In.XS: project for a future spaceborne hard X-ray all-sky survey

Philippe Marty\textsuperscript{a}, Juho Schultz \textsuperscript{b}, Clemens Bayer \textsuperscript{c,d}, Alexander Fritz \textsuperscript{c,e}, Martin Netopil \textsuperscript{c}, Walter Nowotny \textsuperscript{c}, Michael Carr \textsuperscript{f}, Carlo Ferrigno \textsuperscript{g}, Christophe Jean \textsuperscript{h}, Walter Kropolin \textsuperscript{c}, Jesper Rasmussen \textsuperscript{i}, Laura Tanuva \textsuperscript{c}, Ivan Valtchanov \textsuperscript{j}, Marcos Bavdaz \textsuperscript{k}, Rudolf Much \textsuperscript{k}, Arvind Parmar \textsuperscript{k}

\textsuperscript{a} Institut d’Astrophysique Spatiale
Université Paris-Sud - Bât.121, F-91405 Orsay cedex
\textsuperscript{b} Helsinki Observatory
University of Helsinki, P.O. Box 14, FIN-00014 Tähtitorninmäki
\textsuperscript{c} Institut für Astronomie
Universität Wien, Türkenschanzstr. 17, A-1180 Wien
\textsuperscript{d} Inst. of Astronomy, University of Cambridge, Madingley Road, CB3 0HA Cambridge, UK
\textsuperscript{e} Göttingen Obs., Universitätssternwarte, Geismarlandstr. 11, D-37083 Göttingen
\textsuperscript{f} Dunsink Observatory
Shool of Cosmic Physics, Castleknock Dublin 15, Ireland
\textsuperscript{g} S.R.O.N.
Sorbonnelann 2, NL-3584 CA Utrecht
\textsuperscript{h} Institut d’Astrophysique et de Géophysique
Université de Liège, 5 av. de Cointe, B-4000 Liège
\textsuperscript{i} Astronomical Observatory
University of Copenhagen, Juliane Maries Vej 30, DK-2100 Copenhagen
\textsuperscript{j} C.E.A. / Service d’Astrophysique
Orme des Merisiers, Bat. 709, F-91191 Gif/Yvette cedex
\textsuperscript{k} E.S.T.E.C. / Astrophysics division
PO BOX 299, Keplerlaan 2, NL-2200 AG Noordwijk

ABSTRACT
The latest all-sky survey in hard X-ray band was performed by the HEAO-1 satellite (13 – 80keV) with an angular resolution of $24 \times 48\text{arcmin}$.\textsuperscript{13} A diffuse hard X-Ray background (HXB) was detected between 3 and 50keV.\textsuperscript{16} The main scientific goal of In.XS is to resolve a large fraction of this HXB into individual sources.

As no distortion by Compton up-scattering is seen in the spectrum of the microwave background,\textsuperscript{17} the hard X-ray background is believed to be mainly due to point sources. “Type I” Active Galactic Nuclei (AGN) have softer X-ray spectra than the hard X-ray background, so other sources must be considered, like faint “Type II” or “absorbed” AGN. These could be distinguished through hard X-ray spectroscopic or hardness ratio observations.

Here we present In.XS - a mission concept designed to conduct the first imaging all-sky hard X-ray (2 – 80keV) survey. The angular resolution of nearly 1arcmin and good sensitivity at high energies is provided by the latest multilayer focussing mirrors, with semiconductor-based (GaAs) arrays of detectors. We also describe the mission operations, and how the all-sky survey will be complemented by follow-up pointed observations of selected fields. The good angular resolution will allow correlations and identification with objects seen at other wavelengths. In addition, since a large fraction of the Type II AGN luminosity is emitted in the hard X-ray band, this survey will provide a large unbiased sample of the AGN population. This may provide constraints on AGN evolution through the possible observation of a turnover in deep field source statistics.

Keywords: Satellite, Hard X-Ray Background, AGN, GaAs, Multilayers...

