XEUS mission concept

1 – Introduction: XEUS assessment study

2 – XEUS mission concept

3 – Programmatic and technology development

4 - Summary
Objectives:

• To refine the XEUS science requirements

• To consolidate the XEUS mission requirements

• To establish a technical definition of the XEUS space segment

• To establish a development plan (including technology preparation activities and pre-developments)

• To quantify development risk and mission cost
1) **Preparation phase:** ( → mid-May 2008)
   - Definition of the preliminary science requirements (SciRD)
   - Preliminary definition of the payload instrumentation (PDD)
   - Building of an international collaboration scheme

2) **ESA internal XEUS mission study:** (Phase 0: mid-May → end June 2008)
   → Mission concept
   → Consolidated payload definition document + mission requirement document

3) **Two parallel Industry system studies:** (Phase A: September 2008 → July 2009)

4) **ESA synthesis of the assessment study:** (September 2009)
   • Mission technical feasibility
   • Payload technical feasibility
   • Technology development status
   • Risks, programmatic and cost
XEUS mission concept

1 – Introduction: XEUS assessment study

2 – XEUS mission concept (CV proposal)
   - Mission profile
   - Mirror spacecraft
   - Detector spacecraft
   - Formation flying

3 – Programmatic and technology development

4 - Summary
The XEUS space segment consists of two spacecrafts:
- a Mirror Spacecraft (MSC) accommodates a large X-ray telescope
- a Detector Spacecraft (DSC) accommodates the focal plane instruments

During science operation, the two spacecrafts operate in formation flying (instruments at telescope focus).
The MSC and the DSC spacecraft are launched together on a single Ariane 5 ECA launcher:
- A5-ECA single launch: ~ 6600 kg @ L2
- Fairing diameter: A5 = 4570 mm
XEUS mission concept: orbit

- Transfer to L2 as single composite
- Large Halo orbit (~ 700,000 km)
- Eclipse free > 5 yr (up to 10 yr)
- Transfer ~ 1 month
- Full-year launch window.
XEUS mission concept (CV proposal)

- Mission profile
- Mirror spacecraft
- Detector spacecraft
- Formation flying
Double-conical approx to Wolter I
Focal length: 35 m
Outer diameter: 4.34 m
FOV: 7 arcmin (diameter)
Hierarchical fabrication of mirror assembly
- Mirror stacks
- Mirror module
- Petals
- Optical bench
Mirror technologies:
(see R. Willingale review presentation)
→recommendation of XEUS telescope working group

Baseline mirror technology: pore optics
(see M. Collon presentation)
- 2 x 45 plates/ MM
- 212 MM in 25 rows/petal
- 8 petals/ telescope
→ Automated mirror plate stacking process

Mirror module prototype using the pore optics technology
(Cosine Research)
Additional telescope functions
- X-ray baffles (integrated on mirror)
- Contamination covers (on petal)
- Sunshield with heat pipes (thermal control - 90°±10° sun aspect angle)
- Skirt (stray-light rejection)

Service module (inner cylinder)
- Communication subsystem
- Data handling subsystem
- Attitude and orbit control subsystem
- Propulsion subsystem
- Power sub-system (solar array on sunshield)
XEUS mission concept (CV proposal)

- Mission profile
- Mirror spacecraft
- Detector spacecraft
- Formation flying
The proposed XEUS model payload consists of 5 instruments:
- Wide field imager
- Narrow field imager
- Hard X-ray camera
- High time resolution spectro
- X-ray polarimeter

During science operation, it shall be possible to place any of the 5 instruments at the focus of the X-ray telescope.

The instruments shall be protected from straylight.
XEUS candidate (non-cryogenic) payload instruments

(see L. Strüder review presentation)

**Wide field imager:**
- Silicon active pixel sensor
- field of view: > 7 arcmin Ø
- energy range: 0.1 … 15 keV
- energy resolution: < 150 eV @ 6 keV
- count rate capability: 8 kcps (< 1% pileup)
- Instrument total mass: 187 kg
- Instrument total power: 260 W

**Hard X-ray imager:**
- Cd(Zn)Te pixel array
- energy range extension to 40 keV
- field of view: 5 arcmin
- located behind WFI
- Instrument mass: 70 kg
- Instrument total power: 46 W
**XEUS candidate (non-cryogenic) payload instruments**

**High time resolution spectrometer:**
19 pixels silicon drift detector (operates out of focus)
- energy range: 0.1 … 20 keV
- time resolution: 10 µs
- energy resolution: 200 eV @ 6 keV
- count rate capability: 2 Mcps
- Instrument mass: 23 kg
- Instrument total power: 71 W

**X-ray polarimeter:**
Proportional counter with micro-pattern readout
- energy range: 1.9 … 6 keV
- field of view: 1.5 x 1.5 arcmin²
- energy resolution: 700 eV @ 2 keV
- Instrument mass: 24 kg
- Instrument total power: 34 W
XEUS candidate cryogenic payload instruments

(see P. de Korte presentation)

**Narrow field imager:**
Transition edge sensors

- FoV: 0.75 arcmin Ø
- energy range: 0.1-10 keV
- resolution: 2 eV @ 0.5 keV
  6 eV @ 6.0 keV

- operation temperature: 50 mK

- total mass and power driven by the cryogenic chain solution
XEUS instruments: accommodation concept

Different cryogenic chain concepts are possible for the cryogenic instrument, e.g.:

