Precollimator for X-Ray Telescope
(stray-light baffle)

Mindrum Precision, Inc

Kurt Ponsor

Mirror Tech/SBIR Workshop

Wednesday, Nov 2017

Overview

Precollimator

- Past
- Present
- Future

Past

- Space X-Ray Telescopes (XRT)
- Basic Structure
- Effectiveness
- Past Construction

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Space X-Ray Telescopes

- XMM-Newton 1999
- Chandra 1999
- HETE-2 2000-07
- INTEGRAL 2002

ESA/NASA

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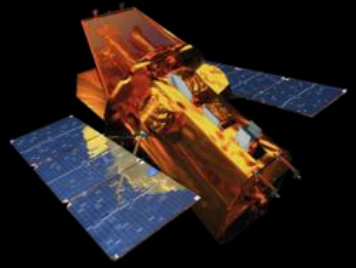
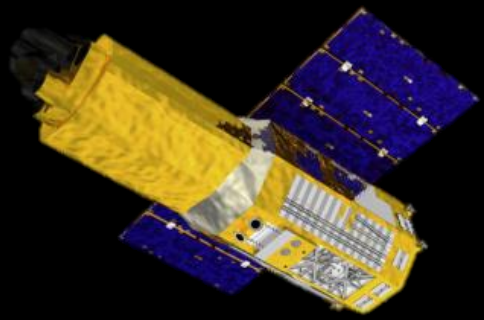
Space X-Ray Telescopes

- Swift 2004

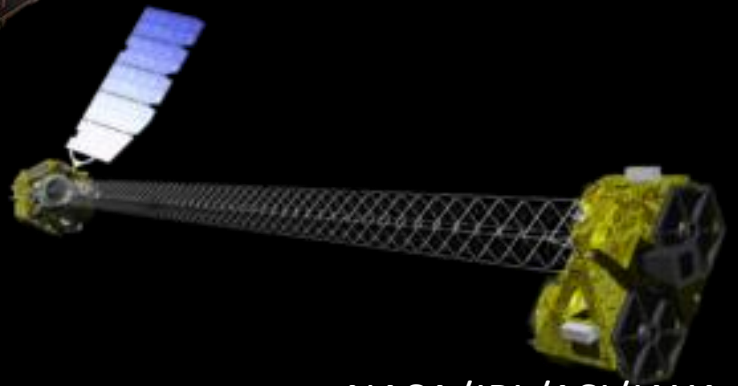


- Suzaku 2005-2015



- AGILE 2007

- NuSTAR 2012



NASA/JPL/ASI/JAXA

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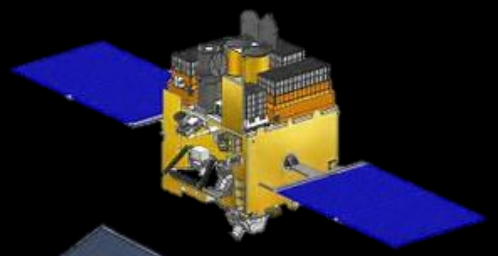
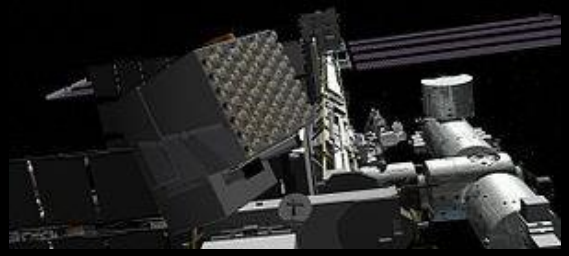
Space X-Ray Telescopes

- Astrosat 2015
- Hitomi (ASTRO-H) 2016-2016
- NICER (ISS) 2017
- HXMT/Insight 慧眼 2017





NASA/JPL/CNSA

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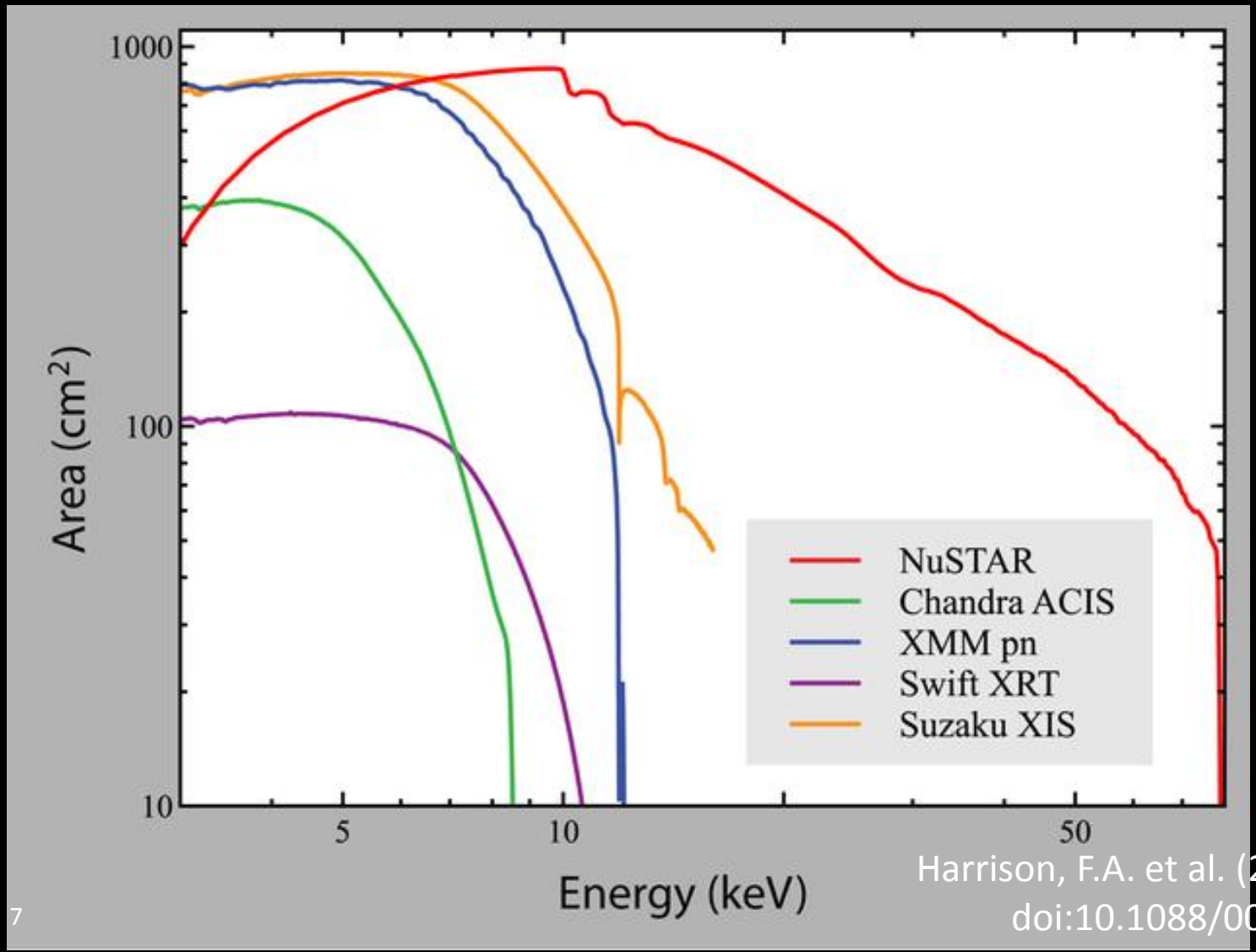
Space X-Ray Telescopes



