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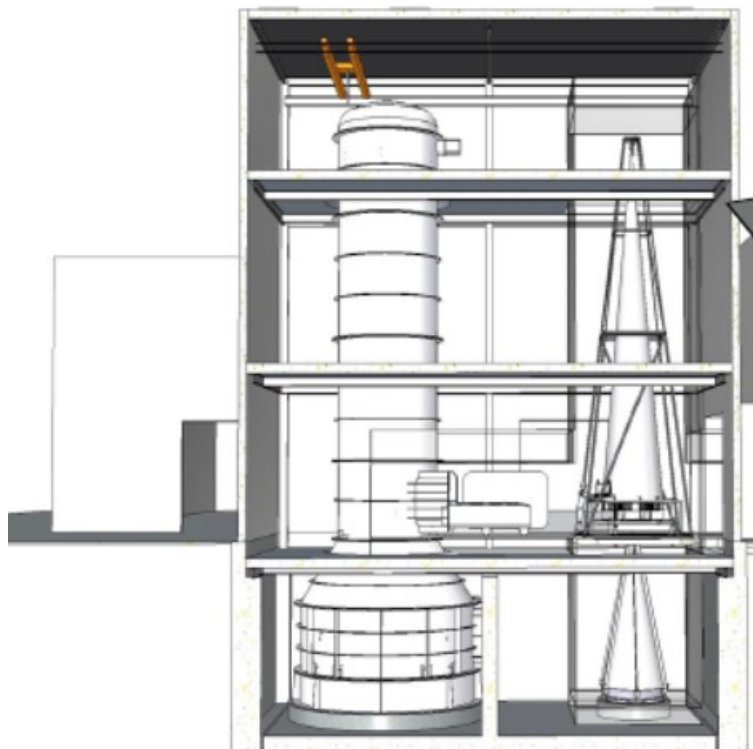


# VERT-X Design of Vertical X-Ray Test Facility for ATHENA

## TN19 SCHEDULE ESTIMATE FOR THE MA QM/FM VERIFICATION AND CALIBRATION CAMPAIGN

Doc: VTX-OAB-IPM-SCH-002

Date: 18 / 09 / 2020



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



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



## 1. INTRODUCTION

### 1.1. SCOPE

The scope of the present document is the illustration of the schedule estimate for the Mirror Assembly (MA) Qualification and Flight Model (QM/FM) verification and calibration activities in the VERT-X facilities, 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 describe the schedule estimate for the MA QM/FM verification and calibration campaign in the VERT-X facility.

### 1.3. ROADMAP

| Document section                                 | Content description                                                                                |
|--------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Section 2 (Applicable and reference documents)   | List of applicable documents and reference documents.                                              |
| Section 3 (Overview)                             | Overview of verification and calibration campaigns in VERT-X facility.                             |
| Section 4 (Test durations)                       | Details of tests durations for HEW and effective area, optical axis, focal length and stray light. |
| Section 5 (MA FM verification campaign schedule) | Details of schedule estimate for MA FM verification campaign in the VERT-X facility.               |
| Section 6 (VERT-X FM calibration campaign)       | Details of schedule estimate for FM calibration campaign.                                          |

Table 1-1: Roadmap of the document

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



## 2. APPLICABLE AND REFERENCE DOCUMENTS

### 2.1. APPLICABLE DOCUMENTS

|     |                                                                                                             |
|-----|-------------------------------------------------------------------------------------------------------------|
| AD1 | AO/1-9549/18/NL/AR - SOW<br>X-ray Raster Scan Facility for the ATHENA Mirror Assembly SOW                   |
| AD2 | VERT-INAFOAB-001<br>VERTICAL X-Ray (VERT-X) Technical Proposal                                              |
| AD3 | ESA-TECMMO-RS-014713<br>Updated Requirements for the ATHENA VERT-X following the System Requirements Review |
| AD4 | ATHENA - MCF URD, IRD & ICD ISSUE 1.3 [ESA].pdf                                                             |
| AD5 | ATHENA - MCF URD, IRD & ICD WORKING DRAFT 04-06-2020                                                        |
| AD6 | ATHENA - Calibration Requirements Document, ESA-ATH-SP-2016-001, issue 0.5.1.pdf                            |
| AD7 | ATHENA - Optics Calibration Plan, ESA-ATHENA-ESTEC-SCI-PL-0001, Issue 1.1.pdf                               |
| AD8 |                                                                                                             |
| AD9 |                                                                                                             |

### 2.2. REFERENCE DOCUMENTS

|     |                                                               |
|-----|---------------------------------------------------------------|
| RD1 | VTX-OAB-ISE-REP-003 D5 Detailed Design Document               |
| RD2 | VTX-OAB-IOP-TEC-001_i01p02_TN11Concept_of_Operation           |
| RD3 | VTX-OAB-ISE-TEC-001_i01p02_TN12_Technical_Budgets             |
| RD4 | VTX-OAB-ISE-TEC-002_i01p00_TN5_X-Ray_Detector_and_(xyz)_Stage |
| RD5 | VTX-EIE-ISE-TEC-002_i02p00_TN3_Raster_Scan_System             |
| RD6 |                                                               |

