Twenty years with XMM (and even more...)

Nicola La Palombara
Astrosiesta 9/12/2010
The prime design drivers for a high throughput spectroscopy mission can, therefore, be summarised as:

- Energy dynamic range: 0.2-10 keV, covering the bulk of the emission in the X-ray band
  - $A_{\text{eff}} \geq 10,000 \text{ cm}^2$ at 2 keV
  - $A_{\text{eff}} \geq 5,000 \text{ cm}^2$ at 8 keV
- Angular resolution: requirement $\leq 30$ arcsec HPW at 7 keV
  - design goal 10-20 arcsec HPW at 7 keV

This provides a dramatic increase of collecting power over the AXAF mission of about 10 at 2 keV and 30 at 8 keV at the expense of angular resolving power.
1. INTRODUCTION

The assessment study of the X-ray Multi-Mirror mission (ref.1) defines two types of telescope, i.e.:

- Low-energy (LE) telescopes with a good spatial resolution (10 arc sec H.P.W.) and with an energy coverage from 0.1 to 2.5 KeV.
- High-energy (HE) telescopes with a large collecting area (~2000 cm² per module) combined to a moderate spatial resolution (30 arc sec) and an energy coverage of 0.1-10 KeV.

In the present concept one foresees 12 LE-telescopes with a total effective area of 5500 cm² and 7 HE-telescopes with a total effective area of 13,000 cm² up to 2 KeV and still 10,000 cm² at 6 KeV.
THE HIGH-THROUGHPUT X-RAY SPECTROSCOPY MISSION

Report of the Telescope Working Group

B. Aschenbach, O. Citterio, J.M. Ellwood
P. Jensen, P. de Korte, A. Peacock
& R. Willingale

Telescope Working Group, February 1987:
“The TWG recommends the use of 7 Wolter I telescopes, each with a focal length of 8 m and an aperture diameter of 70 cm”

G.W Fraser: “X-ray detectors in Astronomy”
Formal proposal: June 1988

(3 telescopes)

One of the four “cornerstone” missions of the ESA science programme “Horizon 2000” (together with SOHO/Cluster, Rosetta and Herschel)
Dear Madam, Dear Sir,

I invite the community to make proposals for involvement in the X-ray Multi-Mirror (XMM) mission.

This Announcement of Opportunity calls for proposals for
- Instruments/Principal Investigators
- Mission Scientists
- Telescope Scientist

within the X-ray Multi-mirror Mission project.

Proposals for Principal Investigators and Mission Scientists can be accepted from individuals or institutes within countries which participate in the ESA Science Programme or the United States of America (under the Agreement of Reciprocity between ESA and NASA). Due to the potentially costly logistics of performing the telescope testing and calibration out of Europe, proposals for the role of Telescope Scientist will only be accepted from individuals or groups resident in an ESA member State.

This AO consists of the Announcement of Opportunity proper, together with three Annexes.

Annex A - The XMM Mission Report contains a description of the XMM mission, the spacecraft, model payload configurations and expected scientific performance.

Annex B - The Payload Requirements Document (EIO Part A) describes in detail the services and resources provided to the user, management requirements are also included.

.../...
Project timeline

The main features are:

- Selection of investigations .......................... June 1989
- Mirror Development Model Delivery .................. Begin 1992
- Instrument Electro-Optical Breadboard Delivery Begin 1992
- Issue of AO for survey scientist ...................... 1992
- Commencement major funding .......................... 1992
- Spacecraft Phase C/D .................................. 1994-1997
- Instrument Qualification Model Delivery .......... June 1994
- Instrument Flight Models Delivery .................. Dec 1995
- Launch .................................................. 1998
Proposal for the focal plane camera: "EPIC" European Photon Imaging Camera
Three focal plane cameras:
2 MOS
1 PN
From the “model philosophy” to the project phases:
Need to coordinate the project

Establishment of the ‘\textit{EPIC System Team}’ at IFCTR/CNR

- technical support to the instrument PI
- system level integration (AIV) $\rightarrow$ definition of the interfaces, both internal (between single instrument units) and external (with the spacecraft)
- system-level management of technical (QA, HW/SW configuration, documentation) and programmatic issues ($\rightarrow$ respect of the time schedule...)
- interface with ESA Project Office and production of required deliverable items (reference documents, TC&TM database, command procedures, ...)
System-level Integration at LABEN-1996/8
Calibrations at the MPE Panter Facility (Munich) 1997-8
Calibrations at the MPE Panter Facility (Munich) 1997-8
Calibrations at the IAS synchrotron of Orsay
1997/8 (Football World Cup Championship...)
Satellite integration at DASA/Dornier Friedrichshafen (D) – 1998/9
FM mirrors delivered at ESA/ESTEC on 5/12/1998 (Sinterklaas in NL)
Satellite integration at ESTEC and TBTV/SVT tests - 1999
Satellite integration at ESTEC and TBTV/SVT tests - 1999
September – December 1999: Launch Campaign at Kourou – French Guyana
The "Big One"
L'erreur de programmation qui a coûté 370 millions de dollars
La missione fallita

