical Note
TVC	Thermal Vacuum Chamber
XSA	X-ray Source Assembly
XTA	X-ray Tube Assembly
XYZS	(x, y, z) stage
WBS	Work Breakdown Structure
WP	Work Package

2.5. TERMS AND DEFINITIONS

VERT-X	The Vertical X-ray testing facility including: the raster scan, the X-ray source, the X-ray collimator, the metrology, the thermal vacuum vessel, all the necessary cabinets and control units, the portion of the building hosting the vessel.
SPO-AIT	The Silicon Pore Optics AIT facility

3. VERT-X FACILITY DEVELOPMENT PLAN

3.1. OVERVIEW

The VERT-X development plan consists in two main phases. In the first phase the most critical parts of the systems will be realized and tested. These are the X-ray source assembly (**XSA**), including both the x-ray source and mirror, and the raster scan mechanism (**RS**), including the tip/tilt metrology. This phase of the plan coincides with the activities proposed in response to the RFQ Request for Quotation RFQ/3-16555/20/NL/IB/gg, with title *Demonstration of critical items for x-ray scanning facility,* RD2.

In the second phase the plan foresees the realization the Thermal Vacuum Chamber together with the remaining elements of the testing system, namely the completion of the RS, the camera and its stage. The integration of the facility in the ML AIT building is the final task of the second phase.

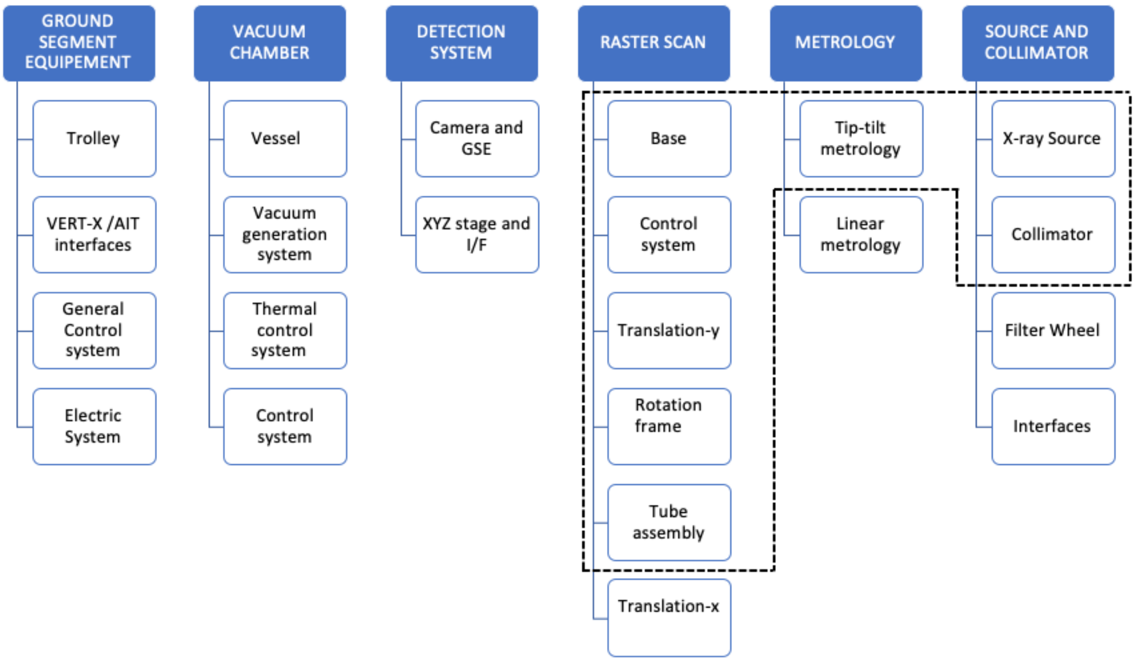


Figure 3-1 Product tree scheme. Elements included in the dashed line are produced in the first phase, under the "Demonstration of critical items" activity.

3.2. FIRST PHASE

The activities in **the first phase** are divided in four main tasks and implemented with logic described as follows.