NASA/JPL-Caltech
Harrison, F.A. et al. (2013; ApJ, 770, 103)
doi:10.1088/0004-637X/770/2/103

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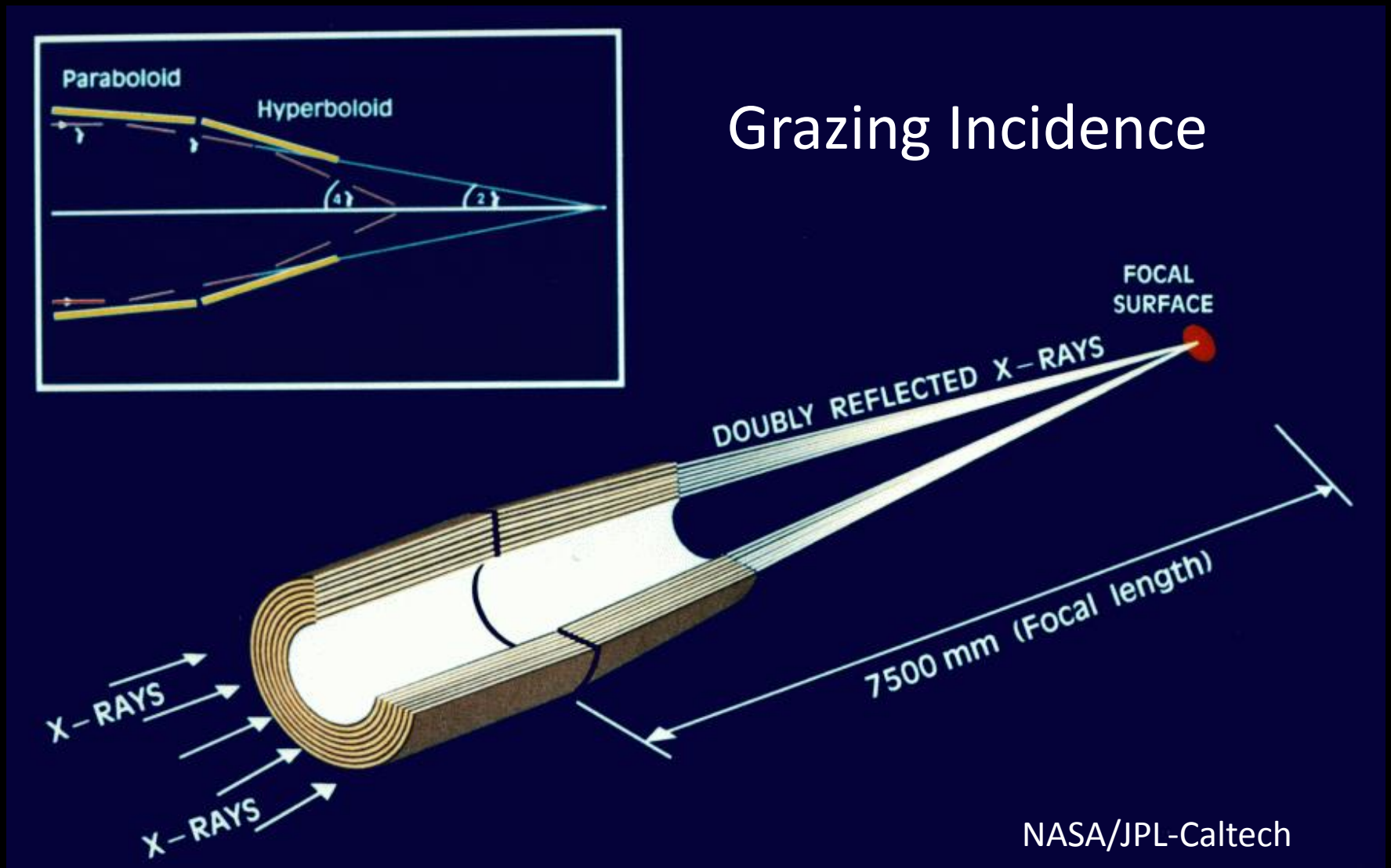
Basic Structure XRT



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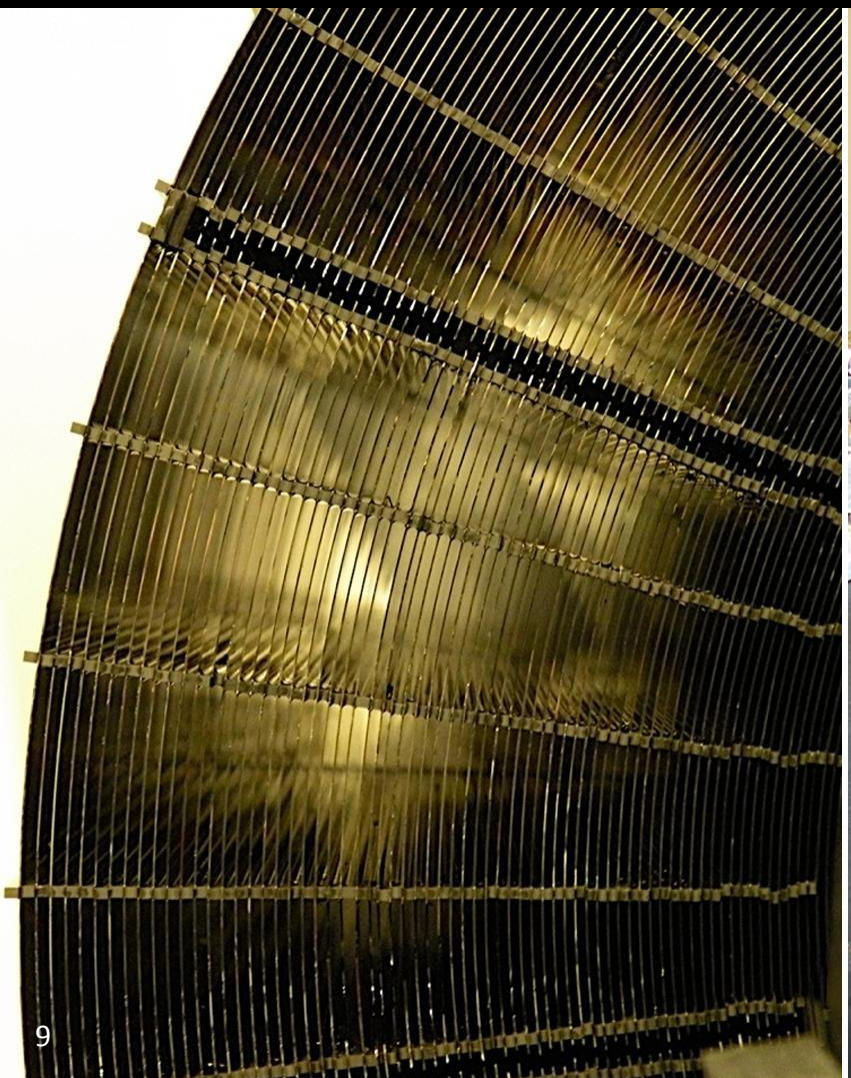
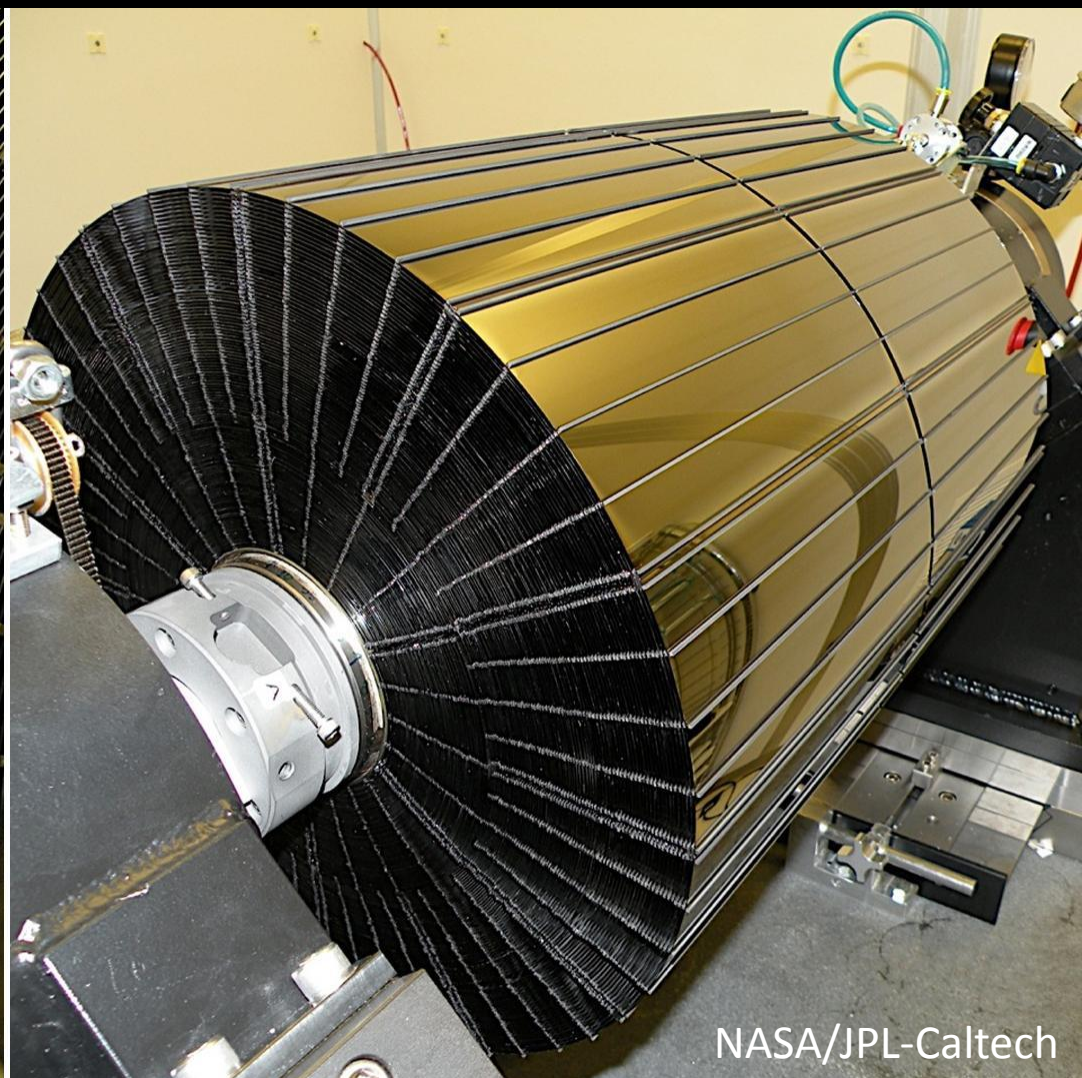
Basic Structure: NuSTAR Mirrors