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



### 2.3. GENERAL SPECIFICATIONS AND STANDARD DOCUMENTS

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

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



### 2.4. LIST OF ACRONYMS

|        |                                                  |
|--------|--------------------------------------------------|
| AD     | Applicable Document                              |
| AIT    | Assembly, Integration and Testing                |
| DDR    | Detailed Design Review                           |
| EA     | Effective Area                                   |
| EIE    | European Industrial Engineering                  |
| ESA    | European Space Agency                            |
| FM     | Flight Model                                     |
| 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                        |
| QM     | Qualification Model                              |
| RD     | Reference Document                               |
| RS     | Raster Scanner                                   |
| 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                           |
| VERT-X | VERTICAL X-Ray                                   |
| VTX    | VERT-X                                           |
| XRS    | X-ray Raster Scanner                             |
| XSA    | X-ray Source Assembly                            |
| XYZS   | (x, y, z) stage                                  |

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



### 3. OVERVIEW

As specified in AD4 during the verification and calibration operations the following campaigns are planned:

1. Performance verification campaign tests for the MA QM (**3 months, start Apr 2025**);
2. Alignment checks during the MA FM integration campaign (**2 years, start Nov/2026**);
3. Performance verification campaign tests for the MA FM (**6 months, Sep/2028**);
4. FM calibration campaign (**6 months, Feb/2029**);

*In AD4 two baselines are present: the first with the only XRCF NASA facility available, the second with both XRCF and VERT-X available for the ATHENA MA verification and calibration test purposes. According to this scheme VERT-X will be used only for the first part of the performance verification campaign tests for the MA QM, Alignment checks during the MA FM integration campaign and the first part of Performance verification campaign tests for the MA FM. Nevertheless, in the present document following the AD1 prescriptions we assume to perform the entire verification and calibration campaign in VERT-X.*

| PHASE                                          | TEST        | MM<br>(TBC) | DATE<br>(TBC) | DURATION<br>(days) |
|------------------------------------------------|-------------|-------------|---------------|--------------------|
| (1)<br>Mirror QM performance & EVT<br>campaign | QM_AA       | 46          | APR 2025      | 6                  |
|                                                | QM_AFT      | 46          | MAY 2025      | 4                  |
|                                                | QM_AFT      | 46          | MAY 2025      | 4                  |
|                                                | QM_FULL     | 46          | JUN 2025      | 4                  |
| (2)<br>Mirror FM integration campaign          | IAC_1       | 96          | MAY 2027      | 6                  |
|                                                | IAC_2       | 288         | NOV 2027      | 6                  |
|                                                | IAC_3       | 492         | MAY 2028      | 7                  |
| (3)<br>Mirror FM performance & EVT<br>campaign | FM_AA       | 678         | OTT 2028      | 7                  |
|                                                | FM_AFT      | 678         | NOV 2028      | 4                  |
|                                                | FM_AFT      | 678         | DEC 2028      | 4                  |
|                                                | FM_FULL     | 678         | JAN 2029      | 4                  |
| Calibration                                    | CALIBRATION | 678         | FEB 2029      | 120                |

