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DOCUMENT

ATHENA – Technology Plan

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1 INTRODUCTION

This document is an instance of the ECSS standard Technology Plan [ECSS-E-ST-10C, Annex E], and is a constituent of SEP_1.0 (Mission), under the responsibility of the ESA Project Office.

It is established for each item of the Function and Product Trees [RD02] (as defined in ECSS-E-ST-10, Annex H), and highlights the technical requirements, and the critical technology of each item.

This document complements the separate Technology Plans for the Mirror Assembly [RD06], CC [RD14], X-IFU and WFI instruments [RD04], [RD05].

2 SCOPE

The main purpose of this document is to:

i. Provide an identification of ATHENA critical technology needs
ii. Provide an overview of the ATHENA Technology Plan, consisting of:
    a) A summary of the plan for those technology developments falling under ESA responsibility (including possibilities for international contributions)
    b) A summary of the plan for those technology developments falling outside of ESA responsibility (at the moment related to the instruments, and excluding discussion of international collaboration.)

[i] The first part of this document summarises the technology development needs of ATHENA.

Note: Currently the basis of this assessment is the preceding ESA IXO Technology Plan [RD09] and the IXO Phase A industrial study Technology Plans [RD10] [RD11], taking into account the evolution in technology needs from IXO to ATHENA identified from the recently completed ATHENA CDF study [RD12].

[ii-a] The second part of this document outlines the planned and running technology development activities (TDAs) under ESA responsibility, with the objective of retiring as much technology risk as possible prior to implementation of the ATHENA mission.

Note: It is mandated by [RD03] that ESA must prepare technologies for this mission such that it can be undertaken independently if necessary. However, while no international agreements currently exist, there is keen interest from both NASA and JAXA to contribute. Accordingly, this section of the document also summarises technologies/developments in the critical areas from outside of ESA (NASA/JAXA), and which raise the possibility of their contribution in these areas.

[ii-b] In the final part of this document, oversight is given of the technology developments related to the Payloads which are largely the responsibility of the member states (ESA also has some involvement in technology development for the instrument). Detailed information concerning the technology development of these products is provided in the X-IFU and WFI Technology Plans respectively [RD04], [RD05].

Note: for these items an agreement has been made [RD07] between the ESA Coordination Office and the Instrument Providers that international contributions to the X-IFU and WFI can be agreed bi-laterally without direct ESA involvement. Consequently this section does not discuss possible international contributions to the Payloads.

3 APPLICABLE AND REFERENCE DOCUMENTS

3.1 Applicable Documents

[AD 1] Space engineering: System engineering general requirements, ECSS-E-ST-10C, Issue 3, 06/03/2009.

3.2 Reference Documents

[RD01] Cosmic Vision Technology Development Plan: Programme of Work 2009-2014 and Related Procurement Plan. ESTEC/AC/476-02, ESA/IPC(2014).

[RD02] ATHENA - Product Tree, ATHENA-ESA-PT-0001, Issue 1.0, 12/06/2014.

[RD03] Call for mission concepts for the Large-size 'L2' mission opportunity in ESA's Science Programme.

[RD04] ATHENA - X-IFU Technology Plan, TBW.

[RD05] ATHENA – WFI Technology Plan, TBW.

[RD06] ATHENA – Mirror Assembly Technology Plan TBW.

[RD07] ATHENA – ASST#2 Minutes of Meeting, SRE-SA/ATHENA/2014/02, 20/09/2014.

[RD08] Space Systems – Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment. ISO 16290:2013, ISSUE1.0, 14/10/2013.

[RD09] IXO Technology Development Plan, SRE-PA/2010/072/NR, ISSUE1.0, 15/09/2011.

[RD10] IXO Assessment Study: Technology Development Plan, IXO.ASU.SAT.00002, ISSUE2.0, 01/07/2010.