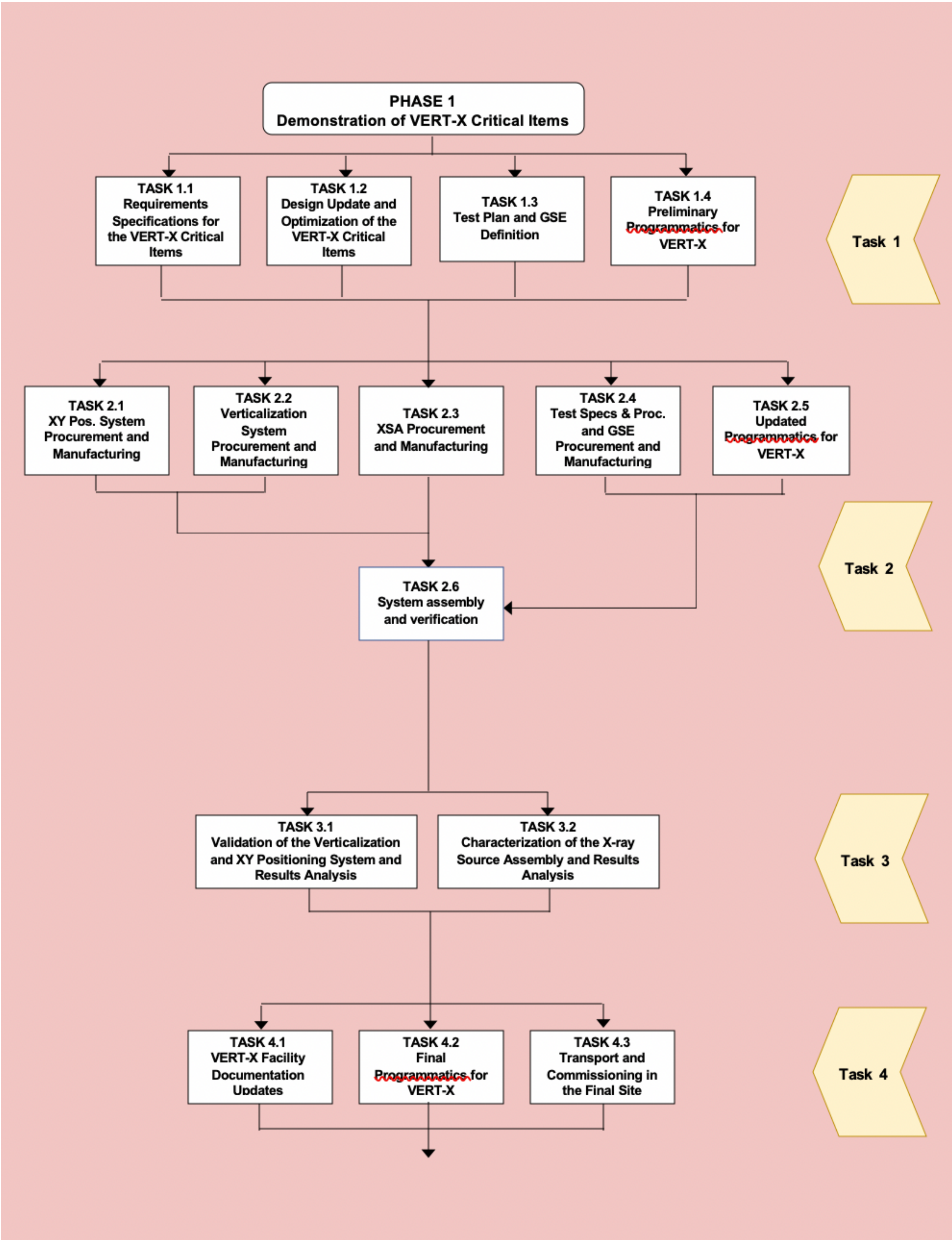
First, the design output of the VERT-X design activity [RD1] will be updated and optimized (**task 1-1.1, 1-1.2**). The design update and their impact on the general design of the VERT-X facility will be caught and traced by a specific activity (**task 1.4**). In parallel to this activity, two specific test plans for XSA and RS respectively will be defined together with the necessary equipment (GSE) for the test set-ups. In particular the XSA test will require the availability of ad-hoc structure providing the vacuum and the X-ray detector (**task 1-1.3**).

Then XSA and RS single parts defined by the product tree will be manufactured or purchased (**task 1-2.1, 1-1-2.2, 1-2.3**). Due to the different time scale in the development of the two systems, we included in the schedule two different assembly check points (ACP1 and ACP2), the first at T0+10m for the RS, the second at T0+13m for the XSA. In the second part and following the respective ACP, RS and XSA will be finally assembled (**task 1-2.6**). Splitting the ACP in two parts, three months apart, accounts for the need of a longer manufacturing for the mirror on one side and of a longer integration for the RS. In parallel, the test plan procedure will be finalized and the necessary GSE will be realized (**task 1-2.4**). VERT-X design and relevant documentation will be updated correspondingly (**task 1-2.5**). Furthermore, an Intermediate Review (IR) is foreseen, to characterize the tilt-meter noise figure and defining the selection of the tip-tilt metrology (**task 1-2.1, 1-2.2**).

The third task consists in the test campaigns (**task 1-3.1, 1-3.2**) performed independently at the EIE premises for the RS and Panter laboratory for the XSA.

The fourth and final activity will include the update of the VERT-X documentation and the storage of the systems (**task 1-4.1, 1-4.2, 1-4.3**).

Figure 3-2 shows the block diagram describing the development plan of VERT-X, with more details on the second phase of the project.


PHASE 1
Demonstration of VERT-X Critical Items
TASK 1.1 Requirements Specifications for the VERT-X Critical Items
TASK 1.2 Design Update and Optimization of the VERT-X Critical Items
TASK 1.3 Test Plan and GSE Definition
TASK 1.4 Preliminary Programmatics for VERT-X
Task 1
TASK 2.1 XY Pos. System Procurement and Manufacturing
TASK 2.2 Verticalization System Procurement and Manufacturing
TASK 2.3 XSA Procurement and Manufacturing
TASK 2.4 Test Specs & Proc. and GSE Procurement and Manufacturing
TASK 2.5 Updated Programmatics for VERT-X
TASK 2.6 System assembly and verification
Task 2
TASK 3.1 Validation of the Verticalization and XY Positioning System and Results Analysis
TASK 3.2 Characterization of the X-ray Source Assembly and Results Analysis
Task 3
TASK 4.1 VERT-X Facility Documentation Updates
TASK 4.2 Final Programmatics for VERT-X
TASK 4.3 Transport and Commissioning in the Final Site
Task 4

3.3. SECOND PHASE

The activities in the **second phase** are divided in six main tasks and implemented with logic described as follows.

First, the Project Office of VERT-X is established, having in charge not only the coordination of the activities for the implementation of VERT-X itself, the development of the relevant documentation, and all the usual project Management, System Engineering and Product Assurance activities; it also has the important task of coordinating with the analogous project office of SPO-AIT, in order to harmonize the development of the two facilities. All of these activities are included in the **task 2-1**.

The requirements of the thermal vacuum chamber, of the camera and its stage will be reviewed and their design will be updated and optimized accordingly (**task 2-2).** This activity will exploit the output of the tasks 1-1.4, 1-2.5, 1-4.1, and 1-4.2 of the first phase.