Table 3-1: Verification and calibration campaigns overview

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

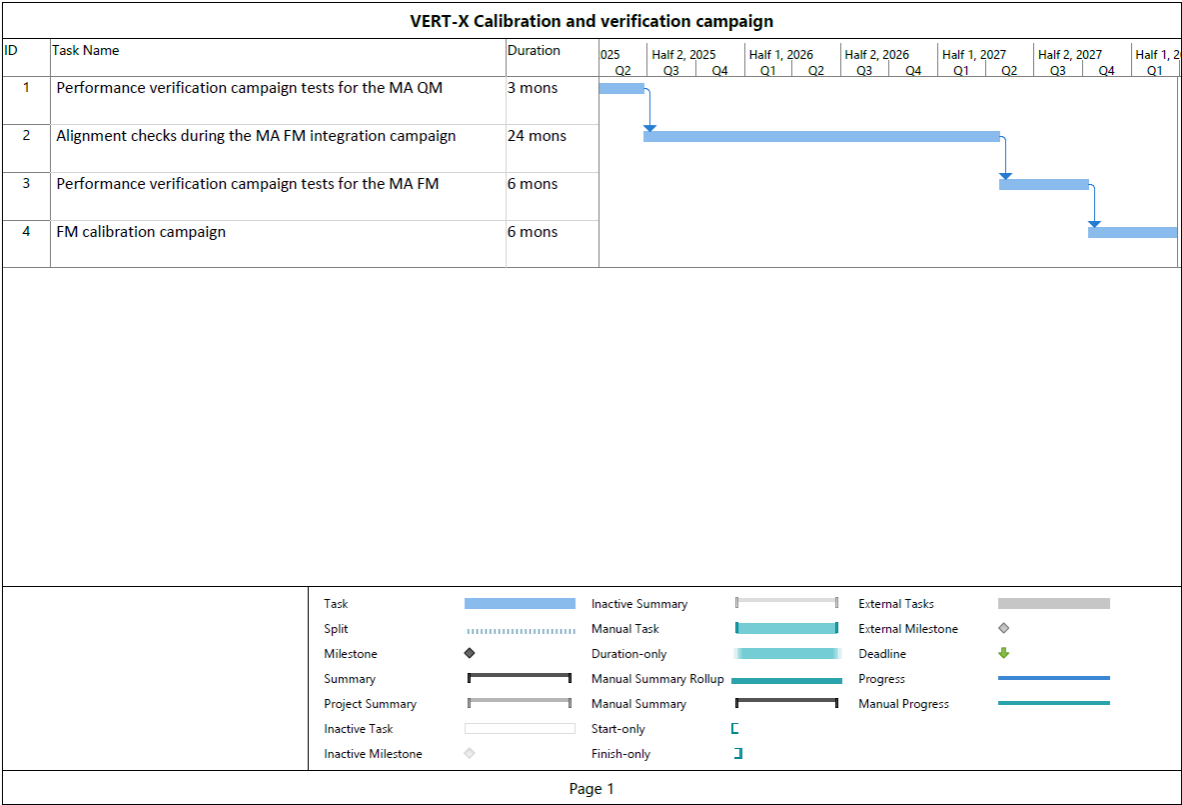


Figure 3-1: VERT-X calibration and verification campaign schedule

### 3.1. VERIFICATION TEST CAMPAIGN

Verification (points 1,2,3 of the previous table) will consist in different sequences of four tests, according the scheme defined in the Integration & Verification flows tab of AD5.

These four different tests are:

- Alignment acceptance (**AA**)
- Intermediate alignment acceptance (**IAC**);
- Abbreviated functional test (**AFT**);
- Full functional tests (**FULL**).

AA coincides with IAC, while FULL will perform the same tests of AFT at three energies instead of 1 energy with the MA TCS operating.

Scope and requirements of the four tests are the following.

**AA** and **IAC** shall determine:

- The MA optical axis; AKE ≤10" with 68% confidence.
- The MA on-axis A<sub>eff</sub>; AKE ≤10% with 68% confidence.
- The MA focal length; AKE ≤100µm with 99.7% confidence at one energy (e.g. Al-K)

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



- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 3 energies (unless above otherwise specified, e.g.: C-K, Al-K, Ti-K), under a uniform temperature of  $20^{\circ}\text{C} \pm \text{TBD}^{\circ}\text{C}$  (thermal conditions mimicking the MM-->MA integration, and nominal flight operation), with the MA TCS not operating.

### AFT shall determine:

- The MA on-axis  $A_{\text{eff}}$ ; AKE of  $\leq 10\%$  with 68% confidence.
- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 1 energy, under a uniform temperature of  $20^{\circ}\text{C} \pm \text{TBD}^{\circ}\text{C}$  (thermal conditions mimicking the MM-->MA integration, and nominal flight operation), with the MA TCS not operating.

### Full shall determine:

- The MA on-axis  $A_{\text{eff}}$ ; AKE of  $\leq 10\%$  with 68% confidence.
- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 3 energies (e.g.: C-K, Al-K, Ti-K), under TBD temperature conditions, with the MA TCS operating.

As said, the three verification campaigns will consist in several sequences of these 4 tests according the following scheme as defined in the Integration & Verification flows tab of RD3 (this is an initial specification of the performance verification requirements of the MA, and will be revised by the Primes):

1. Mirror QM performance: AA+AFT+AFT+FULL on the QM (1,8,15 rows, 2 sextans, 46 modules in total, TBC)
2. Mirror FM integration: three repetitions of IAC on FM with 1-3, 1-8, 1-12 integrated rows respectively
3. Mirror FM performance: Consists in the sequence: AA+AFT+AFT+FULL on the FM (15 rows, 6 sextans, 606 modules in total).

The list of the required measures during the verification phase are listed in Table 3-2.

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



| WHERE   | GOAL             | ACCURACY    | ENERGY                  | REQ                    | WHEN          | WHAT                          |
|---------|------------------|-------------|-------------------------|------------------------|---------------|-------------------------------|
| On Axis | FOCAL LENGTH     | 1mm (99.7%) | 1 (Al-K $\alpha$ )      | LB-URD-365             | AA, IAC       | QM, FM1-3, FM1-8, FM1-12, FM. |
| On Axis | OPTICAL AXIS     | 10" (68%)   | 3 (C,Al,Ti-K $\alpha$ ) | LB-URD-365-366         | AA, IAC       | QM, FM1-3, FM1-8, FM1-12, FM. |
| On Axis | HEW              | 2% (68%)    | 1 (C,Al,Ti-K $\alpha$ ) | LB-URD-368             | AFT           | QM, FM1-3, FM1-8, FM1-12, FM. |
| On Axis | A <sub>eff</sub> | 10% (68%)   | 1 (C,Al,Ti-K $\alpha$ ) | LB-URD-368             | AFT           | QM, FM1-3, FM1-8, FM1-12, FM. |
| On Axis | HEW              | 2% (68%)    | 3 (C,Al,Ti-K $\alpha$ ) | LB-URD-365-366-368-369 | AA, IAC, FULL | QM, FM1-3, FM1-8, FM1-12, FM. |
| On Axis | A <sub>eff</sub> | 10% (68%)   | 3 (C,Al,Ti-K $\alpha$ ) | LB-URD-365-366-368-369 | AA, IAC, FULL | QM, FM1-3, FM1-8, FM1-12, FM. |

Table 3-2: Summary of the Verification tests and corresponding required accuracy [RD3].

### 3.2. CALIBRATION TEST CAMPAIGN

Calibration consists in a 6-month test campaign starting in February 2029 (AD5). Goals and required accuracies are reported in AD6 and AD7 as summarized in RD2. While the calibration requirement on the HEW is not significantly different from verification, the main differences between verification and calibration are the following: (i) off-axis tests in 20 different positions; (ii) out of FOV test for the stray-light calibration purposes; (iii) required effective area calibration accuracy is significantly higher both in absolute and relative terms.

