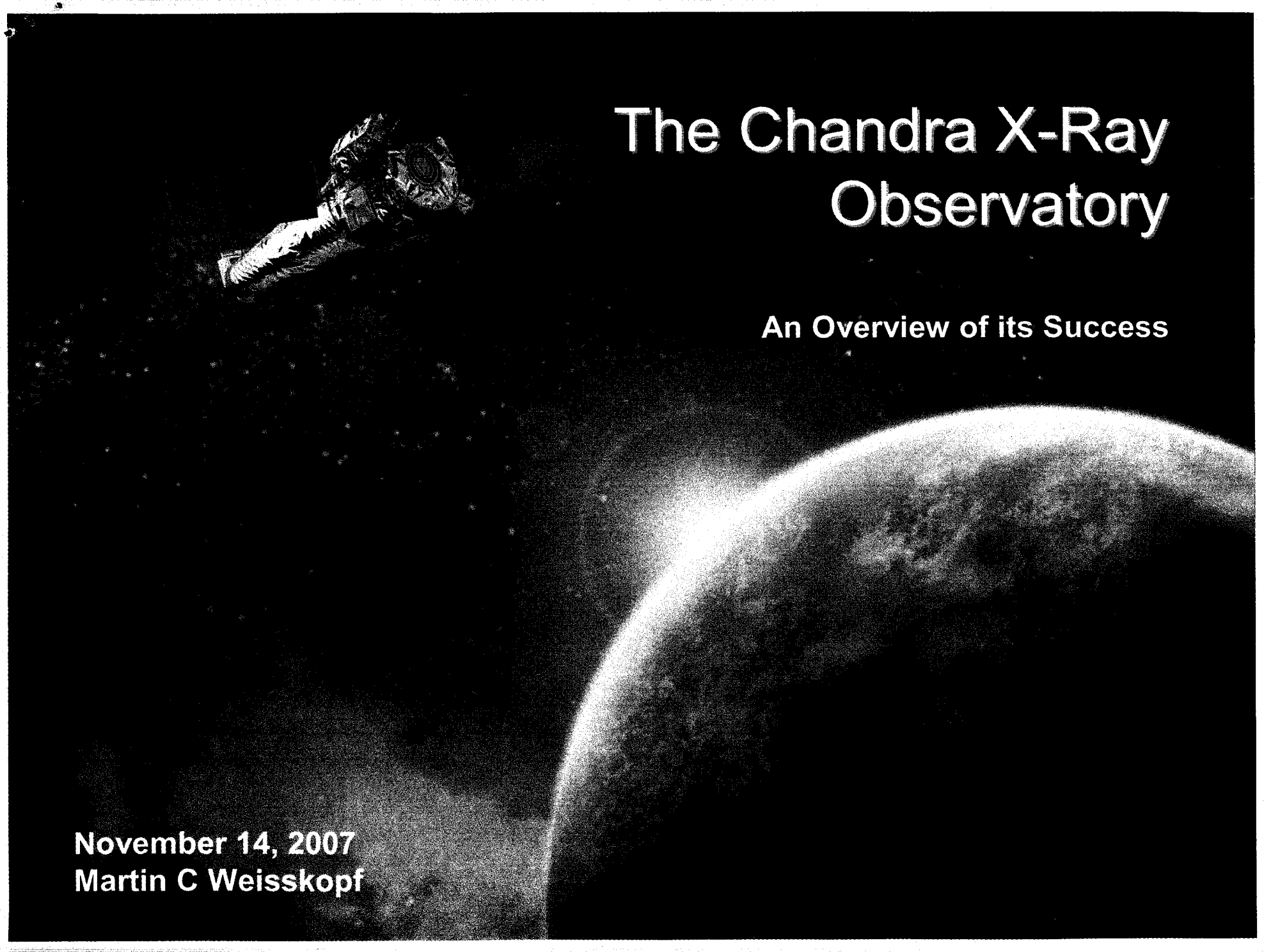
MSFC-583_ Abstract

My title is: "The Chandra X-Ray Observatory"

My Abstract is: The Chandra X-Ray Observatory, the X-Ray component of NASA's Great Observatory Program has been an outstanding scientific and technical success. Designed for a three year lifespan, Chandra is now beginning its 8-th year of scientific operation. Some of the history of the Project, including a discussion of the design, development, and calibration of the X-Ray optics will be presented. Of course the highlights of several of the myriad discoveries will be shown concerning topics ranging from solar system objects to dark matter studies in clusters of galaxies.

MSFC-583_Presentation



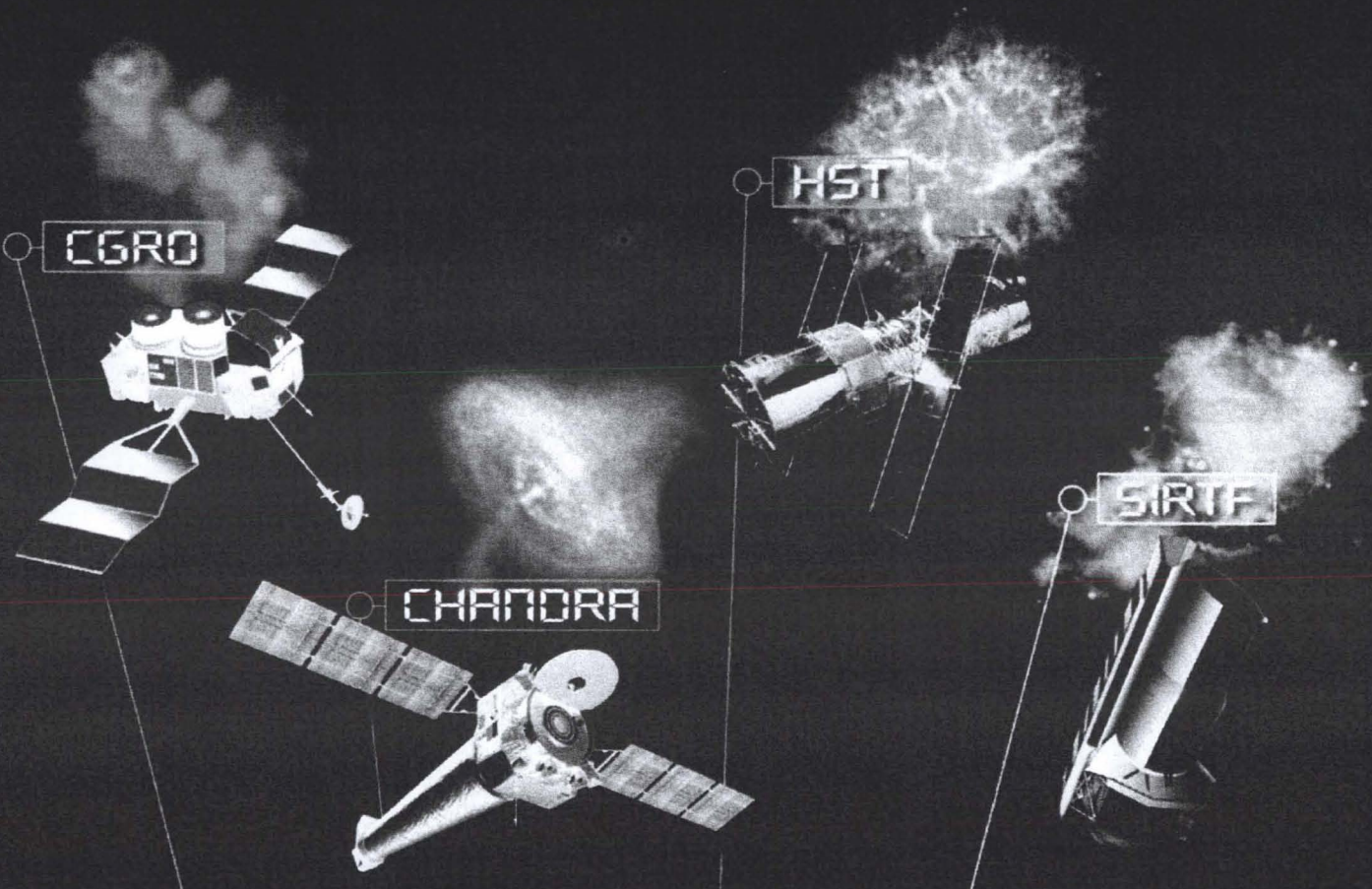
The Chandra X-Ray Observatory

An Overview of its Success

November 14, 2007

Martin C Weisskopf

The Great Observatories

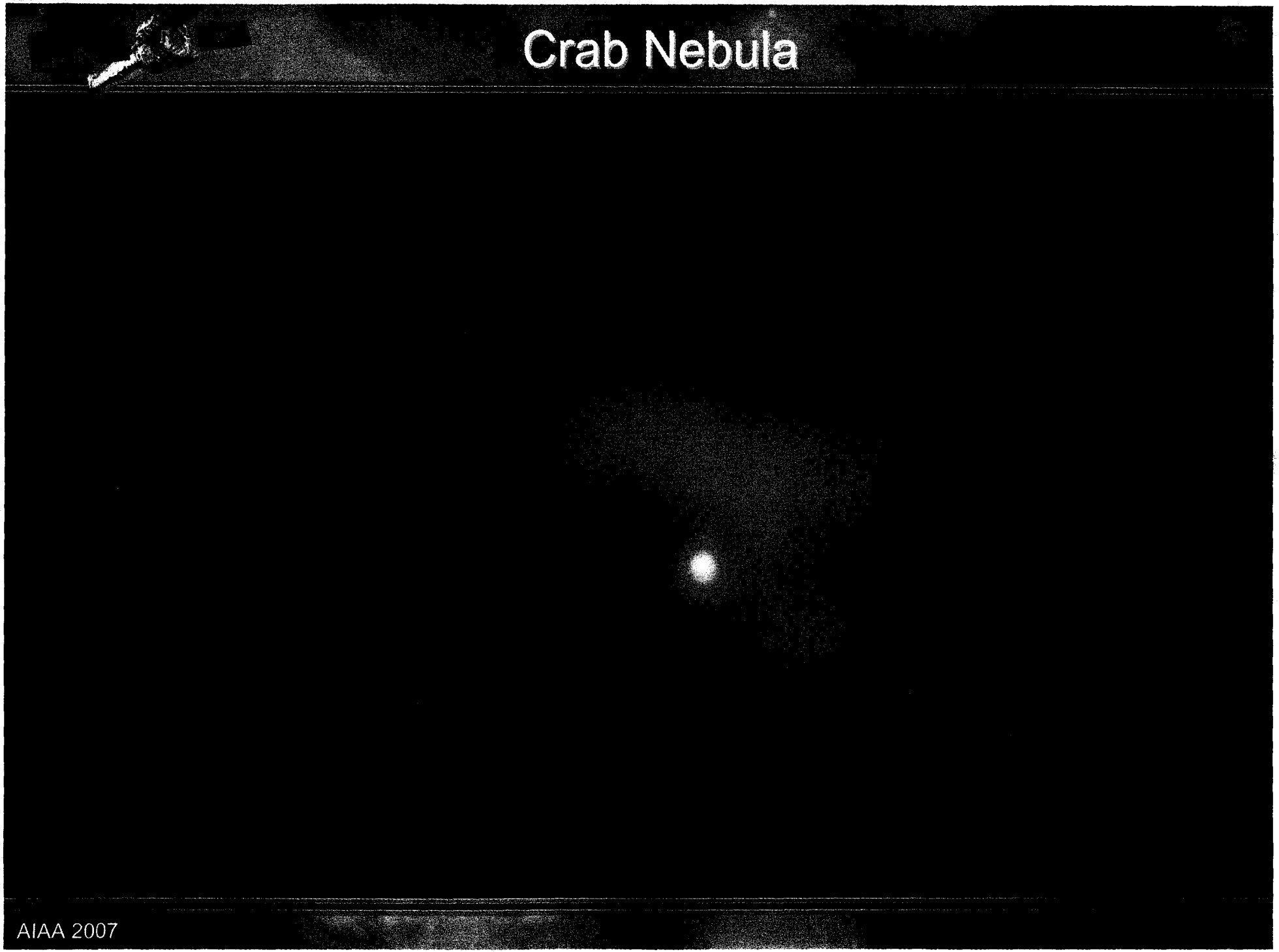


	gamma	x-ray	visible light	infrared	
WAVELENGTH	0.0005	0.5	500	10,000	5,000,000,000 nanometers
ENERGY	2,480,000	2,480	2.48	0.124	0.000000248 electron volts

