The Making of the *Chandra* X-ray Observatory:

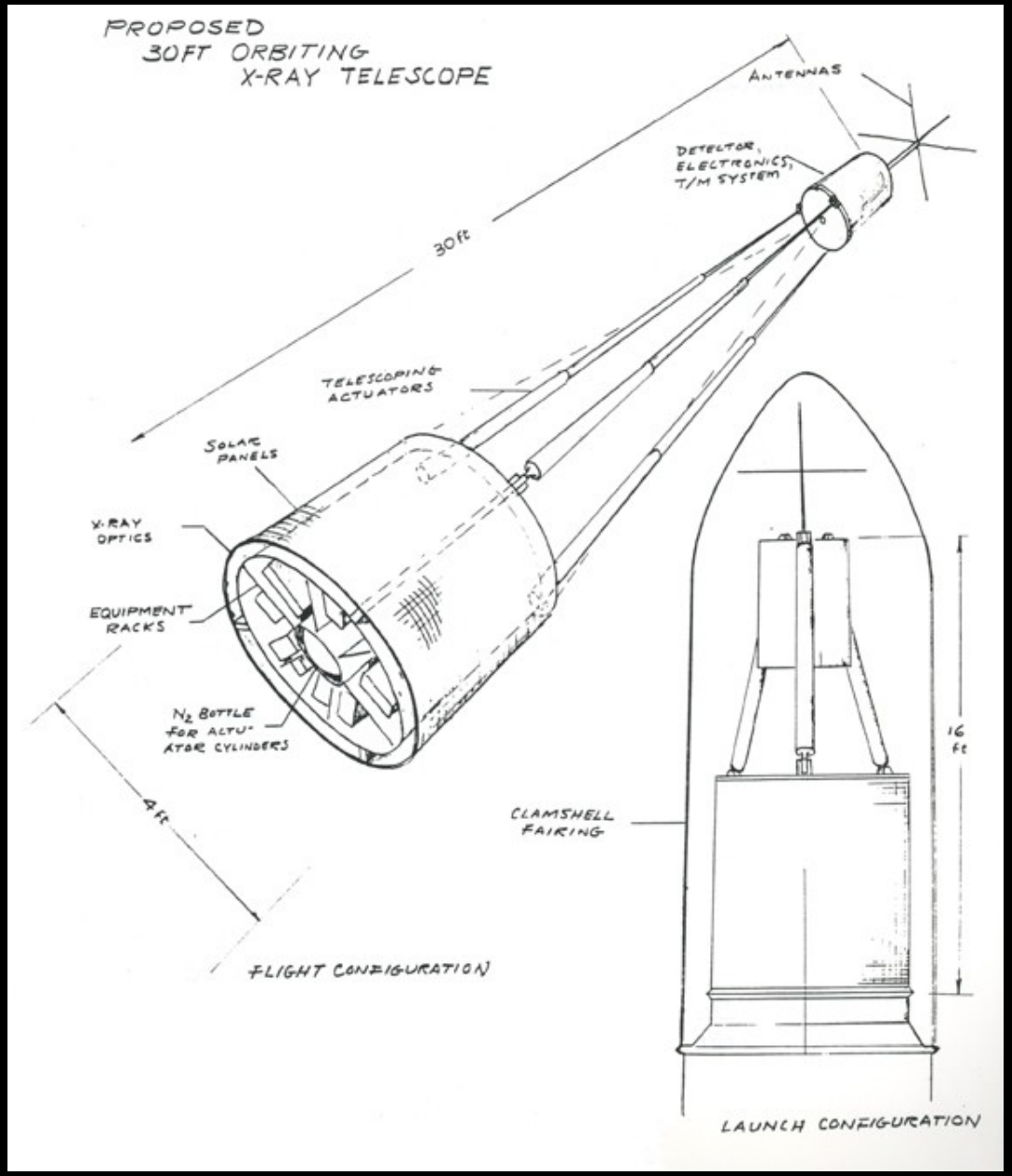
The Project Scientist's Perspective

September 22, 2009

Martin C. Weisskopf

The Beginning

1963



My Introduction to X-Ray Astronomy

"SEX" & the "PIG"

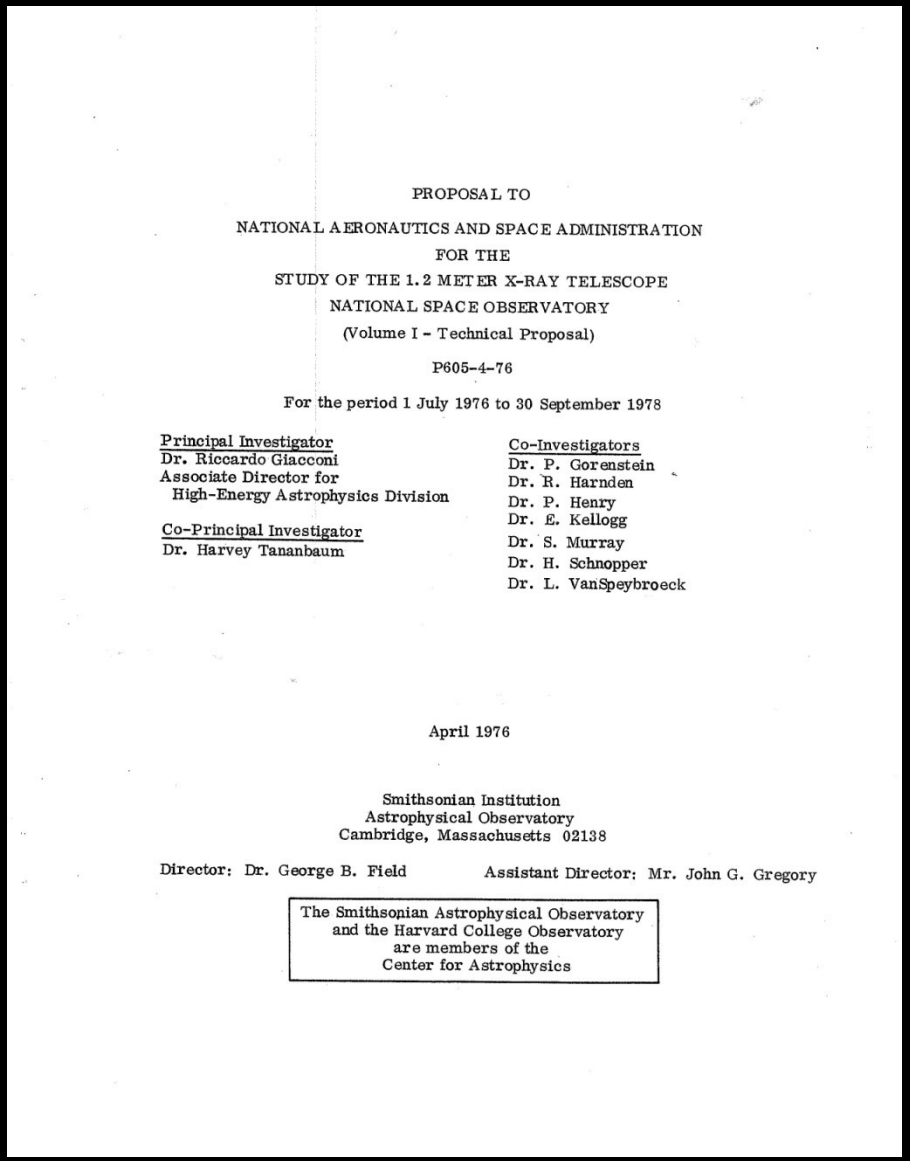
SEX = ***S***uper ***EX***plorer

PIG = ***P***rincipal ***I***nvestigator ***G***roup

1969

The Proposal

For the Study of the 1.2 Meter X-Ray Telescope National Observatory



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

1976

The Competitors

- MSFC and SAO
- JPL and Cal Tech
- GSFC

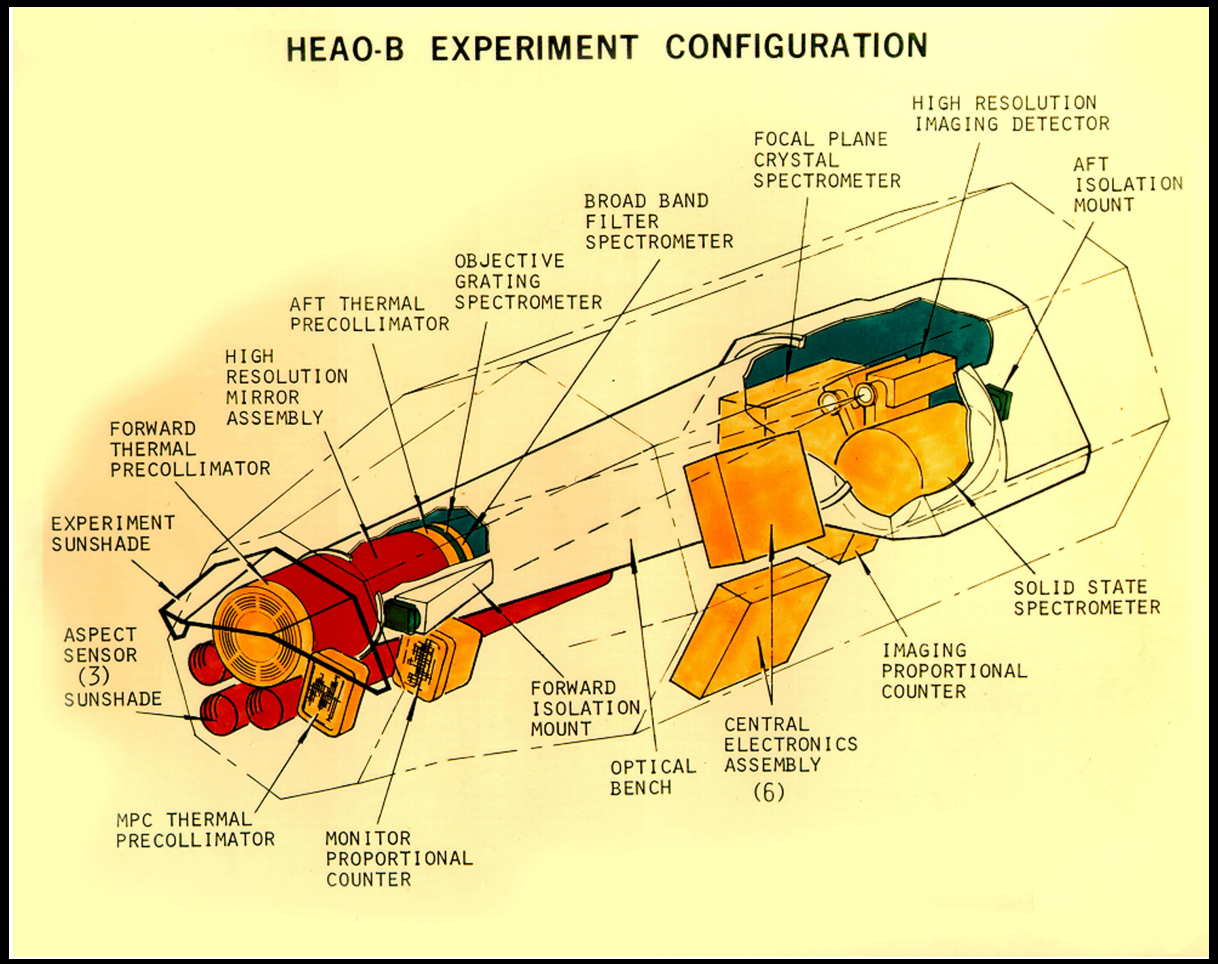
1976/77

First SWG

- R. Giacconi – Chairman
- M. Weisskopf – Vice Chairman
- A. Opp (NASA HQ) – Ex Officio
  - E. Boldt (GSFC)
  - G. Clark (MIT)
  - G. Garmire (CIT)
  - R. Novick (Columbia)
  - H. Tananbaum (SAO)
  - K. Pounds (Leicester)
  - S. Bowyer (UCB)
  - A. Davidsen (JHU)
  - B. Krasheur (Wisc)
  - S. Shulman (NRL)
  - A. Walker (Stanford)
  - J. Truemper (MPE)