Further author information: (Send correspondence to P.M.)
P.M.: E-mail: philippe.marty@ias.u-psud.fr
1. INTRODUCTION

Since the first (1964) observational proof of the existence of a cosmological radiation background (CRB) in radio waves,\textsuperscript{20} the question has been raised of its extension along the electromagnetic spectrum and its origin.

If the radio wave background, as well as its extension into microwaves later (1990) observed by the COBE satellite, is now widely admitted to originate around the time of recombination ($z=1000$), other diffuse emissions have been detected at different wavelengths and their origins still remain hypothetical. A strong background has indeed been discovered in the far-infrared data from COBE.\textsuperscript{22} The energy contained between wavelengths 6 $\mu$m and 1 mm is about twice the energy contained in the ultraviolet-visible part of the spectrum\textsuperscript{7} and is by far the most dominant component of the CRB after the microwave background itself.

1.1. The X-ray Background (XRB)

In 1967, isotropic X-ray emission was evidenced after rocket experiments in the 4 – 40 keV band with a somewhat powerlaw-like spectrum\textsuperscript{24} and was hence primarily thought to be due to inverse Compton scattering of microwave photons on electrons in a hot intergalactic medium.\textsuperscript{2} But as no strong distortion by Compton up-scattering is seen in the spectrum of the microwave background,\textsuperscript{17} this scenario shall be disregarded.

While 75% of the soft XRB (0.5 – 2 keV) has been since resolved into individual sources\textsuperscript{9} by ROSAT, as well as 75% of the mid XRB (2 – 10 keV) by the Chandra satellite,\textsuperscript{18} this is not true for the hard X-ray component (10 – 100 keV) of the background.

Apart from invoking exotic models there are two main sources of radiation in the universe in the period following recombination during which structures form: gravitational energy of contracting or accreting objects and nucleosynthesis in stars of H and He into heavier elements. In the first case, only Black Holes can radiate a substantial fraction of their rest mass during formation or accretion processes.\textsuperscript{26} In the second case, starburst in galaxies can radiate five times as much energy as galactic black holes.\textsuperscript{12}

1.2. Active Galactic Nuclei (AGN)

Individual sources powering softer components of the XRB were demonstrated to be mainly Seyfert galaxies,\textsuperscript{21} not surprisingly of that kind presenting a strong evidence for an accreting supermassive black hole at their center. In the framework of the AGN unified scheme (Fig.1), these galaxies are refered to as “Type 1 AGN”. The problem is that their spectra do not account for the bump in the harder XRB components, so that other sources must be considered.\textsuperscript{14}

Nevertheless, a large (> 90%) fraction of the hard X-ray background (XRB) spectral intensity could be well reproduced by the combined emission of unobscured (type 1) and obscured (type 2) Seyfert galaxies and quasars with a distribution of absorption column densities and luminosities.\textsuperscript{4} The key ingredient of this model is the presence of obscured AGN whose emission in the traditional 2 – 10 keV band is blocked by the dust torus but allows to fit the bump around 30 keV.

It is likely that the energy density of the absorbed AGN which would peak in the soft X-rays is reradiated in the far-infrared and assuming that the 30 keV peak of the XRB provides an unobscured estimate of the integrated AGN energy density, the obscured AGN responsible for the hard XRB could account for no less than 15% of the far-infrared background\textsuperscript{5} and as much as 50%.\textsuperscript{15} On the other hand, it is shown on the basis of spectroscopy (carried out with ISO) of luminous and ultraluminous IR galaxies, that the fraction of the energy coming from the central AGN is in general smaller than the fraction coming from starburst activity but increasing with luminosity.\textsuperscript{6}

The far-infrared and the hard X-ray bands should hence be the best two regions of the spectrum to select AGN in a manner insensitive to their level of obscuration.

2. IN.XS MISSION CONCEPT

The latest all-sky survey in hard X-ray band was done by the HEAO-1 satellite. Its A-2 instrument detected 72 point sources\textsuperscript{13} to the limit of 13.3 mCrab in the 13 – 80 keV band with an angular resolution of $24 \times 48 \text{arcmin}$. A diffuse hard X-ray background\textsuperscript{16} of $5.13 \times 10^{-9} \text{erg} \cdot \text{keV}^{-1} \cdot \text{sr}^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ at 10 keV was also detected.