NASA/JPL-Caltech

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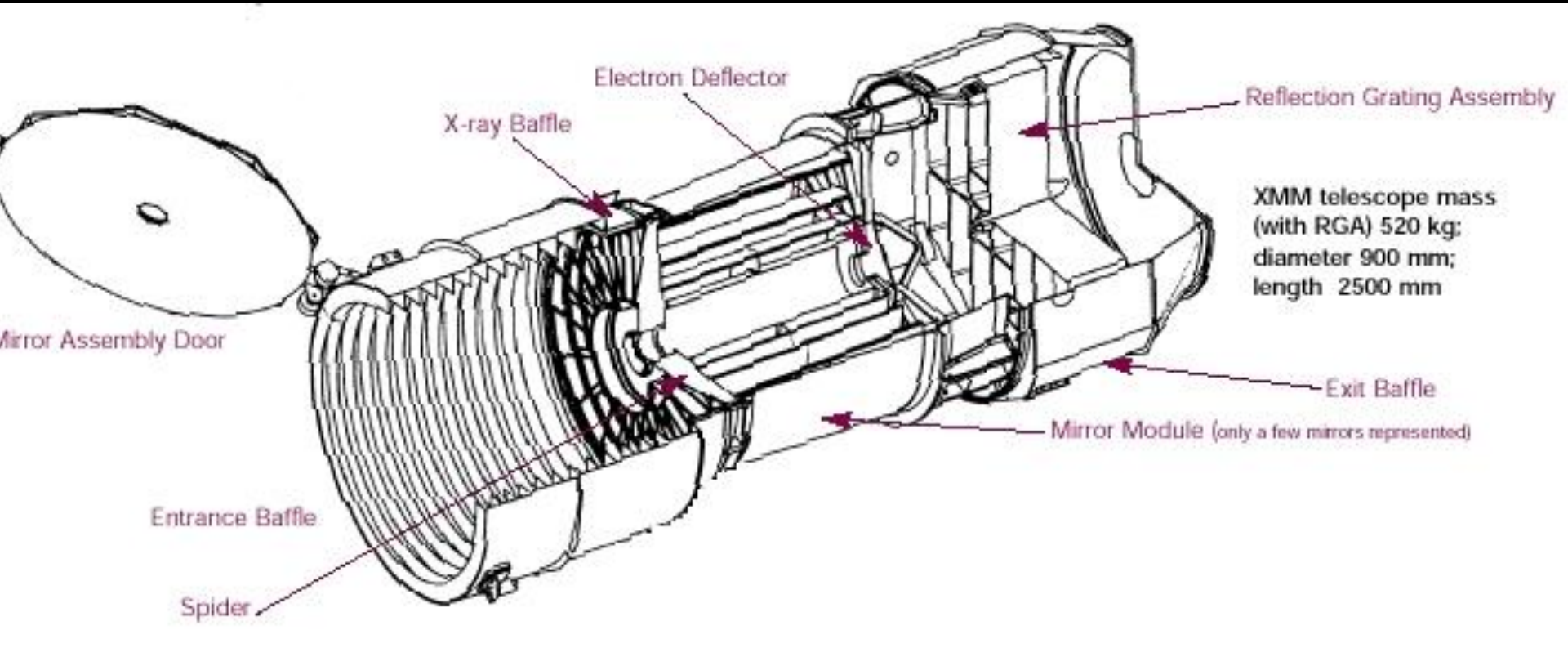
Basic Structure XRT