Chandra History Overview

- 1976: Program start
  - MSFC/SAO Collaboration selected by HASA HQ
- 1985: Instrument selection
- 1988: New Start
- 1999: Launch

Crab Nebula

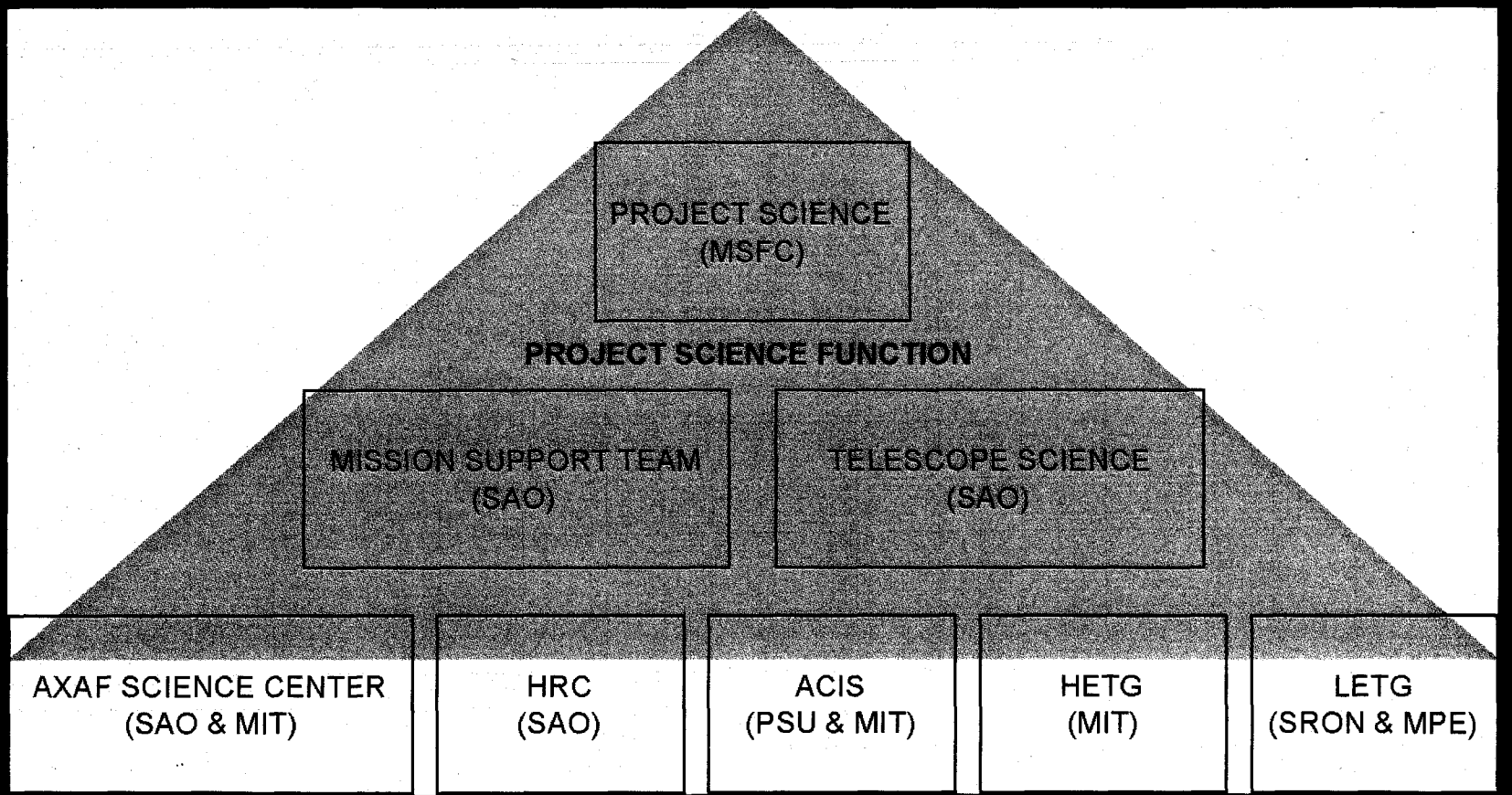


Recipe for Success

- Team effort
- Science-driven requirements
  - Project Science Team
- Stability of requirements
- Technology programs
- Calibration program

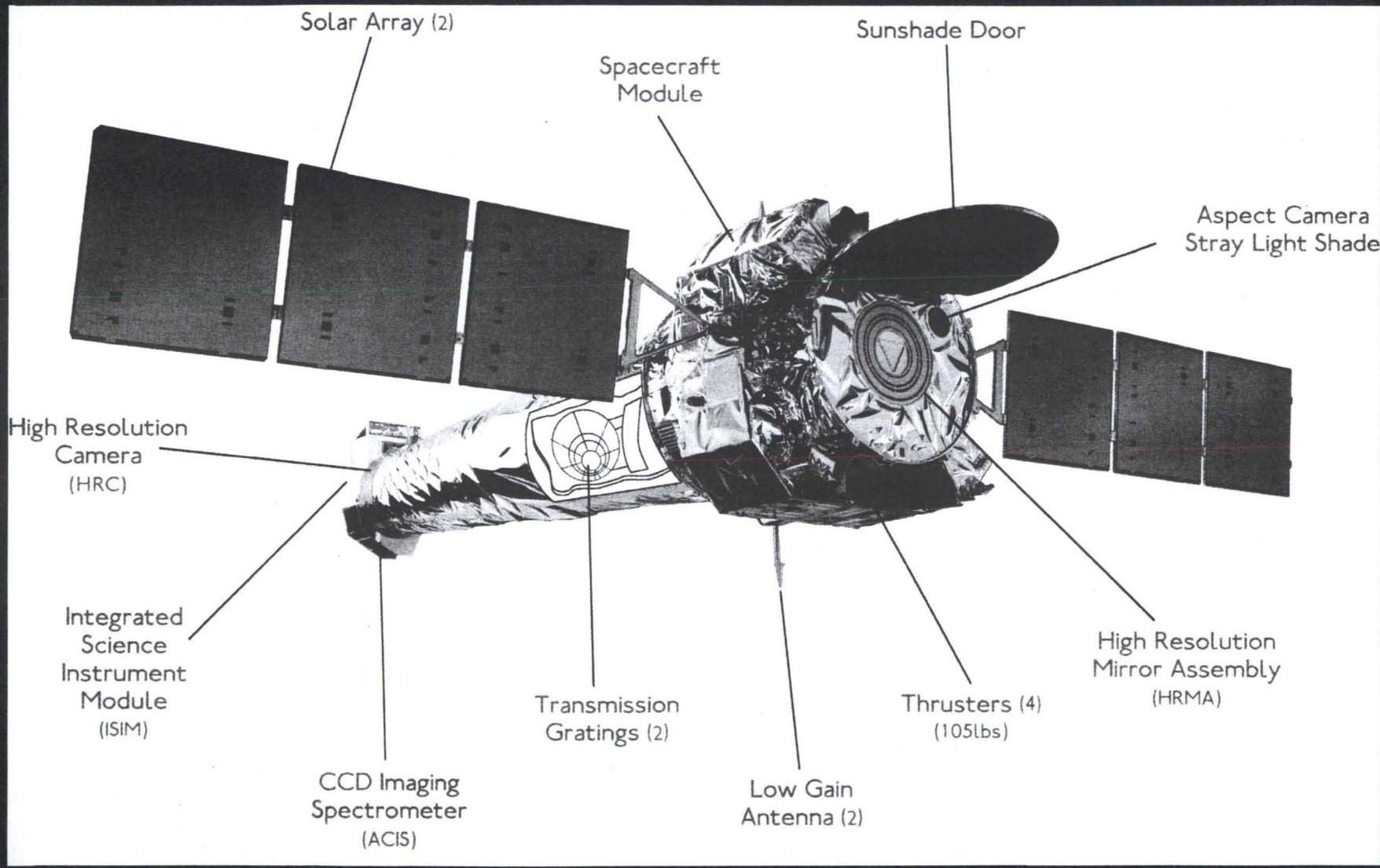
Project Science

- More than a single person



- On all review boards --- to level 3

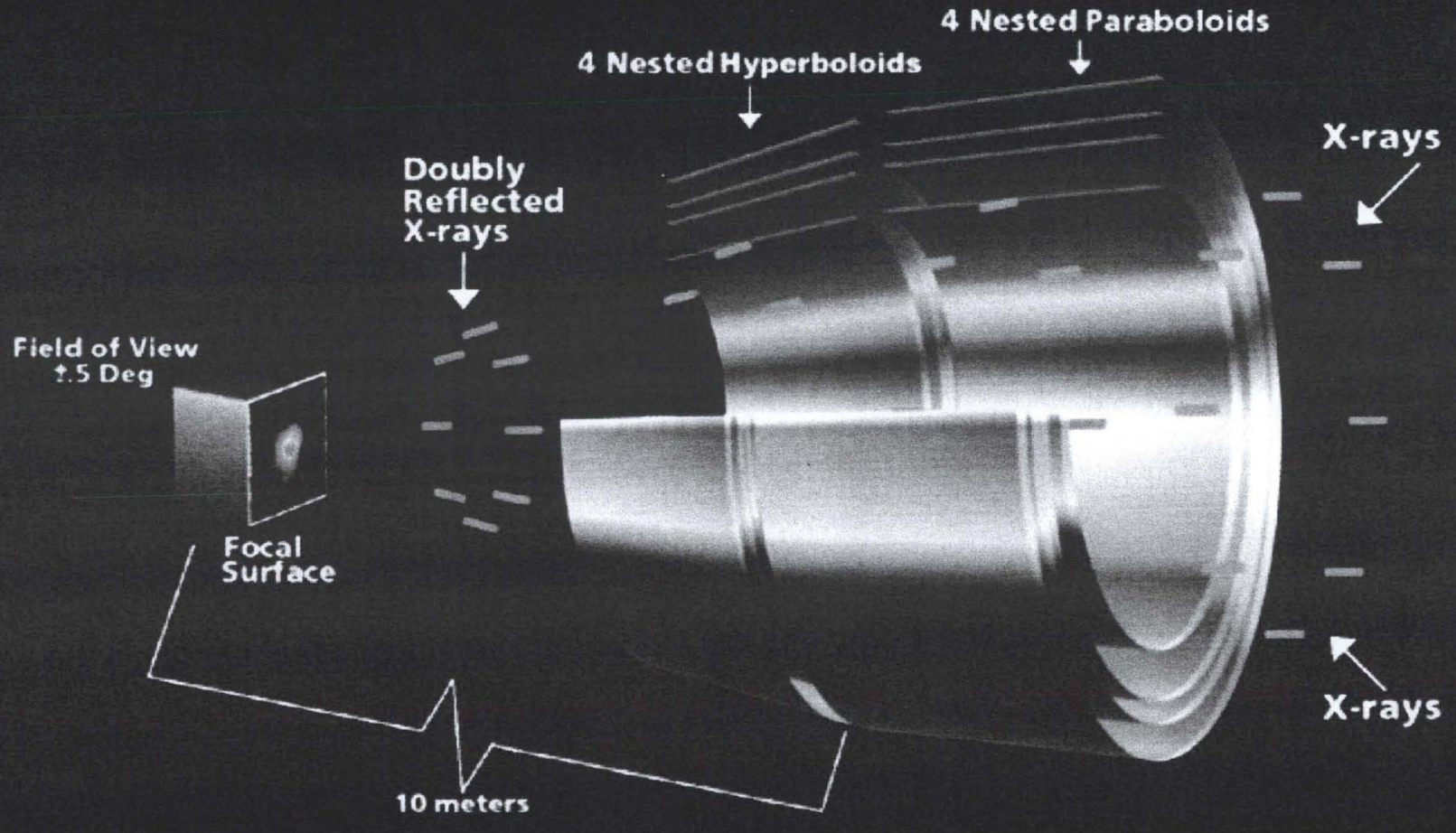
The Observatory



Project Sciencs

- More than a single person
- On all review boards to level 3

Chandra Optics



Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter

The Beginning - 1976

- 1976 – Proposal was submitted
  - This was the "formal" beginning

PROPOSAL TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOR THE

STUDY OF THE 1.2 METER X-RAY TELESCOPE

NATIONAL SPACE OBSERVATORY

(Volume I - Technical Proposal)

