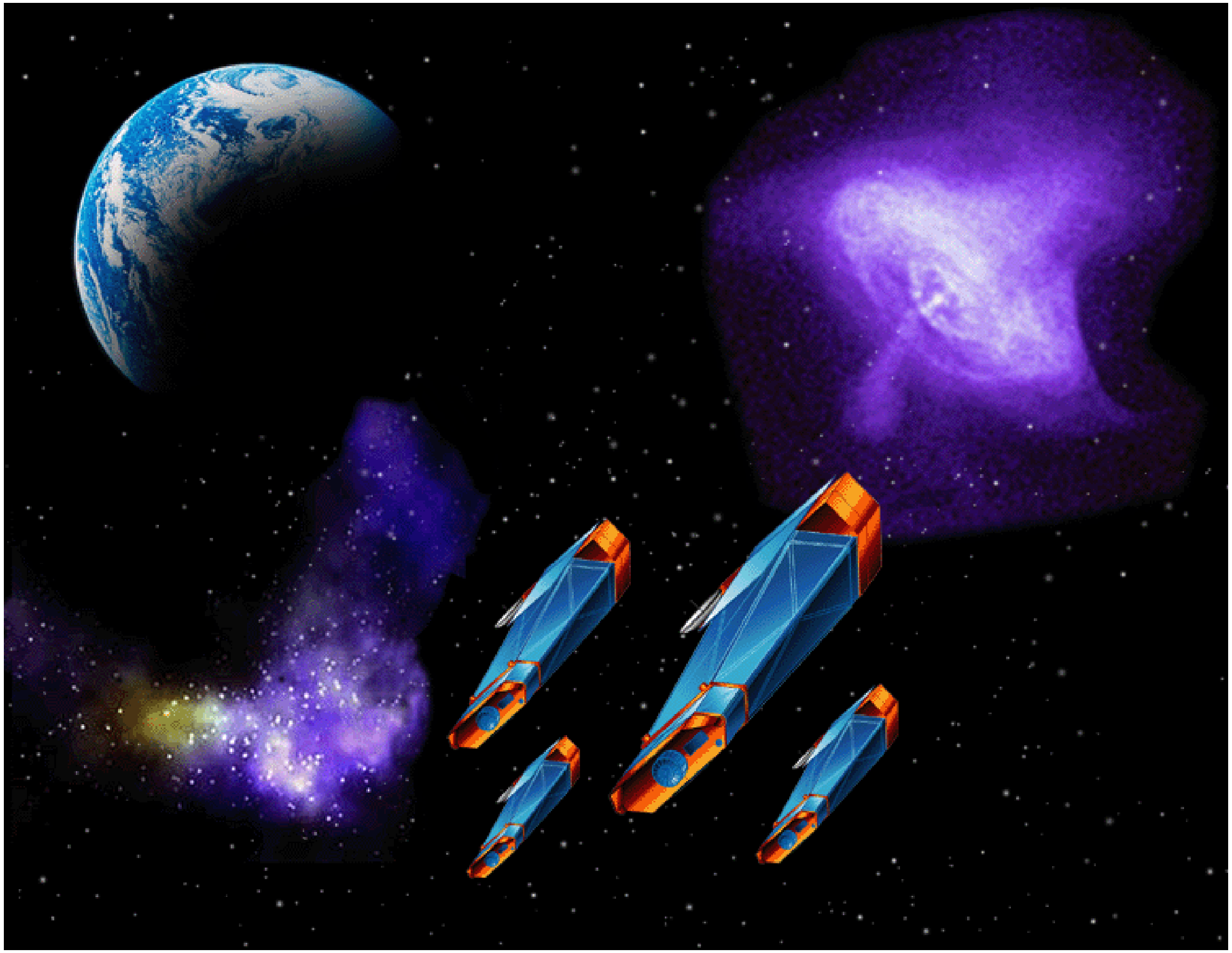
Constellation X-ray Mission



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http://constellation.gsfc.nasa.gov

Highlights from the Past Year

Mission Accomplishments

- Baselined fixed bench configuration for Reference Configuration
- Identified launch vehicle options
- Continue rigorous requirements flow down documentation

Technology Progress

- Prioritized segmented optics technology as prime
- Demonstrated mandrel-limited performance on small scale replicated reflectors
- Generated segmented optics modular demonstration approach and began detail design of initial unit
- Initiated procurement of large (1.6 m) segment mandrel
- Achieved flight required energy resolution on single pixel X-ray calorimeters
- Demonstrated ability to make small, close packed TES arrays
- Built first very small X-ray calorimeter TES arrays

Positioned technology to begin flight scale demonstration

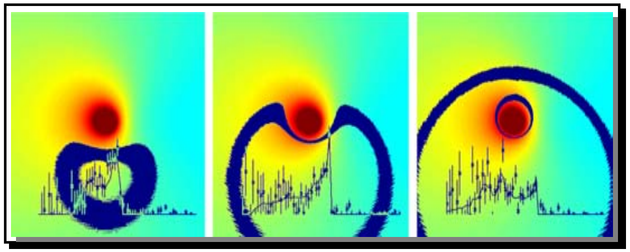
The Constellation X-ray Mission

Constellation-X is X-ray astronomy's equivalent of the Keck telescope

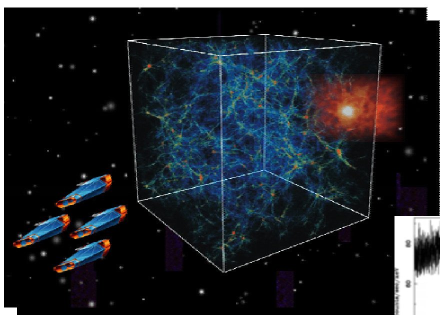
- **Collecting area: 30,000 cm^2 at 1 keV**
  25 to 100 times Chandra and XMM for high resolution spectroscopy
- **Spectral resolving power: 3,000 at 6.4 keV**
  25 times Chandra grating
  5 times Astro-E2
- **Band Pass: 0.25 to 40 keV**
  100 times more sensitive than Rossi XTE at 40 keV

Science Overview

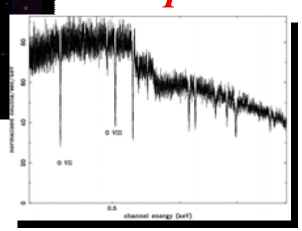
Constellation-X will open new windows towards understanding the Universe



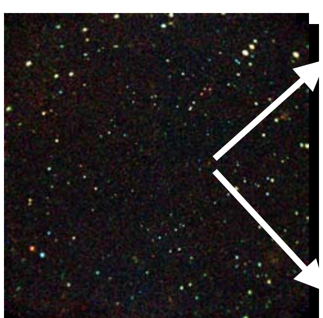
- **Observe the effects of General Relativity near black hole event horizons**
  - Probe 100,000 times closer to black hole than before
  - Determine black hole spin and mass from iron profiles over a wide range of luminosity and redshift



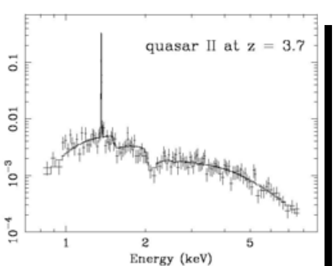
Absorption



- **Map formation and evolution of dark matter structures throughout the Universe**
  - Detect ionized gas in the hot Inter Galactic Medium via absorption lines in spectra of background quasars
  - Map the distribution of dark and baryonic matter trapped in the gravitational potential of clusters
  - Observe the faintest, most distant clusters to determine redshift and mass to constrain Cosmological models and parameters