- XMM Newton XRT



ESA

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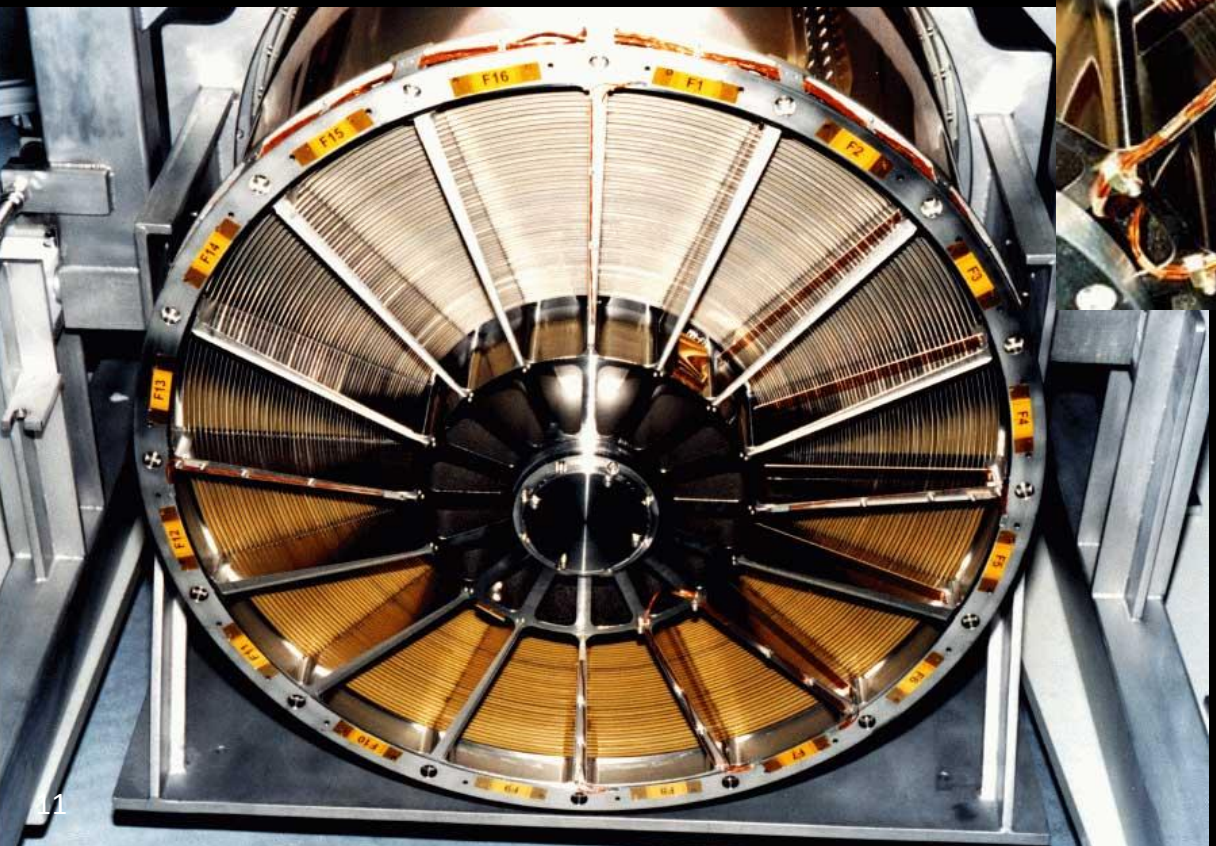
Basic Structure XRT

- XMM-Newton mirrors



D. de Chambure, XMM Project (ESTEC)/ESA

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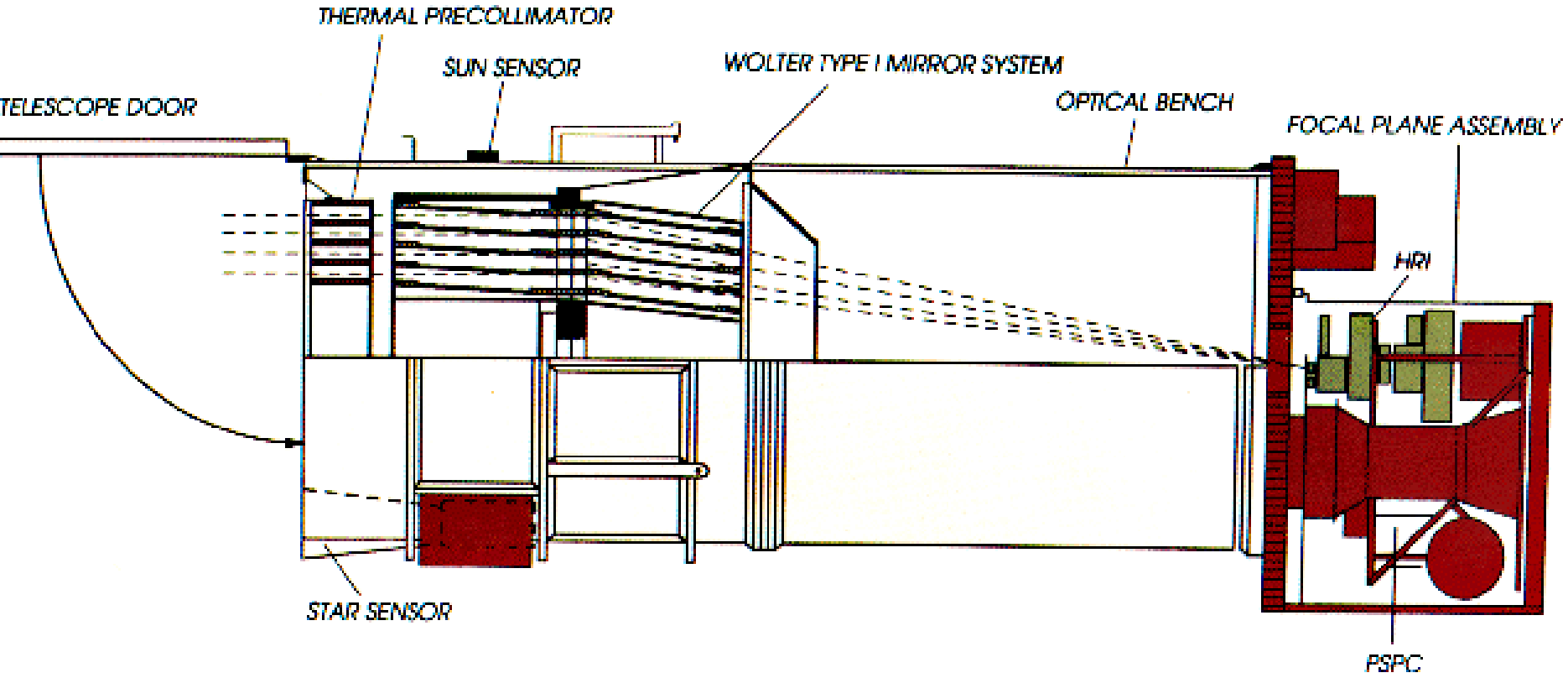
Basic Structure XRT