1978

Einstein Observatory

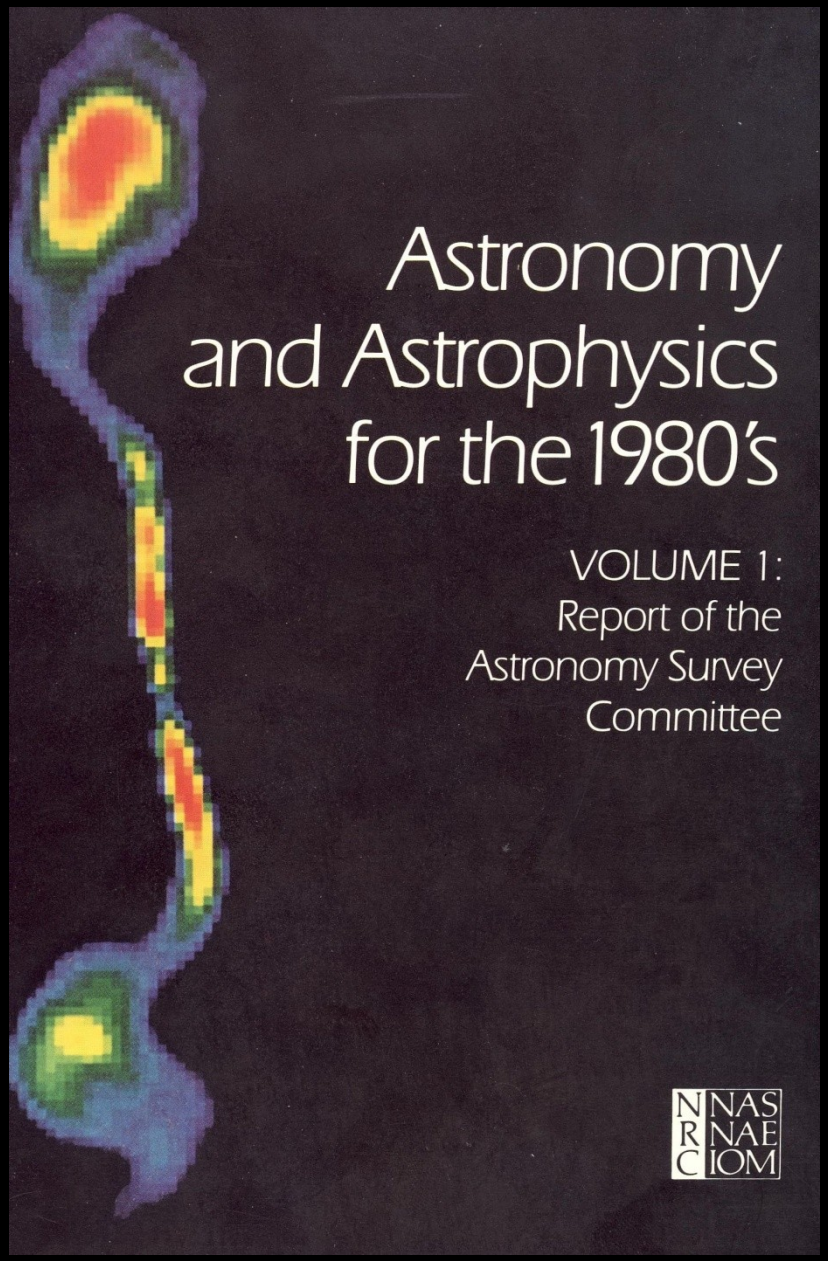


1979

The Decadal Survey

Major New Programs:

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



1981

Instruments

- ACIS
- HRC
- LETG
- HETG
- FPCS – Focal Plane Crystal Spectrometer
  - Removed in 1988
- XRS – X-Ray (Calorimeter) Spectrometer
  - AXAF-S - 1991
  - Removed in 1993