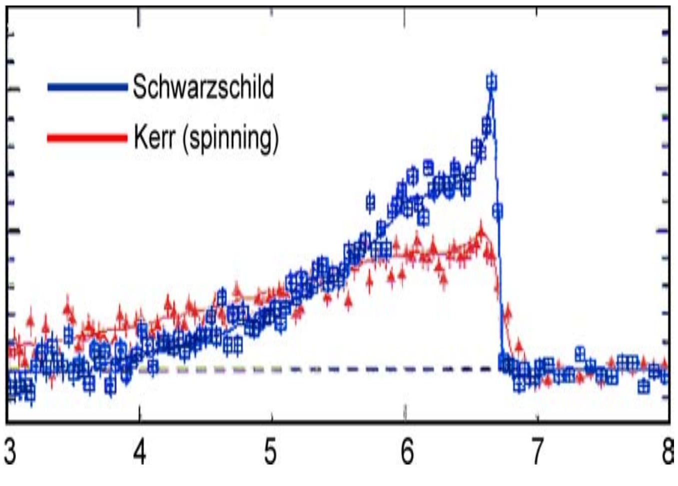


Chandra Deep Field

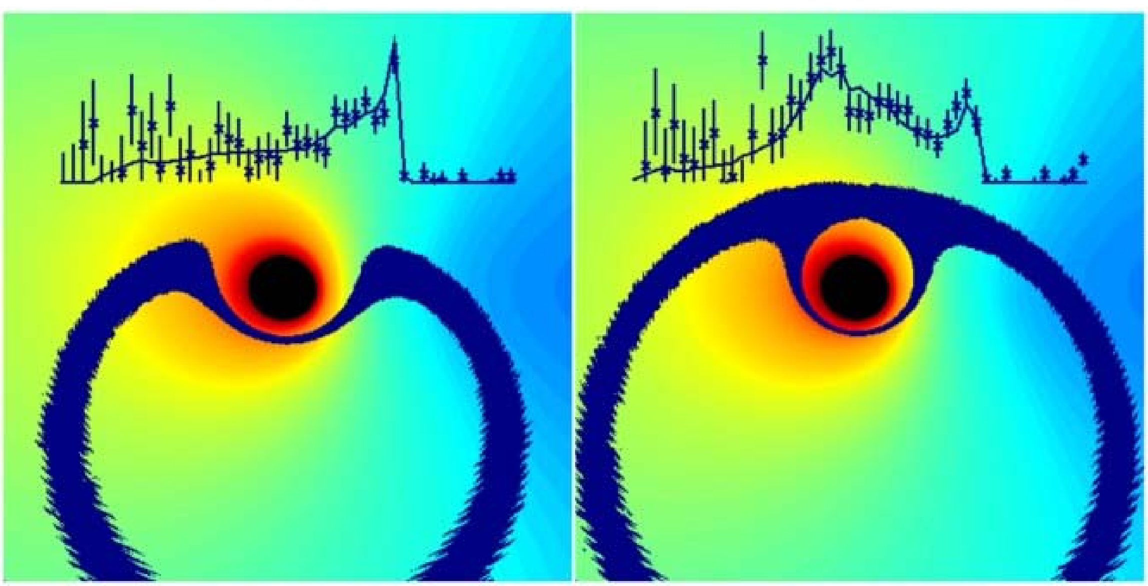


- **Determine the nature of faint X-ray sources discovered by Chandra**
  - Obtain detailed spectra to determine physical processes prevalent in redshifts ranging to ~5

Probing Black Holes



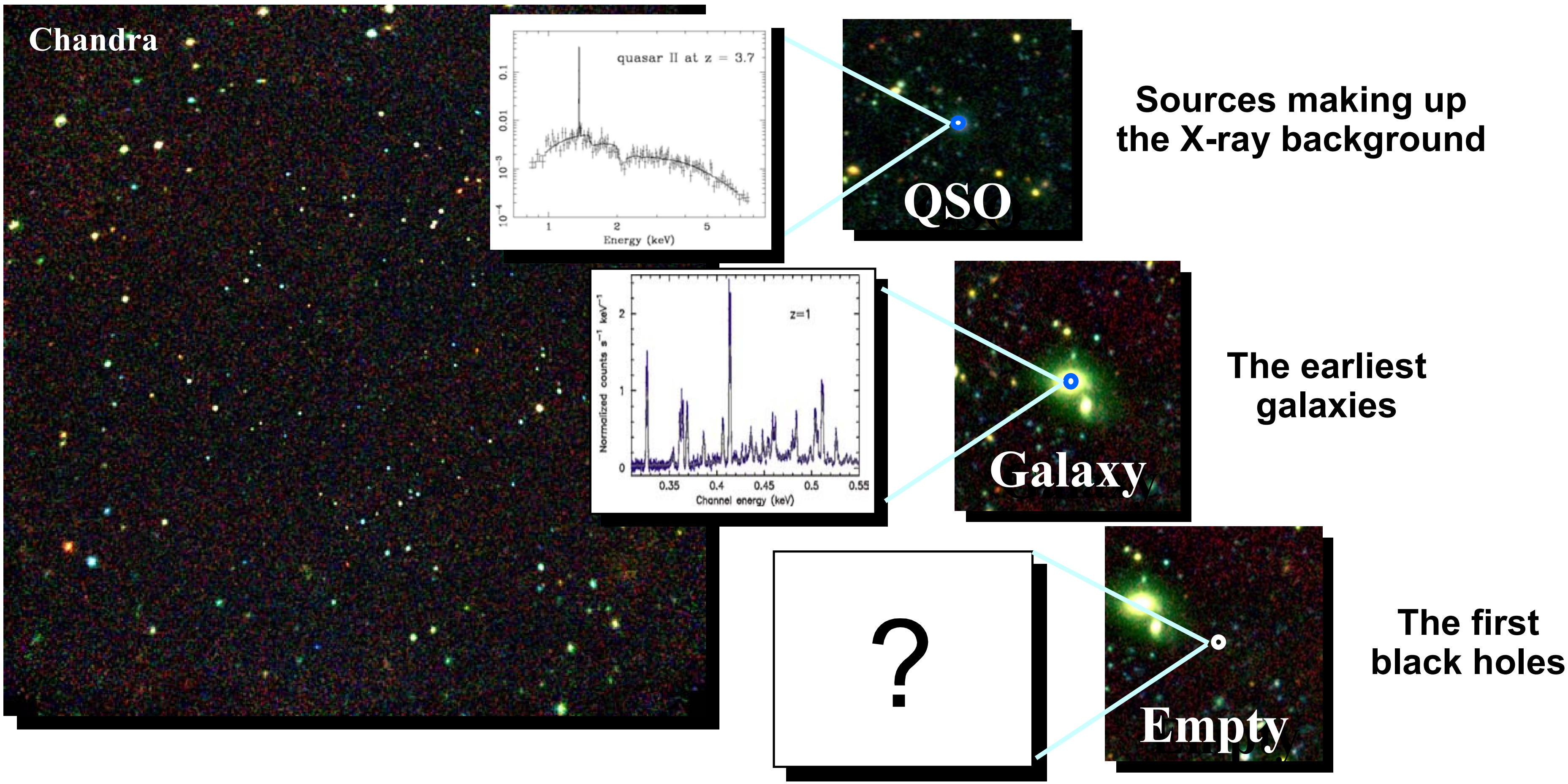
- **Constellation-X will probe close to the event horizon with 100 times better sensitivity than before**
  - Observe iron profile from close to the event horizon where strong gravity effects of General Relativity are seen
  - Investigate evolution of black hole properties by determining spin and mass over a wide range of luminosity and redshift



Simulated images of the region close to the event horizon illustrate the wavefront of a flare erupting above material spiralling into the black hole. The two spectra (1000 seconds apart) show substantial distortions due to GR effects.