In the following table we report a summary of the calibration requirements (RD2)

| WHERE    | GOAL                   | ACCURACY     | ENERGY                                            | REQ                         |
|----------|------------------------|--------------|---------------------------------------------------|-----------------------------|
| ON Axis  | Focal length           | 1mm (99.7%)  | 3(Al-K $\alpha$ , Ti-K $\alpha$ , Cu-K $\alpha$ ) | LB-URD-374<br>CAL-AST-R-002 |
| On Axis  | Optical axis           | 36" (99.7%)  |                                                   | LB-URD-373<br>CAL-AST-R-005 |
| On Axis  | HEW                    | 0.1" (68.3%) | 7 (C-K / Ge-K)                                    | LB-URD-376<br>CAL-PSF-R-001 |
| On Axis  | PSF                    | 5% (68.3%)   | 7 (C-K / Ge-K)                                    | LB-URD-376<br>CAL-PSF-R-001 |
| Off-Axis | HEW                    | 0.1" (68.3%) | 7 (C-K / Ge-K)                                    | LB-URD-376<br>CAL-PSF-R-001 |
| Off-Axis | PSF                    | 15% (68.3%)  | 7 (C-K / Ge-K)                                    | LB-URD-376<br>CAL-PSF-R-001 |
| On Axis  | A <sub>eff</sub> (abs) | 6% (68.3%)   | 10 (TBD 0.2-12.0 keV)                             | LB-URD-379                  |

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|           |             |               |                                                      |                             |
|-----------|-------------|---------------|------------------------------------------------------|-----------------------------|
|           |             |               |                                                      | CAL-EEF_R-001               |
| On Axis   | A_eff (rel) | 2% (68.3%)    | 0.2-12.0 keV continuum, step 1/3 spectral resolution | CAL-EEF_R-003               |
| Off Axis  | A_eff (rel) | 3% (68.3%)    | 0.3-7.0 keV continuum, step 1/3 spectral resolution  | LB-URD-382<br>CAL-EEF-R-004 |
| OUT Fov   | Stray-light | 5% (99.7%)    | 2 (Al-K $\alpha$ , Fe-K $\alpha$ )                   | LB-URD-383<br>CAL-PSF-R-003 |
| Out focus | HEW         | 0.5'' (99.7%) | Not specified                                        | LB-URD-377                  |

*Table 3-3: Summary of the calibration requirements [RD3].*

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### 4. TEST DURATIONS

The key factors in estimating the VERT-X test durations are:

- the detector sustainable count rate (allowing <1% pile-up level, as required by AD6). As described in RD3 and RD4 the expected value is 40 count/s in the single pixel event assumption.
- the scan time, which is the time needed by the raster-scan to cover the entire MA. It is estimated in RD5. At the nominal velocity of 30 mm/s the scan time is 3429s, including 504s of overhead for acceleration and deceleration at the row extremities. This time can be reduced down to 1970 s, doubling the scan velocity for the purposes of the stray-light calibration.
- the detector dimensions, which affects only the stray-light calibration.

#### 4.1. HEW AND EFFECTIVE AREA

As reported in RD2 and RD3 we plan to perform PSF and EA calibration by means of a set of photon-counting observations using the bremsstrahlung continuum and exploiting the detector energy resolution; collecting 50,000 / KeV would allow to meet both the EA and PSF calibration requirements. In the case of Bremsstrahlung continuum, the calculation of the necessary exposure time  $T_{EXP}$  is not straightforward. This is because photon distribution is not uniform over the required energy band. Simulations described in RD2 show that time needed to cover a limited energy range (e.g. 0.2-4.0) in 11000 s. interval.

Moreover, our simulations showed that the fastest way to accumulate the required photons all over the 0.2-12.0 keV range, is to split the test in 3 different energy bands, by means of 2 different high pass filters, obtained by thick Be windows.

This results in a total of  $T_{EXP} \sim 56,000$  s, to cover the full 0.2-12.0 energy band, accounting also for  $\sim 22,500$  s for the direct beam calibration (flat field) useful for the EA calibration.

Although the expected durations vary from filter to filter (2-5% variations), in the following we adopt for each filter an average  $T_{EXP} := T_{FILTER} = 19000$  s per each filter.

#### 4.2. OPTICAL AXIS

Optical axis will be measured by maximizing the flux over a set of  $N \sim 10$  PSF observations separated by an angular distance of  $\sim 10''$  (TBC). Exposure time of these observations is  $T_{SCAN}$ .

Note that, when the MA is not fully populated, like in the QM case or during the integration phase tests, the  $T_{SCAN}$  linearly scales with the occupation fraction.

#### 4.3. FOCAL LENGTH

MA focal length will be measured by maximizing the flux over a set of  $N \sim 10$  intra and extra focus observations. Exposure time of these observations is  $T_{SCAN}$ .

Note that, when the MA is not fully populated, like in the QM case or during the integration phase tests, the  $T_{SCAN}$  linearly scales with the occupation fraction.