In addition, there is currently an ongoing effort to re-analyse BATSE data with a novel analysis technique and perform a sensitive all sky survey in the 20 – 300 keV range. The 3 sigma flux sensitivity for a survey performed using 50 days of continuous data is $\sim 15 \text{mCrab}$ with an angular resolution of 1 deg.\textsuperscript{25}
Figure 1. Sketch of the Unified AGN model. Type 1 are those seen along the direction of the jet while Type 2 are those seen from the torus side.

The main scientific goal of the International X-ray Surveyor (In.XS) is to resolve a large fraction of this diffuse hard X-ray background into individual sources, mainly AGN hidden in other wavelength bands. A comparison between the high performance of In.XS with that of other missions is made in Tab. 1.

Table 1. Comparison to other missions.

<table>
<thead>
<tr>
<th>Mission/Instrument</th>
<th>FOV (degrees)</th>
<th>Resolution (arcmin)</th>
<th>Energy range (keV)</th>
<th>Sensitivity (mCrab) (*not all-sky survey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In.XS *</td>
<td>0.5</td>
<td>1</td>
<td>2 – 80</td>
<td>5 · 10⁻² – 5 · 10⁻⁴</td>
</tr>
<tr>
<td>HEAO-1 A-2</td>
<td>1.5 × 20</td>
<td>24 × 48</td>
<td>13 – 80</td>
<td>13.3</td>
</tr>
<tr>
<td>Granat ART-P</td>
<td>1.8</td>
<td>5</td>
<td>4 – 60</td>
<td>1 * (in 8 hours)</td>
</tr>
<tr>
<td>BATSE</td>
<td>60</td>
<td>20 – 300</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>ROSAT</td>
<td>0.5 – 0.7</td>
<td>0.5 – 2</td>
<td></td>
<td>10⁻⁴ – 10⁻⁵</td>
</tr>
<tr>
<td>XMM-Newton or Chandra</td>
<td>0.5</td>
<td>0.1</td>
<td>0.5 – 10</td>
<td>10⁻³ – 10⁻⁴</td>
</tr>
<tr>
<td>INTEGRAL JEM-X * (2002)</td>
<td>4.8</td>
<td>3</td>
<td>3 – 35</td>
<td>10 * (in 15 min)</td>
</tr>
<tr>
<td>SWIFT * (2003)</td>
<td>80</td>
<td>22</td>
<td>10 – 150</td>
<td>1.3</td>
</tr>
<tr>
<td>ISS EXIST * (2007)</td>
<td>160 × 40</td>
<td>5</td>
<td>10 – 100</td>
<td>0.05</td>
</tr>
<tr>
<td>SRG MARTLIME *</td>
<td>6</td>
<td>9</td>
<td>5 – 150</td>
<td>1 * (in 24 hours)</td>
</tr>
<tr>
<td>CHIP *</td>
<td>60</td>
<td>26</td>
<td>2 – 100</td>
<td>1 (in 1 hour)</td>
</tr>
</tbody>
</table>

2.1. Scientific Goals

With a detection limit of 10⁻¹² erg·s⁻¹·cm⁻² in the 10 – 70 keV band, approximately 20000 new sources are expected, most of them AGN. This source count estimate is derived from a LogN – LogS relation with –3/2 slope, consistent with HEAO-1²¹ and ASCA²⁷ observations. A fraction of 1 – 10% of the new sources would be galactic, most of them accreting X-ray pulsars. Crude variability estimates would be obtained, as the satellite will scan the sky twice, with six months between 2 exposures of 60 sec each (cf. Sec. 4.1.).
The planned angular resolution of nearly 1 arcmin allows for correlation with other deep X-ray surveys or infrared background surveys, for easier identification of counterparts in other wavelengths and provides a limited level of sources confusion.