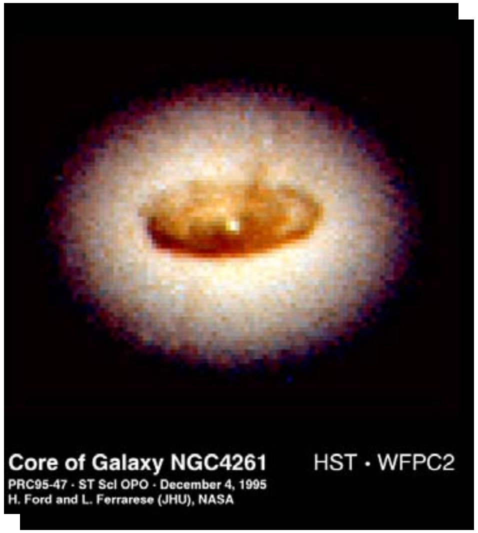
Chandra Finds Black Holes Are Everywhere!

Chandra deep field has revealed what may be some of the most distant objects ever observed

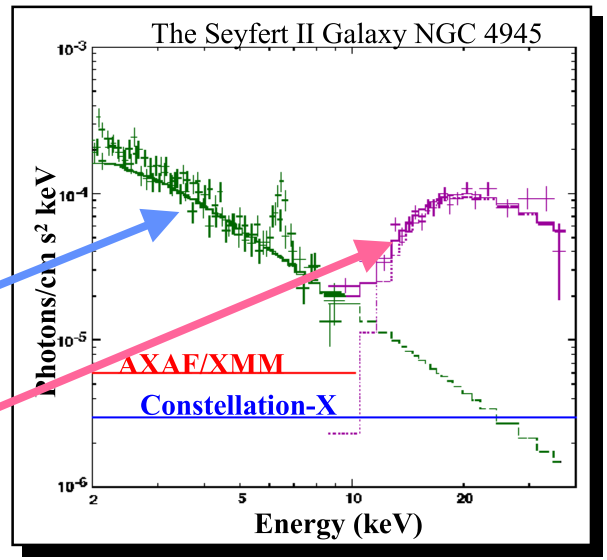


Constellation-X will obtain high resolution spectra of these faintest X-ray sources to determine redshift and source conditions

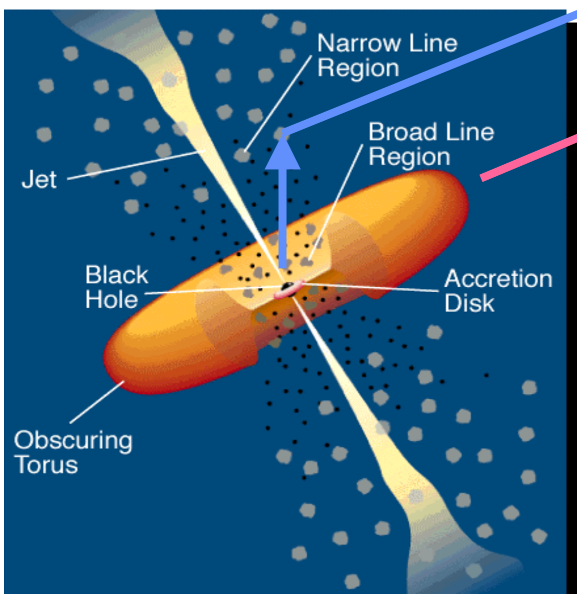
Hidden Black Holes



Many black holes may be hidden behind an inner torus or thick disk of material



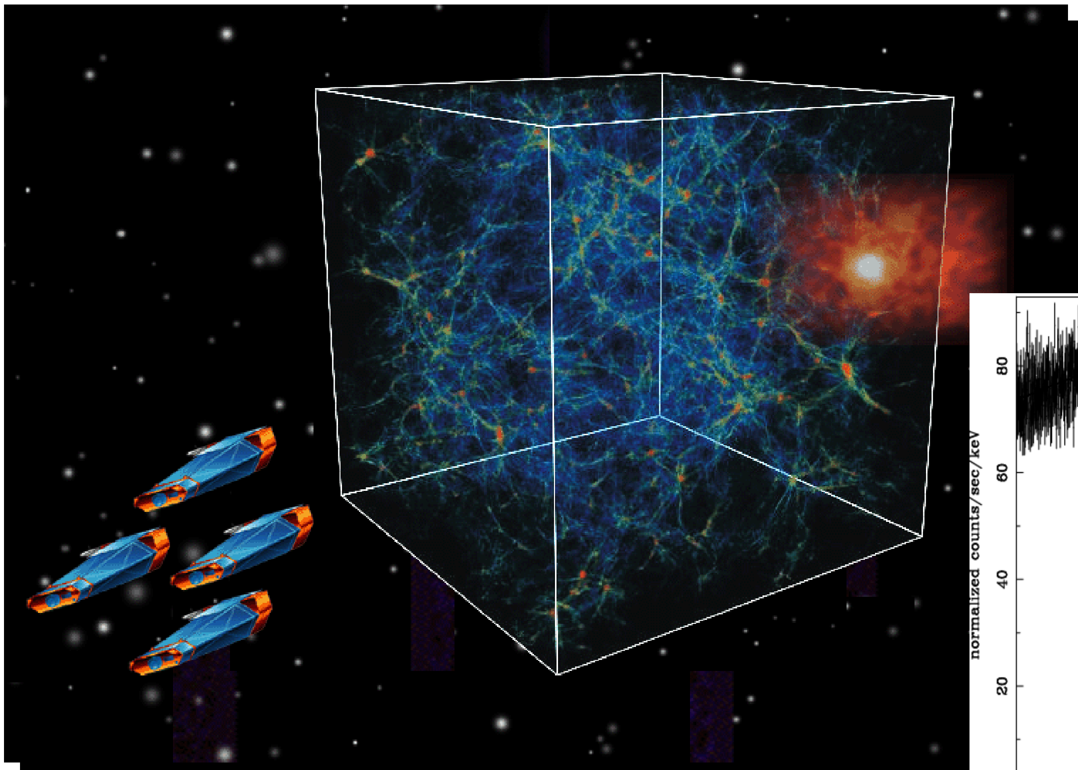
Only visible above 10 keV where current missions have poor sensitivity



Constellation-X will use multi-layer coatings on focusing optics to increase sensitivity at 40 keV by >100 over Rossi XTE