The Second SWG

1985

The Second SWG

Andrew Wilson

Andy Fabian

Jeff Linsky

Harvey Tananbaum

Alan Bunner

Steve Holt

Martin Weisskopf

Riccardo Giacconi

Bert Brinkman

Steve Murray

Gordon Garmire

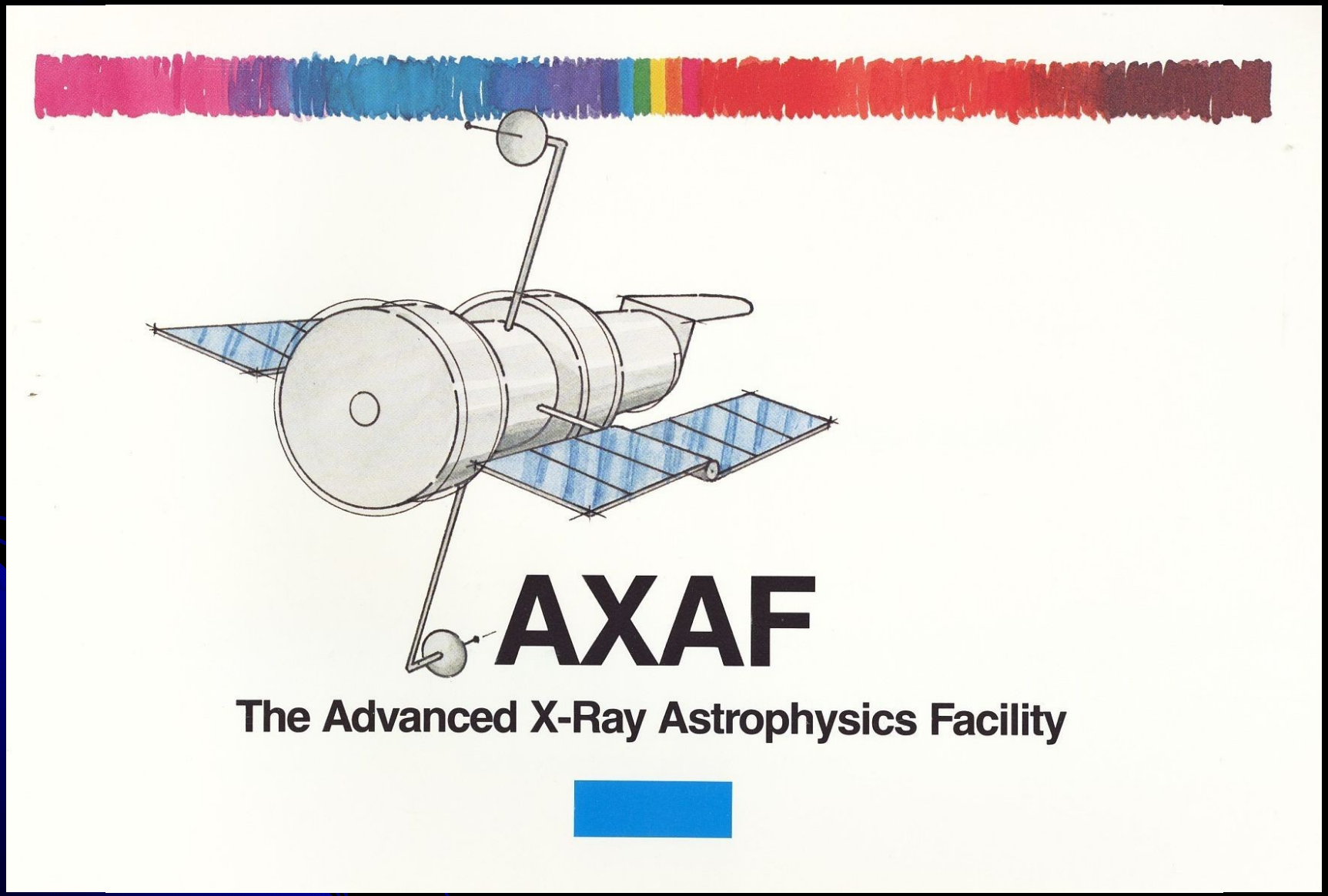
Leon van Speybroeck

Claude Canizares

Richard Mushotzky

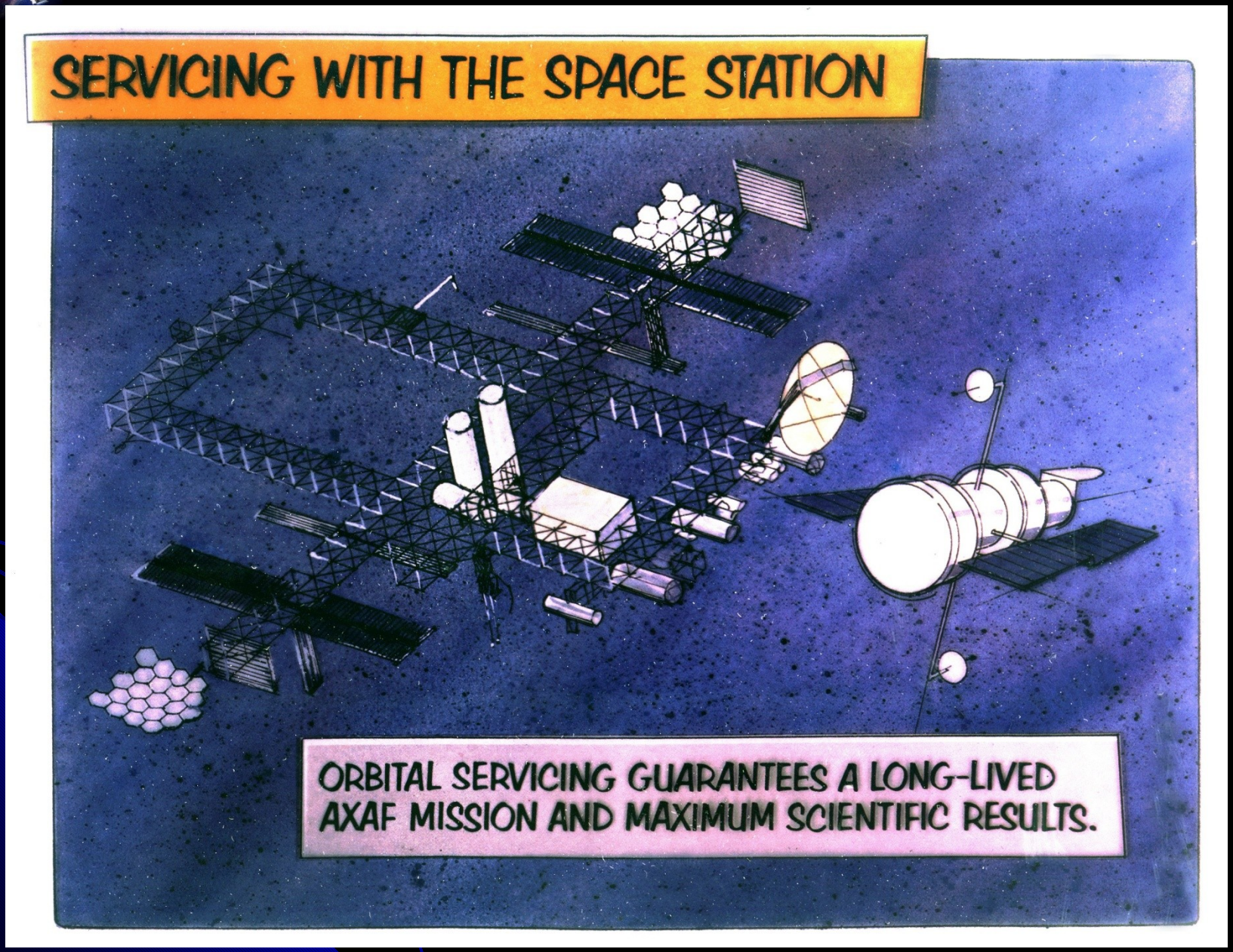
1985

Brochures

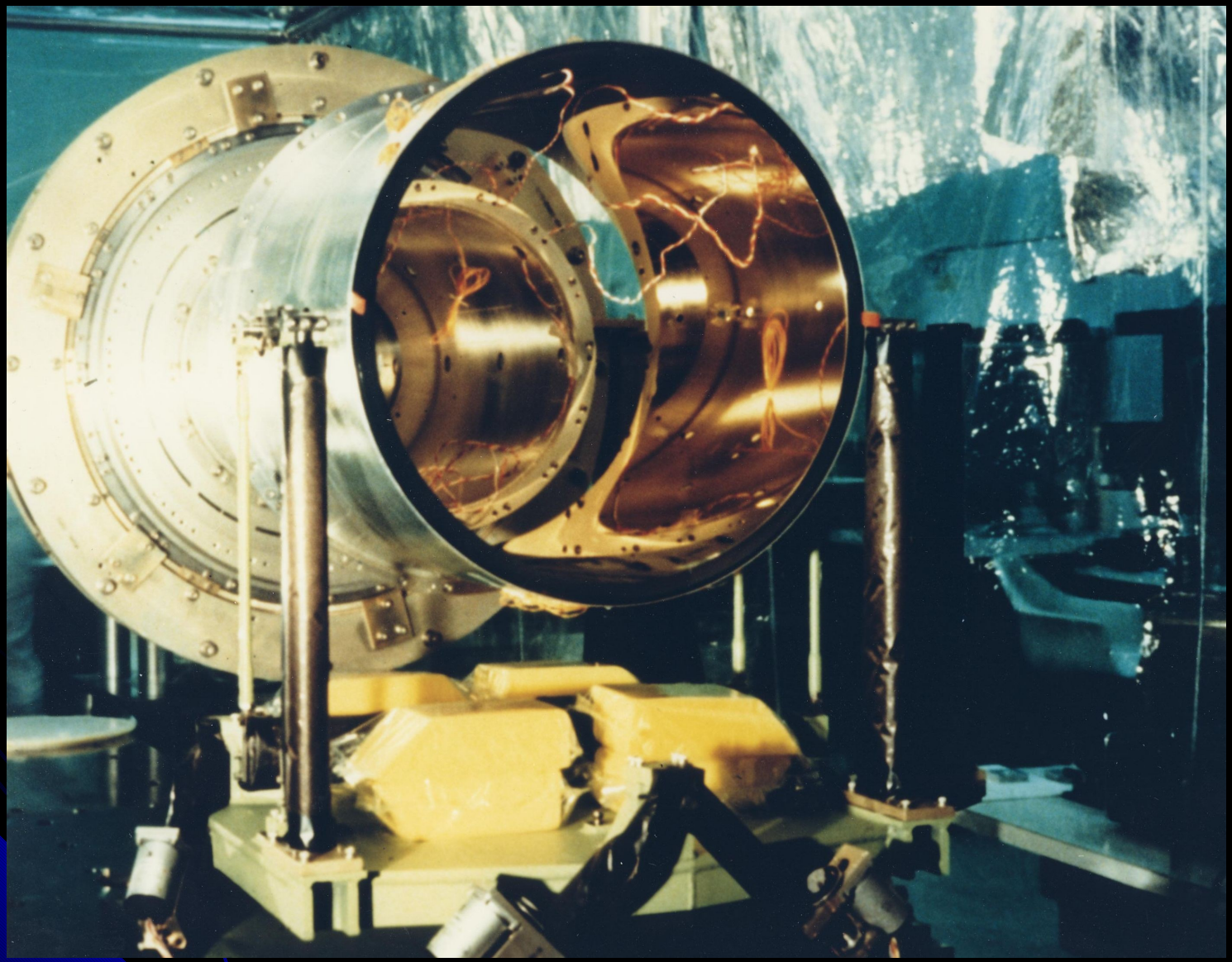


1986

Space Station Appears



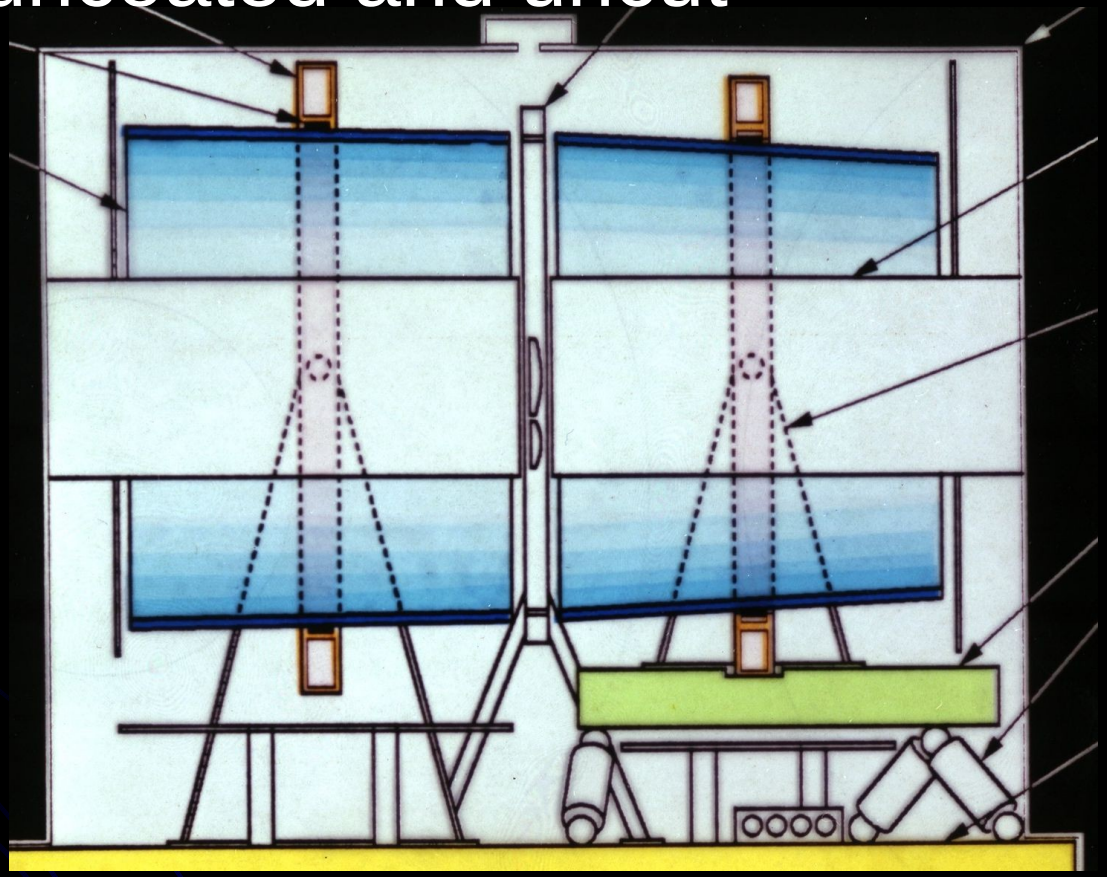
