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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



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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

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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
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	

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2.3. GENERAL SPECIFICATIONS AND STANDARD DOCUMENTS

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

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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	
ІТТ	Invitation To Tender	
MA	Mirror Assembly	
MLS	Media Lario S.r.I.	
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	
ТВА	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	

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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	DATE	DURATION
		(TBC)	(TBC)	(days)
(1)	QM_AA	46	APR 2025	6
Mirror QM performance & EVT	QM_AFT	46	MAY 2025	4
campaign	QM_AFT	46	MAY 2025	4
	QM_FULL	46	JUN 2025	4
(2)	IAC_1	96	MAY 2027	6
Mirror FM integration campaign	IAC_2	288	NOV 2027	6
	IAC_3	492	MAY 2028	7
(3)	FM_AA	678	OTT 2028	7
Mirror FM performance & EVT	FM_AFT	678	NOV 2028	4
campaign	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

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	VERT-X	Calibration an	on and verification campaign								
ID	Task Name	Duration	025	Half 2, 2025	Half 1, 2026	Half 2, 2026	Half 1, 2027	Half 2, 2027	Half 1, 2		
1	Performance verification campaign tests for the MA QM	3 mons									
2	Alignment checks during the MA FM integration campaign	24 mons		•							
3	Performance verification campaign tests for the MA FM	6 mons					•				
4	FM calibration campaign	6 mons						•			
	lask		Inactive S	ummary		1 External lask	5				
	Spirt	۵	Duration	ask only		 External Mile Deadline 	stone V				
	Summary	·	Manual S	ummary Rollup		Progress					
	Project Summarv		Manual S	ummary		Manual Prog	ress				
	Inactive Task	-	Start-only	, , , ,	C						
	Inactive Milestone	0	Finish-on	ly .	3						
		Pa	ige 1								

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_{eff} ; AKE $\leq 10\%$ with 68% confidence.
- The MA focal length; AKE ≤100µm with 99.7% confidence at one energy (e.g. Al-K)



The MA on-axis PSF HEW; AKE of ≤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° C ± TBD°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_{eff}; AKE of ≤10% with 68% confidence.
- The MA on-axis PSF HEW; AKE of ≤2% with 68% confidence.

At 1 energy, under a uniform temperature of 20°C ± TBD°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_{eff}; AKE of ≤10% with68% confidence.
- The MA on-axis PSF HEW; AKE of ≤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.

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WHERE	GOAL	ACCURACY	ENERGY	REQ	WHEN	WHAT
On Axis	FOCAL LENGTH	1mm (99.7%)	1 (Al-Kα)	LB-URD-365	AA, IAC	QM, FM1-3, FM1-8, FM1-12, FM.
On Axis	OPTICAL AXIS	10" (68%)	3 (C,Al,Ti-Kα)	LB-URD-365- 366	AA, IAC	QM, FM1-3, FM1-8, FM1-12, FM.
On Axis	HEW	2% (68%)	1 (C,Al,Ti-Kα)	LB-URD-368	AFT	QM, FM1-3, FM1-8, FM1-12, FM.
On Axis	A _{eff}	10% (68%)	1 (C,Al,Ti-Kα)	LB-URD-368	AFT	QM, FM1-3, FM1-8, FM1-12, FM.
On Axis	HEW	2% (68%)	3 (C,Al,Ti-Kα)	LB-URD-365- 366-368-369	AA, IAC, FULL	QM, FM1-3, FM1-8, FM1-12, FM.
On Axis	A _{eff}	10% (68%)	3 (C,Al,Ti-Kα)	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 bot 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-Kα,Ti-Kα,Cu-Kα)	LB-URD-374
				CAL-AST-R-002
On Axis	Optical axis	36" (99.7%)		LB-URD-373
				CAL-AST-R-005
On Axis	HEW	0.1" (68.3%)	7 (C-K / Ge-K)	LB-URD-376
				CAL-PSF-R-001
On Axis	PSF	5% (68.3%)	7 (C-K / Ge-K)	LB-URD-376
				CAL-PSF-R-001
Off-Axis	HEW	0.1" (68.3%)	7 (C-K / Ge-K)	LB-URD-376
				CAL-PSF-R-001
Off-Axis	PSF	15% (68.3%)	7 (C-K / Ge-K)	LB-URD-376
				CAL-PSF-R-001
On Axis	A_eff (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	LB-URD-382
			spectral resolution	CAL-EEF-R-004
OUT Fov	Stray-light	5% (99.7%)	2 (Al-Kα,Fe-Kα)	LB-URD-383
				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 photoncounting 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 ~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~10 PSF observations separated by an angular distance of ~ 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~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.