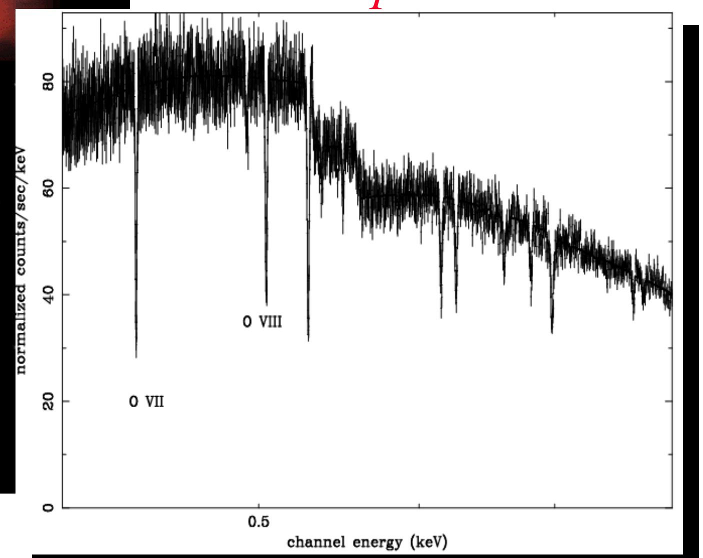
“X-raying” the Cosmic Web

- **Constellation-X will search for the missing baryons trapped in the Cosmic Web of dark matter**



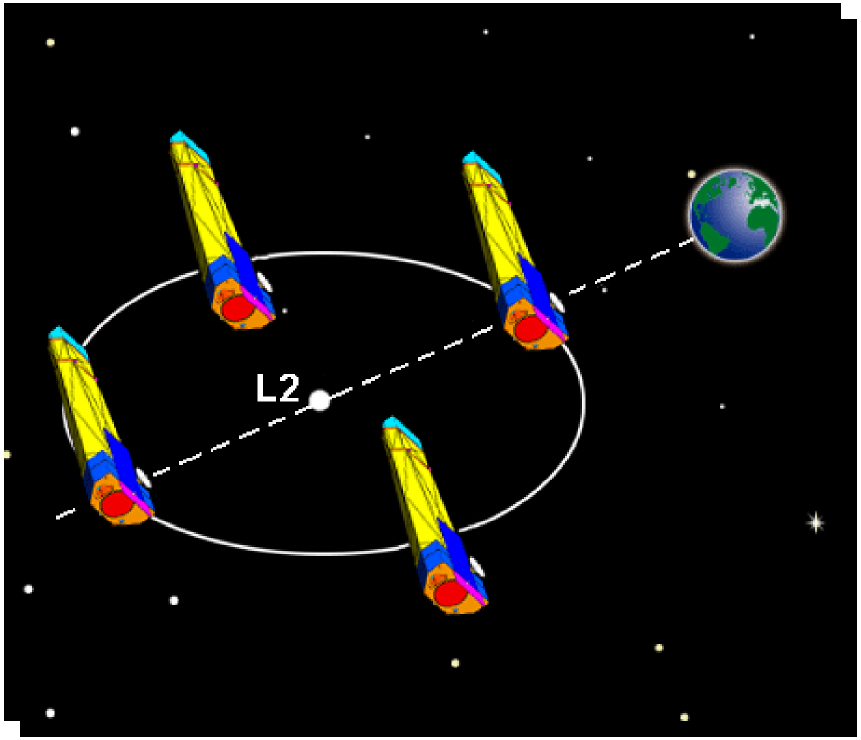
- Detect ionized gas in the hot Inter Galactic Medium via absorption lines in spectra of background quasars

Absorption



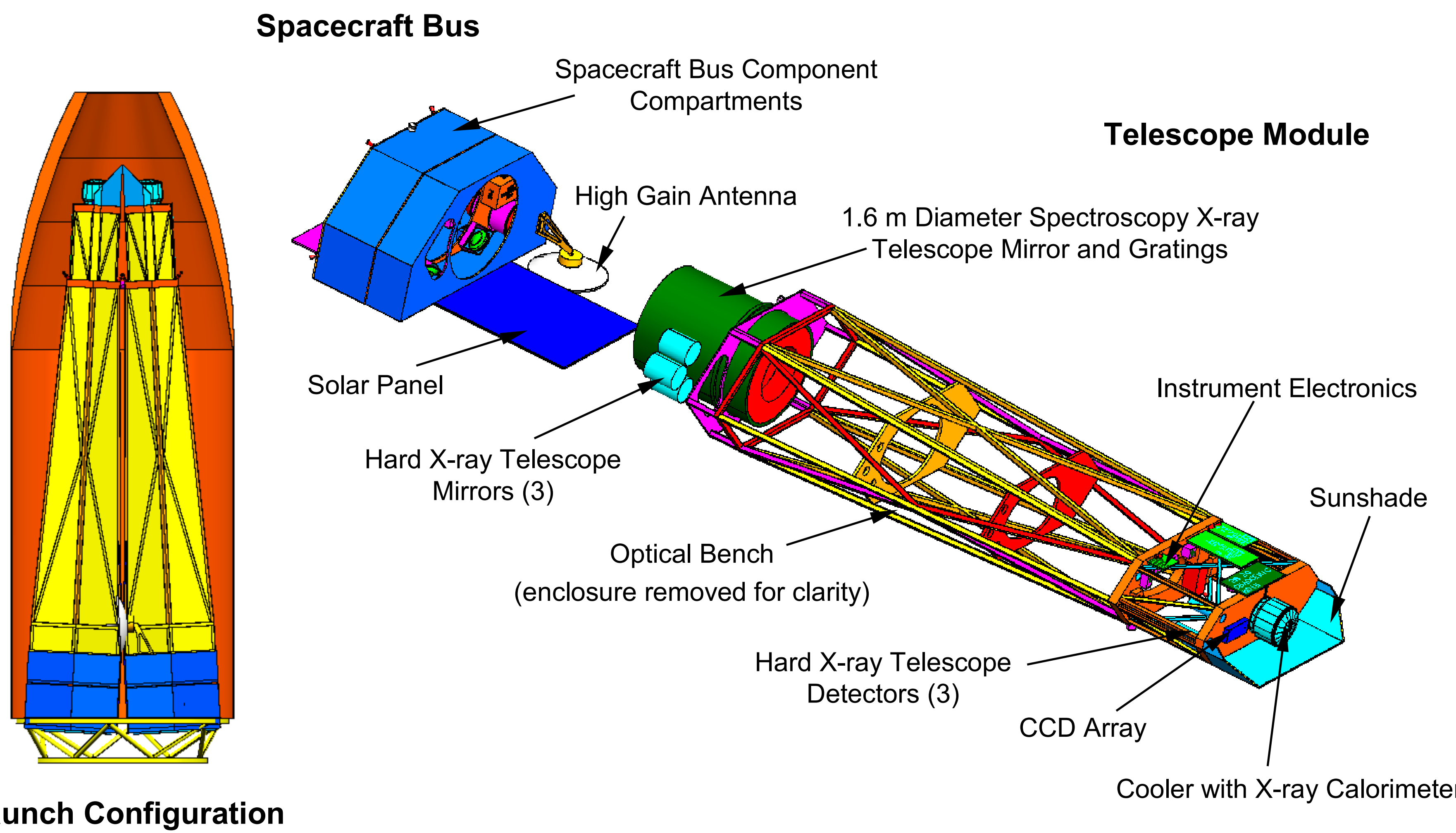
Constellation-X will probe up to 70% of the hot gas at low redshifts through OVII & VIII resonant absorption