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### 4.4. STRAY-LIGHT

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Since we expect that stray-light is an extended emission, covering at least 2 quadrants of the FOV, for each required position (out of the FOV), a 20'x10' (7 cm x 14 cm) area (at least) should be covered. Assuming a 6 cm x 6 cm detector.

$$T_{EXP} = 4 \times T_{SCAN} = 9752 \text{ s} * (6 \text{ cm} / \text{DET\_SIZE})^2$$

If necessary, the exposure time of these observations can be reduced increasing the scan velocity up to 60 mm/s.

---

### 4.5. SUMMARY

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Summarizing: the relevant time scales to estimate schedules for both calibration and verification are

$$T_{SCAN} = 3429 \text{ s}$$

$$T_{FILTER} = 19000 \text{ s}$$

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



### 5. VERT-X MA FM VERIFICATION CAMPAIGN SCHEDULE

#### 5.1. ALIGNEMENT ACCEPTANCE

**AA** shall determine:

- The MA optical axis; AKE  $\leq 10''$  with 68% confidence.
- The MA on-axis  $A_{eff}$ ; AKE  $\leq 10\%$  with 68% confidence.
- The MA focal length; AKE  $\leq 100\mu m$  with 99.7% confidence at one energy (e.g. Al-K)
- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 3 energies (e.g.: C-K, Al-K, Ti-K), under a uniform temperature of  $20^{\circ}C \pm TBD^{\circ}C$  (thermal conditions mimicking the MM-->MA integration, and nominal flight operation), with the MA TCS not operating.

We define E1:=C-K, E2:=Al-K and E3:Ti-K. For the purposes of the AA test and the following we assume to cover E1 and E2 with the same high-pass filter, while E3 will be covered in a second observation with the second high-pass filter.

In the following the schedule of the FM\_AA; we estimated a shorter  $T_{SCAN}$  and 6 day duration for the case of QM\_AA

| OPERATION                          | Energies Required | N filter | N test | Exposure              | Tot duration (hr) | schedule (day) |
|------------------------------------|-------------------|----------|--------|-----------------------|-------------------|----------------|
| MA positioning and vacuum creation | -                 | -        | -      | -                     | 8                 | 1              |
| Focal length                       | 1                 | 1        | 10     | $T_{SCAN}$            | 10                | 2-3            |
| Optical axis                       | 3                 | 2        | 10     | $T_{SCAN}$            | 20                | 3-5            |
| EA+HEW+PSF on axis                 | 3                 | 2        | 1      | $T_{FILTER}$          | 11                | 5-6            |
| Mask change and vacuum creation    | -                 | -        | -      | -                     | 8                 | 6              |
| Single MM characterization         | 1                 | 1        | 1      | $T_{SCAN}^* \times 5$ | 5                 | 7              |

Table 5-1: Alignment acceptance tests preliminary schedule

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

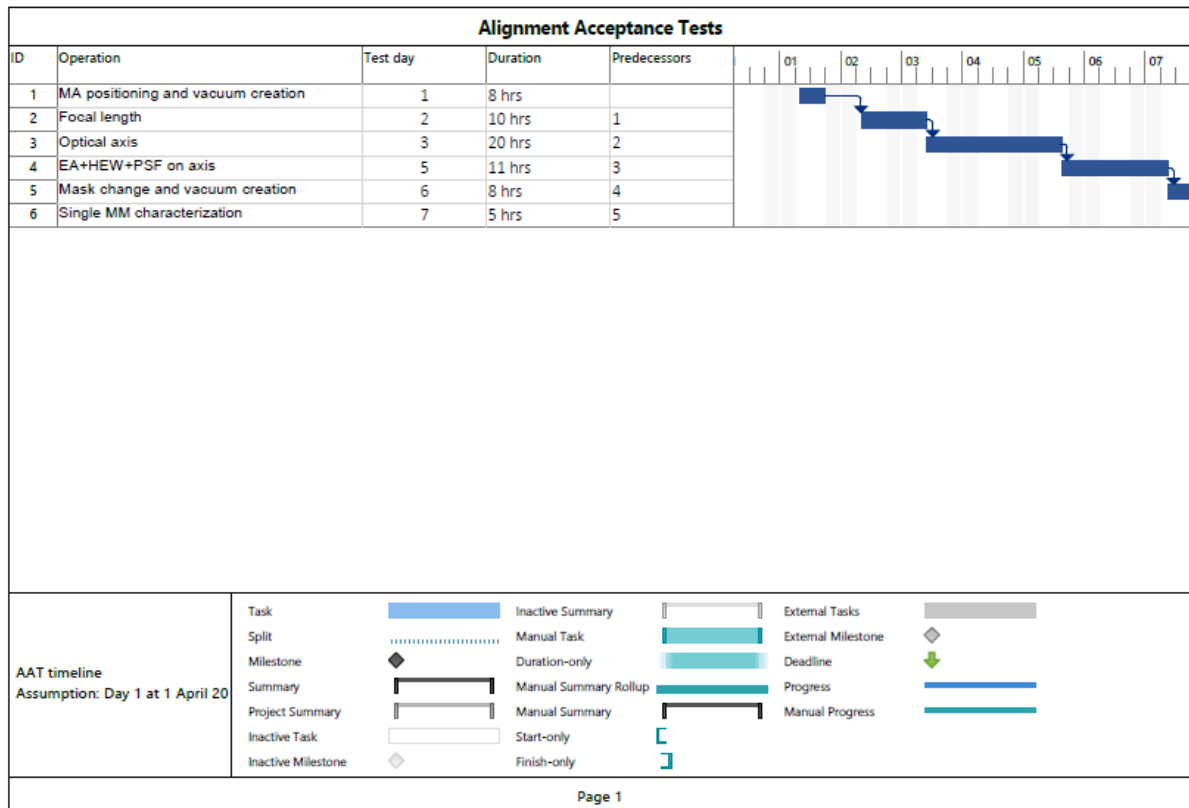


Figure 5-1: Alignment acceptance test preliminary schedule (for reference only)