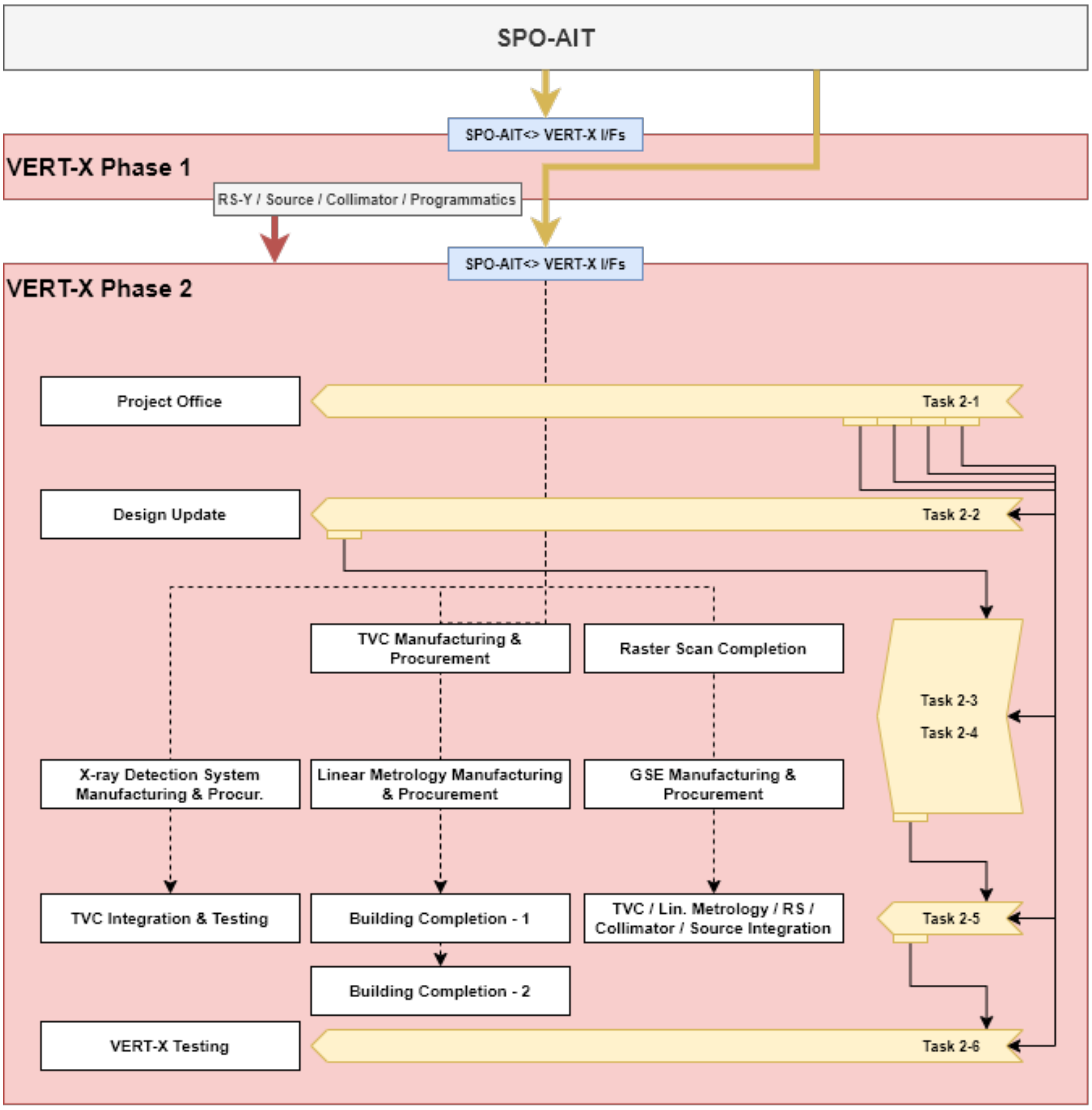


Figure 3-2: VERT-X development plan and interactions with SPO-AIT.

Then, the elements of the updated design will be manufactured or purchased (**task 2-3**). Each item will then be independently tested in order to obtain the authorization to proceed to the installation at the final site premises (**task 2-4**). While some elements of VERT-X can undergo an extensive testing phase, we remark that for what concerns the Thermal Vacuum Chamber its global functional and performance tests can only be completed once the whole system is installed on-site. For this reason, a Factory Test & Acceptance task is foreseen (**task 2-4.1**). Similarly, the other systems will be tested and accepted in the vacuum environment only after their installation inside the vessel. Preliminary Factory tests are also included for such elements (raster scan, detection system).

The next step of the plan foresees the integration of the entire facility in the AIT ML building (**task 2-5**). It is important to underline that such task shall require an accurate coordination with the SPO-AIT facility. Furthermore, it is important to properly schedule the integration steps, since the acceptance of the whole Thermal Vacuum Chamber shall be performed before the integration of the raster scan inside of it. This approach has two advantages. First, it allows the pursuing of recovery actions in case of leakage detection during the testing phase of the TVC. Second, it makes possible to distinguish between the vessel performances and any possible outgassing contribution due to the raster scan, thanks to the comparison of the evacuation time measured before and after the installation of the raster scan.

Finally, once the whole system is installed, it will undergo the final acceptance tests (**task 2-6**).

3.4. VERT-X / SPO-AIT I/F MANAGEMENT

We underline that the development of the second phase of VERT-X shall be coordinated with the development of the SPO-AIT facility, in order to:

1. Reducing as much as possible any possible impact, due to the integration of VERT-X, on the integration of SPO-AIT and on its operations.

2. Avoiding that the integration of SPO-AIT is made in such a way that the building configuration prevents the installation of the vessel.