Il lancio-disastro del razzo europeo in Guyana: 13 mila miliardi di lire e 10 anni di lavoro in fulno dopo 66 secondi

Berlinguer: ma indietro non si torna, abbiamo già sbagliato per chimica e nucleare

14.36'14''
Il computer di bordo comanda l’autodistruttorre del razzo

14.35'49''
Si perdono le comunicazioni, il razzo non trasmette più dati telemetrici. A 3,800 metri d’altezza, l’Ariane si spezza ma continua a volare

14.35'45''
Gli ugelli di scarico dei tre motori divennero inutili dall’incoscienza originale: il razzo si piomba volando una traiettoria anomala

14.35'08''
L’Ariane decolla

IN PRIMO PIANO

La mission fallita

IN PRIMO PIANO

Il volo di Ariane è durato un minuto

Berlinguer: ma indietro non si torna, abbiamo già sbagliato per chimica e nucleare

L’INTERVISTA

Il ministro: responsabilità soprattutto dei francesi

Tre mesi fa il Toulouse, che strappò il galassaggio e si perde nel vuoto siste- nico, era un esordio di Ariane nel mare della Guyana francese. Dieci anni di ricerche, milioni di dollari investiti in fumo. Quattro satelliti sono caduti in mare. E’ responsabile del progetto europeo che giurano non cambia nulla, ancora avanti lo stessi. Ne dovevano la pena? "Non... piano —dice- Luigi Berlinguer—. Lo sono contrario a prendere de- cisioni affrettate, sull’o- da delle motivazioni popo- larin e un errore che ab- biamo già cominciato al- co due volte in passa- to, per la chimica e per il nucleare. Il l’esplosione è un settore strategico, destinato ad avere un ruolo primario nel pross- imi anni, anche nella creazione di nuovi punti di lavoro..."

La responsabilità dell’industria dei sistemi di telecomunicazioni è stata ben chiara nel caso del l’esplosione, ma non è stata né chiara né inevitabile. Chi è responsabile del progetto europeo ammessa, pari al 19% del costo complessivo, ma includere anche il pro- toco deputato a sviluppo. Nessun ripensamento, nessun cambiamento...

Nei mesi che seguono l’esplosione, l’Europa è stata sconvolta. Le E. S. S. (la Società Europea di Spazio) ha subito un forte calo di magazzino e di offerta. La sintesi è stata iniziata a Toulouse, dove è stato installato un nuovo centro di controllo, e in Guyana, dove è stato installato un nuovo centro di ricerche. La missione è stata in corso per tutto il 1989.

L’ESPRESSO
Integration of Ariane 504 for XMM launch
The instrument team
Increasing pre-launch problems...

• GSE not ready (useless Quick-look analysis)
• Leakage in the MOS FM2 camera-head (=> swap in August 1999)
• Uncertainties about the Ariane V vibration figures
• *Millennium bug* => launch in December and parking in space
• Short-circuit in 1 of the 4 quadrants of the PN camera
The last straw:

Dear colleague,

In the spirit of cooperation I am sending you this e-mail. We have an unexplained anomaly with a subset of the CCDs aboard Chandra - the front-illuminated devices. If you desire a briefing on this subject I would be able to discuss this with you at 8:00 am tomorrow (my time - Central time zone USA) so that you might assess the implications for your mission. If so, please inform me of a number you can be reached at. Perhaps you might wish to arrange a conference call including other members of your team that you feel appropriate to this discussion. If so, please let me know and I will provide you with a list of numbers to include from this side.

We would appreciate your not discussing these matters with the press as we are in the process of trying to understand the problem.

Martin C. Weisskopf
Chandra Project Scientist
The soft-protons problem

Dear Colleagues,

This is to update you on the EPIC proton saga. Basically we are ok. I will detail the reasons and history below.

At the FAR it became clear to me that there was a significant risk to EPIC MOS from solar flare protons. It was already determined that the RGS was ok, and that the PN is not sensitive to soft protons (caveat-damage to the implant by soft protons TBD). The quoted solar flare fluence was dangerously close to giving EPIC MOS about 3 months life. Since then I have been carefully over the figures, and conducted a battle with ESTEC over their bland assumption that everything was ok. I have now checked all the figures, and the bottom line is that with conservative assumptions and judicious use of the closed positon we can guarantee 5 years for epic mos at the cost of an average 10% loss of observation time.
Proposed solution

The formula determining the actual instrument lifetime considering both the soft-solar flare protons and the 'regular' mission dose is:

$$\text{Lifetime} = 10\text{yrs} \cdot \frac{1}{1 + \frac{\text{Factual}}{10^6 \text{p}+/\text{cm}^{**2}}}$$

Based on all this, we agree that EPIC-MOS can safely be launched provided that the filter wheel be closed for ALL major solar flares (actual level TBD).