- Thermal Precollimator on ROSAT



http://www.xray.mpe.mpg.de/

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Basic Structure XRT

- AGILE Precollimator

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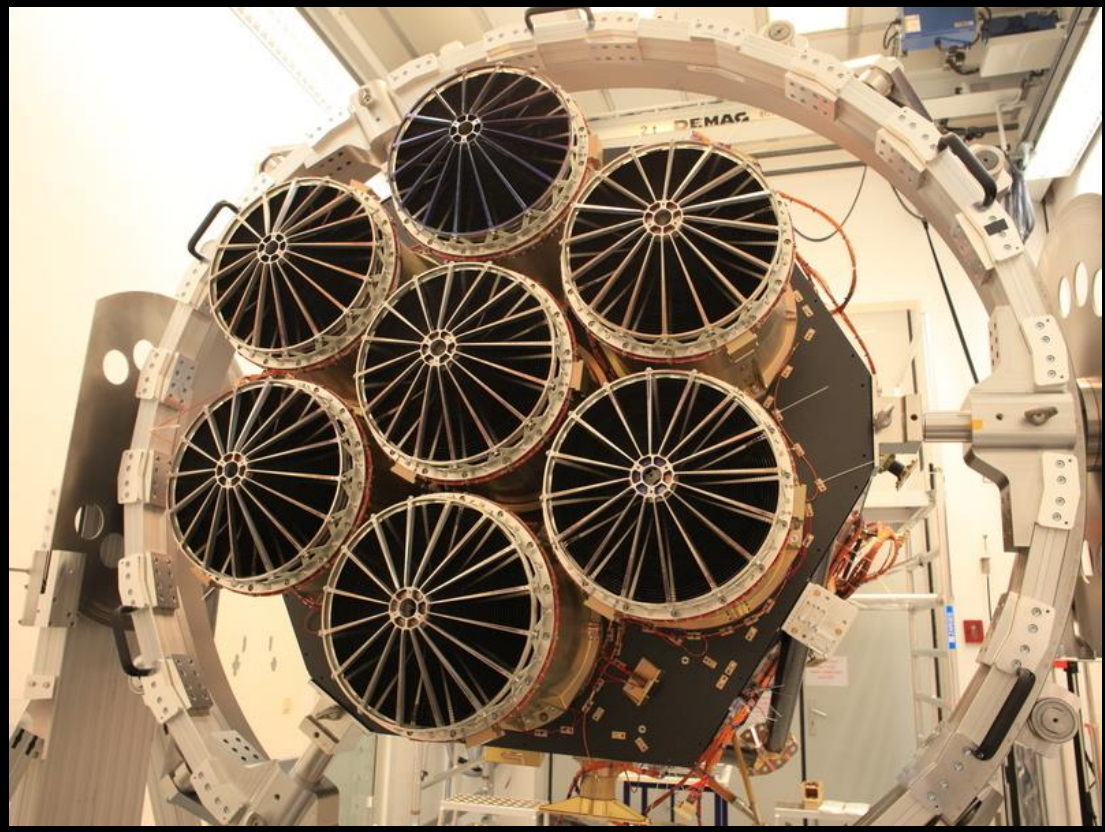
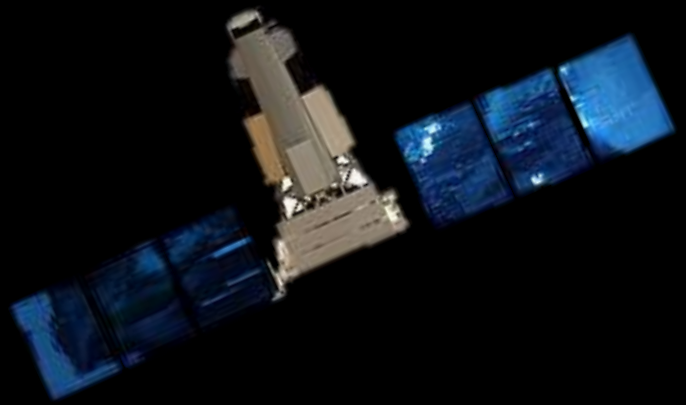
Basic Structure

- Spektr-RG 2018





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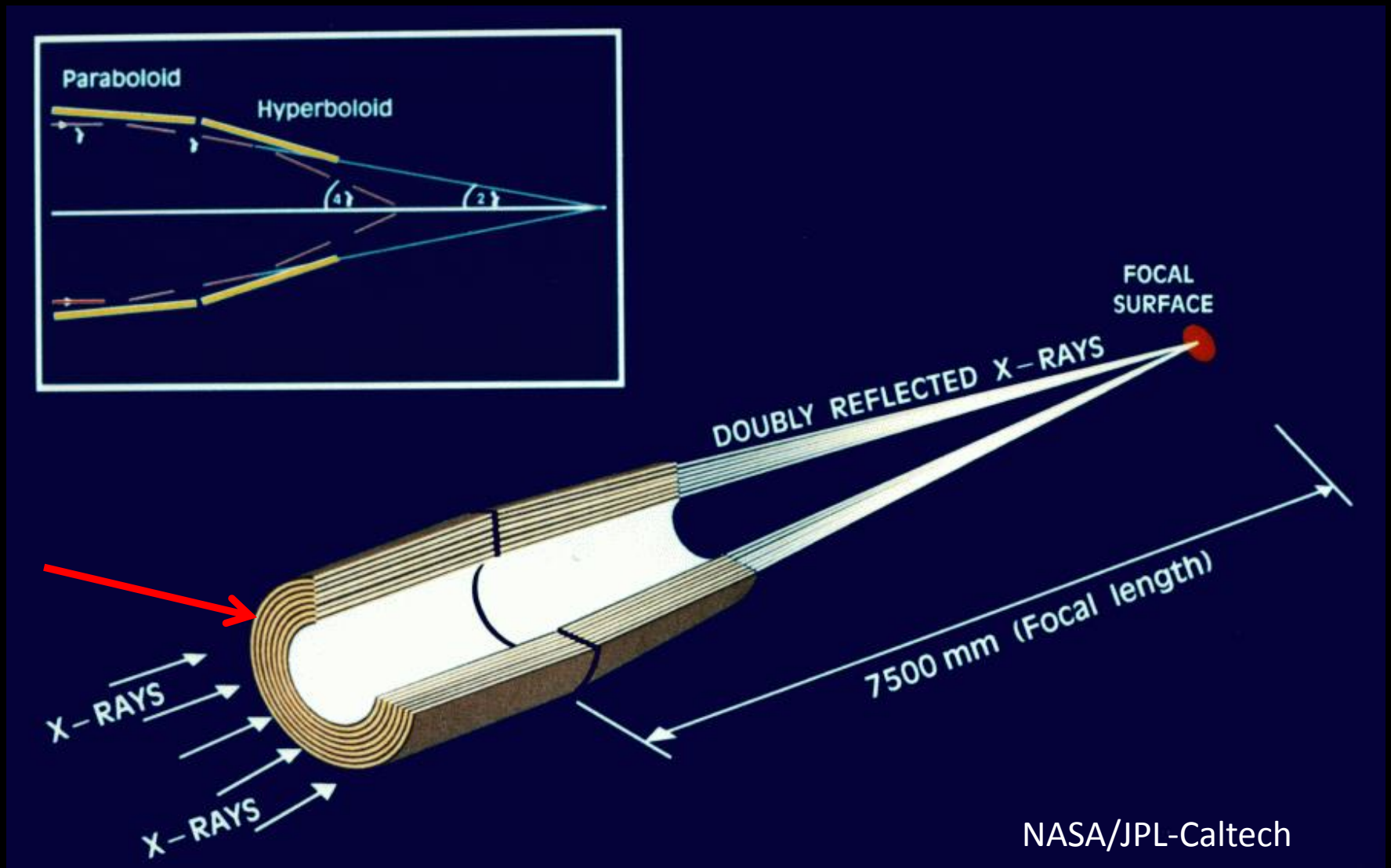
Basic Structure: Stray X-Rays