**Solution A:** (good flight heritage)
- 2 Stirlings (300K $\rightarrow$ 80K $\rightarrow$ 18 K)
- + 2 JT (18K $\rightarrow$ 4K)
- + dADR (4K $\rightarrow$ 50 mK)
- $P = 700$ W

**Solution B:**
- V-grooves and radiators ($\rightarrow$ 50K)
- + 2 pulse tubes (50K $\rightarrow$ 18K)
- + 2 He-3 JT (18K $\rightarrow$ 2.5K)
- + sorption cooler based ADR (2.5 K $\rightarrow$ 50 mK)
- $P = 470$ W
XEUS mission concept (CV proposal)

- Mission profile
- Mirror spacecraft
- Detector spacecraft
- Formation flying
Leader-follower architecture:

Mirror S/C uses:
- a “classical” 3-axis guidance, navigation and control (GNC) system

Detector S/C uses:
- a “classical” 3-axis GNC system for attitude control
- a 3-axis relative distance measurement and control (translation)
  • Radio frequency subsystem for coarse 3D relative distance measurement
  • Optical metrology for fine range and lateral relative distance measurement
XEUS formation flying concept

Free Flying phases

- Formation Deployment
  - DSC Replacement
  - Formation Acquisition
    - Switch to RF metrology
    - ISL becomes active
  - Formation Initialisation
    - ISD decreased to 35 m
    - Switch to optical metrology
      when ISD ≥ 120 m
  - Science Observation
    - Inertial observation
    - Retargeting manoeuvres
    - Lateral displacement manoeuvres
    - Orbit maintenance (for MSC)
    - Earth communication

XEUS mission phases

- upon failure
## XEUS formation flying concept

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<th>Equipment</th>
<th>DSC</th>
<th>MSC</th>
<th>Formation Deployment Mode</th>
<th>Formation Initialisation Mode</th>
<th>Formation Acquisition Mode</th>
<th>DSC Lateral Displacement Mode</th>
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<th>Observation Mode</th>
<th>Earth Communication Mode</th>
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<th>Formation Safe Mode</th>
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(1) Retro-reflectors or Diode.
(2) After completion of the individual S/C initialisation mode
⊙ Used for anti-collision surveillance.

## GNC equipment vs mode

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**Science Payload & Advanced Concepts Office**
Formation flying requirements in observation mode:

- Relative distance error: ±1 mm lateral (instrument FOV)
  ±0.3 mm longitudinal (PSF degradation by defocus)

- Relative distance measurement accuracy:
  ±0.17 mm lateral (image reconstruction)
  ±0.15 mm longitudinal
At L2, differential solar radiation pressure is the main disturbance source

\[
\frac{A_{DSC}}{M_{DSC}} \approx 3 \times \frac{A_{MSC}}{M_{MSC}},
\]

\[a_{SRP}^{relative} = 5.5 \times 10^{-8} \text{ m/s}^2\]

\(\Rightarrow\) Control strategy (thruster’s life and minimum propellant consumption):

- e.g. bang-bang control of on-off thrusters (20 mN cold gaz thrust every 350 s)
**XEUS formation flying concept**

**Complexity of formation flying (vs single S/C operation):**

- Number of actuators and sensors,
- Number of modes (stability) and mode transitions (convergence),
- Guidance, navigation and control (GNC), vehicle management, failure detection identification and recovery shared between spacecraft and with the ground.

→ **Importance of formation flying verification approach:**

- Test at individual components or subsystems (e.g. optical metrology)
- System software simulators (to generate external stimuli, to test the whole functional response of the system)
- Avionics test beds (to test the interconnected electronics subsystems of the spacecraft computers)
- Formation flying ground test beds (to test a functional chain of metrology and simulated actuators that demonstrates specific functionalities)
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XEUS formation flying concept challenges

1 - Programmatic and cost:

2 - MSC: high throughput X-ray telescope
   - Performance requirements (PSf, Aeff) vs technology, available resources (mass, volume), on-ground verification approach

3 - DSC: cryogenic instrument
   - Performance requirements (ΔE, FOV) and operation temperatures vs technology, available resources (mass, power)

4 - Formation flying
   - complexity/ verification approach
XEUS programmatic and cost

XEUS formation flying mission cost (excluding payload instruments) is larger than ESA’s budget envelope for a large mission

An international collaboration scheme is needed

XEUS mission concept shall be commensurate with funding scheme
An ESA funded XEUS technology development program is in preparation
- X-ray mirror technologies, telescope structure, testing facilities
- Upper-stage cryogenics
- Formation flying

Nationally funded XEUS payload development program is being defined
- dedicated instrument design definition studies
- cryo-detectors
- read-out electronics
- last stage cryo-coolers

➔ component and/or breadboard validation in laboratory (TRL 4)
and possibly in relevant environment (TRL 5) needed by June 2009
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XEUS mission concept: summary

- Current XEUS mission concept consists of a mirror spacecraft and a detector spacecraft operating at L2 in formation flying.

- XEUS mission challenges are the mission cost, the manufacture of X-ray telescope, the development of the cryogenic instrument and the formation flying.

- A XEUS technology development program is being prepared that shall demonstrate TRL 4-5 by June 2009.

- XEUS assessment study is in a preparation phase where science req. are refined, a candidate payload suite is defined, and an international collaboration scheme is being set-up.

→ International collaboration will play a major role in the evolution of the XEUS mission concept.