P605-4-76

For the period 1 July 1976 to 30 September 1978

Principal Investigator
Dr. Riccardo Giacconi
Associate Director for
High-Energy Astrophysics Division

Co-Principal Investigator
Dr. Harvey Tananbaum

Co-Investigators
Dr. P. Gorenstein
Dr. R. Harnden
Dr. P. Henry
Dr. E. Kellogg
Dr. S. Murray
Dr. H. Schnopper
Dr. L. VanSpeybroeck

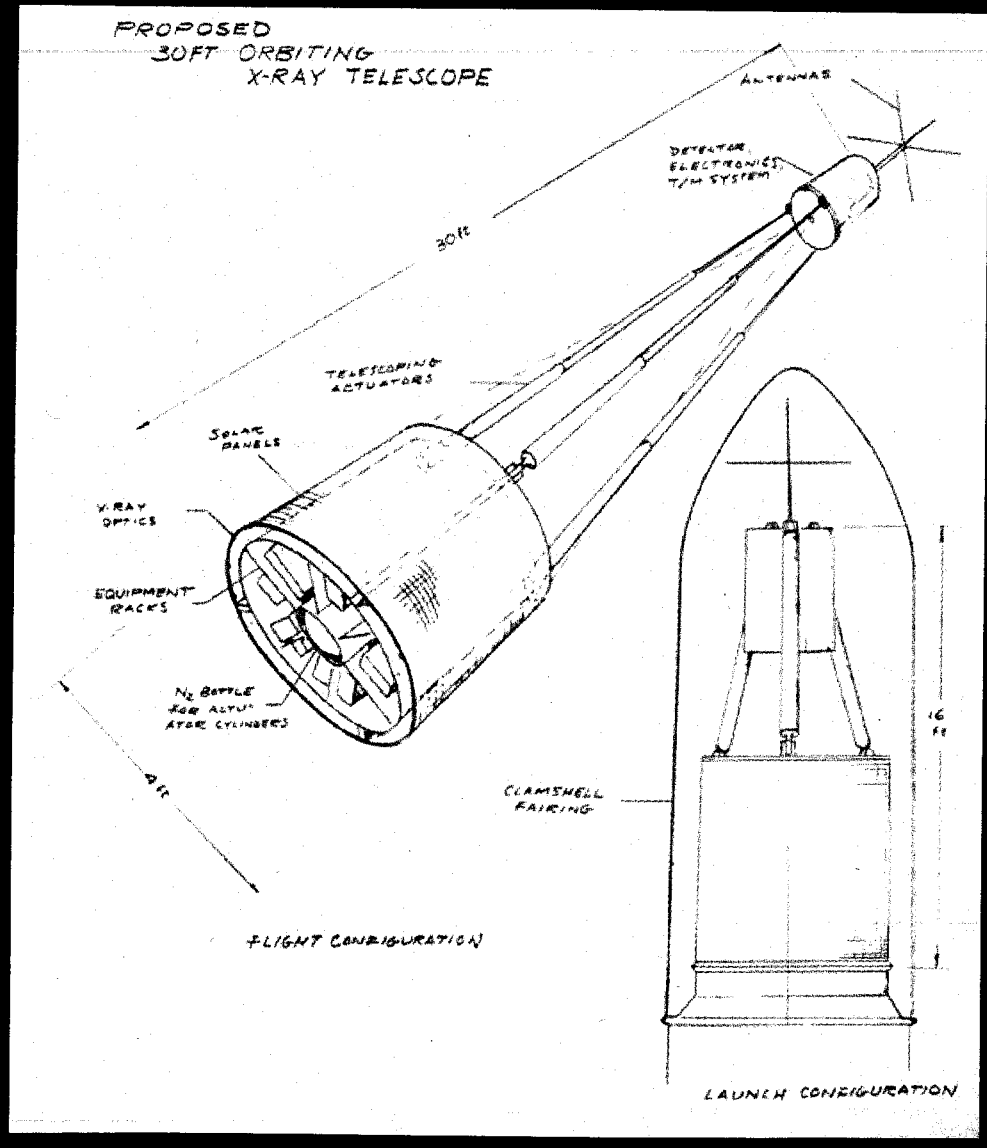
April 1976

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

Director: Dr. George B. Field Assistant Director: Mr. John G. Gregory

The Smithsonian Astrophysical Observatory
and the Harvard College Observatory
are members of the
Center for Astrophysics

The Real Beginning - 1963



A Proposal for

AN EXPERIMENTAL PROGRAM
OF EXTRA-SOLAR X-RAY
ASTRONOMY

Prepared for

National Aeronautics and Space Administration
Washington 25, D. C.

Prepared by

American Science and Engineering, Inc.
11 Carleton Street
Cambridge 42, Massachusetts

25 September 1963

Approved:

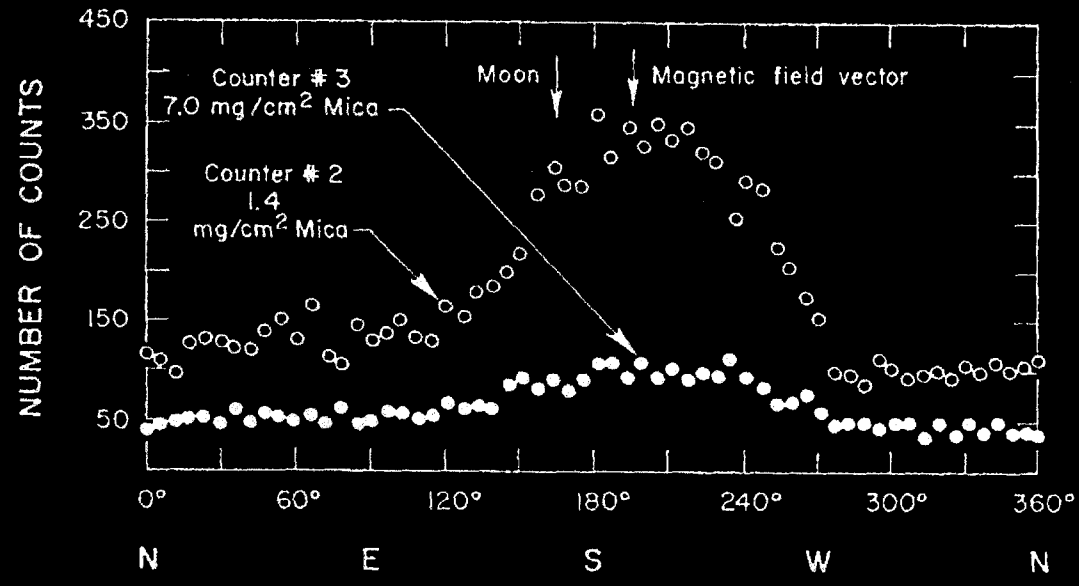
This document consists of 45 pages.
Copy No. 4 of 4 Series A

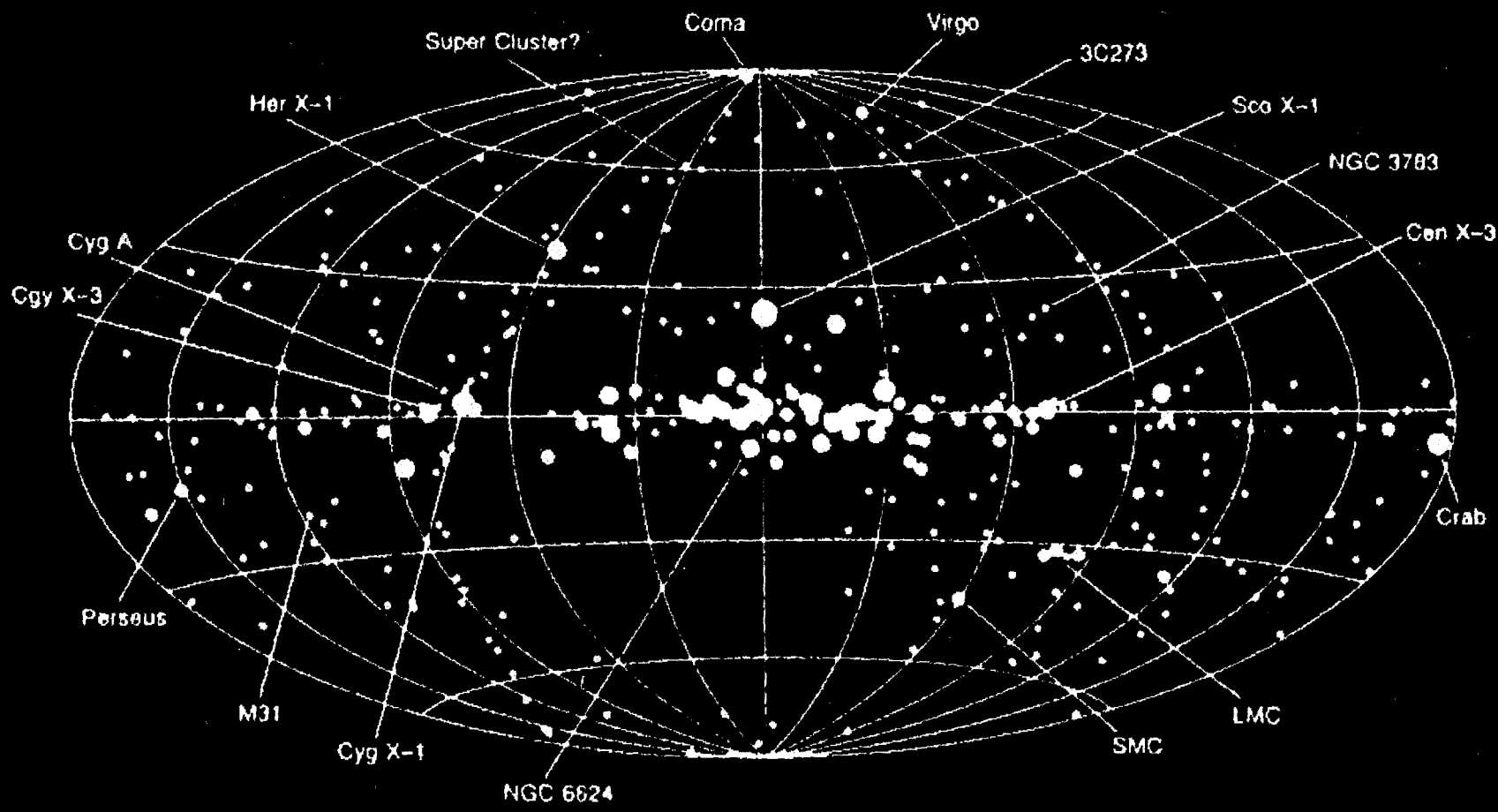
Riccardo Giacconi
Vice President
Space Research and Systems Division