Technology Mirror Assembly



1985-1989

The Next Hurdle

P1/H1 – uncoated and uncut



Needed Test Facility at least one year earlier than scheduled

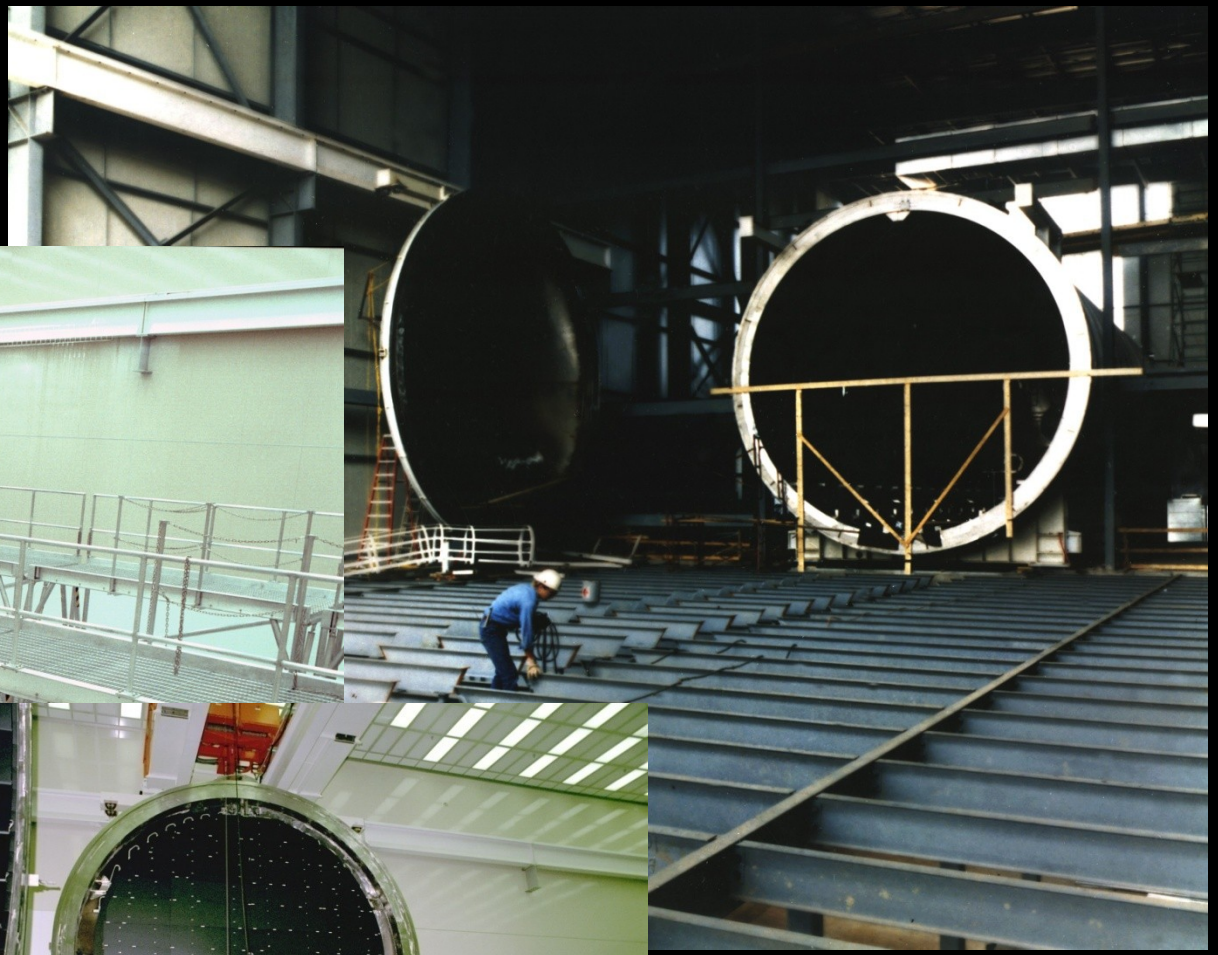
1990

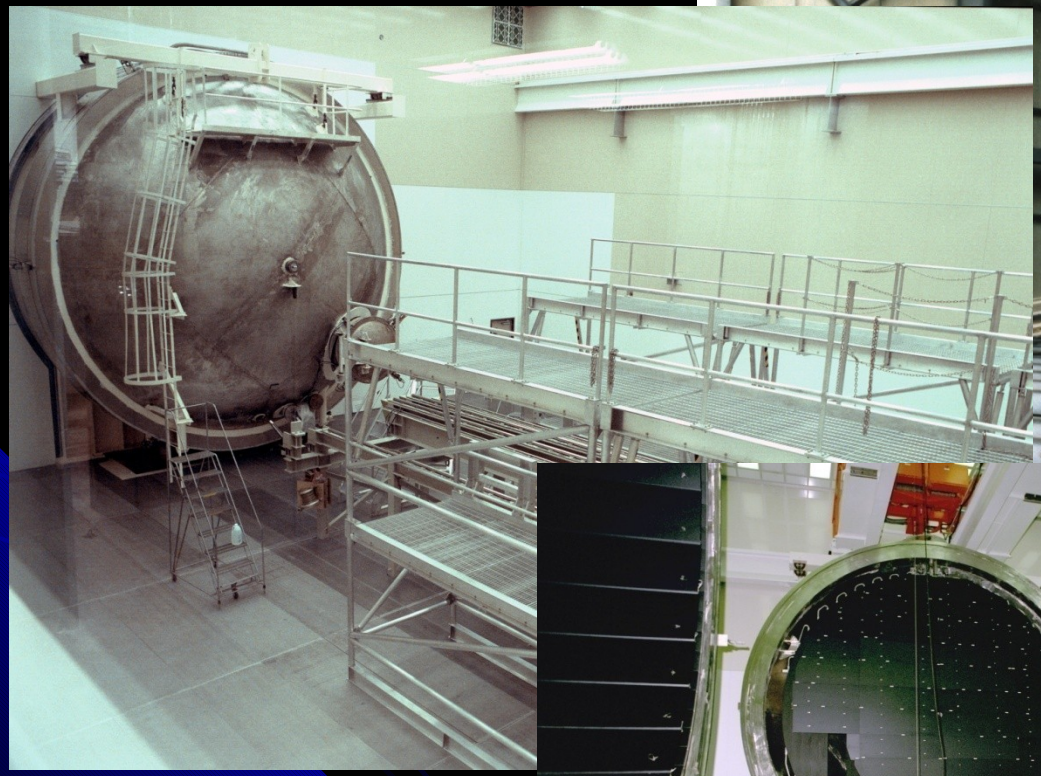
XRCF

XRCF

XRCF

XRCF

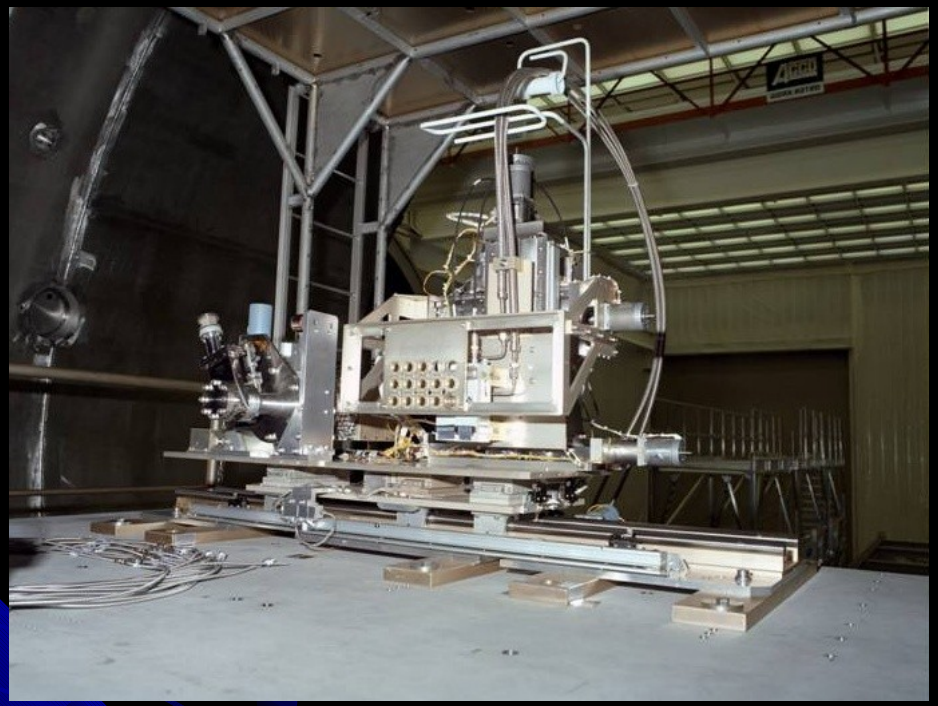




XRCF

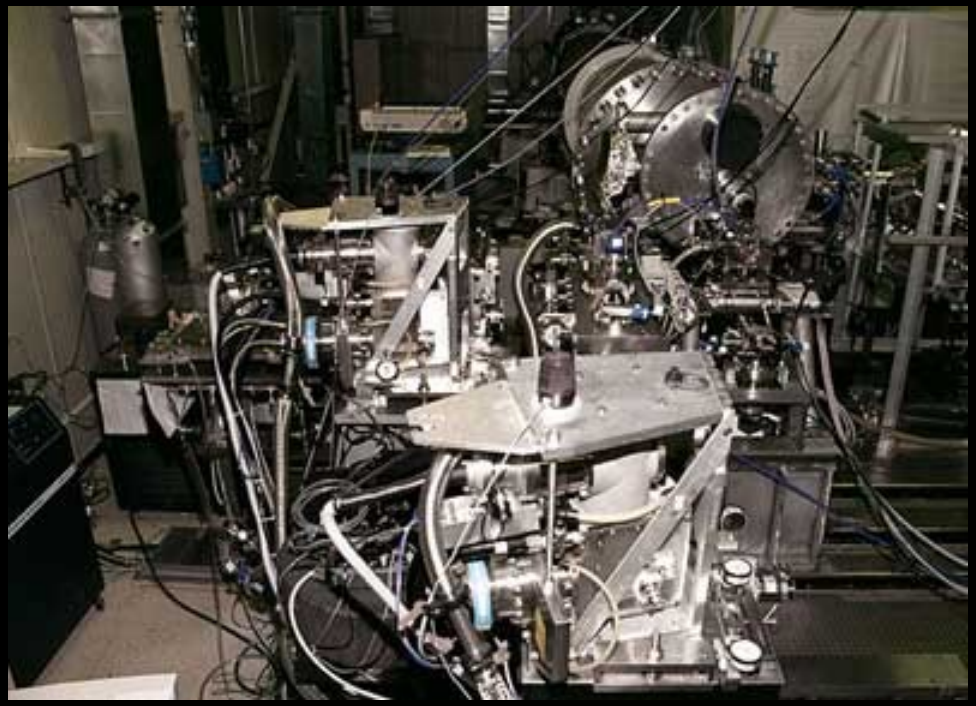
XRCF

XRCF



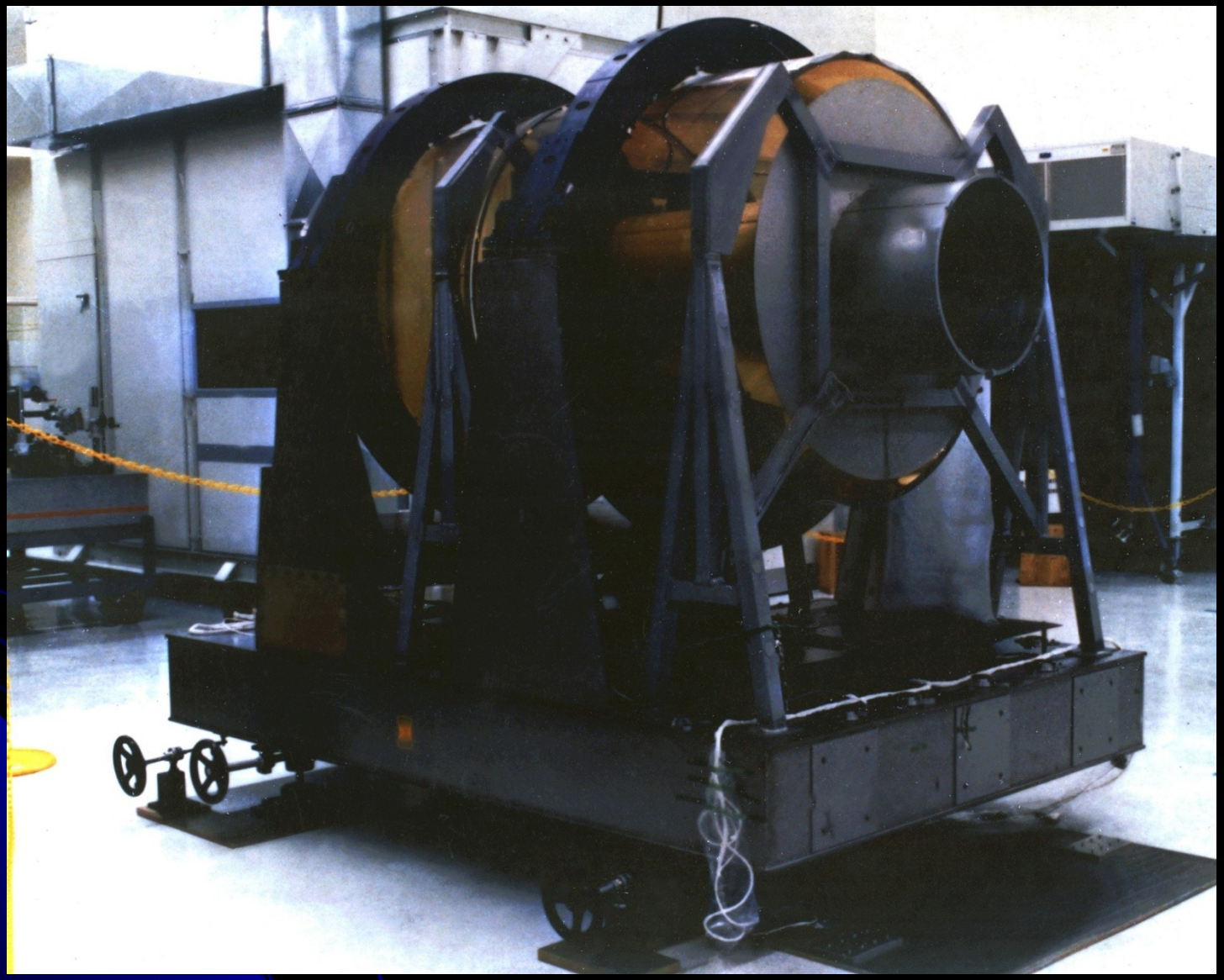
Focal Plane Detectors

X-Ray Sources