To this aim, it is proposed to define an interface document “VERT-X <> SPO-AIT Interfaces”, which should outline and describe at least the following interfaces:

- Mechanical interfaces
  This section of the document shall include the list of every mechanical interface between VERT-X and SPO-AIT. Such mechanical interfaces includes the

- Civil works interfaces

- Electrical interfaces

- Plant interfaces

- Schedule interfaces

4. WORK BREAKDOWN STRUCTURE

4.1. PHASE 1 – DE-RISKING ACTIVITIES

1-1.1: Requirements Specifications for the VERT-X Critical Items

1-1.2: Design Update and Optimization of the VERT-X Critical Items

1-1.3: Test Plan and GSE Definition

1-1.4: Preliminary Programmatics for VERT-X

1-2.1: Y Positioning System: Procurement and Manufacturing

1-2.2: Verticalization System: Procurement and Manufacturing

1-2.3: X-Ray Source Assembly: Procurement and Manufacturing

1-2.4: Test Specs & Procedures and GSE Procurement and Manufacturing

1-2.5: Updated Programmatics for VERT-X

1-2.6: System Assembly and Verification

1-3.1: Validation of the Verticalization and XY Positioning System and Results Analysis

1-3.2: Characterization of the X-ray Source Assembly and Results Analysis

1-4.1: VERT-X Facility Documentation Updates

1-4.2: Final Programmatics for VERT-X

1-4.3: Transport and Commissioning of Critical Items in the Final Site

4.2. PHASE 2 – VERT-X INTEGRATION

In the following we outline the main Work Packages needed to reach the completion of VERT-X. The Work Packages are identified as elements of the Work Breakdown Structure, needed to achieve the result. In this sense, we added to the list the Project Office of VERT-X, which has the important task, among others, to coordinate the activities within the various elements of VERT-X *and* to coordinate the activities of VERT-X with those of SPO-AIT.

2-1: Project Office

2-2: Design Update and Optimization

2-3.1: Manufacturing and Procurement of the Thermal Vacuum Chamber

2-3.2: Completion of the Raster Scan

2-3.3: Manufacturing and Procurement of the Camera System

2-3.4: Manufacturing and Procurement of the Linear Metrology System

2-3.5: Manufacturing and Completion of the GSE

2-3.6: Definitive acquisition of the X-ray source

2-4.1: TVC Factory Testing & Acceptance

2-4.2: Raster Scan Factory Testing & Acceptance

2-4.3: Detection System Factory Testing & Acceptance

2-4.4: Linear Metrology Testing & Acceptance

2-4.5: GSE Testing & Acceptance

2-5.1: TVC Integration, Site Testing & Acceptance

2-5.2: Building Completion - 1

2-5.3: Building Completion - 2

2-5.4: RS / Source / Collimator / Linear Metrology | TVC Integration

2-6.1: RS Site Testing & Acceptance

2-6.2: Source Site Testing & Acceptance

2-6.3: Detection System Site Testing & Acceptance

2-6.4: Linear Metrology Site Testing & Acceptance

5. WORK PACKAGE DESCRIPTION

5.1. PHASE 1 – DE-RISKING ACTIVITIES

1-1.1: Requirements Specifications for the VERT-X Critical Items

Review of the functional and performance requirement specifications (RD1 and reference therein) of the following VERT-X critical items:

- The XY positioning system including (non-precision) linear motors and linear encoders.
- The Verticalization (tip/tilt) system for the X-ray source assembly, providing:
  - Required inclination range.
  - Metrology of the pointing angle in respect to gravity vector.
  - Control of set pointing angle to the required accuracy, using a dedicated control loop.
- The X-ray source assembly, including the X-ray source, collimator mirror and assembling structure.

1-1.2: Design Update and Optimization of the VERT-X Critical Items

Review of the final design (RD1 and reference therin) of the following VERT- X critical items:

- The XY positioning system including (non-precision) linear motors and linear encoders.
- The Verticalization tip/tilt system for the X-ray source assembly. Adetailed trade-off shall be performed regarding the tube material.
- The X-ray source assembly, including the X-ray source, collimator mirror and assembling structure (e.g. the tube). Regarding the collimator mirror, a detailed trade-off shall be performed regarding the technical options of the implementation with particular focus on monolithic or two-block mirror.

1-1.3: Test Plan and GSE Definition

Definition of the test activities to validate and characterise the performance of the VERT-X critical parts.

1-1.4: Preliminary Programmatics for VERT-X

First iteration of the schedule, costs and critical areas associated with the development of the full VERT-X facility, on the basis of the updated design.

1-2.1: X Y Positioning System: Procurement and Manufacturing

Procurement and development of all the subsystems to be assembled in the XY positioning stage for the translation of the X-ray source assembly.

The task also includes the experimental characterization of the tip-tilt metrology. Two solutions are currently under evaluation, namely:

- The utilization of electrolytic tilt-meters.
- The utilization of an optical metrology system based on the usage of commercial, long range autocollimators.

The former shall be tested to measure its noise figure error under representative motion conditions, to measure the sensor noise under different motion conditions (i.e. velocity of the translation). The latter shall be verified to test the alignment procedure and to define the calibration curve of the mirror mount support against temperature variations. In addition, the necessary manufacturing verifications on the final assembled system shall be performed.

The characterization of the tip-tilt metrology is fundamental to verify the possibility of using the tilt meters as metrology tools for the tracking control system.

The purpose of the de-risking activity is to verify the capability of the system to properly correct the pointing misalignments by means of the metrology and the pointing control system. Such evaluation shall be performed once the system moves along the linear axis. Attitude variations induced by such motion occur both on roll and pitch, even if only one axis is realized. One linear axis motion is then sufficient to characterize the system performances, including the tip-tilt metrology. Taking into account the budget constraints, we then propose to build only one of the two linear axes, and in particular that which is more prone to deformations (Y translation).

1-2.2: Verticalization System: Procurement and Manufacturing

Procurement and development of all the subsystems to be assembled in the verticalization system, according to the design approved by the Agency at the DR. This includes the rotation stages for the X-ray source assembly, metrology and control loop.