Fred Jansen
XMM Project Scientist

Martin Turner
EPIC PI
10 December 1999: a perfect launch!
EPICi colleghi.

tra mezz'ora (17.00) inizieranno le operazioni per l'apertura delle Door.
Si partirà con il MOS1 e, poi, ad intervalli di circa 1h 30m, si passerà al PN ed al MOS2. Incrociate le dita, fate tutti gli scongiuri del caso (presentabili e non...) e speriamo in bene.

Per il momento è tutto: non ci resta che aspettare...

Ciao

Nicola
The first light – 20 January 2000
Commissioning Phase (Jan-Mar 2000): main results

- **b) Instrument Commissioning**
  - Switch-on OK
  - Functional check-out OK
  - Opening of internal doors OK
  - Decontamination activities:
    - not required for CP (to be executed end of CP)
  - Filter integrity check
    - wrong pointing
    - MOS noise high, p-n offset
    - Used filters do not show any evident problem
    - OM filter check performed with ENG4 instead that imaging
  - CCD functional check
    - on ground short of p-n CCD1 Q2 have disappeared
    - noise on some MOS CCD
    - Failure in driving electronic for RGS2 CCD4
    - OM detector OK
  - Functional verification on sources and cal source

- **d) S/C performance (mainly pointing)**
  - Excellent pointing stability when stars are not lost from Star Tracker
  - limited experience on thermo-elastic distortion due to rather constant SAA
  - Start tracker offset correction as from yesterday night
  - preliminary instrument boresite in line with ground measurements

- **e) Effects of Radiation environment**
  - In general underestimated on all instruments
  - p-n on board MIP rejection insufficient
  - OM memory SEU and DEU
  - high number of cosmic rays has required new thresholds setting on RGS
  - residual events after pattern recognition on MOS higher
  - noise problem on MOS CCD’s?
  - RAD MON correlation with particle flux through mirrors somewhat ambiguous
  - RAD MOM warning thresholds lowered by a factor 10
  - No significant degradation of RGS and EPIC CCDs

- **Instruments (general):** the main finding from all instrument teams is that the particle background rate is a factor 2 to 3 higher than expected. This questions the validity of pre-launch predictions.
  - Another important finding is that there are no signs of a significant degradation of the CCD CTE beyond specifications for any of the instruments so far. However, the relatively short period of time over which the CTE was measured restricts the accuracy of the CTE degradation evaluation. It is thus important to continue monitoring the CTE degradation carefully. Finally, several instrument anomalies have been uncovered which need to be properly documented, formally recorded and put under configuration control in the NCR database. Instrument teams are requested to raise NCR (Non Conformance Report) as appropriate.
# Commissioning Phase: SW debugging