ASE Log No. 63-104-4

X-Ray Astronomy

- Solar Studies in late 40's
  - Solar corona produces X-Rays
- Discovery of first extra-solar source in 1962
  - Also discovery of faint glow - the "diffuse" background

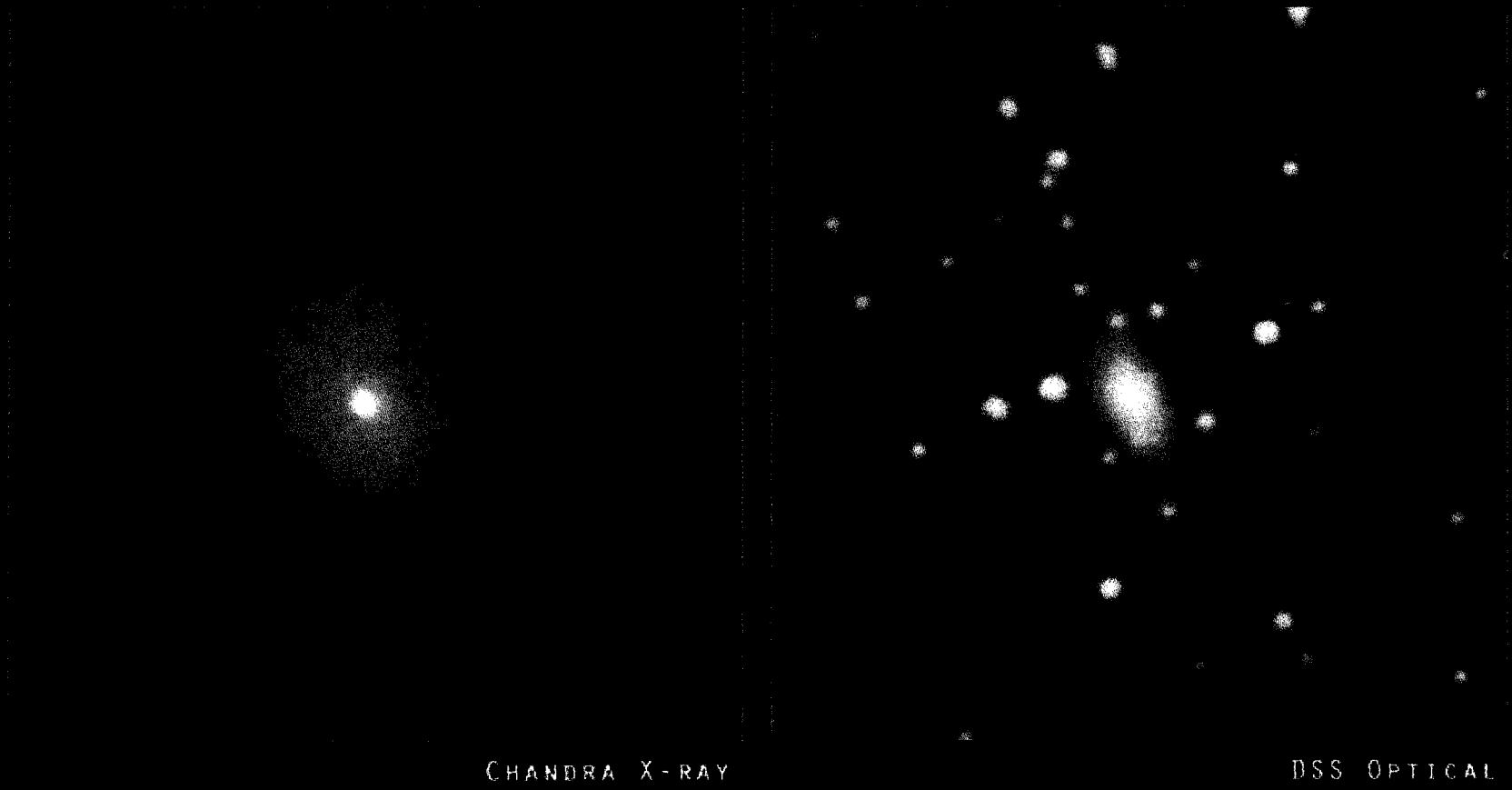




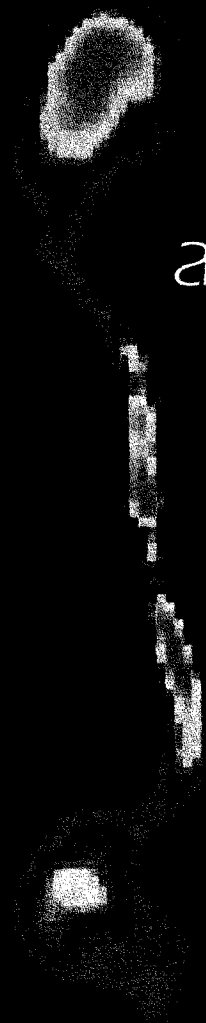
Uhuru (SAS-1) Conducted the First All Sky Survey of Cosmic X-Rays in 1971

X-Ray Astronomy

- We now know that most of the matter that we "see" is visible to us from its X-Ray emission
- The bulk of this matter is hot, X-Ray-emitting, gas in the great galaxy clusters



The Third Decadal Survey - 1981



Astronomy and Astrophysics for the 1980's

VOLUME 1:
Report of the Astronomy Survey Committee

Major New Programs:

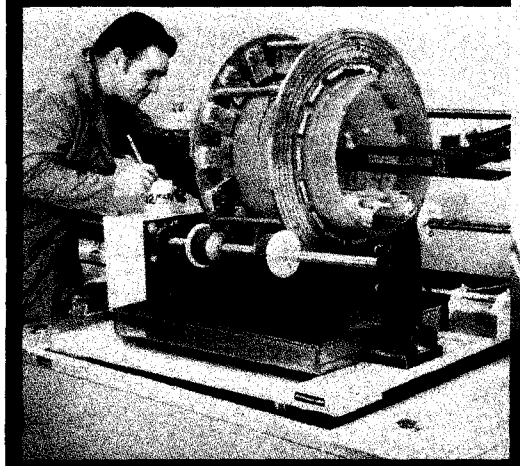
#1: An Advanced X-Ray Astrophysics Facility (AXAF)

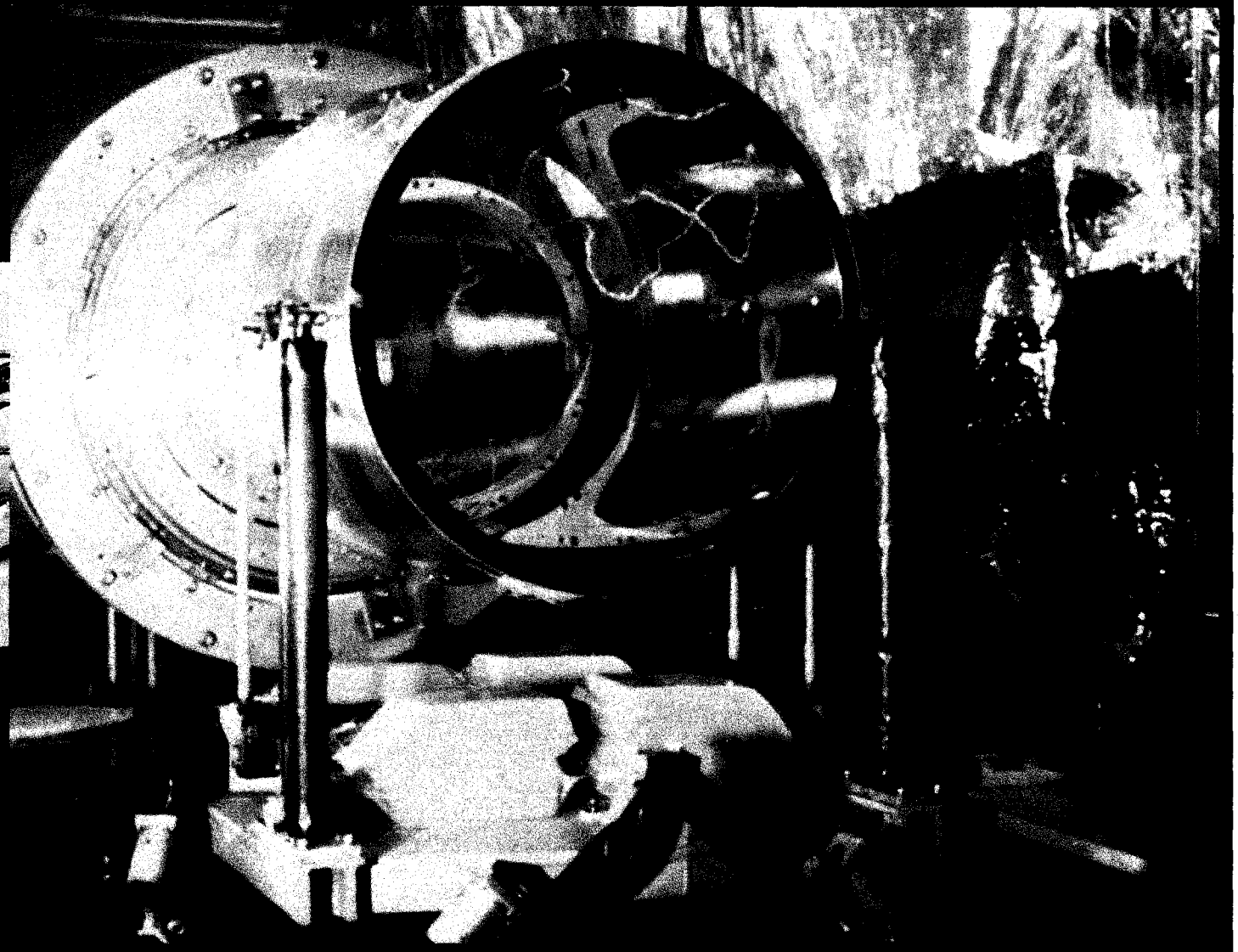
NRC NAS NAE IOM

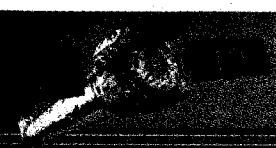
The Technology Mirror Assembly

- Single mirror pair
- Scaled (2/3) Version of innermost mirrors
- 6-m focal length
  - Allowed for testing in existing test facility
- 0.41-m element length
- 0.42-m diameter
- Gold coated (baseline at the time)