The observed hardness ratios of sources would allow crude division between AGN type 1 and type 2. The ratio of AGN I to AGN II would hence allow estimates of the average dust torus size and AGN I/II ratio versus redshift would give some constraints on dust torus evolution. As a large fraction of the AGN luminosity is emitted in the hard X-ray band, and only a few small classes of other sources are seen in this band, a good population synthesis of AGN would be easiest to obtain from a large sample of AGN observed in hard X-rays.

2.2. Secondary Goals

The main result of the first mission phase, the all-sky survey, will be a large source catalogue. In the second phase of the mission pointed observations will be conducted, whereby interesting targets could be selected from the source catalogue compiled during the first phase. This can also include raster scans of selected regions and deep field observations of a few very interesting regions (e.g. Galactic Centre and Lockman Hole). The deeper observations are needed to calibrate the hardness ratio - AGN type relation by obtaining a sufficient sample of AGN with known types and better spectra, and should lead to about 300 sources deg$^{-2}$ in the 10 – 40 keV range with a detection limit of $3 \cdot 10^{-14}$ erg s$^{-1}$ cm$^{-2}$ in 100 ksec.

The AGN evolution models would be constrained if the turnover of the $\log N - \log S$ relation is seen in the deep field observations. Since the sources of the all-sky catalog contribute to roughly half of the diffuse X-ray background, there is a good chance to reach the turnover point in the deep field observations.

Furthermore, in addition to the test of the unified model of AGN provided by the correlation between X-rays and existing IR surveys (ISO FIRBACK and ELAIS), the combination of infrared probes of dust conditions (to be conducted in the forthcoming years with SIRTF and FIRST-Herschell), together with radio and hard X-ray data probing supernovae and X-ray binaries activity, should lead to major constraints on starburst evolution models in galaxies. Also, having both IR and X-ray photometry for these objects should enable a detailed study of how X-ray photons are reprocessed by the dust torus, and facilitate the estimation of the intrinsic spectrum of these X-rays.

Finally, this all-sky survey should be compared with its submillimeter counterpart to be realized by the Planck satellite by the end of the decade and which should provide us with maps of the Sunyaev-Zel’dovich (SZ) effect, Compton recoil of the CRB photons on the hot electronic gas of clusters of galaxies (ClG), and deep ClG catalogs. This comparison could put further constraints on the possible diffuse component of the XRB and possibly maps of the Hubble parameter $H_0$, since the SZ effect is not dependant on the redshift of the source object.

3. IN.XS INSTRUMENT PAYLOAD

The scientific goals, as outlined in previous section, define the scientific mission requirements to be achieved as listed in Tab. 2.

<table>
<thead>
<tr>
<th>FOV (deg)</th>
<th>Resolution (arcmin)</th>
<th>Energy range (keV)</th>
<th>Sensitivity (mCrab)</th>
<th>Energy Resolution (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1</td>
<td>2 – 80</td>
<td>$5 \cdot 10^{-2}$</td>
<td>$\leq 1$ at 40 keV</td>
</tr>
<tr>
<td>(to allow scanning all-sky in 6 months from LEO)</td>
<td>(to allow correlations and cross-identifications)</td>
<td>(to explore absorbed regions of X-ray spectrum)</td>
<td>(to allow unbiased sampling of AGN population)</td>
<td>(to discriminate between AGN types spectra)</td>
</tr>
</tbody>
</table>

3.1. X-ray Telescopes

Since 1978, grazing incidence mirrors using Bragg theory have been the working horse of X-ray astronomy, but these mirrors were limited in energy range. In 1993, this limitation was alleviated from about 4 up to 10 keV, but at the cost of spatial resolution for a (from 4 arcsec for HEAO-2 down to 3 arcmin for ASCA), since the Bragg condition
roughly implies $\frac{\theta}{\delta \theta} = \frac{E}{\delta E}$, where $\theta$ is the critical incidence angle, $\delta \theta$ half the FOV, $E$ the considered energy and $\delta E$ the energy resolution. These grazing mirrors, coated with atomic monolayers (to improve reflectivity) and designed as a combination of paraboloid and hyperboloid surfaces (instead of simple conical surfaces) to improve spatial resolution (XMM-Newton now reaches about 5arcsec spatial resolution) and reduce chromatic aberrations, are still in use in modern X-ray space observatories.