Constellation-X Mission Concept



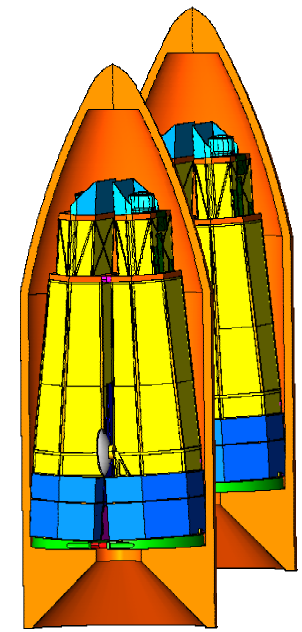
- **A multiple satellite approach:**
  - A constellation of multiple identical satellites
  - Each satellite carries a portion of the total effective area
  - Design reduces risk from any unexpected failure
- **Deep space (L2) orbit allows:**
  - High observing efficiency
  - Simultaneous viewing
- **Reference configuration:**
  - Four satellites, launched two at a time on Atlas V class vehicle
  - Fixed optical bench provides a focal length of 10 m
  - Modular design allows:
    - > Parallel development and integration of telescope module and spacecraft bus
    - > Low cost standard bus architecture and components

Reference Design

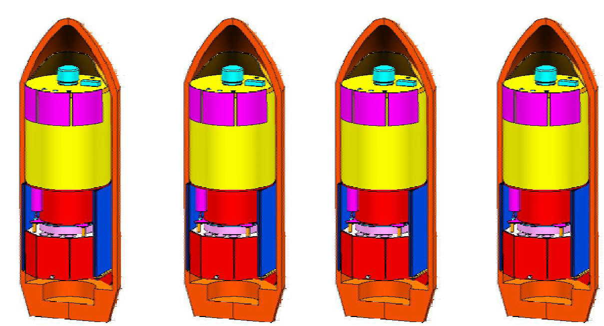


Launch Vehicle Options

- **Atlas V is optimal for Constellation-X (2 launches)**
  - Most effective means to meet full mission performance
  - Thirteen launches currently planned prior to Constellation-X new start in October 2006
- **Delta IV Medium could be used (2 launches)**
  - Requires single deployable extension on optical bench to obtain full 10 m focal length
  - Seventeen launches planned prior to October 2006
- **Delta II could be used (4 launches)**
  - Approximately 12 percent reduction of total mission effective area
  - Requires extendible optical bench
  - Uses solar electric power ion propulsion
  - Takes 450 days to reach L2



Delta IV



Delta II

Constellation-X Requirements Flow Down

Science Goals

Parameters of Supermassive Black Holes

Search for Dark Matter

Investigate Faint Sources

Plasma Diagnostics from Stars to Clusters

Measurement Capabilities

Effective area:
15,000 cm² at 1 keV
6,000 cm² at 6.4 keV
1,500 cm² at 40 keV

Band pass:
0.25 to 40 keV

Spectral resolving power ($E/\Delta E$):
$\geq$ 300 from 0.25 to 6.0 keV
$\geq$ 3000 at 6 keV
$\geq$ 10 at 40 keV

System angular resolution and FOV:
15 arc sec HPD and
FOV > 2.5' (0.25 to 10 keV)

1 arc min HPD and
FOV > 8' (10 to 40 keV)

Engineering Implications

Effective area:
- Light weight, highly nested, large diameter (1.6 m) optics
- Long focal length (8-10 m)

Band pass:
- 2 types of telescopes to cover energy range

Spectral resolving power:
- Dispersive *and* non-dispersive capability to cover energy band

System angular resolution and FOV:
- Tight tolerances on telescope figure, surface finish, alignment
- $\geq$ 30 x 30 array for x-ray calorimeter (pixels ~5")
- Cryocooler driven by array size and readout electronics

Key Technologies

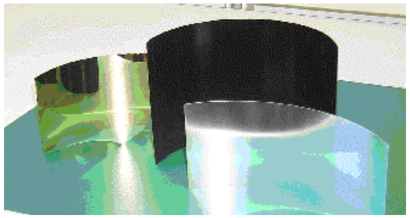
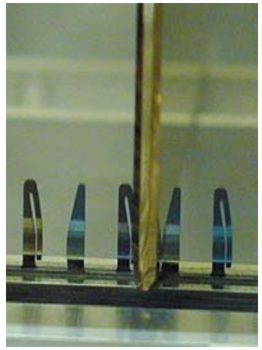
High throughput optics:
- High performance replicated segments and shells
- High reflectance coatings
- High strength/mass materials for optical surfaces

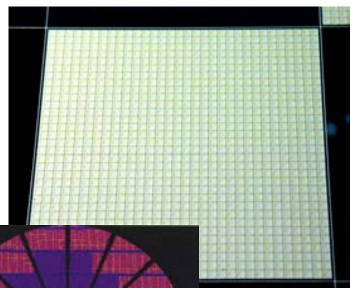
High energy band:
- Multilayer optics
- CdZnTe detectors

High spectral resolution:
- 2 eV calorimeter arrays
- Coolers
- Lightweight gratings
- CCD arrays extending to 0.25 keV