[RD11] IXO Study: IXO Technology Development Plan, IXO-TASF-PL-014, ISSUE1.0, 01/10/2010.

[RD12] ATHENA - CDF Study Report, TBW.

[RD13] ATHENA –Baseline Schedule, ATHENA-ESA-SC-0001, Issue 1.0, 12/06/2014.

[RD14] ATHENA – Cooling Chain Technology Plan, TBW.

4 TRL & SCHEDULE CONSTRAINTS

The programmatic requirement from [RD03] is to reach TRL ≥ 5/6 (according to the ISO standard [RD08]) before the final mission adoption for all mission elements. Accordingly this Technology Plan is to be implemented up until the end of Phase B1 to the satisfaction of the SRR Panel (Q2/2019), with the objective to retire the main development risks before the start of implementation (Q1/2020) [RD13].

5 IDENTIFICATION OF CRITICAL AREAS

Note: this section does not deal with PL-internal technologies.

The ATHENA mission architecture and SC design are in most respects very achievable, with a great deal of flight and study heritage.

A lot of engineering and operational experience now resides in ESA regarding L2 missions, with the successful flight of Herschel, Planck and GAIA, and the forthcoming missions Euclid and Plato. The ATHENA mission has a classic L2 architecture* exhibiting many commonalities with the aforementioned missions, with very modest data-rates.

**Note: A small caveat remains for the achievement of the ToO-response time, which has a number of engineering consequences across the ATHENA mission, but which is currently foreseen to not require technology development.*

The ATHENA SC concept has many commonalities and heritage to exploit from the XMM-Newton and Chandra missions. The SC overall design and configuration is similar (dominated by the required focal length), and exploitation of certain technology items from these missions can be foreseen (e.g. telescope venting doors.)

Predecessors to the ATHENA mission (XEUS, IXO, ATHENA_L1) have been well studied (IXO to Phase A) and a lot of knowledge has been generated that can be applied to the ATHENA Phase o/A.

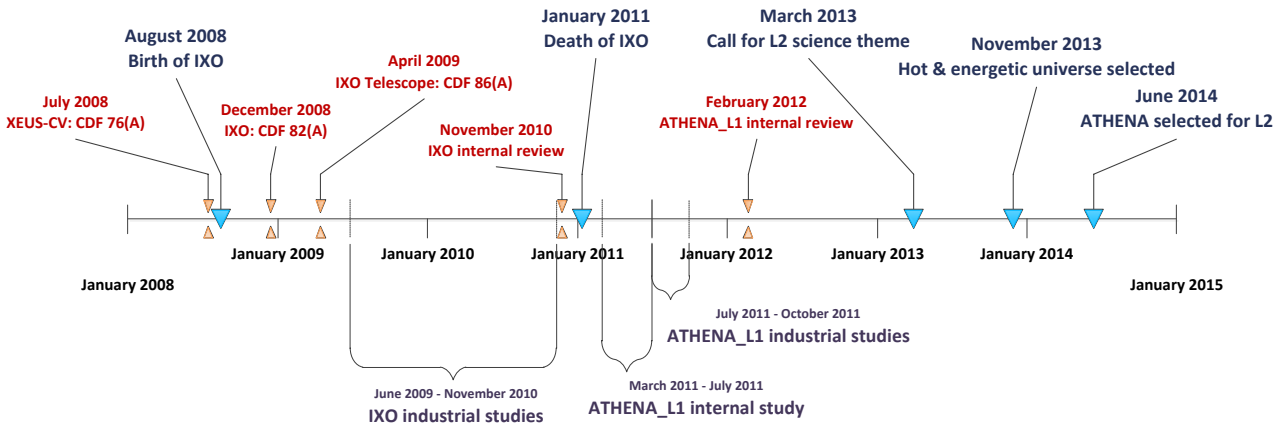

Figure 1: ATHENA study heritage

Nevertheless there are a few critical technology items, most of which have already under development for several years, which are prerequisites for the mission to fly. We separate these here into 'highly critical', 'moderately critical' and 'possible'.