But it has been demonstrated that a multilayer coating enhances the reflectivity beyond the critical angle, up to 100keV, since the photoelectric absorption is less effective in the multilayer structure, so that the Bragg condition still is satisfied over the broad band. Alternance of Pt/C layers is hence proved to be the best combination, in addition to Pt monolayer overcoating.

In order to meet the sensitivity requirements, an effective area of 1500cm$^2$ at 40keV is needed. This will be achieved for a 8m focal length by 19 mirror units, each made of about 100 multi-nested multilayers (40 Pt/C layer pairs) shells (Fig. 2). Each unit has a diameter of 30cm and a length of 20cm.

Finally, applying the former Bragg relation to our science requirements, we find that it should be difficult to achieve more than 0.2deg FOV without reducing performance. However, it is reported that with a higher (9th) polynomial degree in the “Wolter I” approximation of the mirror shape, wider FOV could be reached.

![Figure 2](https://example.com/figure2.png)

**Figure 2.** (LEFT) Sketch of the In.XS mirror platform (left top) and of the entire telescope assembly (left bottom). (RIGHT) Plot of the In.XS 19 telescopes total effective area for 2 different radii of each modules, compared to that of the XMM-Newton 3 telescopes.

This assembly constitutes a major improvement as compared to what is planned for InFOC$\mu$S and Constellation-X designs.

### 3.2. X-ray Solid State Detectors

In a survey of the available detector technologies (cf. Tab. 3), GaAs compound semiconductors were found to fit our science requirements best.

GaAs arrays work perfectly in our required 2 – 80keV energy range. They provide a sufficient spectral resolution (300 to 700eV) already at room temperature, which prevents usage of costly onboard cryogenics (at low earth orbits, spacecraft has to endure substantial thermal variations). An improved energy resolution (by a factor of 2) can be achieved with simple passive cooling down to $-35^\circ$C.
Table 3. Comparison with various detector types.

<table>
<thead>
<tr>
<th>Type</th>
<th>Missions</th>
<th>Energy range (keV)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaAs array</td>
<td>In.XS</td>
<td>0.1 – 200</td>
<td>pixel size &lt; 1mm, (\delta E &lt; 1keV), extremely uniform response</td>
</tr>
<tr>
<td>CdZnTe array</td>
<td>InFOC, µS, CHIP,</td>
<td>1 – 100</td>
<td>pixel size &gt; 1mm, (\delta E &gt; 1keV), discrepancies from pixel to pixel</td>
</tr>
<tr>
<td>TiBr array</td>
<td>Constellation-X</td>
<td>10 – 200</td>
<td>(\delta E &gt; 1keV), (T &lt; -50^\circ C)</td>
</tr>
<tr>
<td>Si(Li) diode</td>
<td>ASCA, XMM, AXAF</td>
<td>&lt; 40keV</td>
<td>big pixels . . .</td>
</tr>
<tr>
<td>Si CCD</td>
<td>MARTLIME, ROSAT rockets</td>
<td>&lt; 20keV</td>
<td>must be cooled . . .</td>
</tr>
<tr>
<td>Gas Prop. Coun.</td>
<td></td>
<td>&lt; 10keV</td>
<td>(\delta E &gt; 1keV), (T &lt; -50^\circ C)</td>
</tr>
<tr>
<td>µCalorimeter</td>
<td></td>
<td>&lt; 1keV</td>
<td>(\delta E &gt; 1keV), (T &lt; -50^\circ C)</td>
</tr>
<tr>
<td>Bolometer</td>
<td></td>
<td></td>
<td>(\delta E &gt; 1keV), (T &lt; -50^\circ C)</td>
</tr>
<tr>
<td>Diamond</td>
<td></td>
<td></td>
<td>(\delta E &gt; 1keV), (T &lt; -50^\circ C)</td>
</tr>
</tbody>
</table>