NASA/JPL-Caltech

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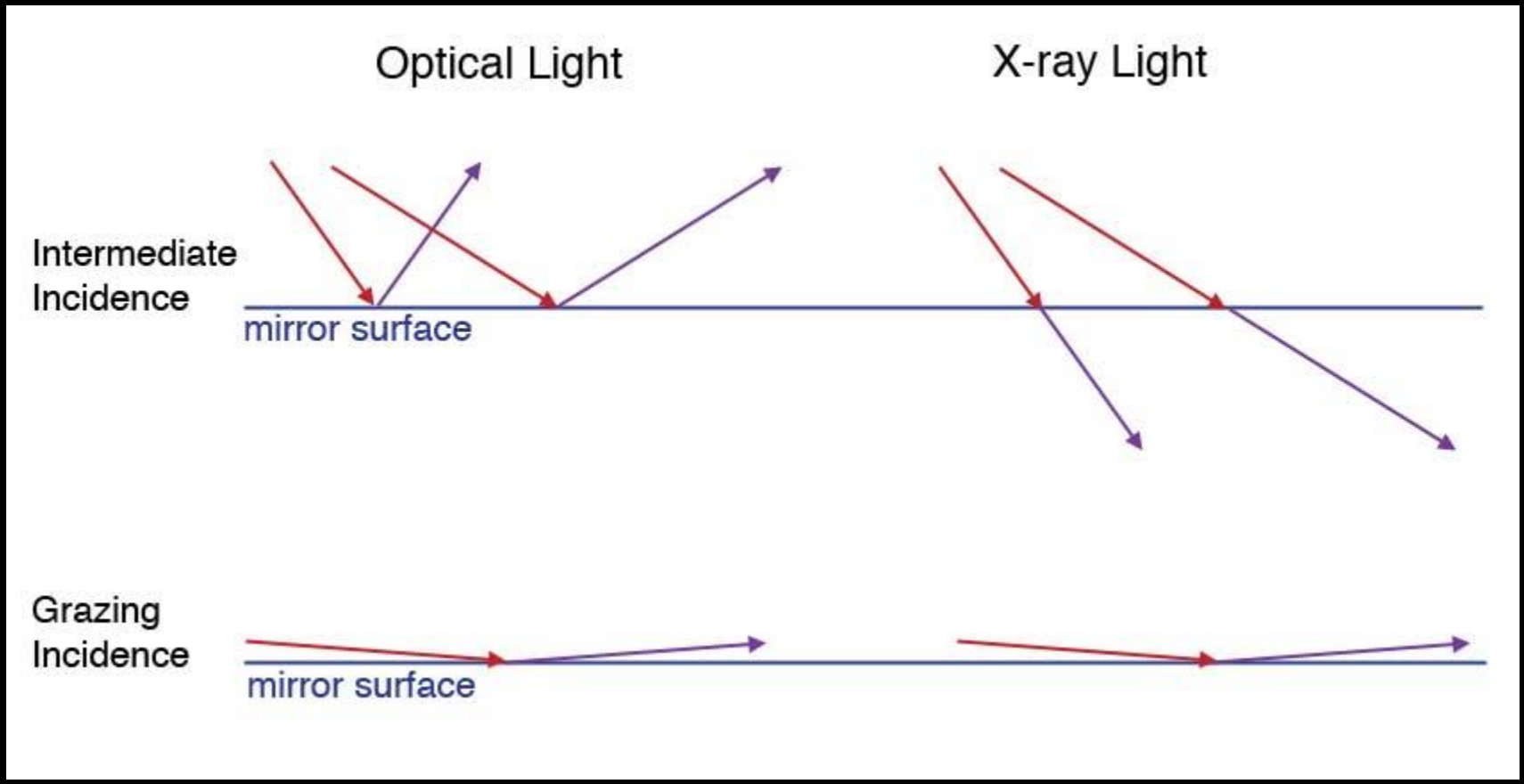
Basic Structure: Grazing



NASA

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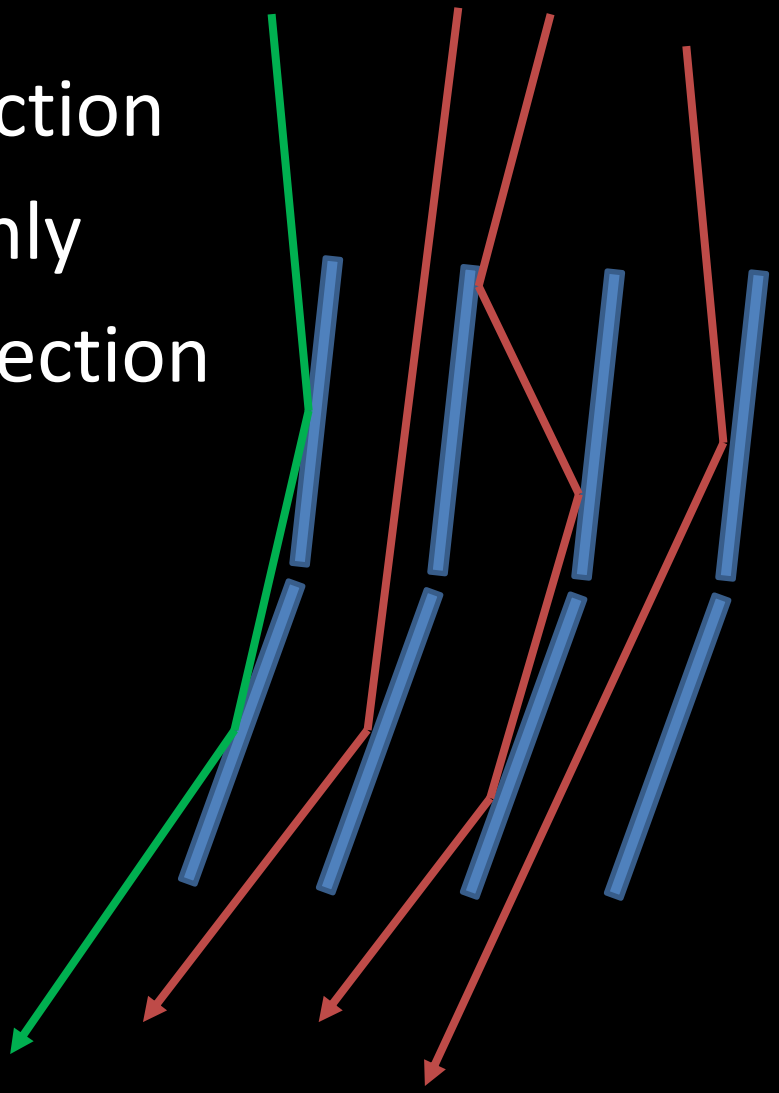
X-Ray Effectiveness: Straylight

- Correct Reflection
- Secondary Only
- Backside Reflection
- Primary Only



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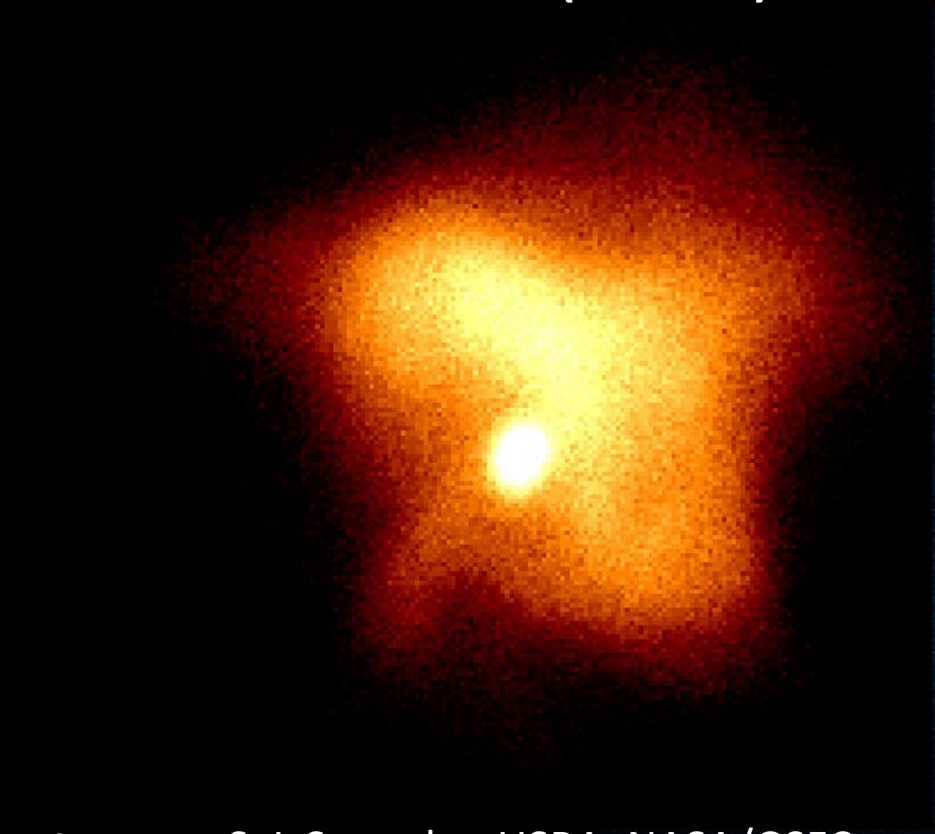
X-Ray Effectiveness