The following technologies are highly critical and require dedicated development activities during Phase A/B1 since they carry significant risk to the project:

- SPO Mirror Modules (MM) & Mirror Assembly (MA)
- The X-IFU Cryogenic Chain (CC).

The following technologies are considered moderately critical and, while technology development during Phase A/B1 is in some cases foreseen, the risk could be accepted by Project during Phase B2/CD:

- MM passive vibration suppression.
- Instrument Switching Mechanism (ISM)
- On-board Metrology (OBM)
- SC Mirror Contamination Cover (MCC)
- Planning S/W & Fast Timeline Generation.

The following on-going or planned technology activities are considered of possible application to ATHENA and are being monitored.

- Platform & PL Sensor/Actuator Bus Nodes
- Ultra-low Roughness Mirror Coating
- CMG-based AOCS
- Next-generation STR.

6 TECHNOLOGY PLAN - ESA RESPONSIBILITY

Figure 2 shows the top-level ATHENA Product Tree from [RD02], with the addition of running/planned ESA-responsible technology development activities, associated with the relevant product and colour coded as follows:

- RED: ATHENA-Specific with highly critical ATHENA Application.
- BLUE: Generic with highly critical ATHENA Application.
- GREEN: ATHENA-Specific with moderately critical ATHENA Application.
- ORANGE: Generic with possible ATHENA Application.
- GREY: Unplanned with Moderately critical ATHENA Application.

Note: 'Planned' in this context includes activities for which IPC-approval has yet to be obtained.

The MSProject file attached to the ATHENA Baseline Schedule [RD13] contains these ESA technology development activities related to ATHENA (corresponding to the above colour-classifications except GREY) along with their schedules showing major milestones (forthcoming activities do not show a schedule). Detailed descriptions of these activities, current/target TRLs etc. can be found in the Cosmic Vision Technology Development Plan draft to the AC [RD01], the ATHENA Mirror Assembly Technology Plan [RD06], and the deliverable documentation from the TDA itself (to be placed on the SRE-F ATHENA area of ECLIPSE.)

6.1 Rationale for Grey Items

- OBM – several TRL 5/6 options already in place, but needs to be reviewed
- SC Mirror contamination cover – needs assessment.
- GS S/W and planning: Assumption at the moment is to take advantage of 'normal' developments in the timeframe of ATHENA (need some supporting statement from ESOC/ESAC that no specific development is needed.)

6.2 International Collaboration

Table 1 collates and summarises the foreseen opportunities for international collaboration for ESA-responsible products undergoing technology development. This is to be revised.