4.4. STRAY-LIGHT

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

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

 $T_{SCAN} = 3429s$

 $T_{FILTER} = 19000s$

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5. VERT-X MA FM VERIFICATION CAMPAIGN SCHEDULE

5.1. ALIGNEMENT ACCEPTANCE

AA shall determine:

- The MA optical axis; AKE ≤10" with 68% confidence.
- The MA on-axis A_{eff}; AKE ≤10% with 68% confidence.
- The MA focal length; AKE ≤100µm with 99.7% confidence at one energy (e.g. Al-K)
- The MA on-axis PSF HEW; AKE of ≤2% with 68% confidence.

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

We define E1:=C-K, E2:=AI-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	TSCAN	10	2-3
Optical axis	3	2	10	TSCAN	20	3-5
EA+HEW+PSF on axis	3	2	1	TFILTER	11	5-6
Mask change and vacuum creation	-	-	-	-	8	6
Single MM characterization	1	1	1	T _{SCAN} * x 5	5	7

Table 5-1: Alignment acceptance tests preliminary schedule

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	Alignment Acceptance Tests											
ID Operation		Test day	Duration	Predecessors		01 02	03	04 05	06 07			
1 MA positioning and vacuu	im creation	1	8 hrs									
2 Focal length		2	10 hrs	1		*	h					
3 Optical axis		3	20 hrs	2			Ť.		n.			
4 EA+HEW+PSF on axis		5	11 hrs	3								
5 Mask change and vacuum	n creation	6	8 hrs	4					Ĭ			
6 Single MM characterizatio	n	7	5 hrs	5								
	Task	_	Inactive Summ	nary		External Tasks						
	Split		Manual Task			External Milestone	\diamond					
A AT Almostine	Milestone	•	Duration-only	,		Deadline	+					
Assumption: Day 1 at 1 April 20	Summary		Manual Summ	nary Rollup		Progress						
resumption, pay 1 at 1 April 20	Project Summary		Manual Summ	nary		Manual Progress						
	Inactive Task		Start-only	E								
	Inactive Milestone	\diamond	Finish-only	Ē								
			Pa	age 1								

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 ≤10% with 68% confidence.
- The MA on-axis PSF HEW; AKE of ≤2% with 68% confidence.

At 1 energy, under a uniform temperature of 20°C ± TBD°C (thermal conditions mimicking the MM-->MA integration, and nominal flight operation), with the MA TCS not operating.

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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	1	1	1	TFILTER	6	2
Mask change and vacuum creation	-	-	-	-	8	3
Single MM characterization	1	1	1	T _{SCAN} x 5	5	4

Table 5-2: Abbreviated functional tests preliminary schedule

	Abbreviated Functional Tests										
ID	Operation		Test day	Duration	Predecessors		05 06	07 08	09 10		
1	MA positioning and vacuu	m creation	1	8 hrs		1					
2	EA+HEW+PSF on axis		5	6 hrs	1		1				
3	Mask change and vacuum	n creation	6	8 hrs	2						
4	Single MM characterizatio	n	7	5 hrs	3			1			
		Tark		Institue Suprom	2		Evtannel Turke				
		Task		Inactive Summa	ry 🛛	1	External Tasks				
		Split		Manual Task			External Milestone	•			
AFT ti	meline	Milestone	•	Duration-only			Deadline	+			
Assun	nption: Day 1 at 5 May 20	Summary		Manual Summa	ry Rollup		Progress				
		Project Summary	0	Manual Summa	ry .		Manual Progress				
		Inactive Task		Start-only	E						
		Inactive Milestone		Finish-only							
				Pag	e 1						