The Technology Mirror Assembly





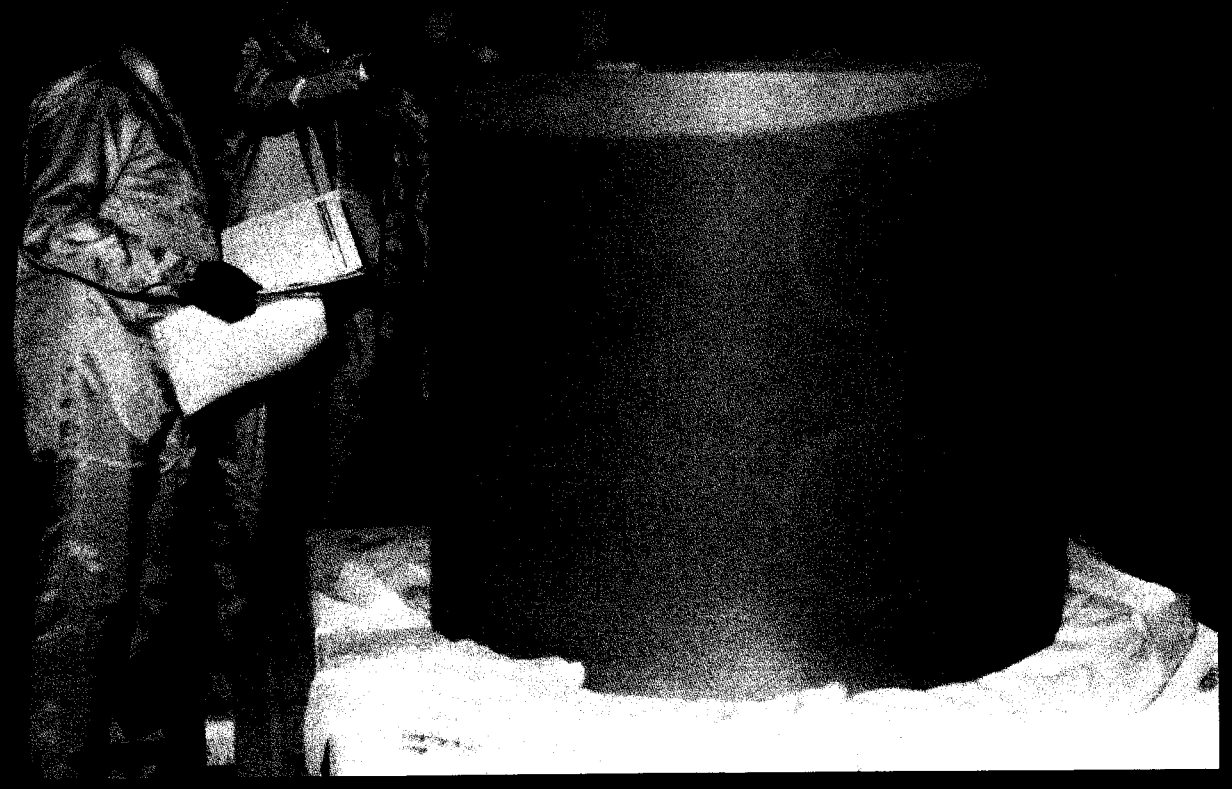


The Technology Mirror Assembly

- First delivery July 1985
  - Resolution better than 0.5”
  - However, near angle scattering
- Second delivery Jan 1989
- Final results were great
  - E.g. FWHM from 0.36” – 0.68”
  - Encircled energy as predicted

Flight Mirror Blanks

- Initiated purchase in 1987

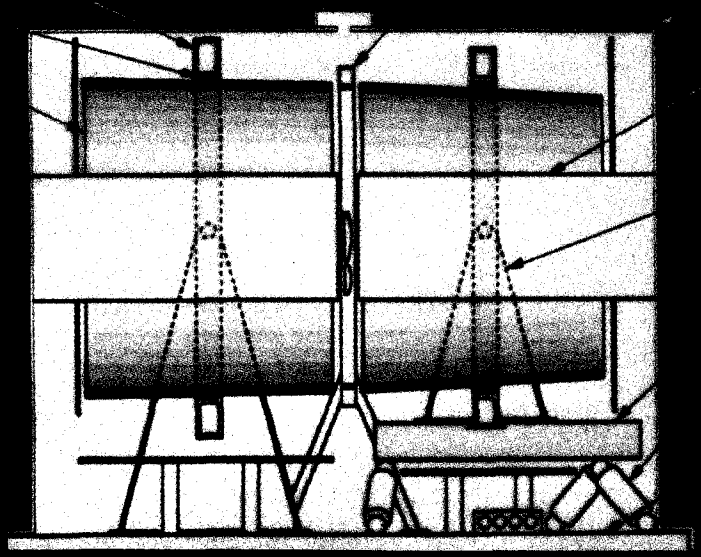


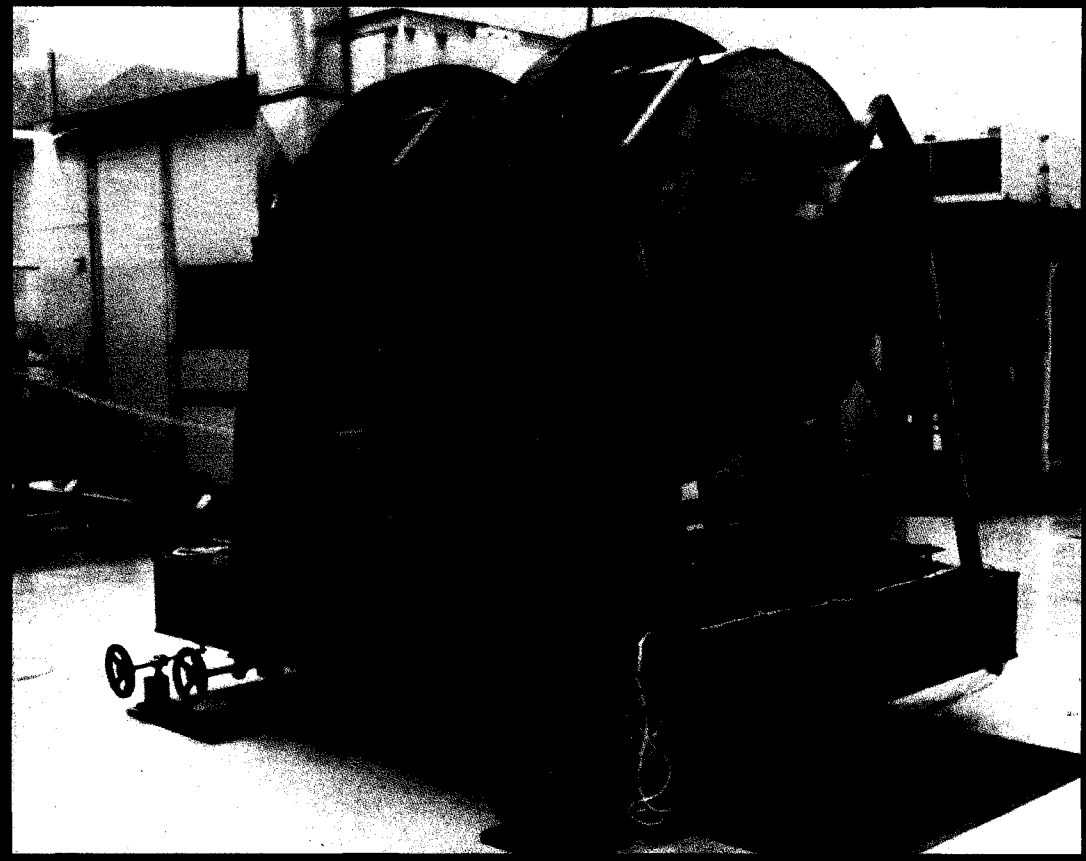
Other Milestones

- Prime contractor selection – 1988
- "New Start" - 1988
- Selection of the Science Center – 1991
- Started the "VETA" program - 1988
  - Verification Engineering Test Article

VETA

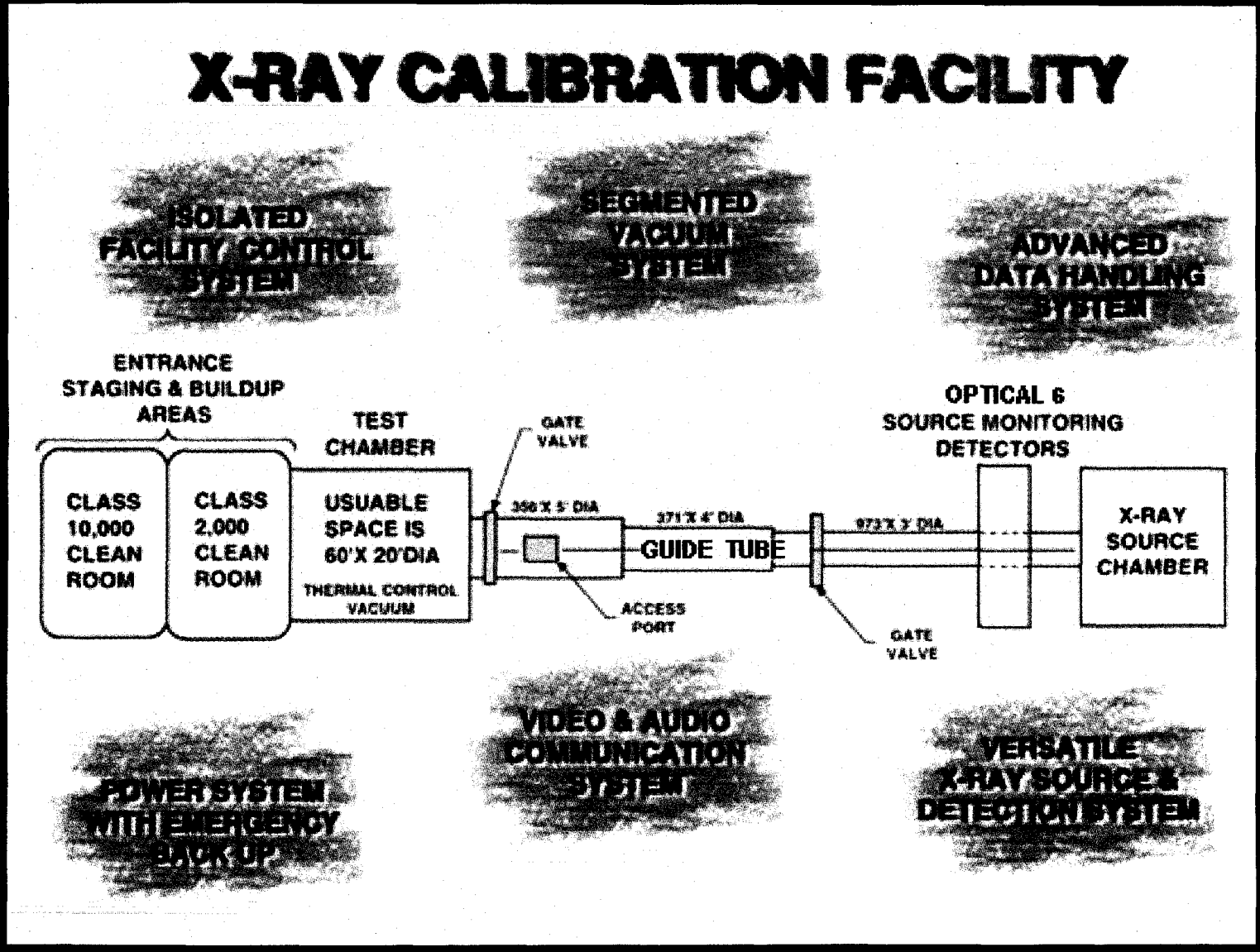
- P1/H1 – uncoated and uncut





- Needed test facility at least one year earlier than planned!