In addition, the necessary manufacturing verifications on the final assembled system shall be performed.

1-2.3: X-Ray Source Assembly: Procurement and Manufacturing

Procurement and development of all the subsystems to be assembled in the X-ray Source Assembly.

This include the X-ray source, the collimator mirror and the assembling structure, the jig.

For the purposes of this activity, the XSA will be assembled with an ad-hoc support to be designed and realized. There are several reasons for this approach, both technical and programmatic (RD2 and reference therein).

First of all, the structural performance of the tube will be evaluated in operational conditions together with the whole RS system, in presence of dummy masses simulating X-ray source and collimator. The test at the X-ray facility (Panter) will be performed in horizontal and will not add any piece of information to the tube qualification. Instead, the lateral gravity is expected to significantly affect the system performance and ad-hoc mitigation systems have to be foreseen. In particular, the interfaces of the collimator with the mirror, which have been designed for the vertical position, should be supported in optimized positions by some ad-hoc structure which will be not part of the final VERT-X system. Note that, in the current design, the mirror protrudes from the tube for half its length and this is expected to significantly affect the performance of the system in presence of lateral gravity. An ad-hoc and basic assembling structure can be designed in order to mitigate this effect with the undoubted advantage of simplifying the interfaces with the GSE for the XSA testing campaign.

From the management point of view the possibility of using an ad-hoc structure instead of the RS tube remarkably simplifies the organization of the assembly integration and test campaigns. Using the RS tube for the XSA assembly would cause some overlapping in the two systems project schedules with the necessity of two displacements of the tube. Instead, using a different structure would make the assembly and test processes of the two systems independent.

First, for the purposes of the present activity, the source will be on lease for twelve months. According the current schedule of the project, the loan of the source will start approximately Oct 2021. This means that the payment to purchase the source can be shifted to Oct 2022.

1-2.4: Test Specs & Procedures and GSE Procurement and Manufacturing

For each of the tests identified in the Test Plan the following activities shall be implemented:

- detail of the test set-up,

- specification of the accuracy required by the testing equipment,
- specification of pass/fail criteria for each test case.

The objective is to demonstrate the fulfilment of the functional and performance requirement specifications defined in the Task 1.1.

The specific ground support equipment necessary to perform full functional and performance tests of the hardware built shall be finally purchased, assembled and calibrated (as needed). For any necessary ad-hoc component, it shall be specified together with an evaluation of procurement cost and schedule, whether the components are manufactured in-house or purchased. For the characterization of the X-ray Source Assembly, the schedule and logistics arranged with the facility selected shall be reported.

1-2.5: Updated Programmatics for VERT-X

Updated iteration of the schedule, costs and risks associated with the development of the full VERT-X facility, on the basis of the newly developed critical systems shall be prepared and reported.

1-2.6: System Assembly and Verification

In this task the XY Positioning System, Verticalization System and X-ray Source Assembly shall be finally assembled with the respective experimental GSE and the necessary verifications shall be performed before starting the performance tests.

1-3.1: Validation of the Verticalization and XY Positioning System and Results Analysis

Test campaign to validate the functionalities and performances of the Verticalization System in the required inclination range and in any condition foreseen by the system operation, and in particular dynamically, i.e. during accelerated and constant-speed motion of the XY positioning system.

1-3.2: Characterization of the X-ray Source Assembly and Results Analysis

This task consists of the implementation of the test campaign to characterise the functionality and performances of the X-ray Source Assembly at the Panter X-ray facility Panter. In particular the goal is to measure the divergence of the X-ray beam which is designed to be close to 1”.

1-4.1: VERT-X Facility Documentation Updates

Following the results analysis and lessons learnt from the performed test campaigns, the design documents, the “Concept of Operations” and all the relevant TNs shall be updated. In particular, an update of the technical and error budget, shall be reported including: (i) the various allocation of mass, volume, power consumption of the different elements of the VERT-X Facility; (ii) HEW errors and effective area losses introduced by the different elements of the VERT-X Facility.

1-4.2: Final Programmatics for VERT-X

Based on the outputs of all the previous tasks, a Final Programmatics set of documents shall be delivered to the Agency.

1-4.3: Transport and Commissioning of Critical Items in the Final Site

Installation or storage of the deliverable hardware at the chosen sites.

5.2. PHASE 2 – VERT-X INTEGRATION

2-1 Project Office

- Maintenance of the living documents (AILs, Master Schedule, etc.)
- Development of the Project Documentation, namely:
    - Manufacturing Plan
    - ICDs
    - Packing and Shipping Plan
    - Product Assurance Plan
    - Assembly Plan
    - Logistic Plan
    - Verification Plan
    - Test Acceptance Reports
    - Facility Management Plan
    - Manuals
- Requirements Specifications Update
- VERT-X Programmatic

2-2: Design Update and Optimization

Review of the final design (RD1 and reference therein) of the following VERT- X product tree items:

- Vessel
- Vacuum generation system
- Thermal control system
- Camera
- Stage
- GSE

2-3.1: Manufacturing and Procurement of the Thermal Vacuum Chamber

This activity refers to the manufacturing and procurement of:

- The vessel mechanical structure (bottom part, conic section, top part, top cover, doors)
- The thermal control system, including:
    - Thermal shrouds (MA and structure)
    - Temperature probes
    - Chiller unit, valves, pumps, pipes
- The vacuum system components, including:
    - Pumps (primary, TMP, cryo+compressor, pre-vacuum for TMP)
    - Sensors
    - Gate valves
    - Compressed air system for valves actuation
    - Dry nitrogen system for vacuum breaking & purging
    - Water cooling system for primary vacuum pumps (chiller, pipes)
- Feedthroughs, viewports, spare flanges
- Control and Power cabinets

2-3.2: Completion of the Raster Scan

This activity refers to the manufacturing and procurement of the X-axis of the raster scan and its integration with the Y axis and with the control system. This includes the procurement of the motors, encoders, limit switches, brakes, the manufacturing of the structure, and the integration of the parts. Testing is described in the next task.