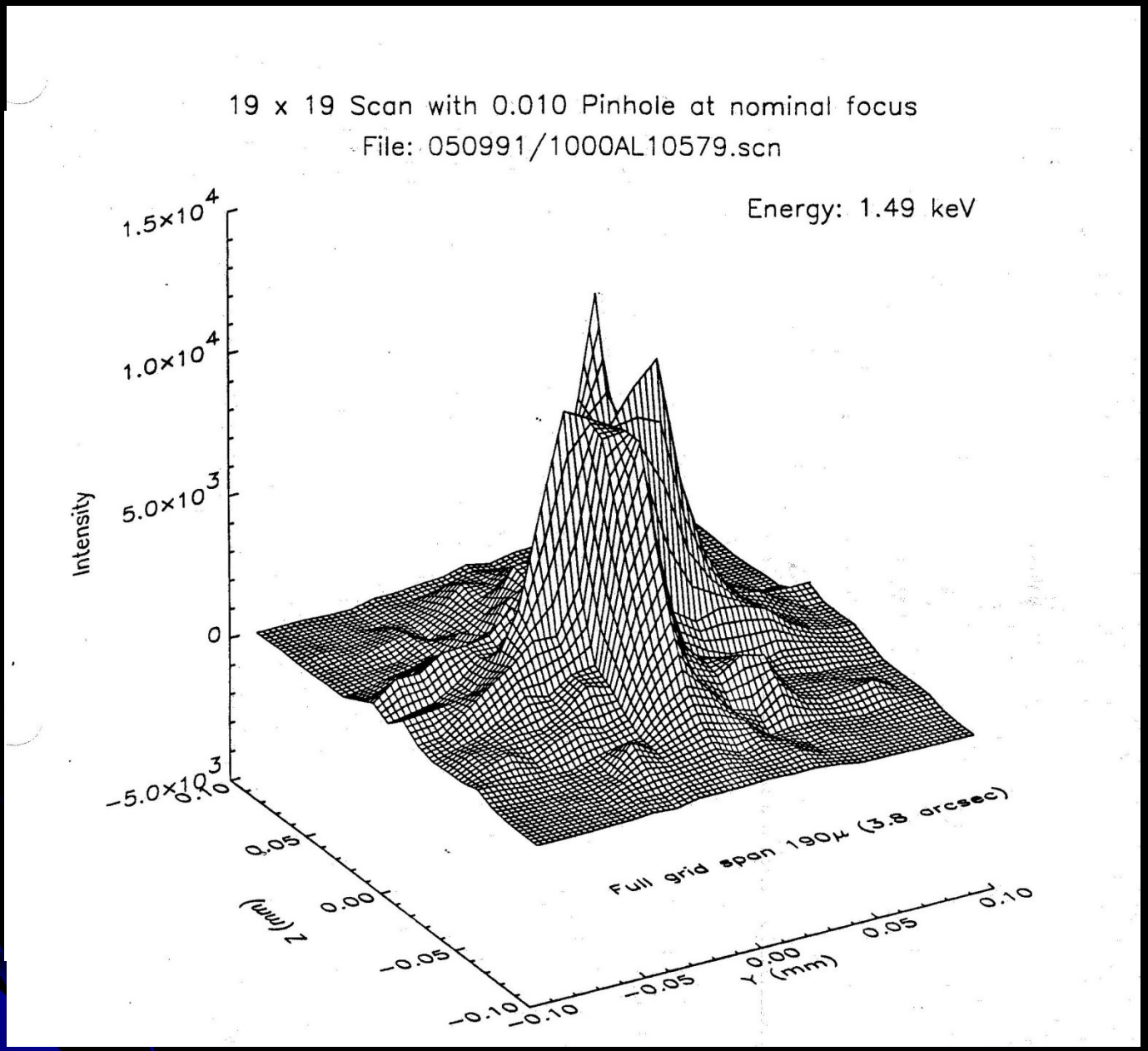
XRCF

Verification Engineering Test Article



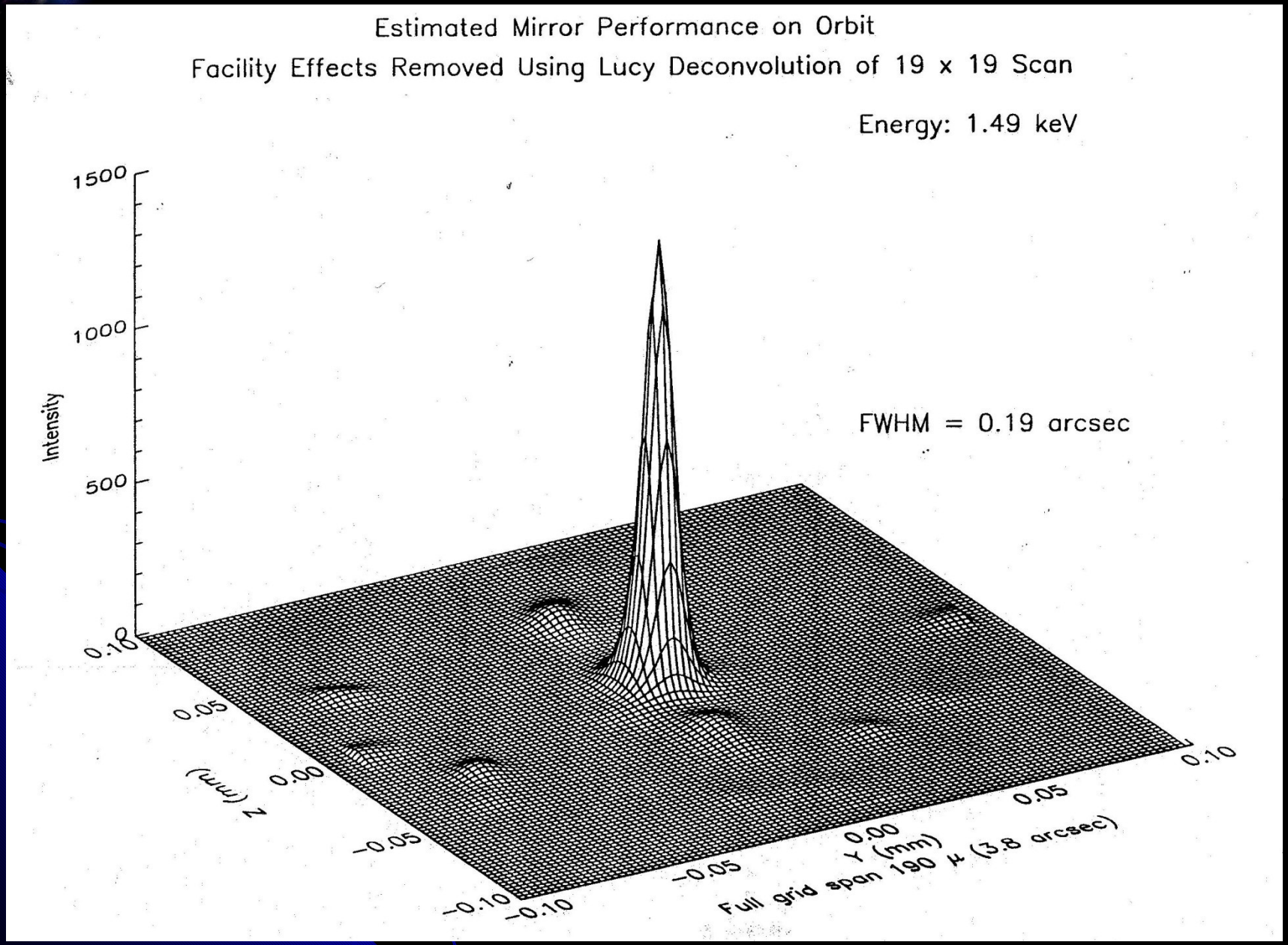
1991

VETA - Hiccup

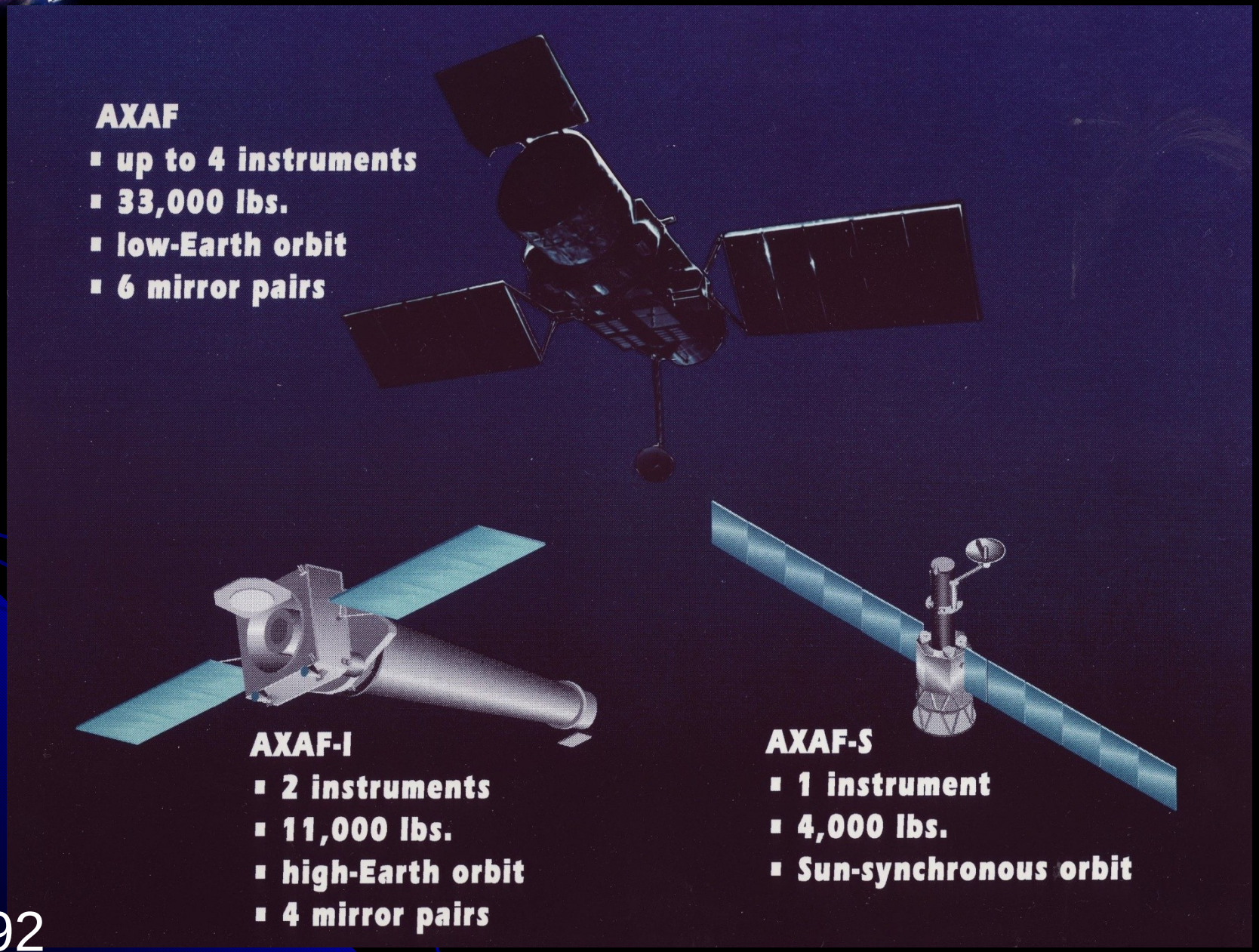


- 1G Effects!

VETA


Estimated Mirror Performance on Orbit
Facility Effects Removed Using Lucy Deconvolution of 19 x 19 Scan
Energy: 1.49 keV
FWHM = 0.19 arcsec
Intensity
1500
1000
500
0.10
0.05
0.00
−0.05
−0.10
Z (mm)
−0.10
−0.05
0.00
0.05
0.10
Y (mm)
Full grid span 190 μ (3.8 arcsec)