## 5.2. ABBREVIATED FUNCTIONAL TEST

### AFT shall determine:

- The MA on-axis  $A_{eff}$ ; AKE of  $\leq 10\%$  with 68% confidence.
- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 1 energy, under a uniform temperature of  $20^{\circ}\text{C} \pm \text{TBD}^{\circ}\text{C}$  (thermal conditions mimicking the MM->MA integration, and nominal flight operation), with the MA TCS not operating.

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| OPERATION:                         | Energies<br>Required | N<br>filter | N<br>test | Exposure              | Tot duration<br>(hr) | schedule<br>(day) |
|------------------------------------|----------------------|-------------|-----------|-----------------------|----------------------|-------------------|
| MA positioning and vacuum creation | -                    | -           | -         |                       | 8                    | 1                 |
| EA+HEW+PSF on axis                 | 1                    | 1           | 1         | T <sub>FILTER</sub>   | 6                    | 2                 |
| Mask change and vacuum creation    | -                    | -           | -         | -                     | 8                    | 3                 |
| Single MM characterization         | 1                    | 1           | 1         | T <sub>SCAN</sub> x 5 | 5                    | 4                 |

Table 5-2: Abbreviated functional tests preliminary schedule

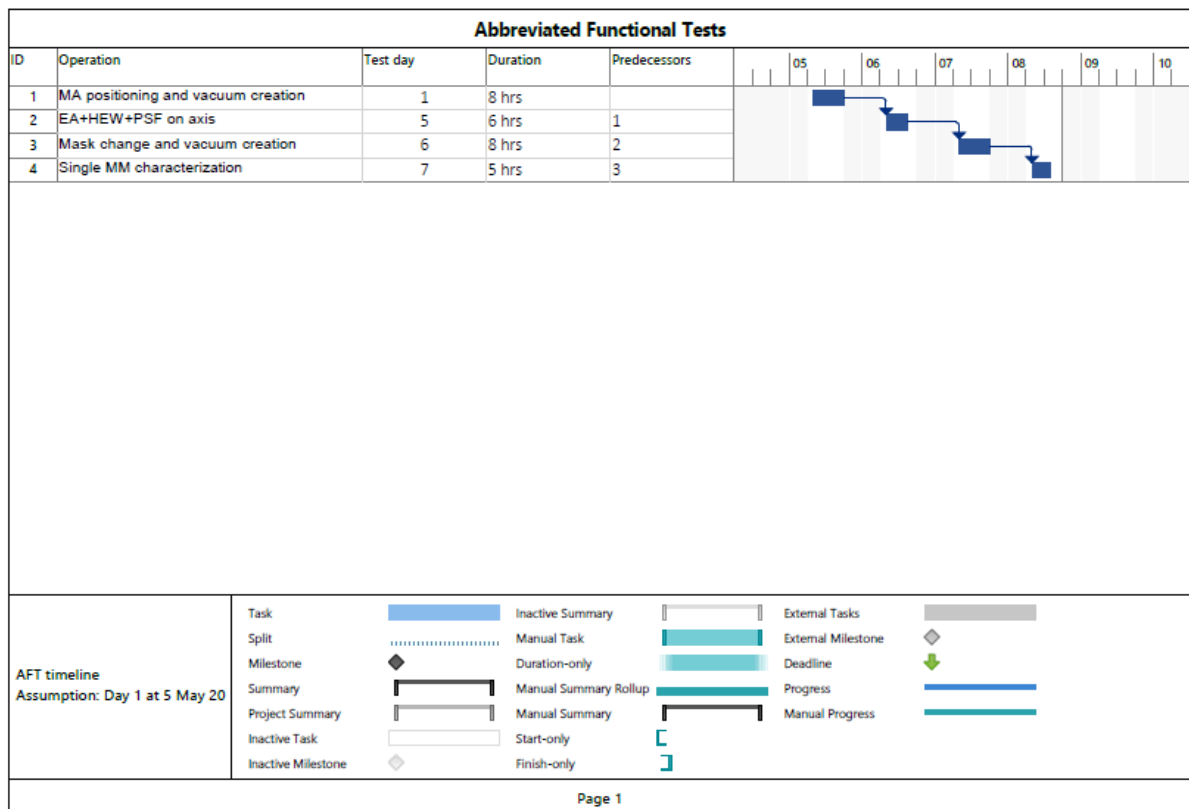


Figure 5-2: Abbreviated functional test preliminary schedule (for reference only)

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### 5.3. INTERMEDIATE ALIGNEMENT ACCEPTANCE (= AA)

**IAC** shall determine:

- The MA optical axis; AKE  $\leq 10''$  with 68% confidence.
- The MA on-axis  $A_{eff}$ ; AKE  $\leq 10\%$  with 68% confidence.
- The MA focal length; AKE  $\leq 100\mu m$  with 99.7% confidence at one energy (e.g. Al-K)
- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 3 energies (e.g.: C-K, Al-K, Ti-K), under a uniform temperature of  $20^{\circ}C \pm TBD^{\circ}C$  (thermal conditions mimicking the MM-->MA integration, and nominal flight operation), with the MA TCS not operating.