The X-Ray Calibration Facility (XRCF)



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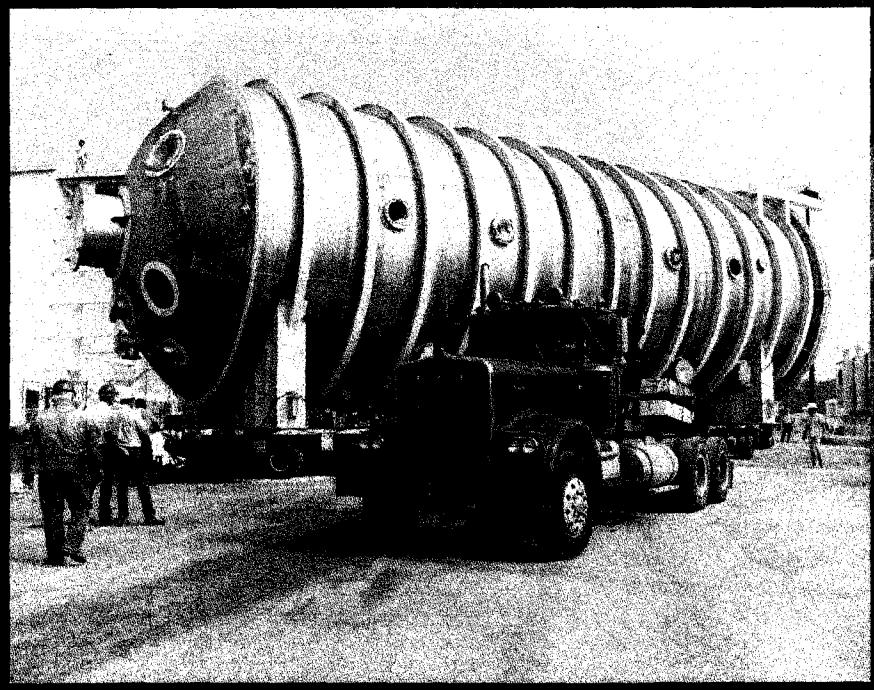
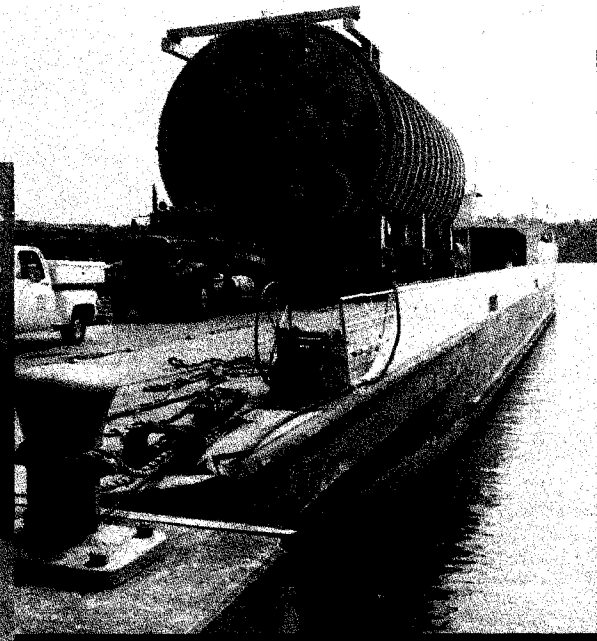
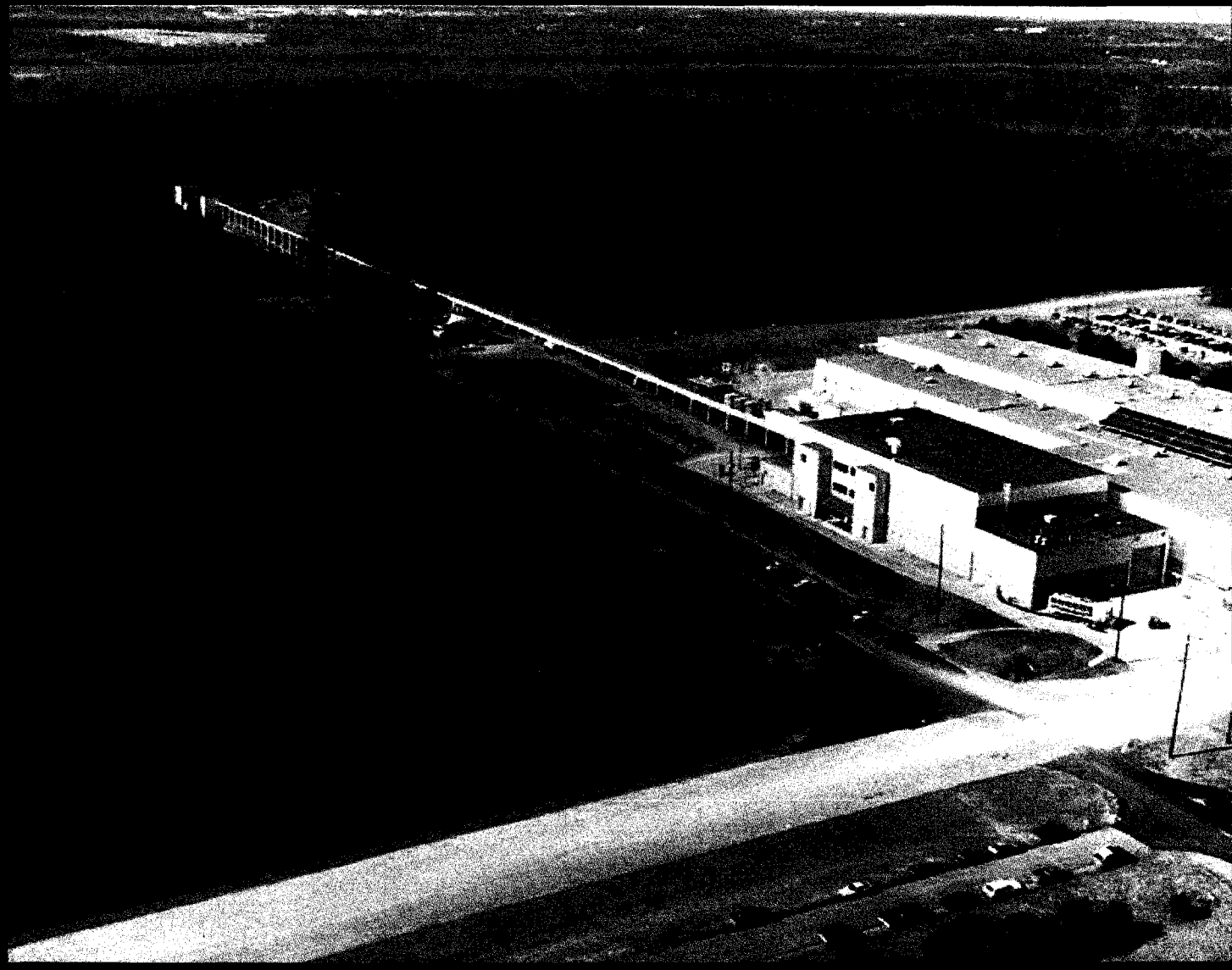
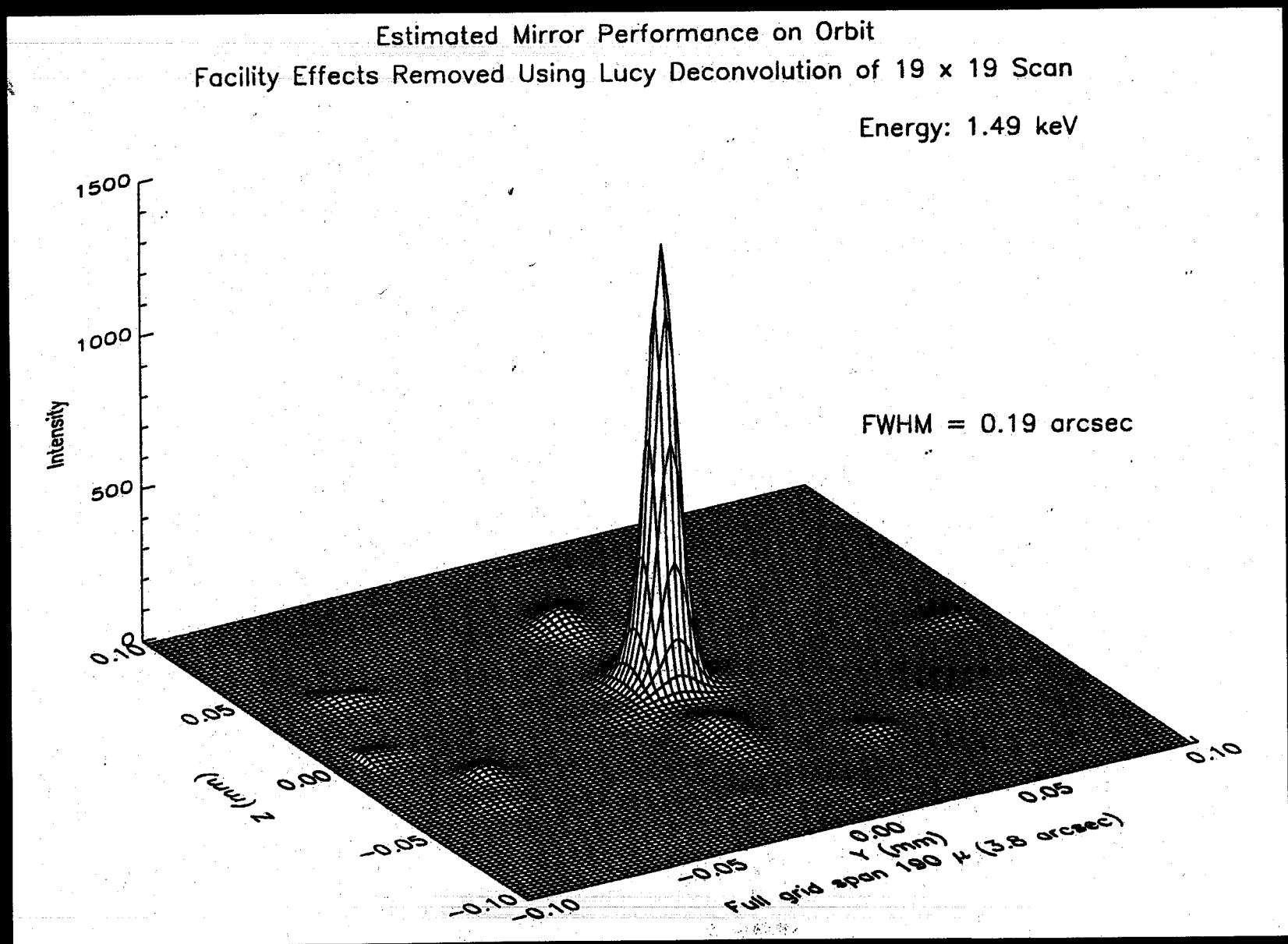