Restructuring

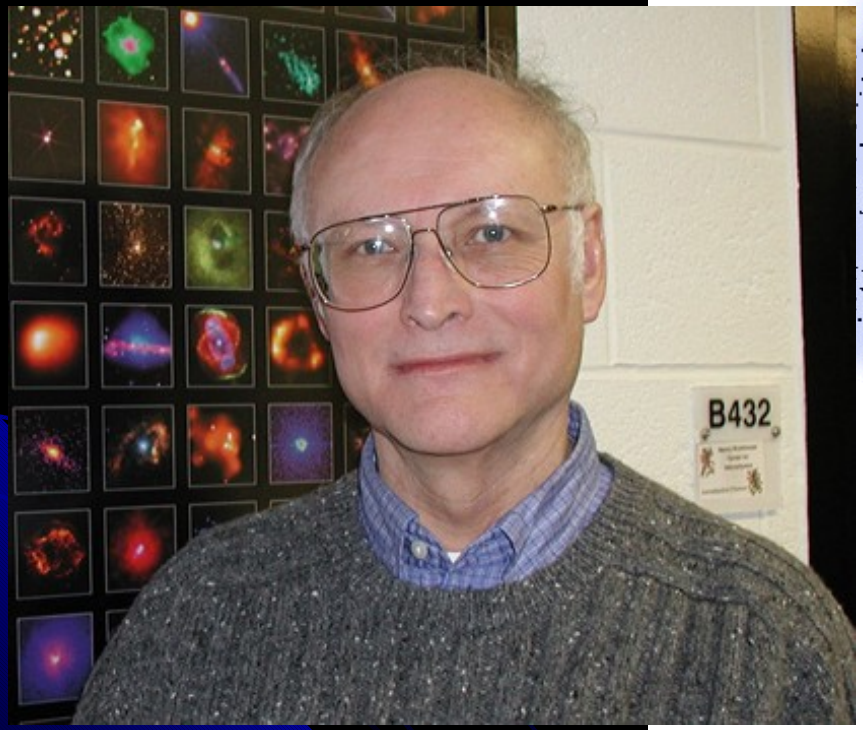


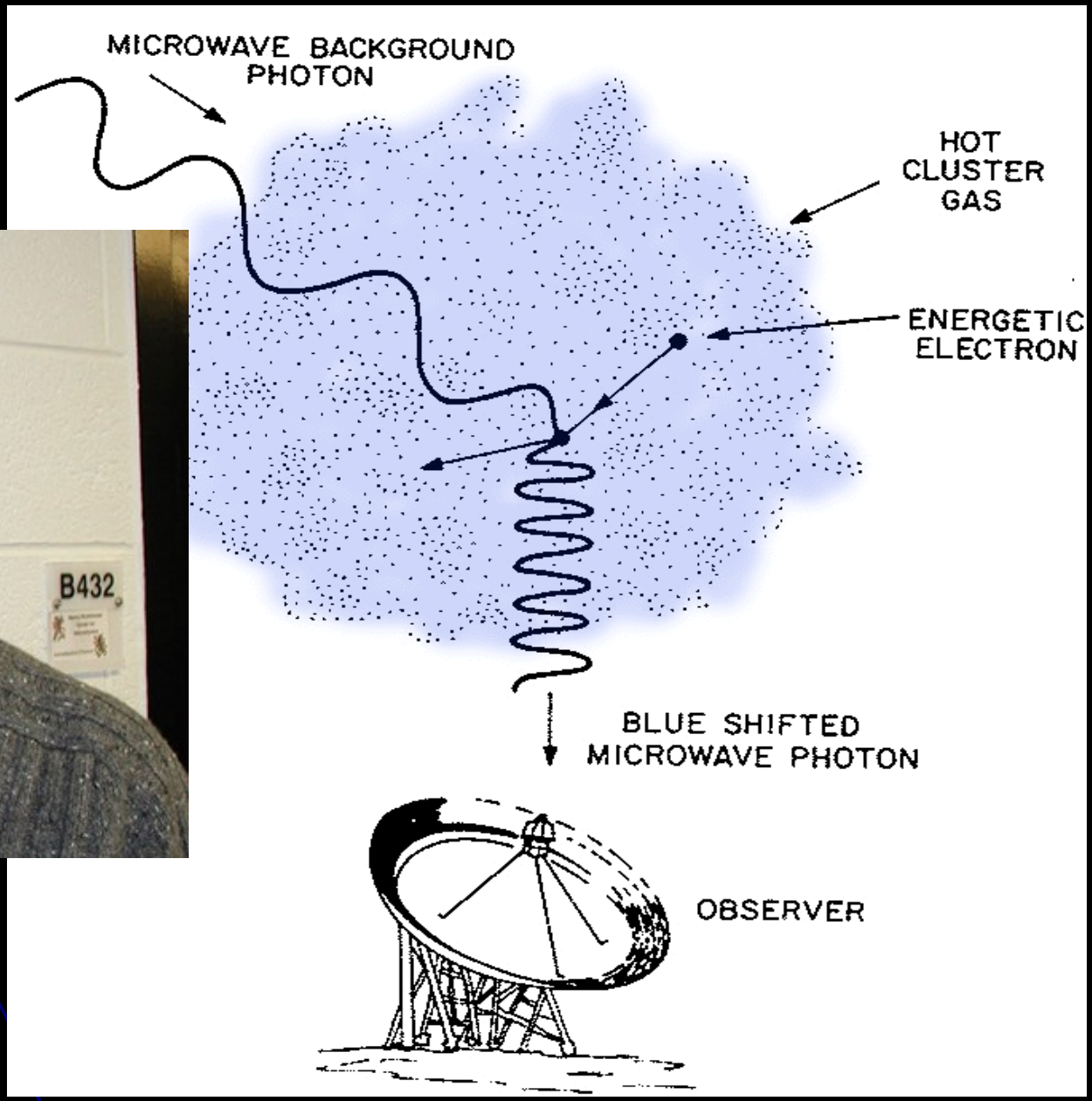
1992

Restructuring

- Servicing Disappears
  - Assured by new orbit
- But benefits
  - Efficiency
  - Thermal
  - Iridium
- At a price
  - Loss of two mirrors
  - Ultimately “loss” of AXAF-S