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



5.3. INTERMEDIATE ALIGNEMENT ACCEPTANCE (= AA)

IAC shall determine:

- The MA optical axis; AKE ≤10" with 68% confidence.
- The MA on-axis A_{eff}; AKE ≤10% with 68% confidence.
- The MA focal length; AKE ≤100µm with 99.7% confidence at one energy (e.g. Al-K)
- The MA on-axis PSF HEW; AKE of ≤2% with 68% confidence.

At 3 energies (e.g.: C-K. Al-K, Ti-K), under a uniform temperature of 20°C ± TBD°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 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	TSCAN	10	2-3
Optical axis	3	2	10	TSCAN	20	3-5
EA+HEW+PSF on axis	3	2	1	TFILTER	11	5-6
Mask change and vacuum creation	-	-	-	-	8	6
Single MM characterization	1	1	1	T _{SCAN} x 5	5	7

Table 5-3: Intermediate aligned acceptance tests preliminary schedule

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Intermediate Alignment Acceptance										
ID Operation		Test day	Duration	8 04	05	06 07 08	09	10 11 12 13		
1 MA positioning and vacuu	um creation	1	8 hrs							
2 Focal length		2	10 hrs		1					
3 Optical axis		3	20 hrs		i i i	1				
4 EA+HEW+PSF on axis		5	11 hrs					1 I I I I I I I I I I I I I I I I I I I		
5 Mask change and vacuur	n creation	6	8 hrs					i i i i i i i i i i i i i i i i i i i		
6 Single MM characterization	on	7	5 hrs							
	Task		Inactive Summar	v	1	External Tasks	_			
	Solit		Manual Task	,		External Milestone	•			
	Milestone	۵	Duration-only			Deadline	ľ.			
IAC timeline	Summany	Ť	Manual Summar	v Rollup		Progress	•			
Assumption: Day 1 at 3 May 20	Depied Summany		Manual Summar			Manual Provinces		_		
	Inactive Task	u	E Manual Summar	, г		manual Progress				
	Inactive Milestone	\diamond	Finish-only	<u> </u>						
			Page	e 1						

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 ≤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} x 5	5	4

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Full Functional Tests											
D Operation		Test day	Duration	Predecessors	02	03	04	05	06		
1	MA positioning and vacuum creation		1	8 hrs							
2	2 EA+HEW+PSF on axis		2	11 hrs	1				h		
3	3 Mask change and vacuum creation		3	8 hrs	2				*	h	
4	Single MM characterization		4	5 hrs	3					Ť.	
		Task		Inactive Sum	mary	External	rasks				
FFT tin	meline nption: Day 1 at 2 Octobe	Split		Manual Task		External	Vilestone	\diamond			
		Milestone	•	Duration-onl	у	Deadline		+			
		Summary		Manual Sum	mary Rollup	Progress					
		Project Summary		Manual Sum	mary	Manual P	rogress				
		Inactive Task		Start-only	E						
		Inactive Milestone	\diamond	Finish-only	3						
	Page 1										

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

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



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	TSCAN	20	2-4
Optical axis	3 (TBC)	2	10	TSCAN	20	4-6
EA+HEW+PSF on axis	10	3	1	TFILTER	16	7-8
EA+HEW+PSF off axis	10	3	20	TFILTER	317	9-48
Stray-light	2	2	10	T _{SCAN} x 4	77	49-58
Out-of-focus HEW	1 (TBC)	1	10	TSCAN	10	59-60
Mask change and vacuum creation	-	-	-	-	8	61
Single MM characterization	1 (TBC)	1	1	T _{SCAN} 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)

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