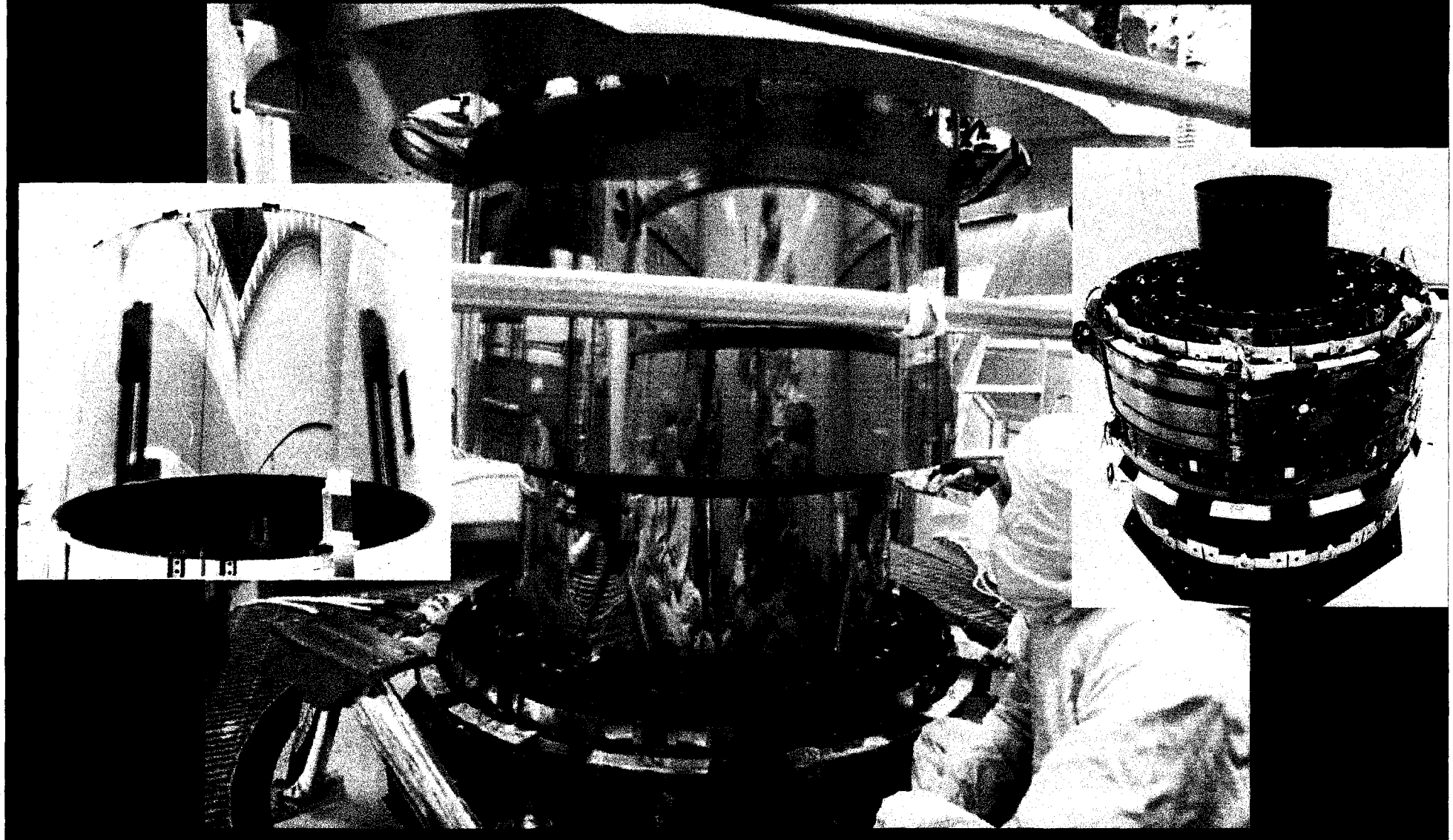
The X-Ray Calibration Facility (XRCF)



The Veta Tests - 1991



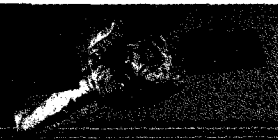
Telescope



Calibration Program

- 6 months at the X-Ray Test Facility

X-ray Calibration (1996-1997)

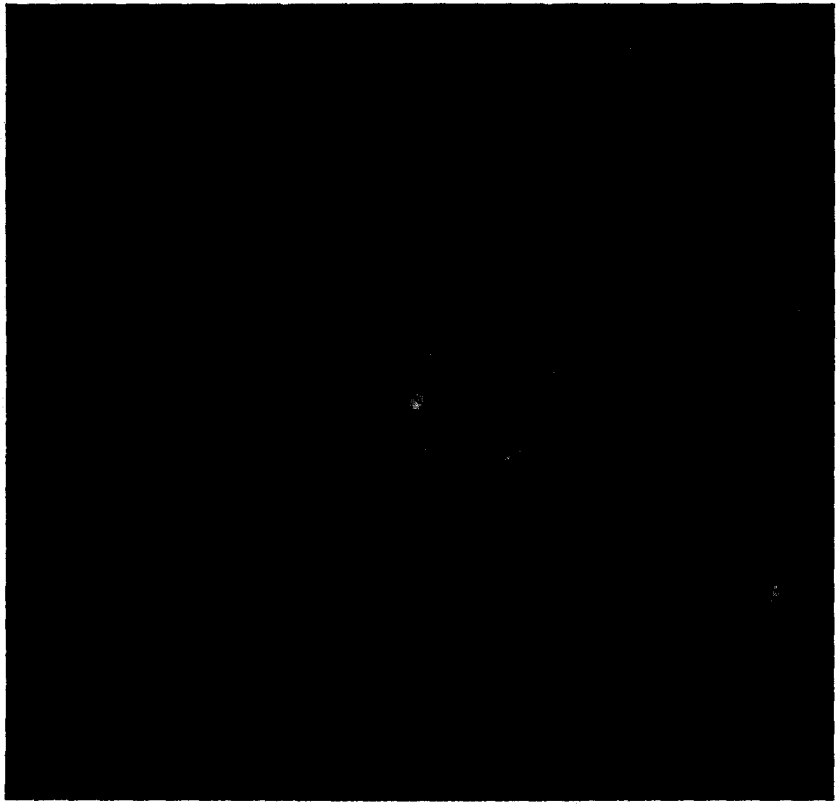


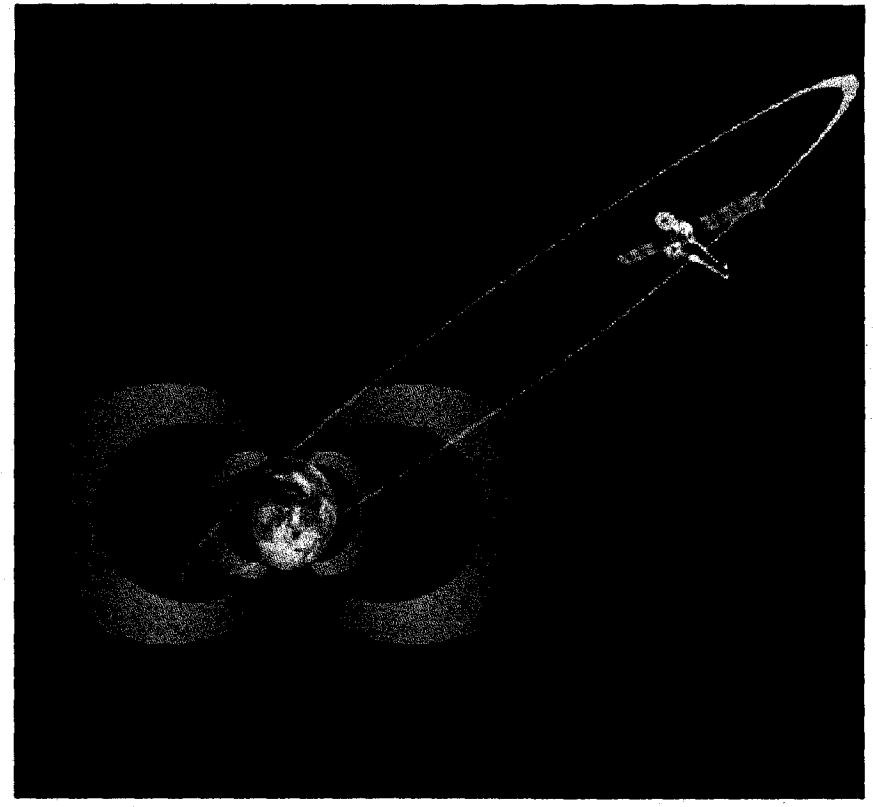
Three Launch Attempts

- Mon/Tue July 19/20
  - Sensor spike hydrogen in the engine compartment
- Wed/Thurs July 21/22
  - Lightning in the vicinity
- Thurs/Fri July 22/23
  - Third time is a charm

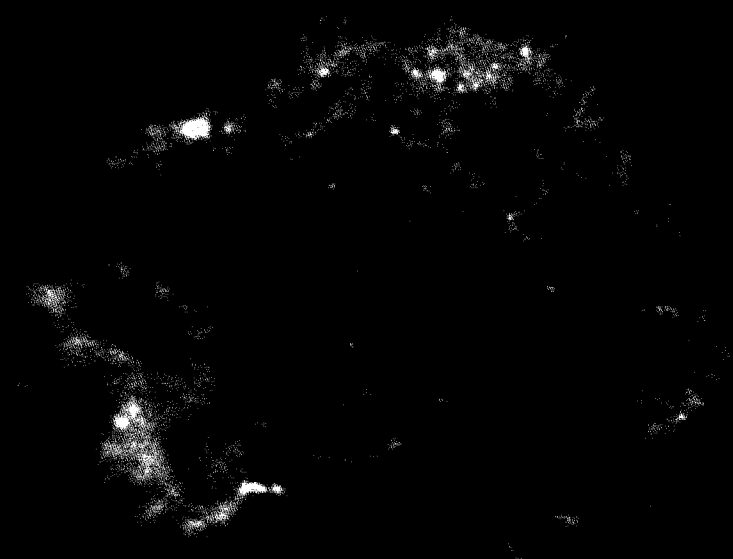
Launch at last! July 23 1999 @ 12:31 a.m.

The Orbit





First Light – Cas A



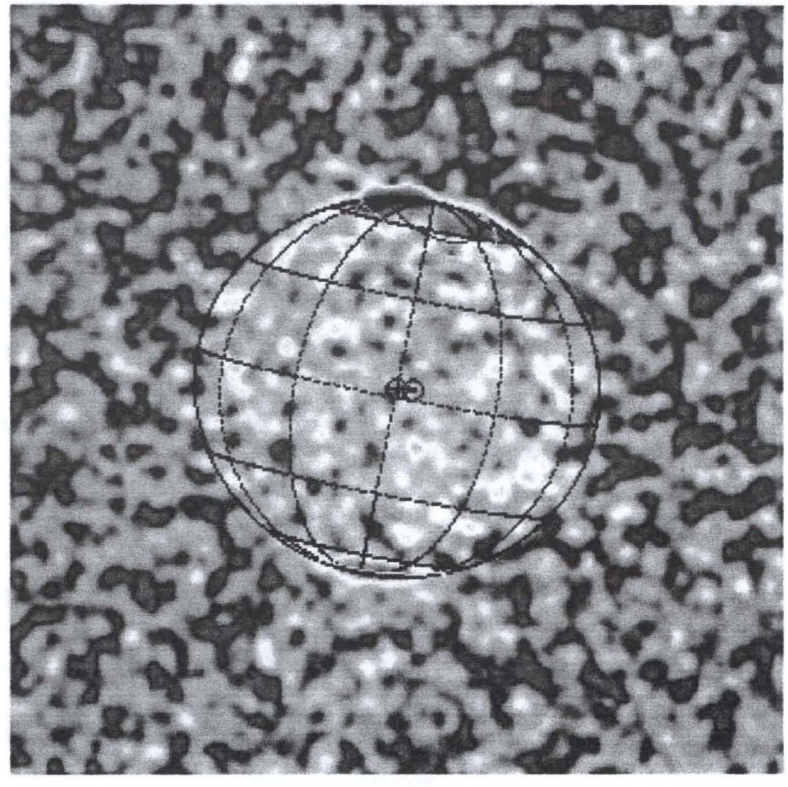
The Moon

Optical: Robert Gendler; X-ray: NASA/CXC/SAO/J.Drake et al.