Clusters and S-Z





S-Z

John Carlstrom & Marshall Joy to the Rescue

*C*onsolidated *Ar*ray for *M*illimeter *A*stronomy

1992

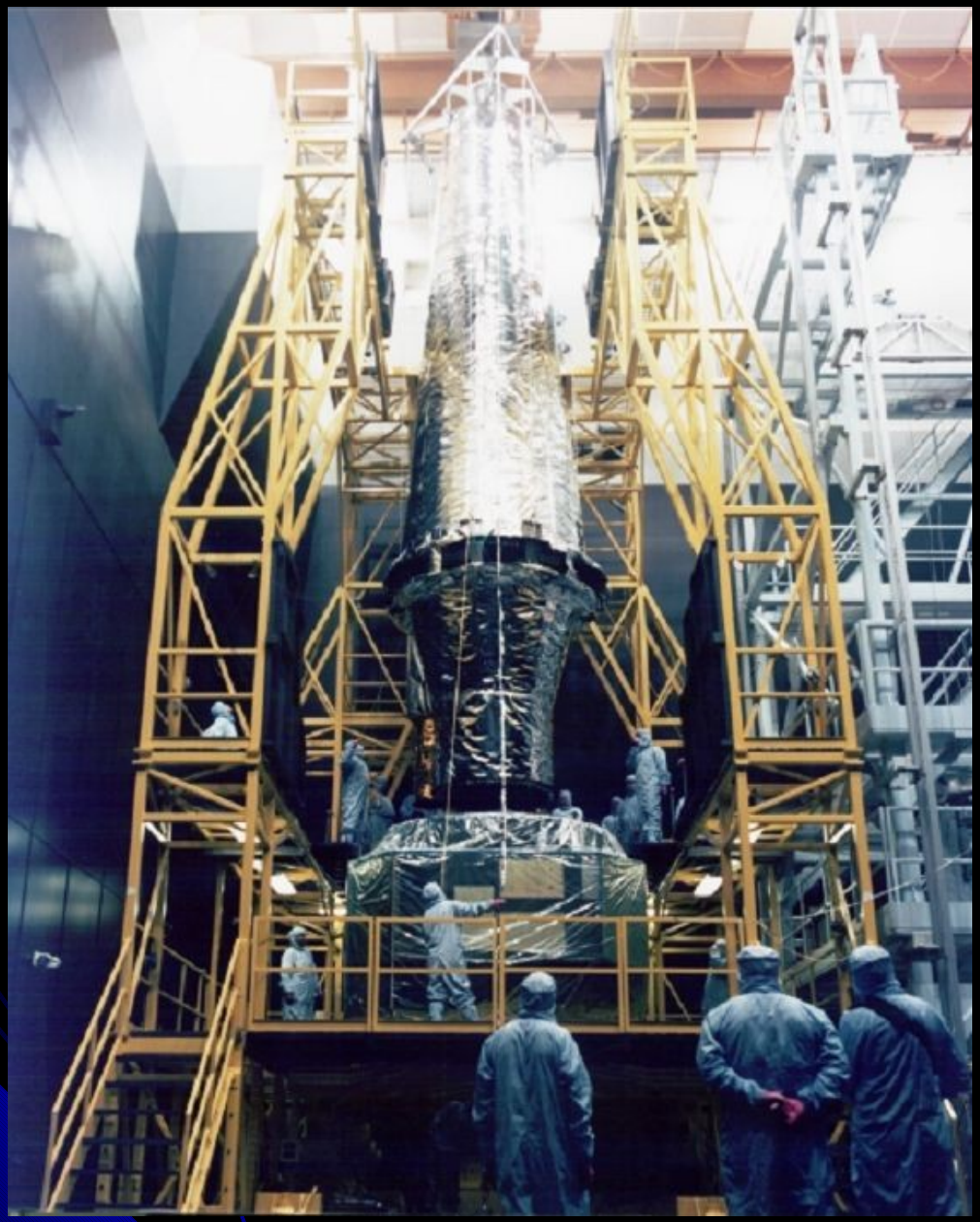
X-Ray Calibration

1996-1997

X-Ray Calibration

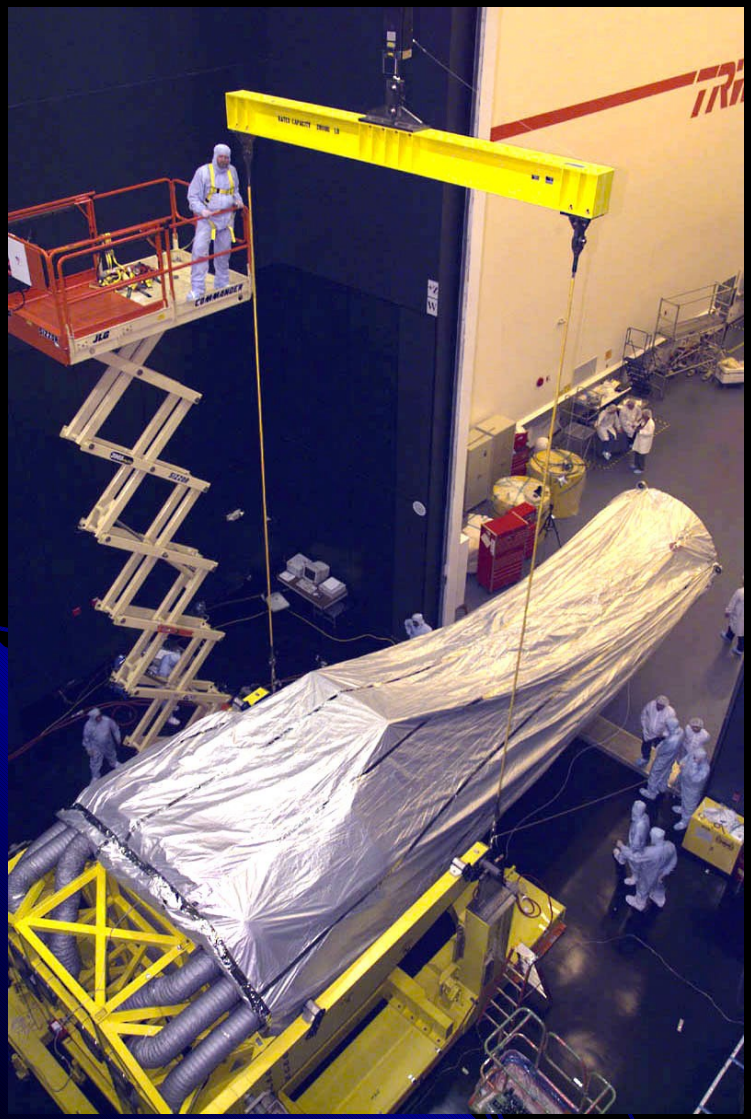
X-Ray Calibration

Integration with the S/C



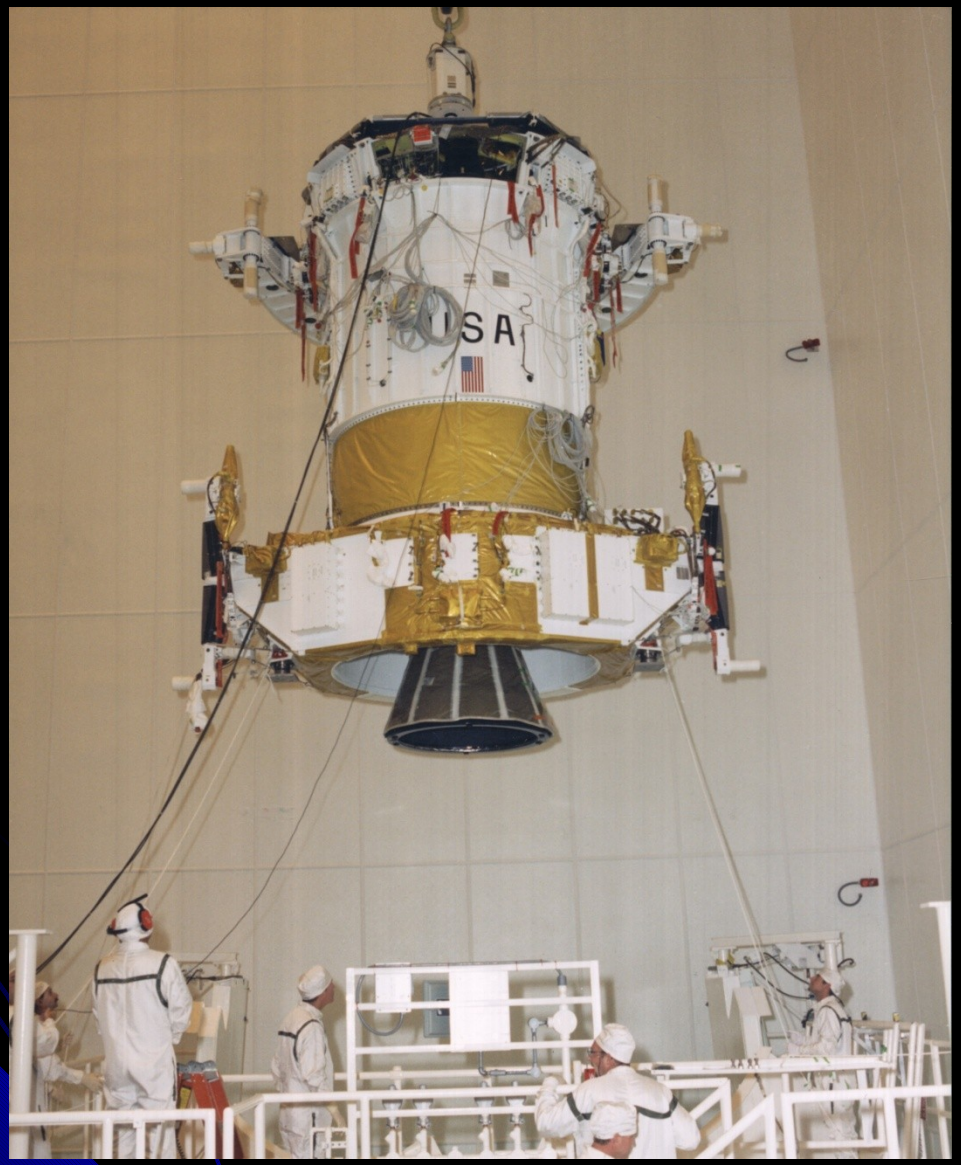
1998

On to the Cape



1999

Mate with the upper stage



At the Launch

Three Launch Attempts

Tue July 20

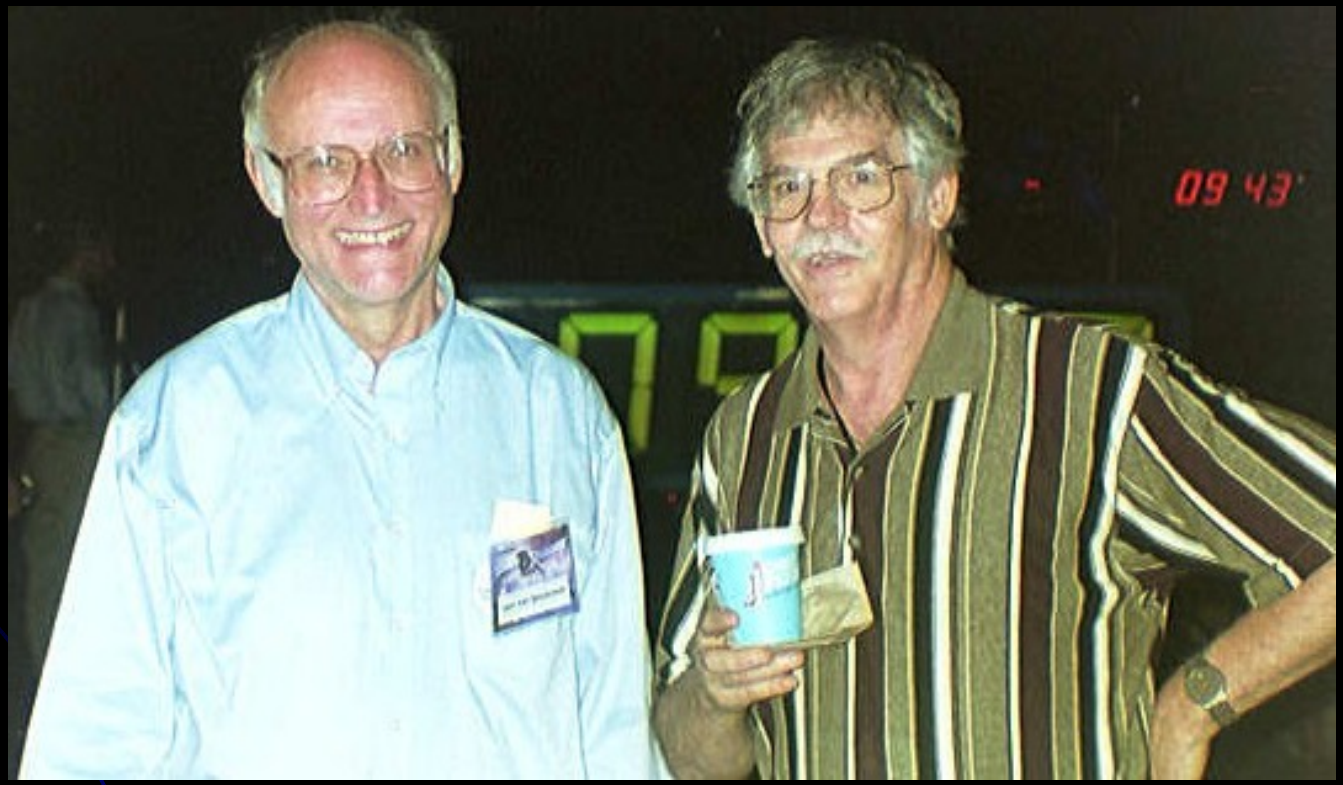
Sensor spike hydrogen in the engine compartment

Thurs July 22

Lightning

Fri July 23

Launch

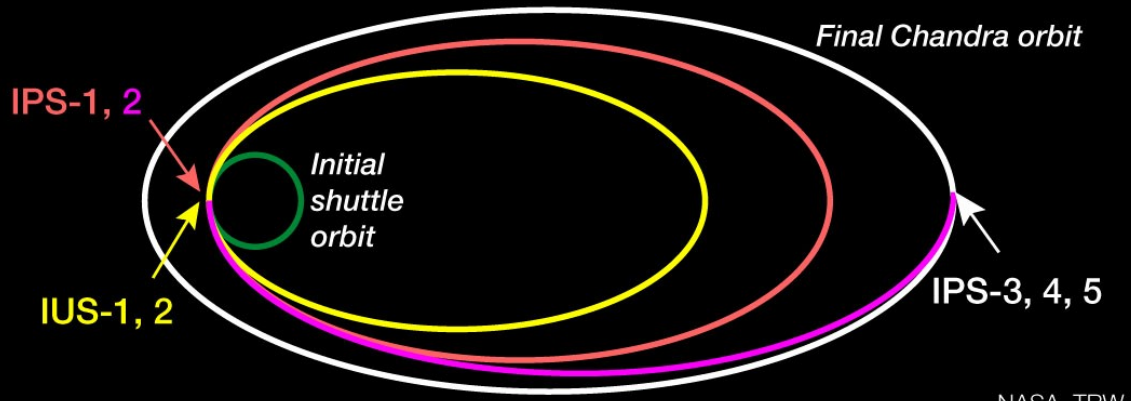


The Launch

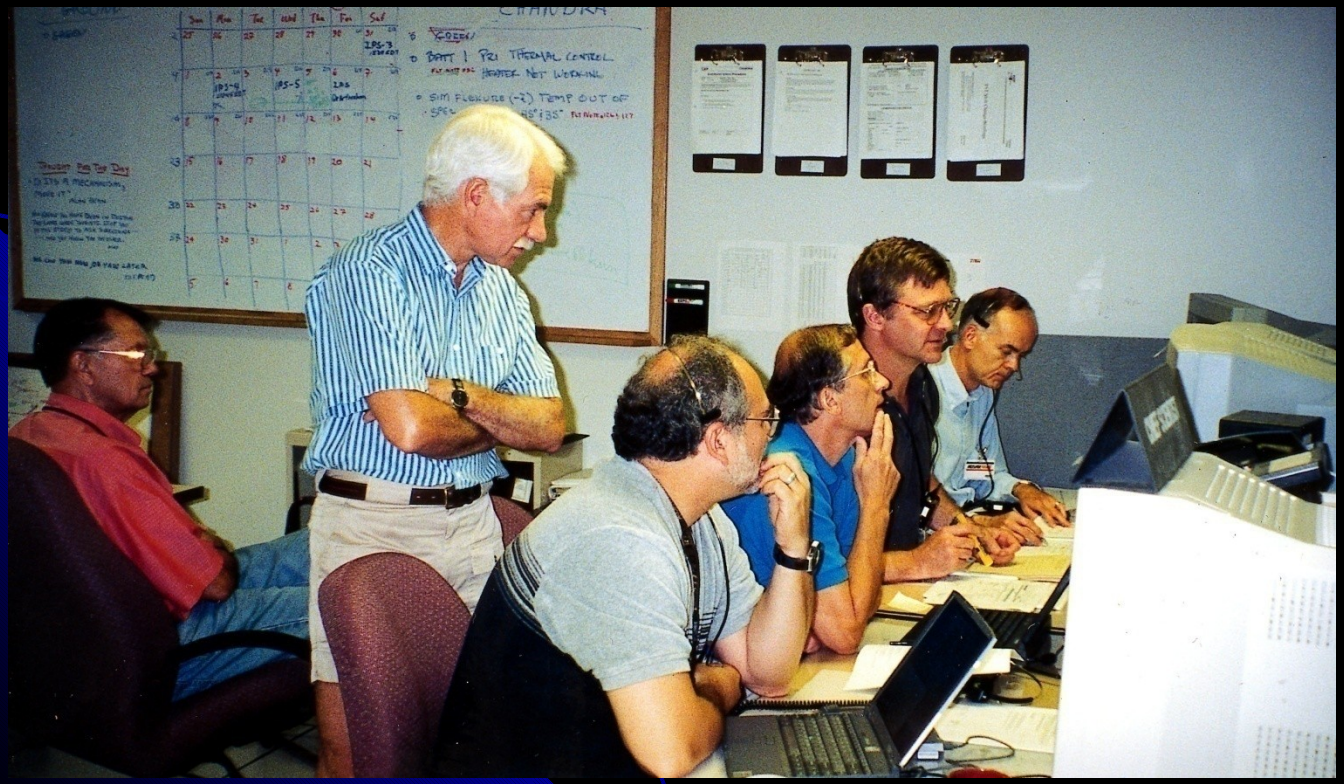
Beyond the Sky
Words and Music by Judy Collins

“And we will fly beyond the sky
Beyond the stars beyond the heavens
Beyond the dawn we'll carry on
Until our dreams have all come true
To those who fly - we sing to you”

In the Control Center



NASA, TRW



Door Openings

August 8 --- ACIS Housing

- Had failed during ground test
- Needed to see a 70º reading
- 18º would indicate the seal was broken