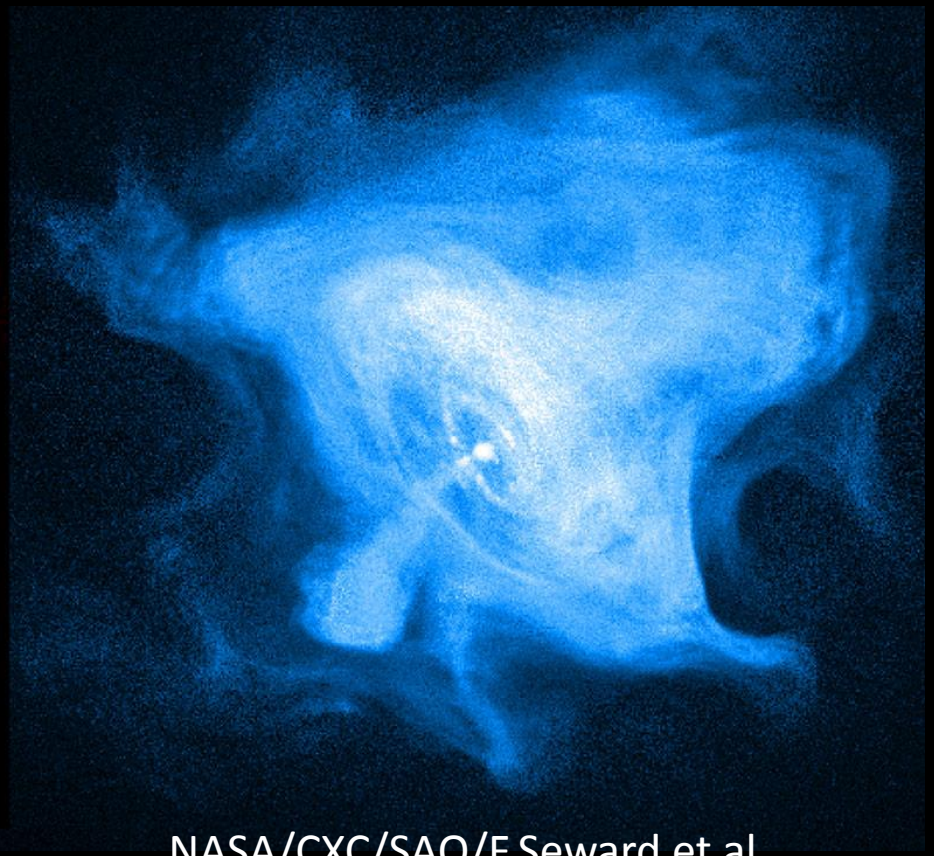
- The Crab Nebula by:

ROSAT (1990)



S. L.Snowden USRA, NASA/GSFC

Chandra



NASA/CXC/SAO/F.Seward et al.

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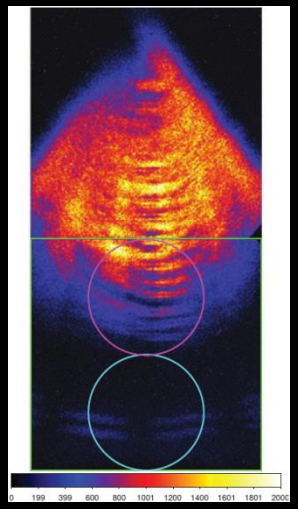
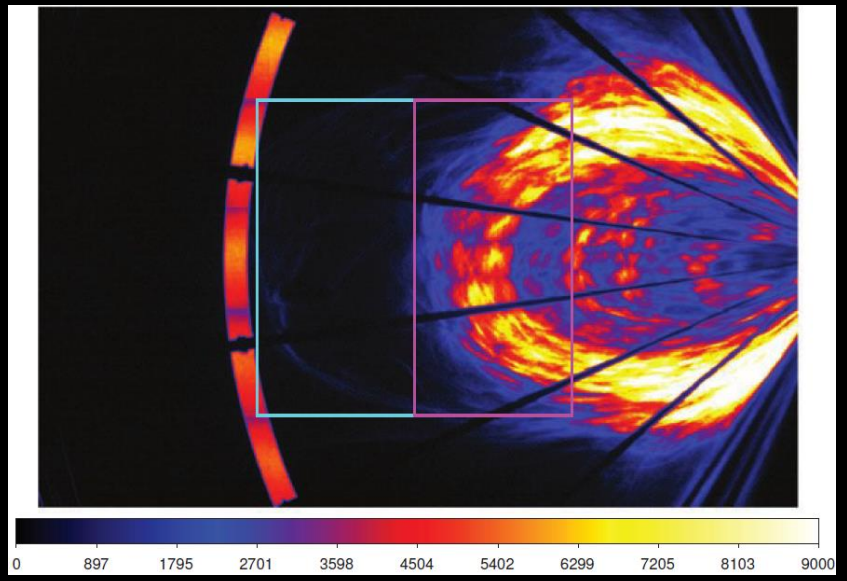
X-Ray Effectiveness

- Straylight Rejection EM
  - Secondary Reflection
  - Backside Reflection





Hideyuki Mori, Yoshitomo Maeda, Manabu Ishida, Takuro Sato, Kou Ichihara, et al., "The pre-collimator for the ASTRO-H x-ray telescopes: shielding from stray lights", *Space Telescopes and Instrumentation 2012: Ultraviolet to Gamma Ray,* Proc. of SPIE Vol. 8443 84435B-1