In the following the schedule of the IAC\_3; we estimated a shorter  $T_{SCAN}$  and a 6 day duration for the case of IAC\_1 and IAC\_2.

| OPERATION                          | Energies Required | N filter | N test | Exposure            | Tot duration (hr) | schedule (day) |
|------------------------------------|-------------------|----------|--------|---------------------|-------------------|----------------|
| MA positioning and vacuum creation | -                 | -        | -      | -                   | 8                 | 1              |
| Focal length                       | 1                 | 1        | 10     | $T_{SCAN}$          | 10                | 2-3            |
| Optical axis                       | 3                 | 2        | 10     | $T_{SCAN}$          | 20                | 3-5            |
| EA+HEW+PSF on axis                 | 3                 | 2        | 1      | $T_{FILTER}$        | 11                | 5-6            |
| Mask change and vacuum creation    | -                 | -        | -      | -                   | 8                 | 6              |
| Single MM characterization         | 1                 | 1        | 1      | $T_{SCAN} \times 5$ | 5                 | 7              |

Table 5-3: Intermediate aligned acceptance tests preliminary schedule

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Figure 5-3: Intermediate aligned acceptance test preliminary schedule (for reference only)

### 5.4. FULL FUNCTIONAL TEST

**Full** shall determine:

- The MA on-axis  $A_{eff}$ ; AKE of  $\leq 10\%$  with 68% confidence.
- The MA on-axis PSF HEW; AKE of  $\leq 2\%$  with 68% confidence.

At 3 energies (e.g.: C-K, Al-K, Ti-K), under TBD temperature conditions, with the MA TCS operating.

| OPERATION                          | Energies Required | N filter | N test | Exposure            | Tot duration (hr) | schedule (day) |
|------------------------------------|-------------------|----------|--------|---------------------|-------------------|----------------|
| MA positioning and vacuum creation | -                 | -        | -      |                     | 8                 | 1              |
| EA+HEW+PSF on axis                 | 3                 | 2        | 1      | $T_{FILTER}$        | 11                | 2-3            |
| Mask change and vacuum creation    | -                 | -        | -      | -                   | 8                 | 3              |
| Single MM characterization         | 1 (TBC)           | 1        | 1      | $T_{SCAN} \times 5$ | 5                 | 4              |

Table 5-4: Full functional tests preliminary schedule

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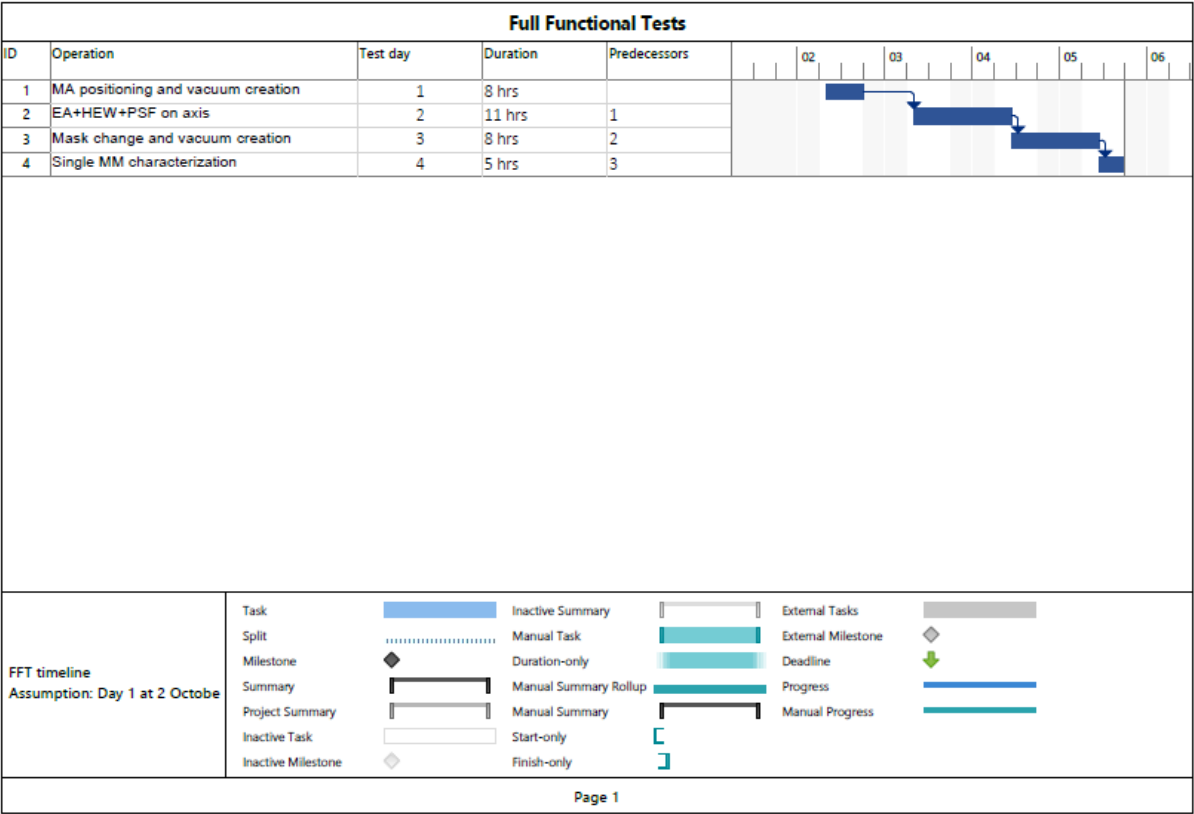