2-3.3: Manufacturing and Procurement of the Camera System

This activity includes the procurement of the camera, the detector and the moving stage.

About the detector stage (XYSZ) technological readiness and procurement, the design baseline involves mature technologies, without expected problems for their deployment.

The FastCCD camera (thick CCD, parallel architecture) developed by LBNL and produced by Sydor, has been identified as preliminary baseline in the SSR. This system is currently available and we are in close contact with the manufacturers in order to study the necessary customization.

In the meanwhile we investigated a new, lower cost solution based on sCMOS sensors developed and commercialized by GPixel inc. Tests on this camera at the SOLEIL facility, scheduled in May 2020 have been postponed to a date to be defined. These systems are experiencing a phase of rapid development. In particular, within the Einstein Probe mission, Gpixel developed a new, larger and thicker sCMOS sensor, HR4040BSI, which will be possibly commercialized in the next few years ((Zhixing Ling, private communication).

2-3.4: Manufacturing and Procurement of the Linear Metrology System

This activity includes the procurement of the laser trackers, the manufacturing of the enclosures used to install them inside the vacuum vessel, the integration of the two systems together. Testing is described in the next task.

2-3.5: Manufacturing and Completion of the GSE

This activity includes the manufacturing of the trolley, including the interfaces with the MA gravity release system and of the VERT-X / AIT interfaces as reported in the document “VERT-X <> SPO-AIT Interfaces”.

2-3.6: Definitive acquisition of the X-ray source

The source loaned for the purposes of the previous phase is compliant with the ATHENA MA Verification requirements, while does not completely fulfill the Calibration requirements. In order to be fully compliant with the Calibration requirement as reported in the VERT-X design, the source would need further customization. This customization would involve the window material. In particular, replacing the standard Beryllium with a different material, would allow to cover the required energy band down to 0.2 KeV.

The proposed plan for the source is the following.

- Purchase to own with a further customization in order to enhance the soft part of the spectrum (< 1keV).
- Performing all the verification campaign (scheduled in 2024-2028) with this source.
- Finally purchasing a fully customized source for the Calibration purposes (scheduled in 2028).

2-4.1: TVC Factory Testing & Acceptance

This task includes every activity related to the acceptance of the manufactured parts (visual inspections, ultrasonic inspections, topographic measurements, etc.), the verification of some sub-system level elements, the packing of the elements for the transport to the site.

2-4.2: Raster Scan Factory Testing & Acceptance

The integrated raster scan is tested in factory using the same approach adopted during the Phase 1, by taking advantage of the lessons learnt during Phase 1. Functional and performance tests are performed using dummies instead of real loads on the XTA structure. This is performed to prevent any possible damage occurring on the collimator unit during testing. At the end of the test campaign and after the acceptance of the system, the raster scan is dismounted into at least three main mechanical assemblies (X axis, Y axis, and XTA) and packed for transport to site.

2-4.3: Detection System Factory Testing & Acceptance

The detection system is checked on individual elements, stage, camera and interfaces in order to verify functional and performance capabilities

2-4.4: Linear Metrology Testing & Acceptance

The assembled linear metrology system is checked on individual elements (laser tracker inside enclosure), to verify functional and performance capabilities. In particular, remote operations are checked in view of the integration into the control system.

2-4.5: GSE Testing & Acceptance

The trolley, including the interfaces with the MA gravity release system and of the VERT-X / AIT interfaces are checked in order to verify functional and performance capabilities.

2-5.1: TVC Integration, Site Testing & Acceptance

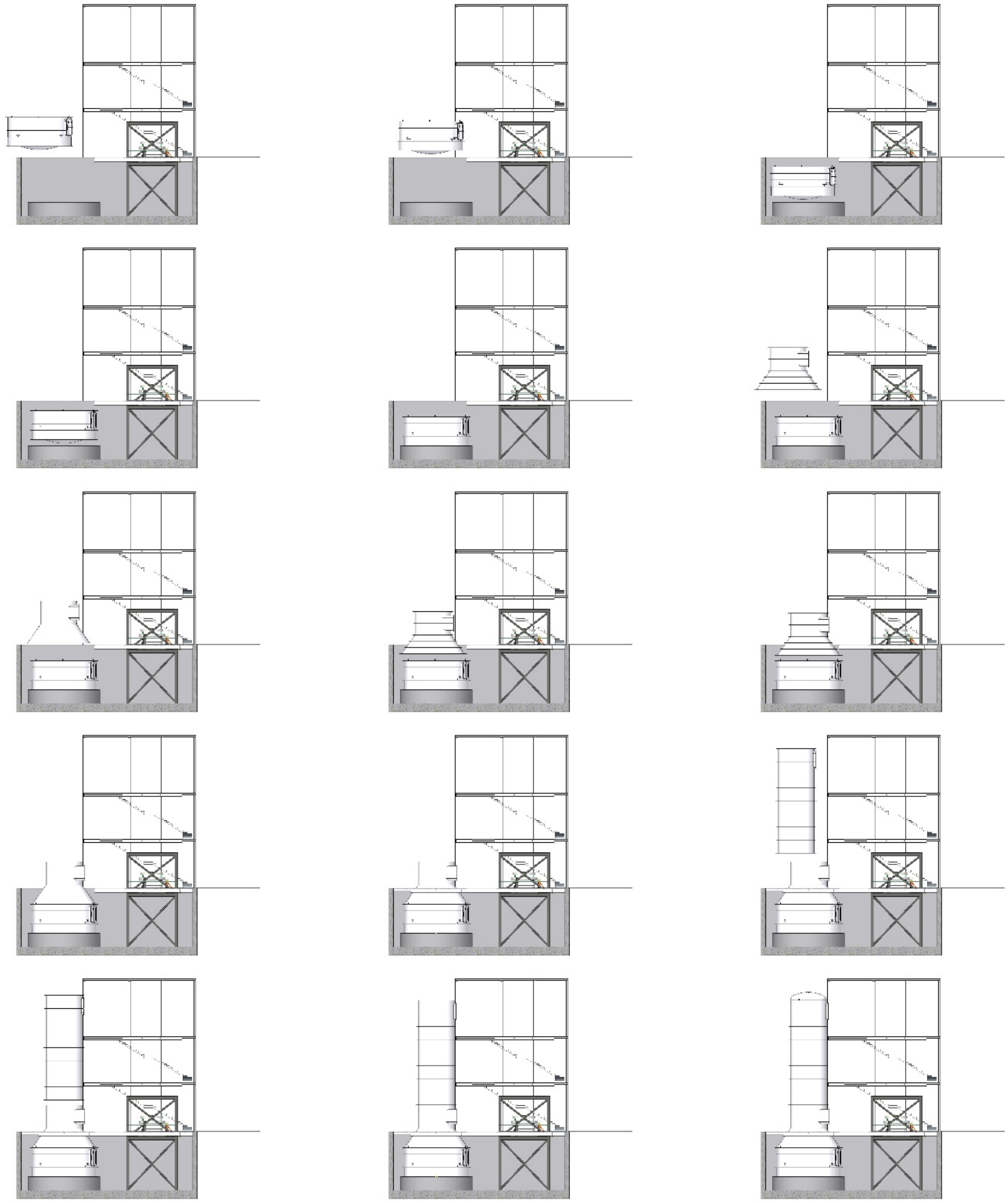
The vacuum vessel is transported to the site into pieces.