Optical bench:
- Stable (time and temp.)
- High strength/low weight materials

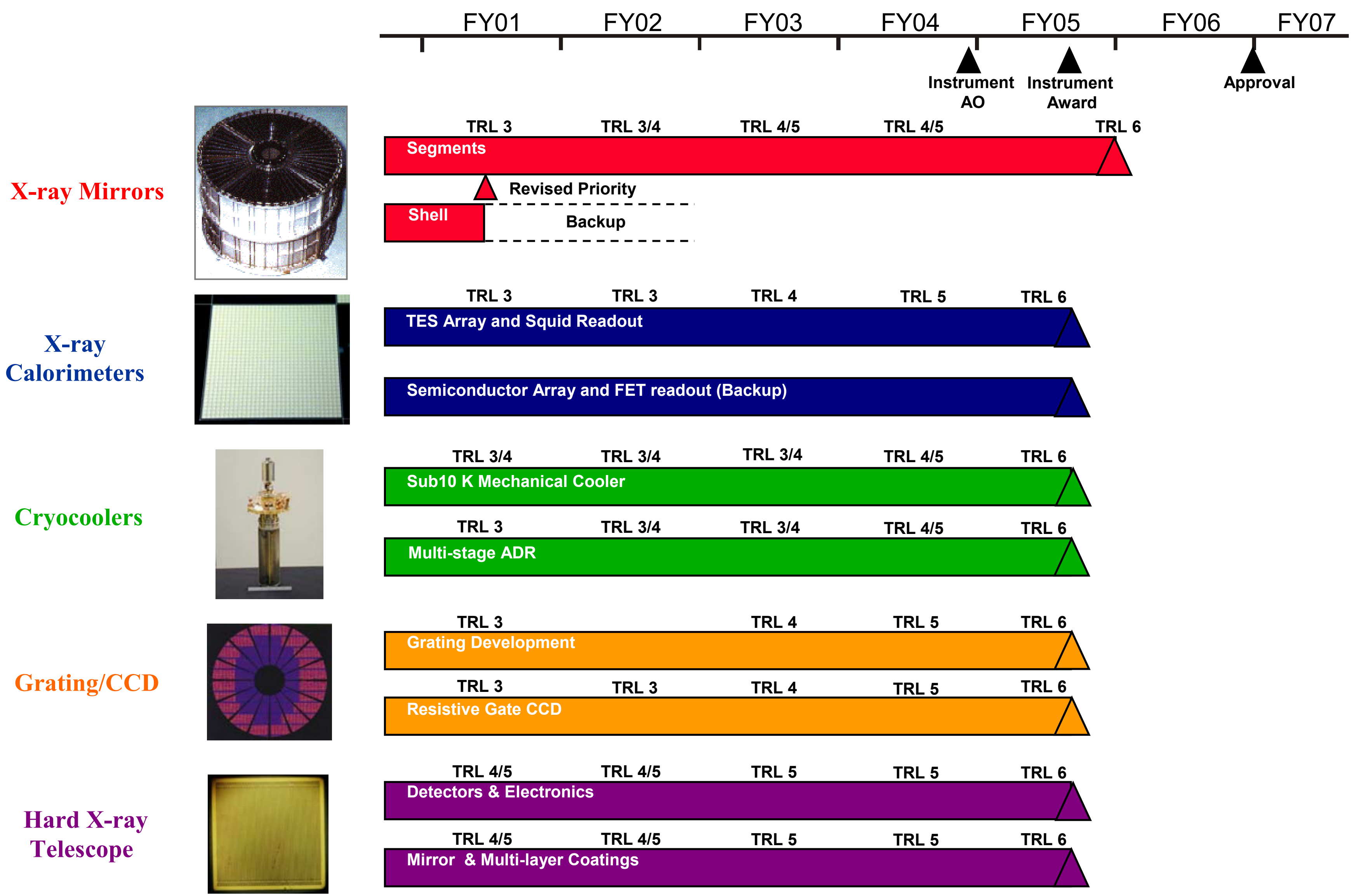
Technology Development Approach



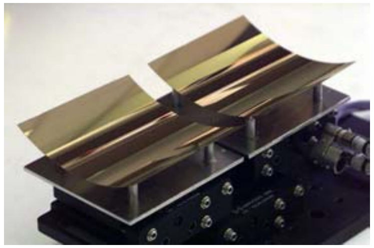

- **Extension of demonstrated technology**
- **Parallel path technology development with defined selection milestones**
- **Leverages other technology investments:**
  - Cross-enterprise (coolers, optics, X-ray calorimeter)
  - SR&T (CdZnTe and calorimeter detectors, multi-layer coatings)
  - NASA Center IR&D and DDF (optics, coolers, calorimeter)
  - SBIR (calorimeter and cooler)
- **Greater investments now required for the transition from component bread boarding to system technology demonstrations**

The Constellation-X Technology Roadmap

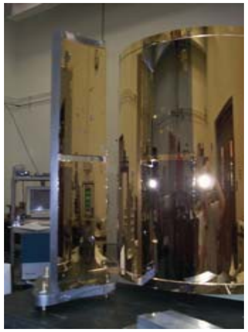


SXT Segmented X-ray Mirrors

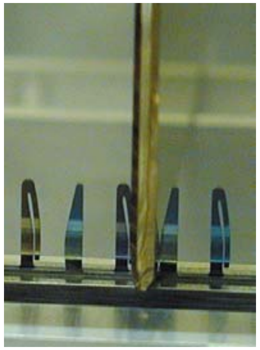
- **Requirement: Highly nested reflectors with 1.6 m outer diameter, low mass and angular resolution $\leq$ 10 arc sec (HPD)**
  - Segmented technology meets mass requirement
  - Requires **10X** improvement in resolution and **4X** increase in diameter compared to Astro-E
- **Progress:**
  - Demonstrated 30 arc sec HPD for glass segment pairs replicated off Astro-E cylindrical mandrels
    - > Performance limited by Astro-E mandrel quality
    - > Preparing to replicate glass using 0.5 m precision Wolter Mandrel
  - Replicated Wolter surface onto 0.5 m Be substrate
  - Began design and procurement of large reflector replication equipment
    - > Received large oven
    - > Invented and demonstrated portable replication device
  - Developed modular flight concept and initiated Engineering Unit design
  - Initiated procurement for 1.6 m diameter segment mandrel
- **Partners: GSFC, MIT, SAO, MSFC**



Small glass segment pair on alignment fixture



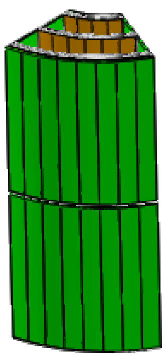
Be replicas and mandrel



Etched Si alignment microcomb

SXT Strawman Design

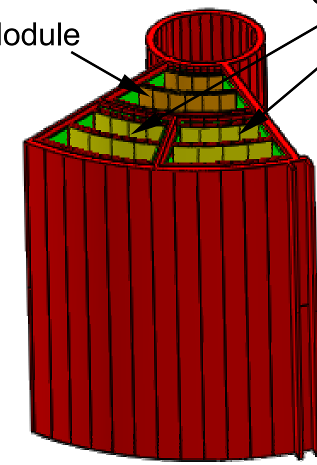
Engineering Unit



Single inner module with

- 0.5 m dia. reflector pair (replicated from Zeiss precision mandrel)
- Parabolic (P) and Hyperbolic (H) submodules
- First modules to be aligned using etched silicon microcombs

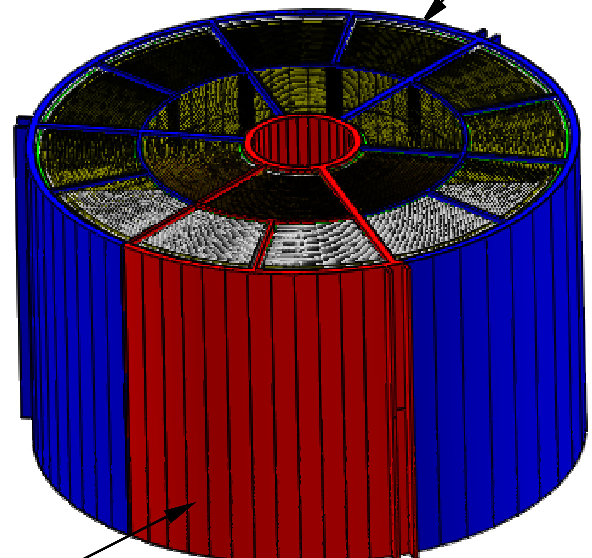
Prototype Unit



Flight Scale Assembly of

- 3 modules (2 outer and 1 inner)
- Largest diameter same as for flight - 1.6 m
- Each module has 3 to 9 reflector pairs
- Demonstrates module to module alignment