Pulse 1 - no motion

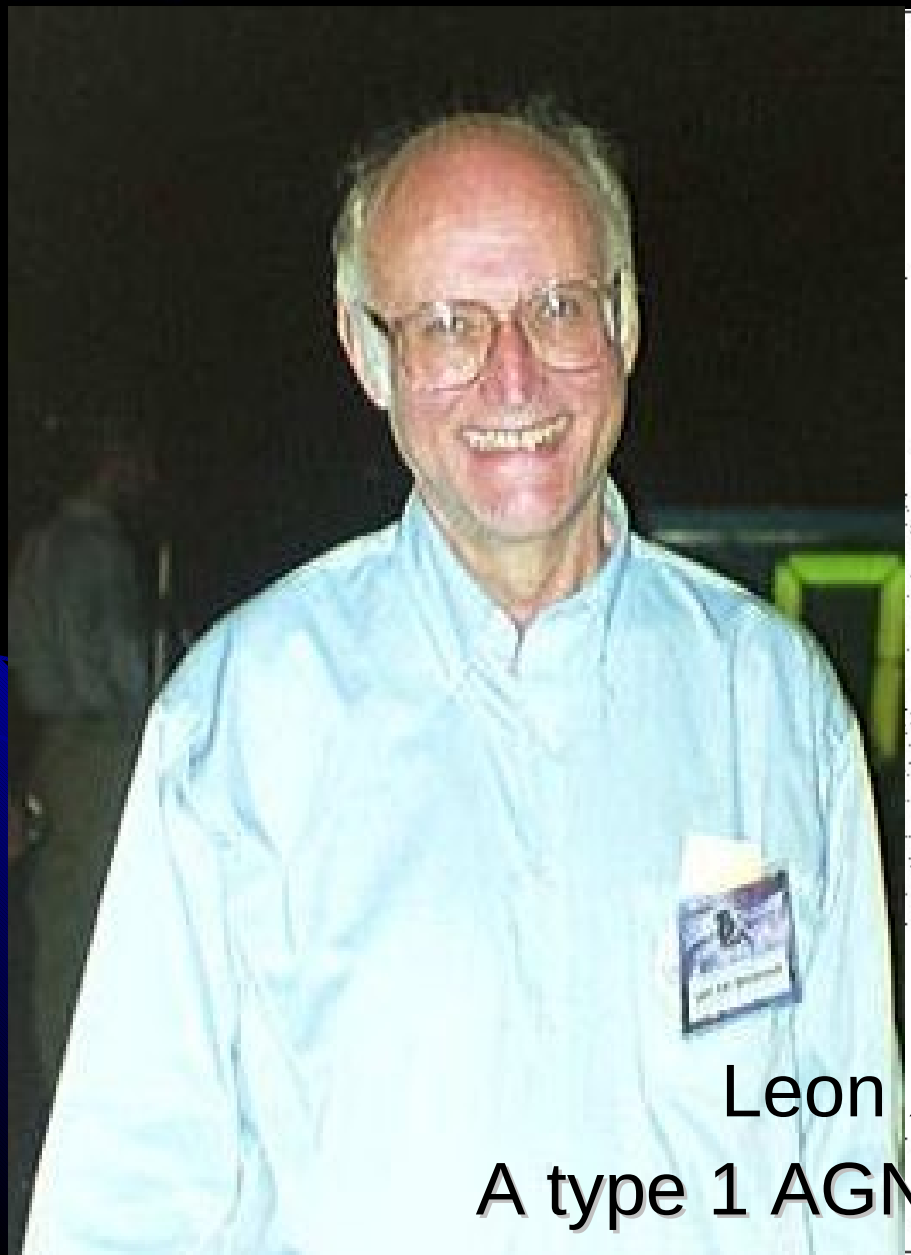
Pulse 2 - 13º

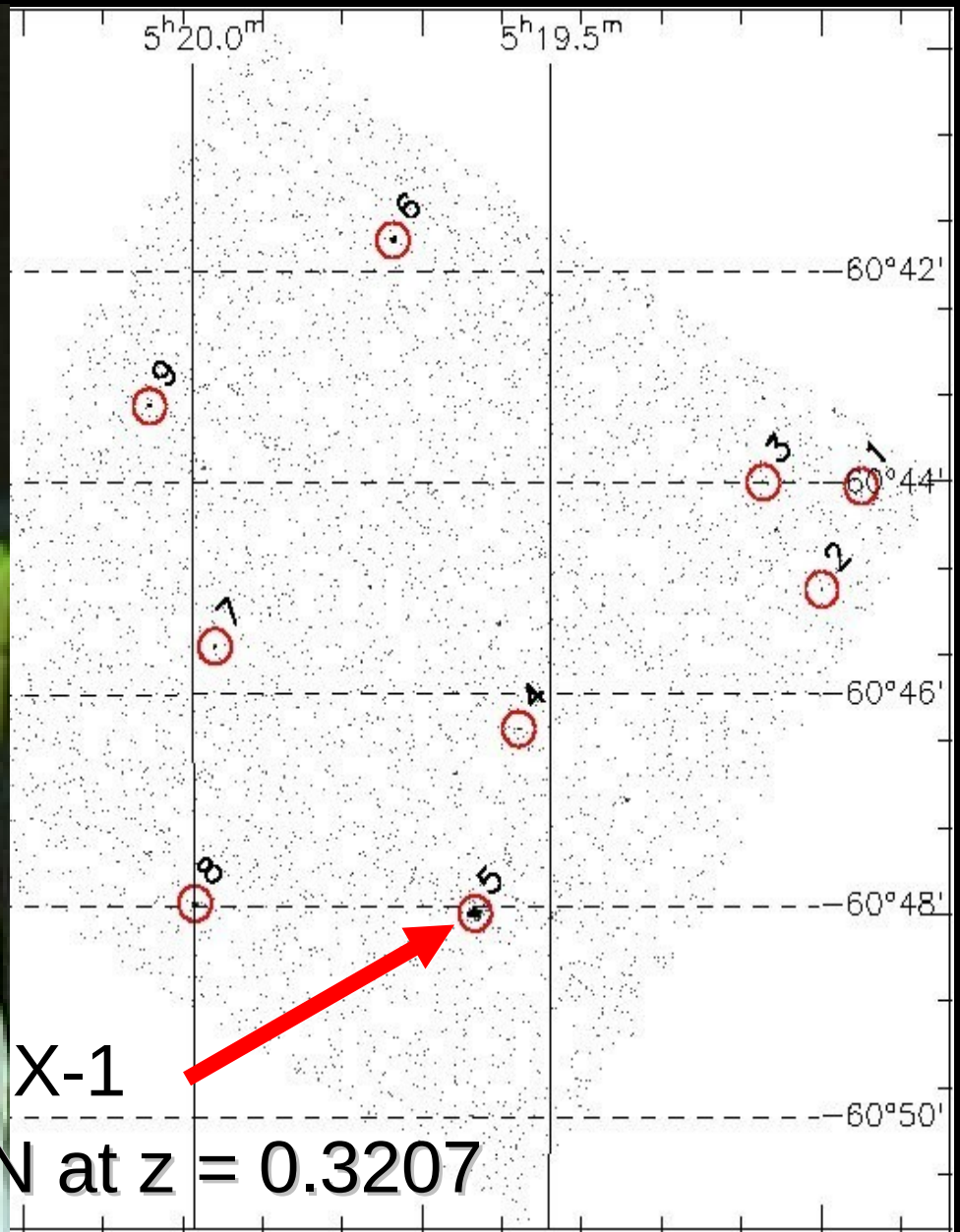
Pulse 3 - 19.5º

Pulse 4 - 36º

Pulse 5 – 71.5º

The Real First Light

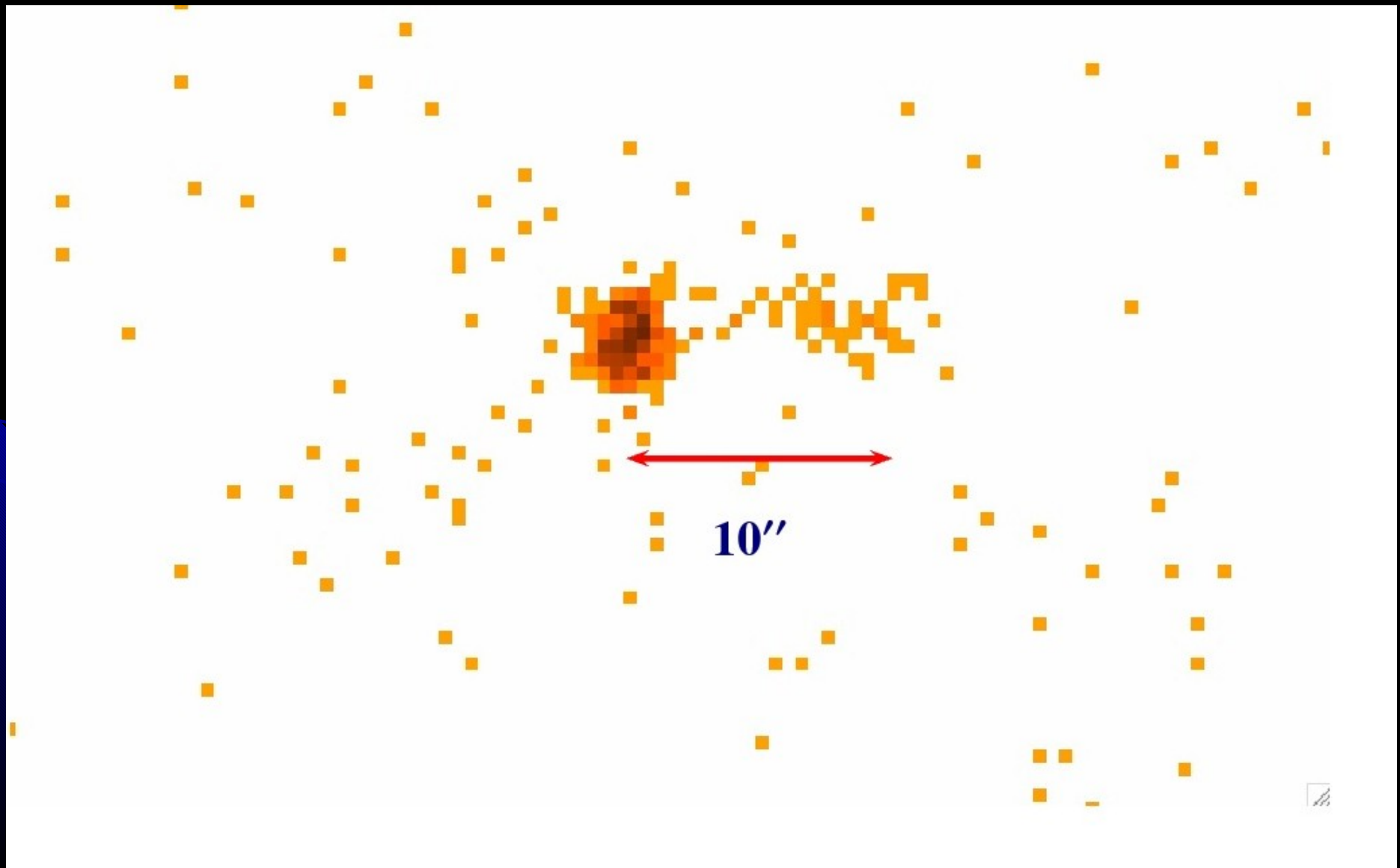




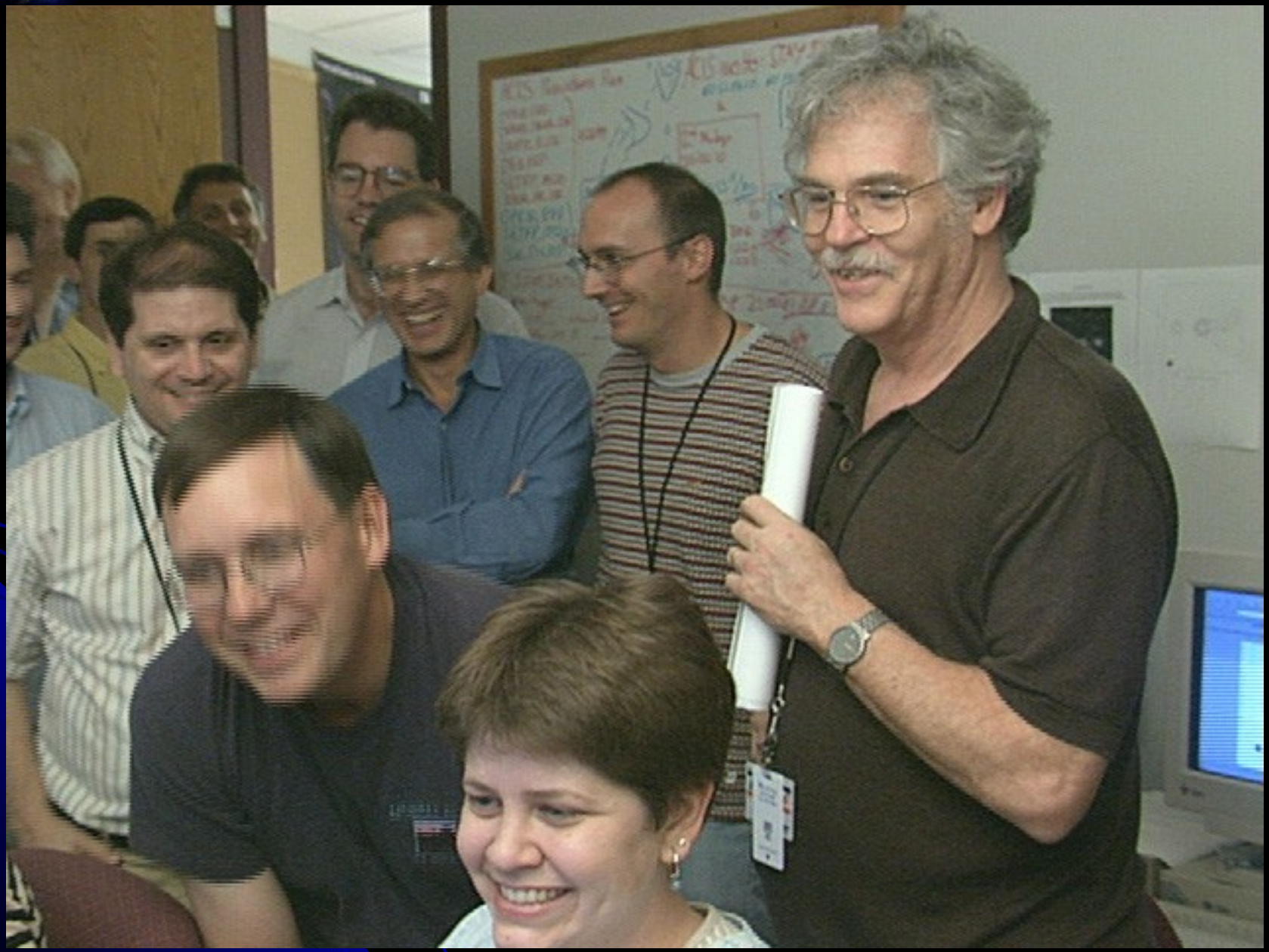
Leon X-1

A type 1 AGN at z = 0.3207

The First Pointing & Focus Adjustment



It Really Works!



☺ ☺ ☺


Chandra's First Decade of Discovery
Boston, Massachusetts
September 22 – 25, 2009