Planets

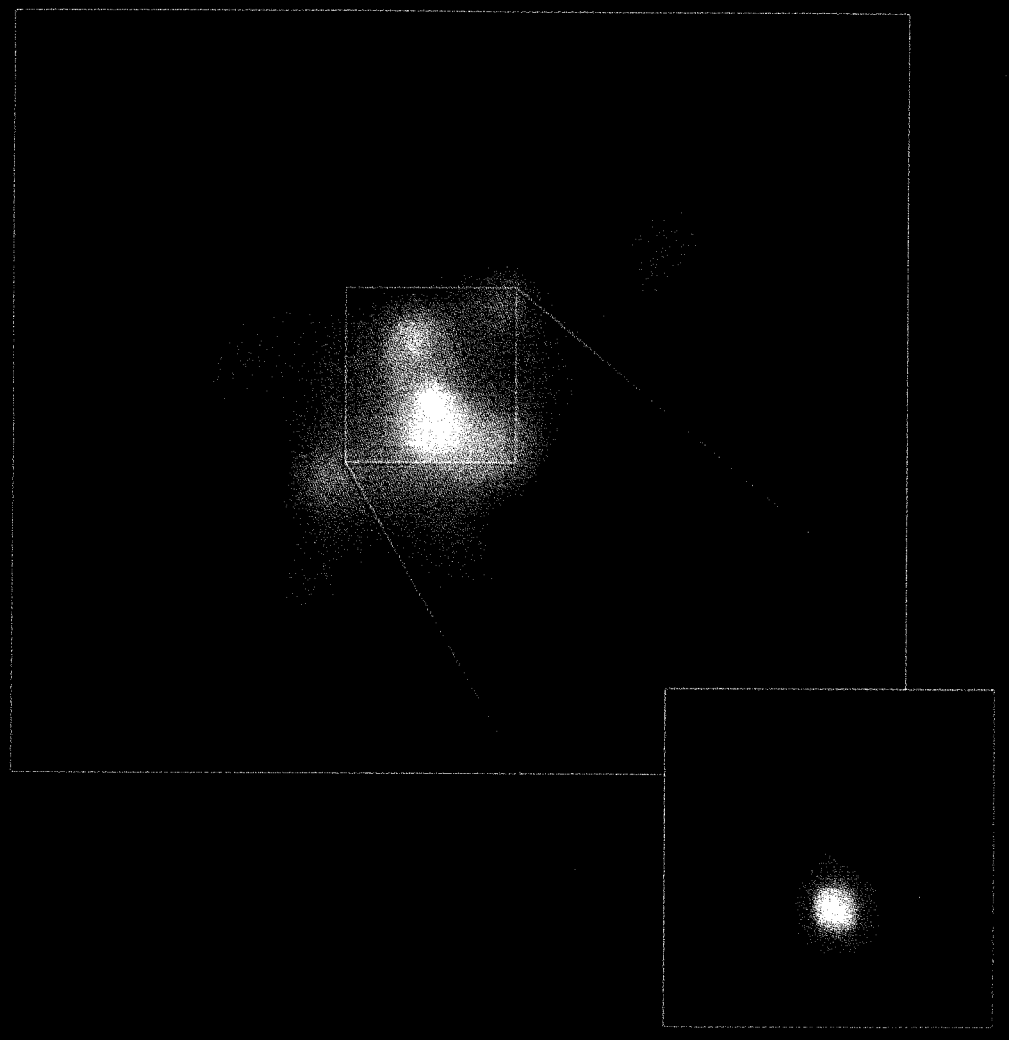
All planets, other than Uranus, are X-ray sources!

- Jupiter
  - Hot spots at high latitudes
    - *Big surprise*
  - Pulsates (45 minute period)



Gladstone et al.(2002) Elsner et al. (2002)

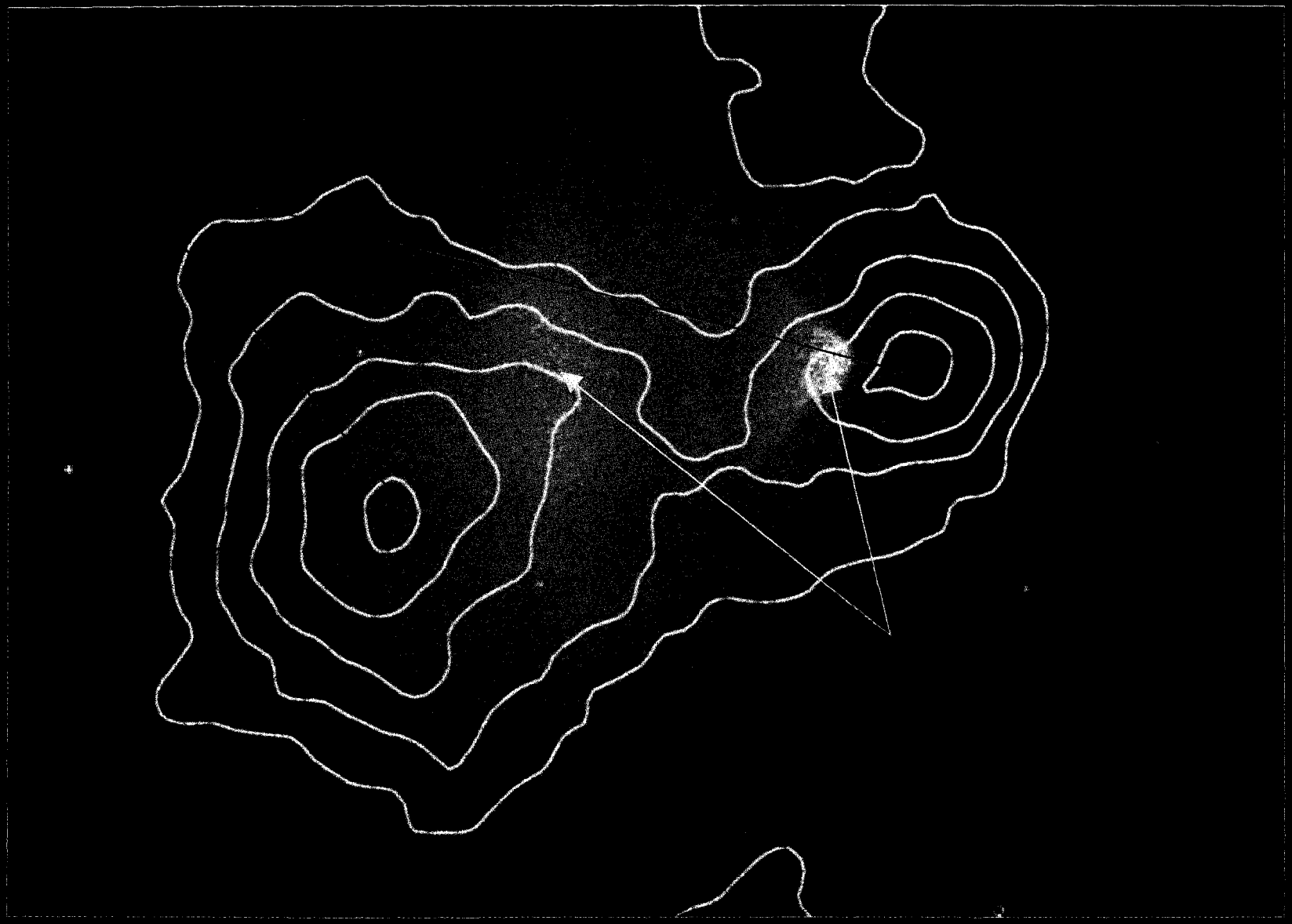
Double Quasar



AIAA 2007

NASA/CXC/MPE/S.Komossa et al

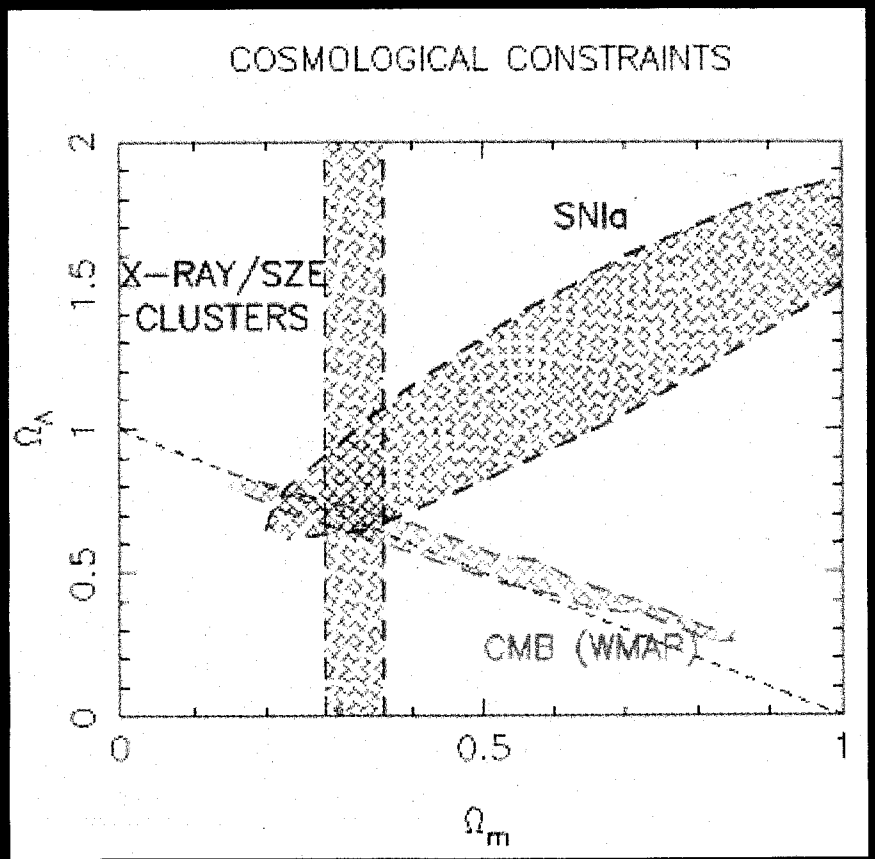
Dark Matter

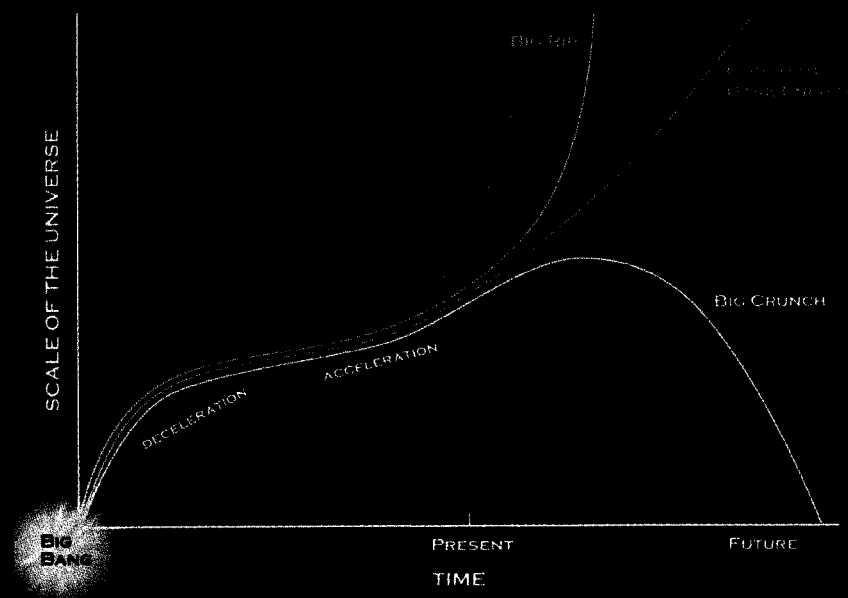


AIAA 2007

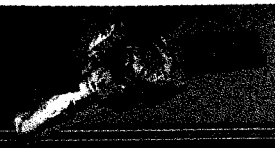
1E0657-56 Chandra image with lensing contours

Dark Matter & Dark Energy





The Nobel Prize - 2002



Summary

- Operations are running smoothly
- Mission success
  - Design of the Observatory
  - Excellent and committed staff
  - Team effort
- Exciting and fundamental scientific results
  - Papers at a rate of ~10 per week
- Visit our web site @ www.chandra.harvard.edu

Chandra Lifetime

- Fuel: >40 years
- Orbit: 30-50 years
- Funding: NASA committed to (at least) a 13 year mission