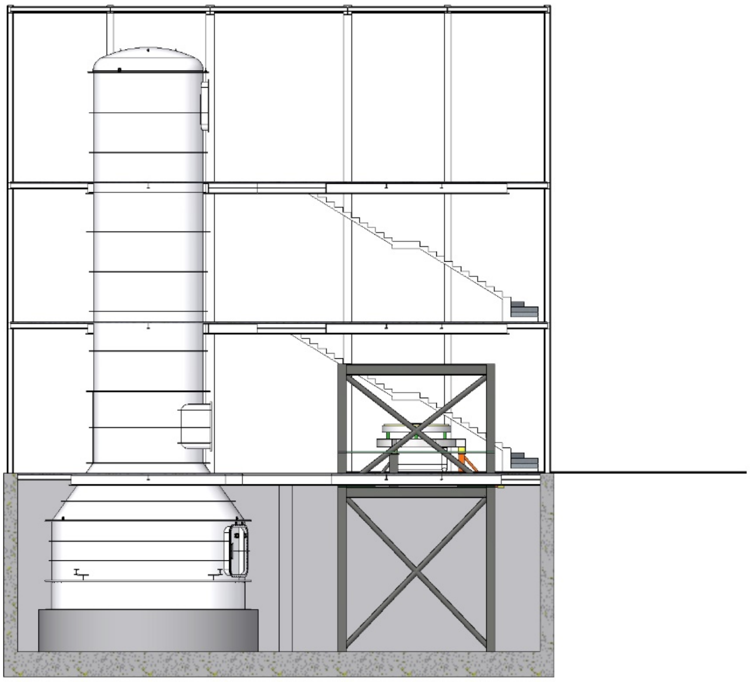
The elements of the vessel are placed in the final position, following the sequence described by the following pictures.

The time needed to install the vessel can vary, depending on weather conditions. The following sequence represents the most conservative approach:

1. Phase 1
    a. Removal of the building temporary cover
    b. Installation of the bottom part of the vessel
    c. Provisional installation of the conic structure (no welding)
    d. Erection of the building structure up to Floor 1.
    e. Installation of temporary cover to the ceiling of Floor 1
2. Phase 2
    a. Welding of the conic structure to the bottom part of the vessel.
    b. Removal of the temporary cover.
    c. Provisional installation of the vessel top part (no welding) and of the cover
    d. Erection of the building structure up to the top
    e. Installation of the cover to the ceiling of the building
3. Starting from end of Phase 2, it is possible to proceed with the finalization of the integration, namely:
    a. Welding of the top part of the vessel
    b. Installation of the building facilities (electrical plant, HVAC, etc.)
    c. Cleaning of the vessel (hot demineralized water, hot air flushing)
    d. Installation of the pumping system (pumps, sensors)
    e. Installation of the compressed air system
    f. Installation of the pumps water cooling system
    g. Installation of the vessel temperature control system (air side)
    h. Installation of the nitrogen purging and breaking system
    i. Installation of the power cabinets and connection of the power cabinets to the building power line
    j. Installation of the control cabinet and connection to the power cabinets.
    k. Functional testing of the subsystems
    l. Leakage testing with Helium
    m. Vacuum testing.
    n. Temperature control system testing.

After the successful completion of the testing, the TVC is ready to host the raster scan. The Vert-X vessel may be installed either before or after the external building is completed. In the latter case it is of course necessary to partially dismount part of its roof and walls. In the following we assume that only half of the building is completed before Vert-X installation.





2-5.2: Building Completion – 1

Following the description of the previous task, this activity includes:

- The removal of the provisional covering of the foundations to allow the installation of the lower part of the vessel.
- Upgrade of the medium voltage substation to increase the available electrical power.
- Distribution of the required power lines, communication and signal lines, and all other required services.
- Realization of a dedicated control room to monitor and command all subsystems pertinent to VERT-X.
- After the installation of the vessel bottom part, of the conic section and of the MA door, the building is developed up to the first floor and covered to protect the system

If the weather conditions do not allow to proceed with the installation of the other segments of the vessel, it is possible to start the installation of building elements at the first floor (electrical plant, lighting, etc.).