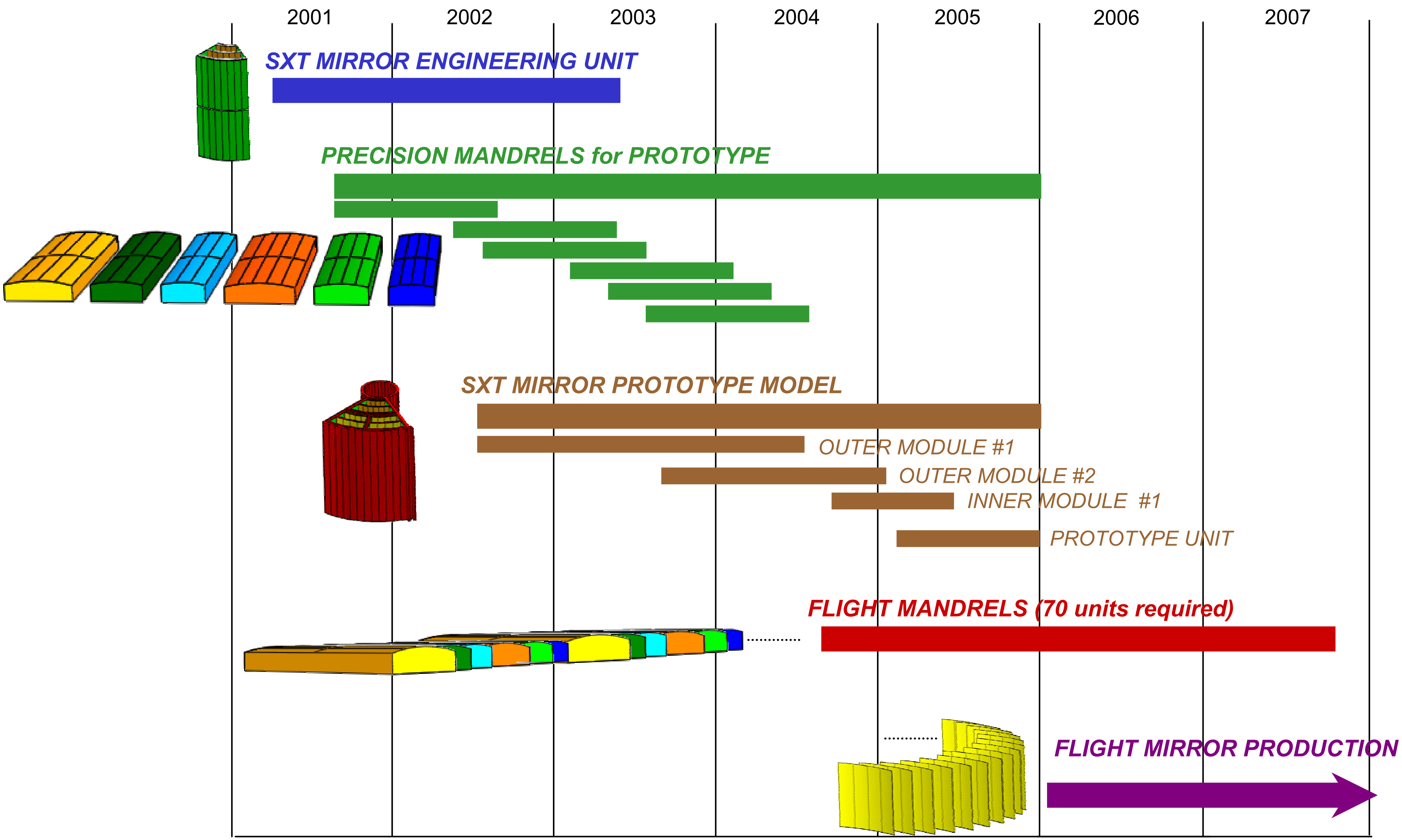
Flight Unit



Full flight Assembly

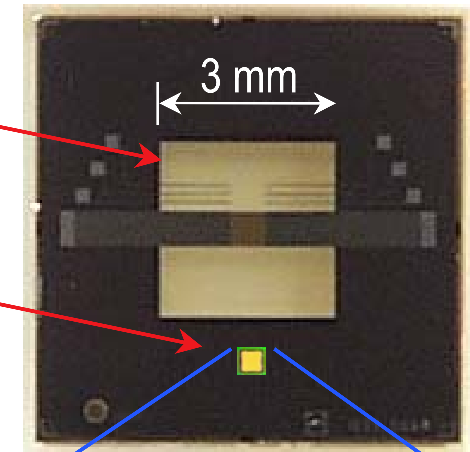
- 1.6 m outer diameter
- 18 Small Modules
- 70 to 170 reflector diameters