The best absorption layer thickness should be around 400 \(\mu m\) for pixels size comprised between 0.2 and 1\(mm\) and a resulting quantum efficiency of 70 to 5% in our energy range.\(^{19}\)

It is reported (Metorex Inc., http://www.metorex.fi, June 2000) that industrial GaAS arrays of 32 \(\times\) 32 pixels are now available, which is enough to sample our 30\(arcmin\) FOV at spatial resolution consistent with mirror PSF (1\(arcmin\)). Given the telescope characteristics, a detector array of 8 \(\times\) 8\(cm\) is needed to fit the focal plane of one unit. However, GaAs wafers yet come no larger than 5 \(\times\) 5\(cm\). Therefore, 4 square arrays of 4 \(\times\) 4\(cm\) each should be considered to provide a total of 64 \(\times\) 64 pixels behind each telescope unit. The needed pixel size would then be around 1\(mm\), corresponding to \(\sim 28arcsec\) on the sky (Shannon sampling of the PSF).

3.3. Readout Electronics

GaAs detectors can be equipped by individual wire bonding (4096 wires per detector unit in our case), thus allowing spectro-imaging by independent energy determination in each pixel of the image. Each pixel is then preamplified (FET) and a global spectro-amplifier feeds a 12\(bits\) digitizer (thus allowing us to divide our 80\(keV\) energy range into 4096 channels of 20\(eV\)).\(^{19}\) These are classical space qualified technologies and the electronic noise is no more than \(10^{-4}cnts\cdot cm^{-2}\cdot s^{-1}\), that is just less than our expected cosmic background at 100\(keV\).

The readout time cycle of the electronics is of the order of a few microseconds, which prevents smearing of the PSF. The sky scanning rate of the satellite is 4\(arcmin\) \(\cdot s^{-1}\) (cf. Sec. 4.1), equivalent to 9 detector pixels per second. Smearing of the PSF over several pixels is hence avoided with a readout cycle faster than \(1/9sec\), which is easily fulfilled.

The encoding of data must be considered through an event list (science data) and housekeeping. Each event should be characterized by its position (telescope number: 5\(bits\), pixel coordinates 2 \(\times\) 6\(bits\), energy (12\(bits\)) and timestamp (a typical long integer on 24\(bits\), for a total of 53\(bits\). The signal may vary from 0.05\(cnts/s\) (30\(keV\) X-ray background flux on our telescopes) up to probably 500\(cnts/s\) for the brightest objects (one hundred times less than the pile-up limit thanks to individual wiring electronics), for a data rate of 2.5\(bits/s\) to 25\(kbit/s\). It seems reasonable to assume an average value of 3.2\(kbits/s\) dominated by the standard housekeeping data rate.

3.4. Instrument Calibrations

A first run of ground based calibrations could be undertaken on monochromatic X-ray sources with large housing capability for effective area and vignetting measurements of mirror modules (like the Panter station in Germany); the detectors could be hosted by white synchrotron facilities (like Bessy in Germany or the new SoLEIL in France) for quantum efficiency, flat field and spectral resolution measurements. One should particularly take care of variation of these parameters with temperature, since the superstructure may have to endure significant thermal fluctuations along its low earth orbit (cf. Sec. 4.1) and that may produce strong variations in the mirror performance and between each detector preamplifying chain.
Onboard radioactive sources ($^{55}Fe$ and $^{241}Am$) as well as well known astrophysical sources (3C273 Quasar, Crab Nebula, etc.) would provide inflight calibrations. Common targets during the second phase (pointed observations) should also be considered for cross-correlations with other observatories like XMM-Newton or INTEGRAL. A filter wheel in front of each detector with different positions (“open”, “filter”, “closed”) would allow adjusting incident flux towards limited damage flux level. In addition, this would ensure protection of the detectors against radiation damage during strong solar flares.