The exploitation of such activity during the installation of the vessel segments is forbidden for safety reasons (hanging loads).

2-5.3: Building Completion – 2

Following the description of the previous task, this activity includes:

- the removal of the provisional covering of the first floor to allow the installation of the remaining part of the vessel.
- After the installation of the vessel, the building is developed up to the top and covered to protect the vessel.
- Completion of the plants (electrical, HVAC, etc.)

2-5.4: RS / Source / Collimator / Linear Metrology | TVC Integration

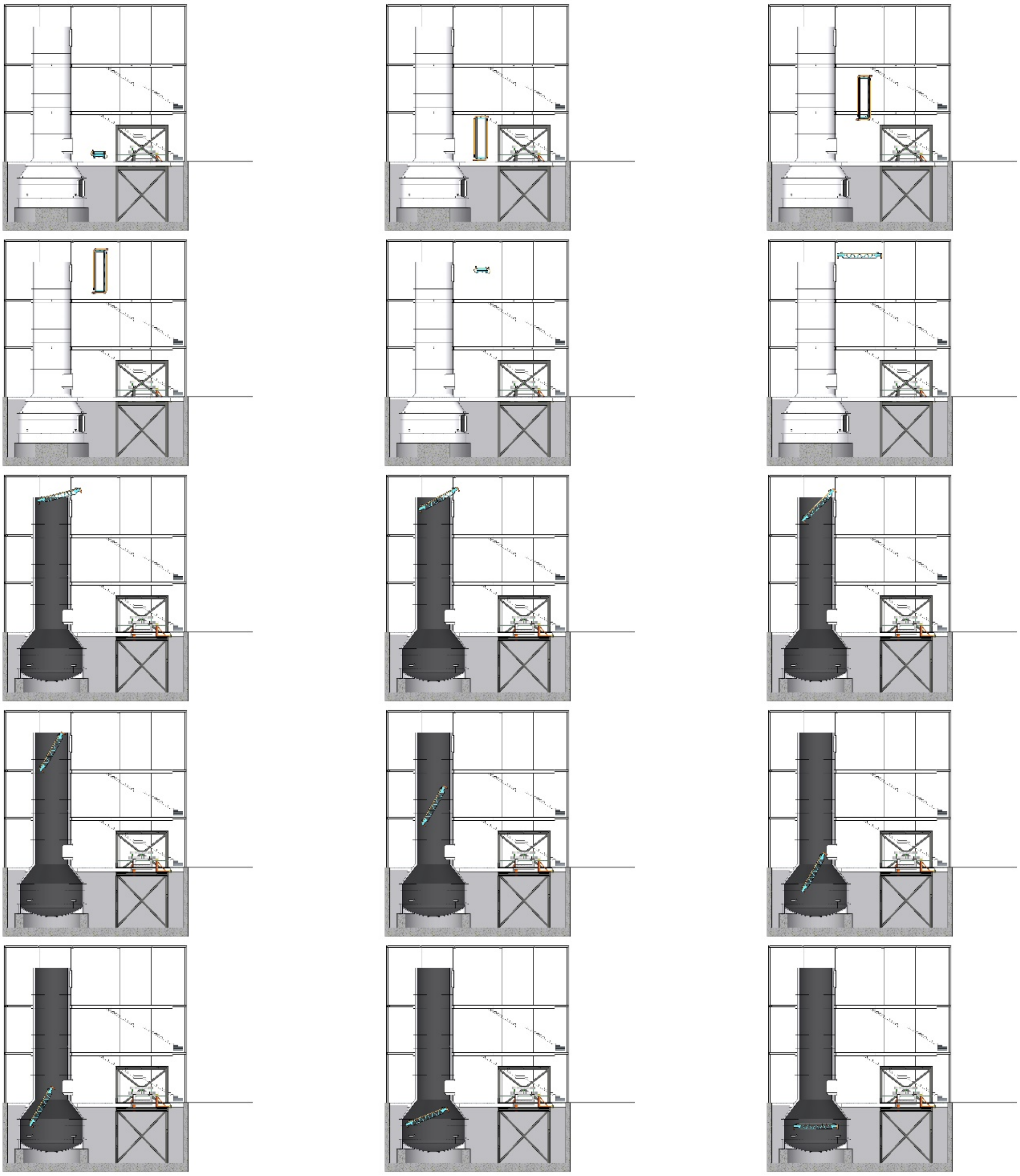
After the acceptance of the TVC, the rest of the system is installed. This task includes the following activities:

- Installation of the Raster Scan
- Installation of the MAIS supports

- Installation of the Linear Metrology System
- Installation of the Detection System
- Functional testing

The installation of the Raster Scan, in particular, requires to follow a certain care. The following pictures shows a possible sequence. Such sequence assumes that the building is equipped with an overhead crane to lift the raster scan and move it down to the position inside the vessel.

The installation of the Raster Scan also includes the cabling and the connection to the vacuum side of the feedthroughs, the connection to the power and control cabinet on the air side, the piping for the cooling system of the source.



RS Site Testing & Acceptance

This activity refers to the repetition of the functional tests and performance tests of the raster scan under vacuum conditions. Preliminary activities also includes:

- Installation of the raster scan cabinets in the proper positions of the VERT-X building
- Cabling, air side and vacuum side
- Piping (of the X-ray source)

2-6.2: Source Site Testing & Acceptance

This part of the activity is performed in the framework of the RS testing inside vacuum.

2-6.3: Detection System Site Testing & Acceptance

The activities include the installation of the detection system inside the vacuum vessel, the cabling (vacuum and air side), the verification of the communication and integration of the DACQ inside the VERT-X control system, the

2-6.4: Linear Metrology Site Testing & Acceptance

The linear metrology testing is repeated after the integration to the whole facility.

END OF THE DOCUMENT