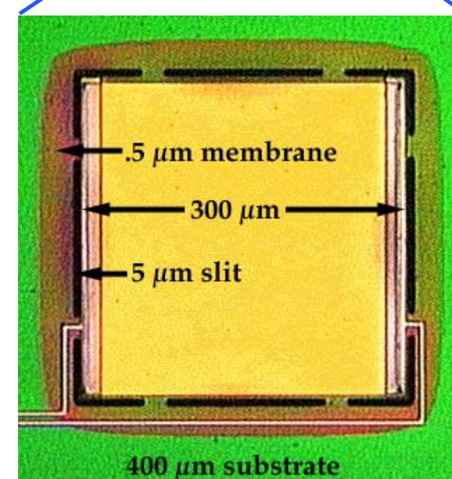
SXT Technology Roadmap



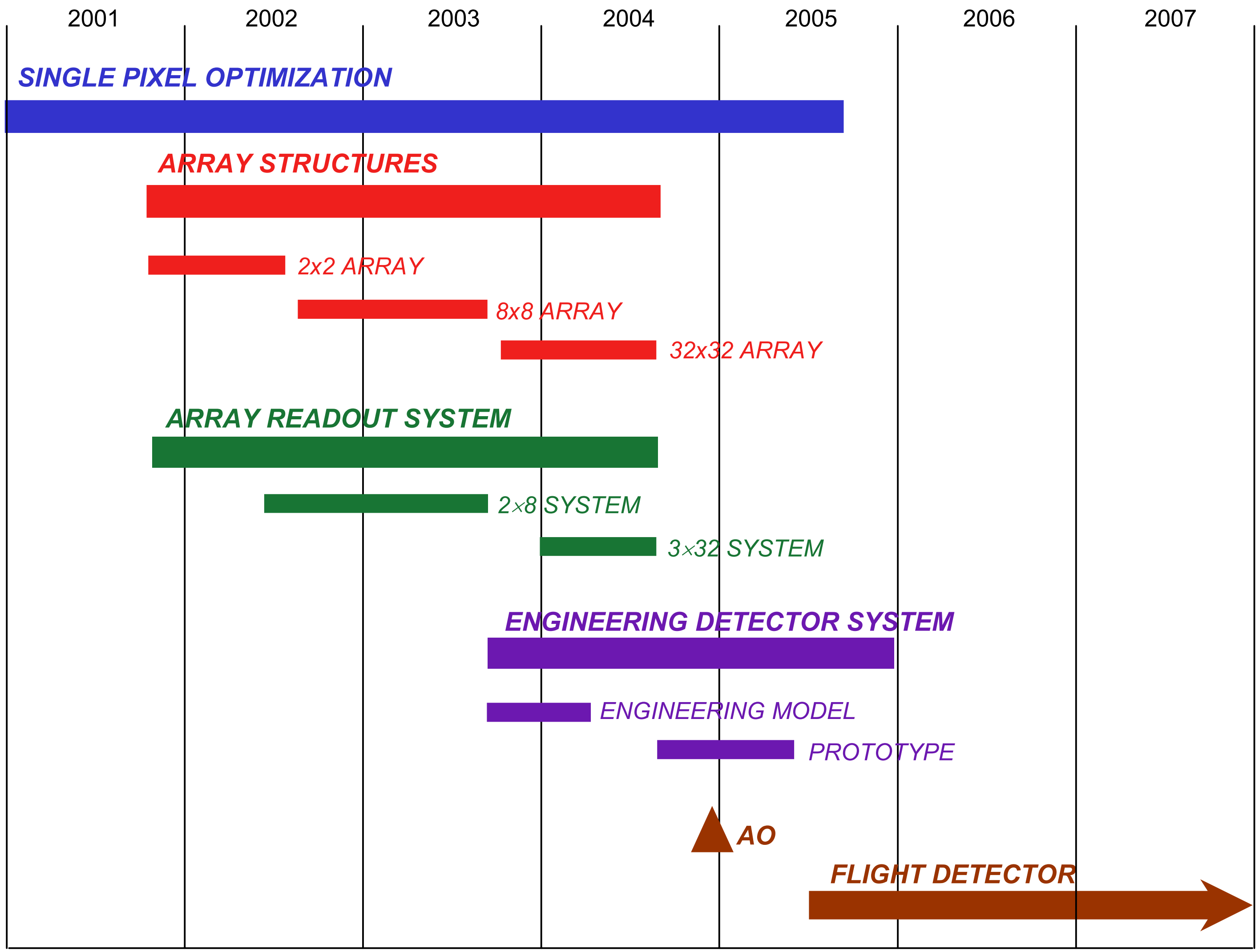
X-ray Calorimeters

- **Requirement: 2 eV FWHM energy resolution from 1 to 6 keV at 1000 counts/s/pixel in 32 x 32 pixel array**
- **Parallel Approach: Transition Edge Sensor (TES) and NTD/Ge Calorimeters**
- **Progress:**
  - Previously demonstrated 2 eV resolution (at 1.5 keV) in TES with large membrane
  - *New!* Achieved adequate thermal isolation using a narrow perforated perimeter of thin silicon-nitride around the TES thermometer. *Obtained 4.0 eV resolution (at 1.5 keV) on first run without optimizing!*
    - > Breakthrough paves the way for the compact pixels required by Constellation-X spatial resolution
  - Quantified noise contributions for current state-of-the-art TES energy resolution budget
  - Fabricated 2 × 2 TES array for initial cross talk measurements
  - Demonstrated a new imaging TES approach that will potentially enable increase in field of view without increase in electronics
  - Achieved 4.8 eV resolution over full range (1-6 keV) with NTD/GE detector
- **Partners: GSFC, NIST, SAO, UW, LLNL, Stanford**





X-ray Calorimeter Technology Roadmap



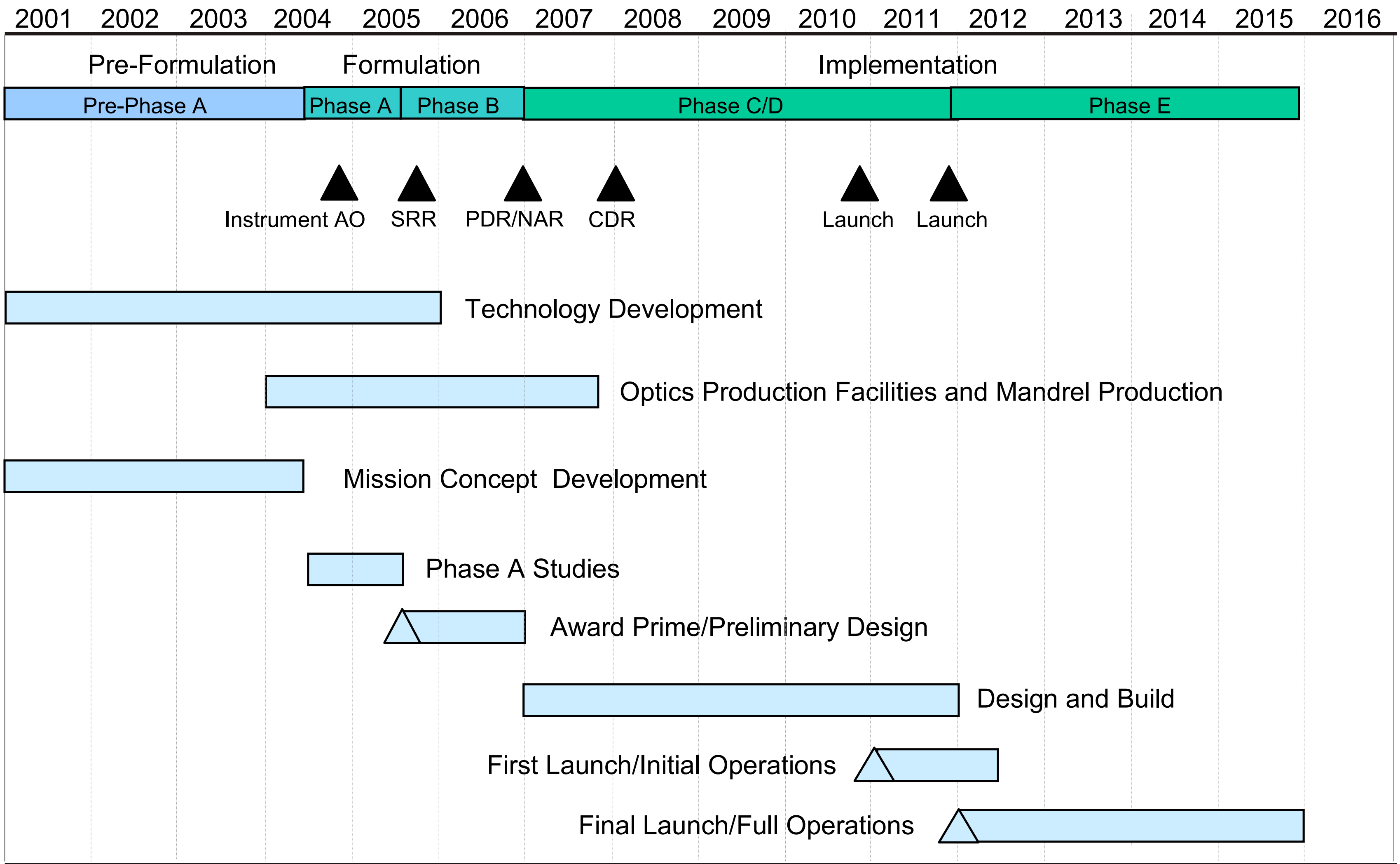
Cooling System for X-ray Calorimeter

- **Requirement: Long life cooling system to provide 40 to 65 milli Kelvin to X-ray calorimeter**
- **Approach: Sub10-Kelvin mechanical cooler to provide heat sink to sub-Kelvin Adiabatic Demagnetization Refrigerator (ADR)**
- **ADR Progress:**
  - Demonstrated operation of two new heat switches: a gas-gap switch and a magneto resistive switch
  - Assembling a three-stage continuous ADR demonstrator using these heat switches and previously developed components over the next few months
  - Identified engineered refrigerants that may offer lower magnetic fields and higher cooling power in the 1-10 K range
  - Funded by Cross Enterprise Technology Development Program
- **Mechanical Cooler Progress:**
  - 70 K turbo-Brayton cooler for HST successfully completed mechanical and thermal testing
  - Performed highly successful 6-10 K flow-through test of the Turbo alternator
  - Funded by Cross Enterprise Technology Development Program and SBIR

Turbo-alternator Test Apparatus

- **Partnership: GSFC, JPL, Creare, Energen, Houston U., Berkley**

Top Level Schedule
(In-guide FY07 New Start)



Summary

- **Constellation-X emphasizes high throughput, high spectral resolution observations – the next major objective in X-ray astronomy**
- **Chandra observations continue to demonstrate the richness of X-ray spectra**
- **Substantial technical progress achieved at component level**
  - Replicated reflector performance
  - Calorimeter single pixel spectral resolution
  - Hard X-ray telescope optics and detectors performance now meets requirements
- **Ready to ramp up technology development to flight scales to demonstrate TRL6**
  - Optics Engineering and Prototype unit demonstrations
  - Flight size reflector replication
  - Large calorimeter arrays and readout systems