4. IN.XS SPACECRAFT AND OPERATION

4.1. Spacecraft Design and Properties

The optimal choice of orbit for our scientific requirements would be a circular low earth orbit (LEO) at an altitude of about 600 km. This choice of orbit allows us to keep the background at the lowest possible level, while at the same time avoiding the radiation belts. Furthermore this choice keeps the operational costs of the mission (launch ...) within reasonable limits. The inclination of the orbit will be 7 degrees. An equatorial orbit is possible, but is not necessary for our purposes.

By choosing a rotational period of the spacecraft around its transversal axis such that it equals its period of revolution $P_{rot} = P_{rev} \approx 97min$ (Fig. 3), we enable the spacecraft to scan the entire sky within 6 months, while at the same time pointing away from the earth at all times. The same result could have been achieved with a polar orbit while constantly pointing away from the earth and the sun, but this would have meant suffering from polar aurorae radiation.

![Figure 3. Sketch of the In.XS orbital phases.](image)

The proposed minimum duration of the first part of the mission should therefore be no less than 1 year (ideally 1.5 years including Com/Cal/PV Phases) to allow for redundancy, instrument failures and in order to cover those FOV obstructed by the Moon in the first run.

It should be noted that, although our choice of orbital motion does allow the solar panels to be pointing towards the sun at all times, the low altitude of the orbit leads to a significant amount of sky shadowing of approximately 130°, resulting in an eclipsing time of 36 minutes per orbit. Therefore we have to account for batteries and data storage on board the spacecraft.

We estimate the total mass of the spacecraft to be approximately 1.8 tons, including 700 kg for superstructure, 500 kg for science payload and 200 kg of monopropellant necessary for altitude corrections and de-orbiting at the end of the mission. Due to the relatively short overall lifetime of the mission (3 to 6 years), further orbit maintenance (i.e. altitude correction of an annual loss of about 30 km) is not vital; this allows us to economize propellant and keep the total mass down.
A Ariane IV class (like U.S. Delta II or Japanese H-1 or Russian Cyclone) launcher should be sufficient considering the relatively low overall mass of the mission. However an extra long fairing configuration of the launcher is needed to host the spacecraft, which is approximately 10m long (Fig. 4) due to the required focal length.

![Figure 4. Sketch of the In.XS spacecraft.](image)

We estimate the total energy consumption for the service module (data handling, antennae, etc.) and payload (detectors, etc.) to be \( \approx 1.1 kW \). This can be provided by solar arrays with a total effective area of \( A_{eff} \approx 15m^2 \) assuming 17% efficiency Si cells and 0.83kW \cdot h \) NiCd batteries (able to endure about 5500 charge/discharge cycles per year) for the eclipsing times*.

The science objectives (Tab. 2) require the Absolute Pointing Error (APE) to be less than 1\( \text{arcmin} \), and the Relative Pointing Error (RPE) should be kept small compared to the PSF, i.e. of the order of 10\( \text{arcsec} \), which is easily achieved with current reaction wheel techniques.

### 4.2. In.XS Groundsegment

Table 4 summarizes the proposed Mission Profile for the In.XS project. It comprises three parts: the first part is dedicated to the commencement of operation of the satellite and the instruments, the two other parts are dealing with the observations as described in the Mission Concept above.

<table>
<thead>
<tr>
<th>Table 4. Mission Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch and Early Orbit Phase</strong></td>
</tr>
<tr>
<td><strong>Commissioning Phase (incl. Outgassing)</strong></td>
</tr>
<tr>
<td><strong>Calibration and Performance Validation Phases</strong></td>
</tr>
<tr>
<td><strong>Whole sky survey</strong></td>
</tr>
<tr>
<td>processed data available 3 months after observation</td>
</tr>
<tr>
<td>→ Catalogue of sources (all data public domain)</td>
</tr>
<tr>
<td><strong>Pointed follow-up observations</strong> of selected objects</td>
</tr>
<tr>
<td>– Observing time divided into guaranteed time (PIs) and open proposals</td>
</tr>
<tr>
<td>– Announcement of Opportunity (AO) and Observation Time Allocation Committee (OTAC)</td>
</tr>
<tr>
<td>– Scheduling and Observation execution</td>
</tr>
<tr>
<td>– Priority rights and Data distribution (PIs or public archives)</td>
</tr>
</tbody>
</table>

The Groundsegment of In.XS has the following duties: providing all facilities and services needed for mission operation on ground, providing the data link from spacecraft to the ground, preparing a timeline for the operation, *This estimate includes 20% overhead.
carrying out the monitoring, controlling and commanding of the spacecraft and instruments, executing transmission and the processing and archiving of the data.