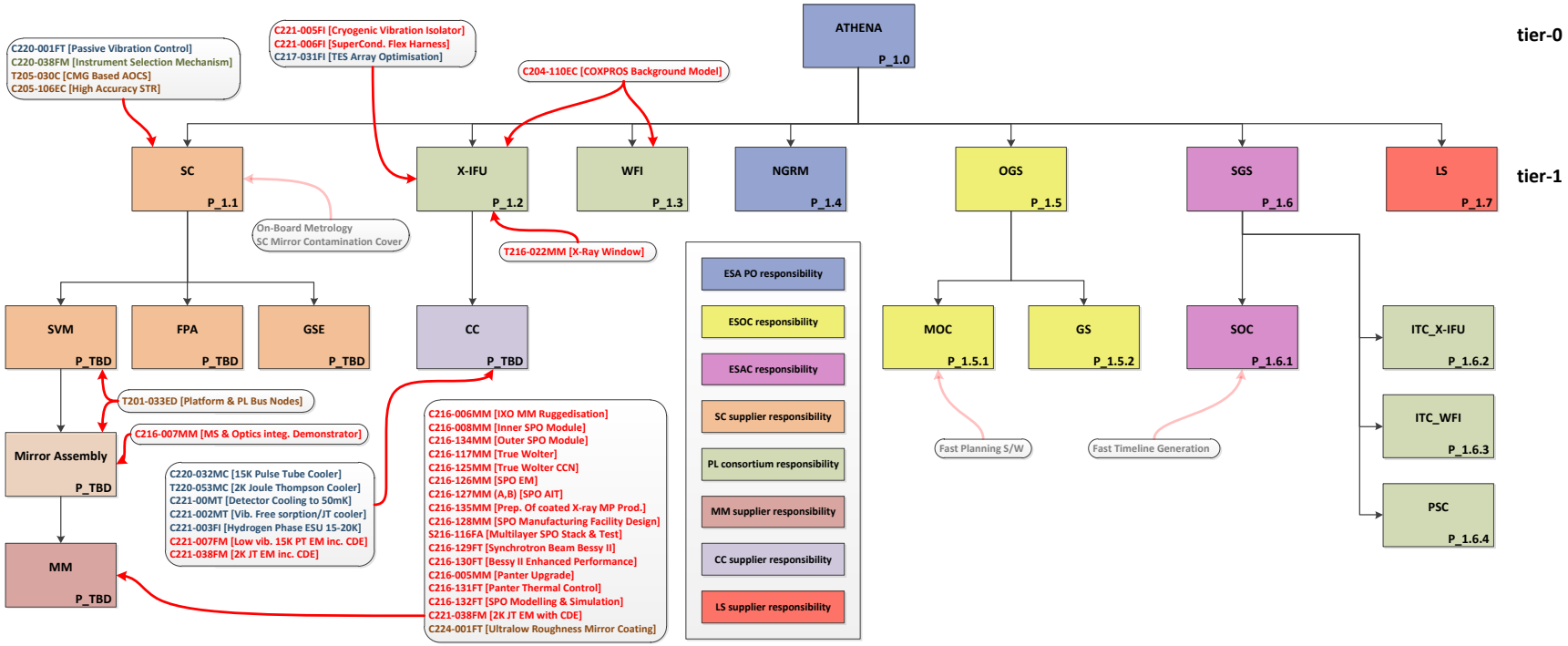

Figure 2: ATHENA top-level Product Tree with technology development activities assigned to products

Table 1: Assessment of technologies available from the prospective partners (NASA/JAXA)

Technology	Europe	TRL	USA	TRL	Japan	TRL
Mirror Modules and Petals	Silicon Pore Optics (TDA)	3	Slumped Glass Optics (TDA)	3	Thin foil mirrors (ASTRO-H) = Hard X-ray Telescope (HXT)	3
	Slumped Glass Optics (TDA)	2				
Hard X-ray Coating	Unknown		Unknown		Multi-layer Pt/C (ASTRO-H)	4
Cryogenics						
50mK cooler	MSSL dADR Cooler	4/5	GSFC multi-stage ADR (based on ASTRO-E/XRS)	4/5	Double ADR at ISAS	4
	CEA ADR/HSC Cooler	3				
2K cooler	RAL J-T Cooler	3	NGST 4-6K Cooler (MIRI/JWST) (but new development required, hence low TRL)	2	2K Cooler	
Two-stage Cooler	Astrium Two-Stage Stirling	4	NGST 18K Pulse Tube (MIRI/JWST) Lockheed 3 or 4 stage Pulse Tube	6	20K Stirling	4/5
On-board Metrology						
Alignment Monitoring Camera (AMC)	New development required, but can be based on existing developments	3	Lockheed AST-301 (with modification)	9	Unknown	
Fiducial Light System (FLS)	Rosat FLS?	9	Chandra FLS	9	Unknown	
	SODERN FLS	2				
Moving Instrument Platform (MIP)	Heritage on mechanisms only		Chandra SIM, but new development required	4/5	Unknown	

7 TECHNOLOGY PLAN - MS RESPONSIBILITY

TBW.