<table>
<thead>
<tr>
<th>NCR</th>
<th>Title</th>
<th>System</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Corrupted VC7 data</td>
<td>RM</td>
<td>Closed: use as is</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Filter wheel movement HK telemetry delayed</td>
<td>MOS</td>
<td>Closed (Fabio e-mail on 2000/05/10), EMDH SW I.I delivered on July 3rd 2001</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Inconsistent imaging correction</td>
<td>PN</td>
<td>Closed</td>
</tr>
<tr>
<td>6</td>
<td>Time Info first word set to 0xFFFF</td>
<td>PN</td>
<td>Closed</td>
</tr>
<tr>
<td>7</td>
<td>Command rejected</td>
<td>PN</td>
<td>Closed (Fabio e-mail on 2000/05/10)</td>
</tr>
<tr>
<td>8</td>
<td>Command rejected</td>
<td>MOS</td>
<td>Closed (Fabio e-mail on 2000/05/10), EMDH SW I.I delivered on July 3rd 2001</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Insufficient MIP reduction</td>
<td>PN</td>
<td>Closed</td>
</tr>
<tr>
<td>11</td>
<td>Low energy noise due to wrong offset</td>
<td>PN</td>
<td>Closed</td>
</tr>
<tr>
<td>12</td>
<td>FIFO overflow causes data corruption</td>
<td>MOS</td>
<td>Closed, EMDH SW I.I delivered on July 3rd 2001</td>
</tr>
<tr>
<td>13</td>
<td>TM Headers and trailers do no match</td>
<td>MOS</td>
<td>Closed (Fabio e-mail on 2000/05/10), EMDH SW I.I delivered on July 3rd 2001</td>
</tr>
<tr>
<td>14</td>
<td>Bright pixel tables not operating correctly</td>
<td>MOS</td>
<td>Closed (Paul e-mail on 2000/04/07)</td>
</tr>
<tr>
<td>15</td>
<td>EPIC Radiation Monitor has a processor reset occasionally</td>
<td>RM</td>
<td>Closed: use as is</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Noise in MOS cameras</td>
<td>MOS</td>
<td>Closed: use as is</td>
</tr>
<tr>
<td>18</td>
<td>MOS Timing mode not working correctly</td>
<td>MOS</td>
<td>Closed (Fabio e-mail on 2000/05/10)</td>
</tr>
<tr>
<td>19</td>
<td>MOS Timing mode: cosmic ray rejection incorrect</td>
<td>MOS</td>
<td>Closed (Philippe e-mail on 2000/04/27)</td>
</tr>
<tr>
<td>20</td>
<td>XMM TM outage and Instrument Safety</td>
<td>MOS&amp;PN</td>
<td>Closed</td>
</tr>
<tr>
<td>21</td>
<td>EPEA quadrants do not always respond to TCs when in observation mode</td>
<td>PN</td>
<td>Closed: use as is</td>
</tr>
<tr>
<td>22</td>
<td>Discarded lines packets are not correctly segmented.</td>
<td>PN</td>
<td>Closed: will be fixed on-ground (XSCX v12)</td>
</tr>
<tr>
<td>23</td>
<td>MOS 2 buffer manager / counting mode failure</td>
<td>MOS</td>
<td>Open (new EMDH SW under test)</td>
</tr>
<tr>
<td>24</td>
<td>MOS 2 timing mode exposure with regular noise pattern</td>
<td>MOS</td>
<td>Open</td>
</tr>
<tr>
<td>25</td>
<td>Failure to reset EPEA on-board time counter for Q2</td>
<td>PN</td>
<td>Open</td>
</tr>
<tr>
<td>26</td>
<td>Operating heater autonomous switch-off</td>
<td>PN</td>
<td>Open</td>
</tr>
<tr>
<td>27</td>
<td>QO stopped working (wrong CKS)</td>
<td>PN</td>
<td>Open</td>
</tr>
</tbody>
</table>
- closure of open NCRs
- request for SW improvements

### SW changes up to 2004
Demanding test-sessions and calibration meetings
Major events during the routine phase

- Micrometeorite impacts: Revolutions 107 (MOS2), 158 (PN), 325 (MOS1), 961 (loss of CCD6 MOS1)

Science Programme Review Team Report 2006:

- Joint management of XMM-Newton and Integral since 2008 to save money

- 18 October 2008: contact lost from ground, due to a failure in the on-board Radio Frequency (RF) switch

The SPRT recommends, having considered the financial position of the Programme in detail, that before launching a Call for Mission Proposals, 200 million €, as a minimum, be taken out of the present suite of commitments.

=> various impacts and several risks

=> communication re-established after 4 days
ESAC, 10 December 2009: XMM 10th Anniversary
Data Processing and Distribution status as of 30-Sep-2010

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of Planned Observations in Routine Phase (revs 0103-1979)</td>
<td>8357</td>
</tr>
<tr>
<td>Total number of Performed Observations in Routine Phase</td>
<td>7974</td>
</tr>
<tr>
<td>Total number of Observation Data Files generated</td>
<td>7829</td>
</tr>
<tr>
<td>Total number of Pipeline/Data Products sets generated and distributed</td>
<td>7749</td>
</tr>
</tbody>
</table>
AO10: 491 proposals
90 Ms of required science time => over-subscription factor = 6.2

• At IASF-Milano:
  12 degree thesis
  9 PhD thesis
XMM current status

• All instrument units working on the primary redundancy

<table>
<thead>
<tr>
<th>Fuel</th>
<th>remaining</th>
<th>76 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use per year</td>
<td>6 kg</td>
</tr>
<tr>
<td></td>
<td>Mileage left</td>
<td>→2019</td>
</tr>
</tbody>
</table>

| Solar array power | Maximum required | 1350 W |
|                   | Current margin      | 550 W  |
|                   | Margin end of 2018   | 350 W  |

| Battery               | According to UHB     | 15+ y  |

• ASI funding of 240 k€ for the three-years period 2010-2012

• Further mission extension: “At their 130th meeting on 18/19 November 2010 ESA's Science Programme Committee approved an extension of XMM-Newton operations until 31 December 2012. They also approved an indicative extension until 31 December 2014, subject to a mid-term review in 2012 on the regular two-year cycle.”
See you in 2014!