Figure 5-4: Full functional test preliminary schedule (for reference only)

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### 6. VERT-X FM CALIBRATION CAMPAIGN

| OPERATION                          | Energies Required | N filter | N test | Exposure              | Tot duration (hr) | schedule (day) |
|------------------------------------|-------------------|----------|--------|-----------------------|-------------------|----------------|
| MA positioning and vacuum creation | -                 | -        | -      |                       | 8                 | 1              |
| Focal length                       | 3                 | 2        | 10     | T <sub>SCAN</sub>     | 20                | 2-4            |
| Optical axis                       | 3 (TBC)           | 2        | 10     | T <sub>SCAN</sub>     | 20                | 4-6            |
| EA+HEW+PSF on axis                 | 10                | 3        | 1      | T <sub>FILTER</sub>   | 16                | 7-8            |
| EA+HEW+PSF off axis                | 10                | 3        | 20     | T <sub>FILTER</sub>   | 317               | 9-48           |
| Stray-light                        | 2                 | 2        | 10     | T <sub>SCAN</sub> x 4 | 77                | 49-58          |
| Out-of-focus HEW                   | 1 (TBC)           | 1        | 10     | T <sub>SCAN</sub>     | 10                | 59-60          |
| Mask change and vacuum creation    | -                 | -        | -      | -                     | 8                 | 61             |
| Single MM characterization         | 1 (TBC)           | 1        | 1      | T <sub>SCAN</sub> x 5 | 5                 | 62             |

Table 6-1: VERT-X FM calibration campaign preliminary schedule

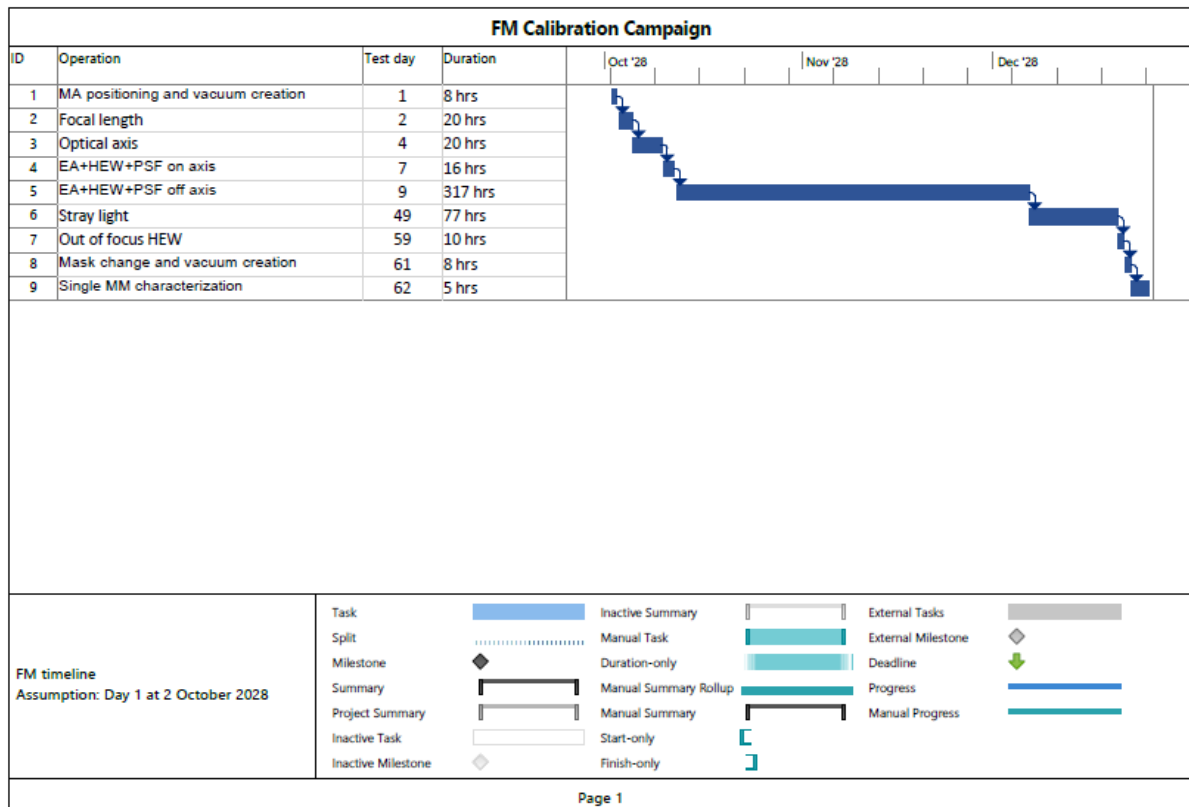


Figure 6-1: VERT-X FM calibration campaign preliminary schedule (for reference only)

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



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