The Groundsegment will consist of the following strongly interacting parts:

- **Groundstations:** the groundstations will be responsible for keeping contact with the satellite and exchange telecommands (TC, controlling) and telemetry (TM, science data and housekeeping), respectively. As we propose a near-equatorial orbit for In.XS, the ESA groundstation in Kourou (French Guyana) is suitable for communication with the satellite, a possible backup station would be the ESA facility in Malindi (Kenya).

- **Mission Operations Center (MOC):** The MOC will be responsible for all mission-operation related activities (safety checks for spacecraft and instruments, storing TM, routing TM to the SOC, TC commanding). In.XS could make use of the existing facilities of ESA/ESOC in Darmstadt (Germany) as MOC.

- **Science Operations Center (SOC):** The SOC will be responsible for all science related activities, i.e. instrument calibration, performance monitoring and survey analysis. Besides, it should perform the mission planning, provide the possibility of a quick-look-analysis on the incoming scientific data, archive the data and make it available for the scientific community. The exact number and location(s) of required SOC(s) is left to be decided on and supported by the PI-teams. In return, PIs will publish the all-sky catalogue and get guaranteed time during the pointed observations phase. For data distribution, use of the ESA OPSNET should be considered.

The maximum data flow for scientific and housekeeping data was calculated to be about 3.2kbits·s⁻¹, which results in 2.3Mo¹ per orbit (35Mo daily). To keep the costs low, we decided to use only one telemetry downlink per day. This means, that we have to provide for 24 hours worth of onboard data-storage. To be on the safe side, total onboard memory storage should amount to 64Mo (almost 2 days, which is very reasonable when compared to the flash-eproms Mo price rate). If one assumes that the satellite will be visible during a 10min window per orbit from the main groundstation and 50% of this time has to be used for telemetry, a minimum transmission rate of 2.4Mbits·s⁻¹·s⁻¹ (90Mo per window) would be enough by far for the daily downlink. For telecommunication with the satellite a parabolic antenna (D = 15m) at the groundstation and 2 low-gain antennae (P = 30W, f_UL = 7.2GHz, f_DL = 8.5GHz) onboard the satellite are required. Calculations show that with this equipment one can reach transmission rates well sufficient to get all the data safely down. The calculated maximum rate for the telecommands (TC) uplink is 64kbits·s⁻¹ (like an InMarSat M-4 terminal), providing sufficient margin considering the expected TC rate of ∼ 2kbits·s⁻¹. One year of all-sky survey raw data archive should hence require 12.4Go mass storage, i.e. roughly one double-sided DVD.

5. CONCLUSION AND FUTURE DIRECTIONS

Assuming that instruments and SOC are provided by the scientific community, this project suffers from no severe cost drivers, since it only uses standard spacecraft technology, limited groundsegment operations and launcher configuration and requires only limited propellant capacity, thermal and attitude control.

Given its high sensitivity, 1arcmin spatial resolution, 1keV spectral resolution, 1year all-sky survey capability in the 2−80keV range, In.XS hence fits a typical high technology - short term profile, suitable for an ESA flexi-mission or a NASA “cheaper - faster - better” concept, which could give important results toward X-ray background studies but also various galactic sources, AGN, clusters of galaxies, etc.

And remember: it is spelled I - n . X - S, but is pronounced “an access” (to the hidden universe) . . .

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¹Mo = MegaOctet = MegaByte = 8Megabits = 8 × 1024kbits
In.XS project: http://www-station.ias.u-psud.fr/inxs

REFERENCES