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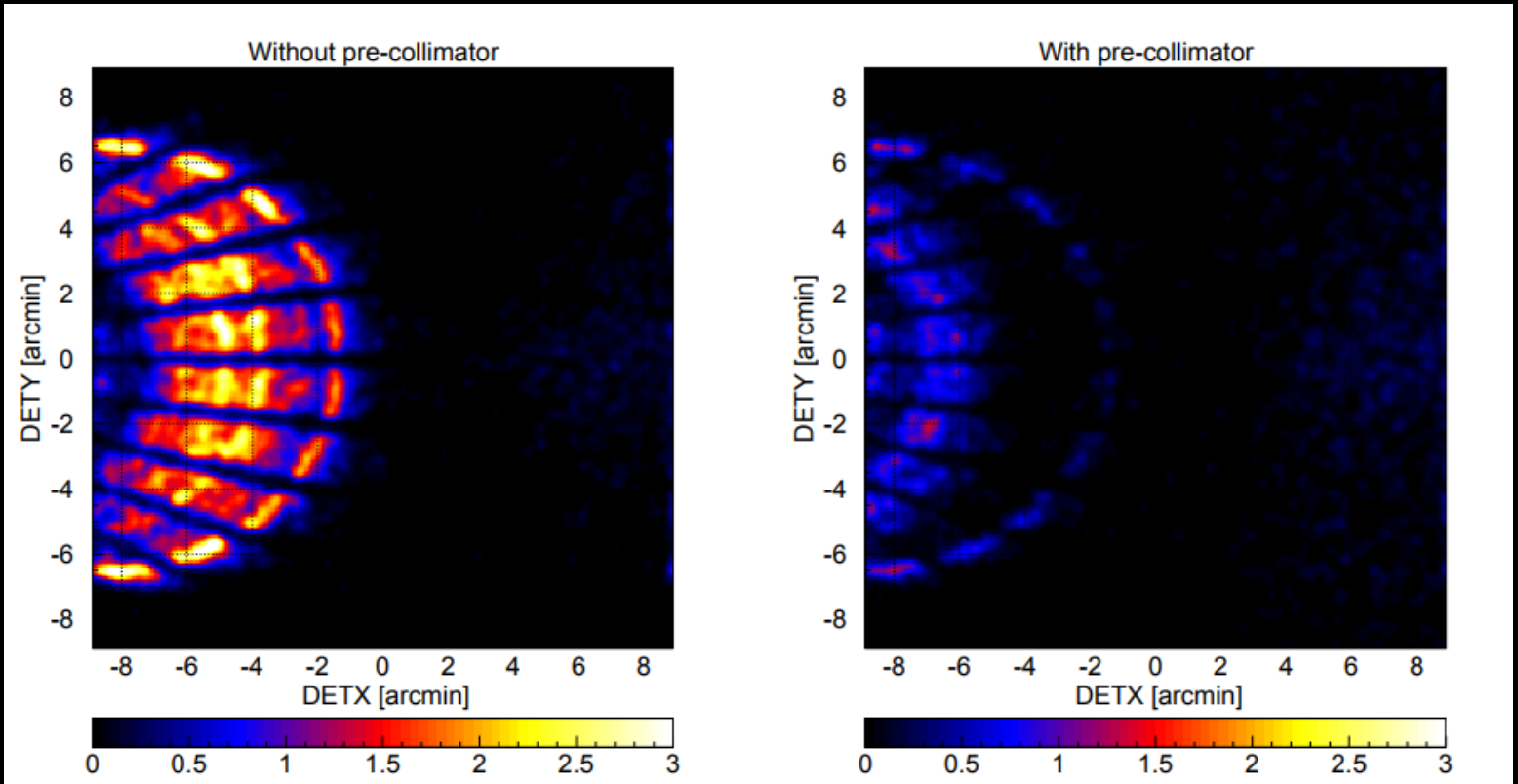
X-Ray Effectiveness

- Crab Nebula Placed Off-Axis
- Stray light with Engineering model



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X-Ray Effectiveness

- Must get better optics
- Physically block straylight
- Must match alignment
  - Mirror and precollimator
  - Unique Trials for Engineering Model

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Precollimator

- *Suzaku* X-Ray Telescope
  - Pre-collimator
  - Mirrors
- Alignment is critical

NASA/JAXA

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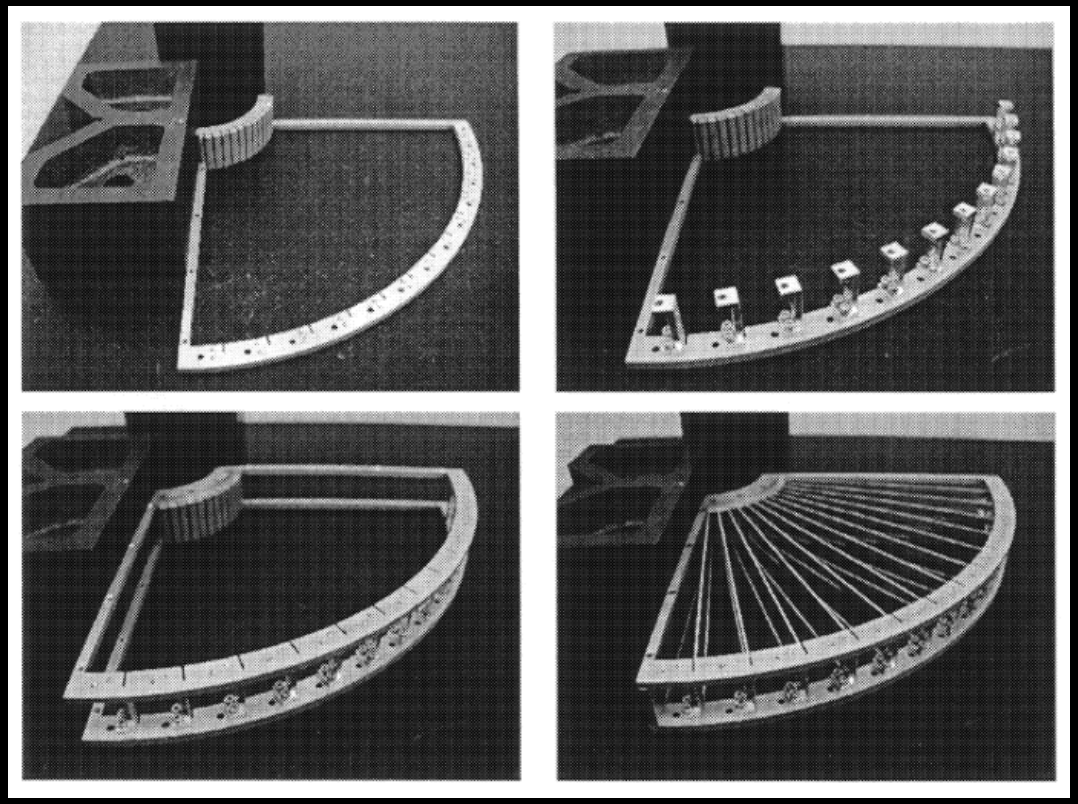
Past Production: Suzaku

- Alignment frame
- Individual metal foil



Hideyuki Mori, et al.,
Development of Astro-E2 XRT pre-collimator or stray—light protection
Optics for EUV, X-Ray, and Gamma-Ray Astronomy, Proc. SPIE Vol. 5168

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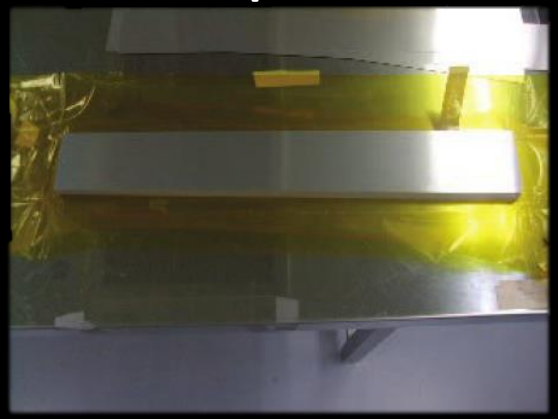
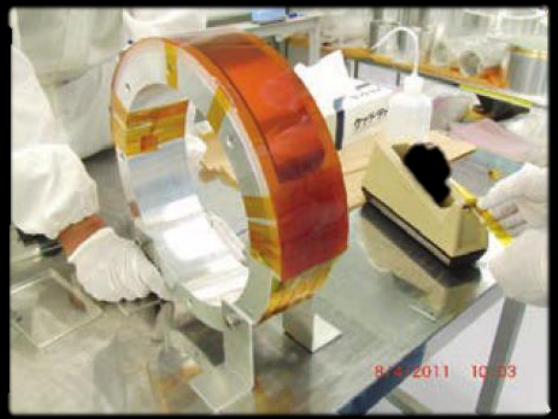
Past Production: Hitomi

- Complex build with individual sheets of foil





* Hideyuki Mori, et al.,
The pre-collimator for the ASTRO-H x-ray telescopes: shielding from stray lights
Space Telescopes & Instrumentation 2012: Ultraviolet to Gamma Ray, Proc. of SPIE Vol. 8443, 84435B

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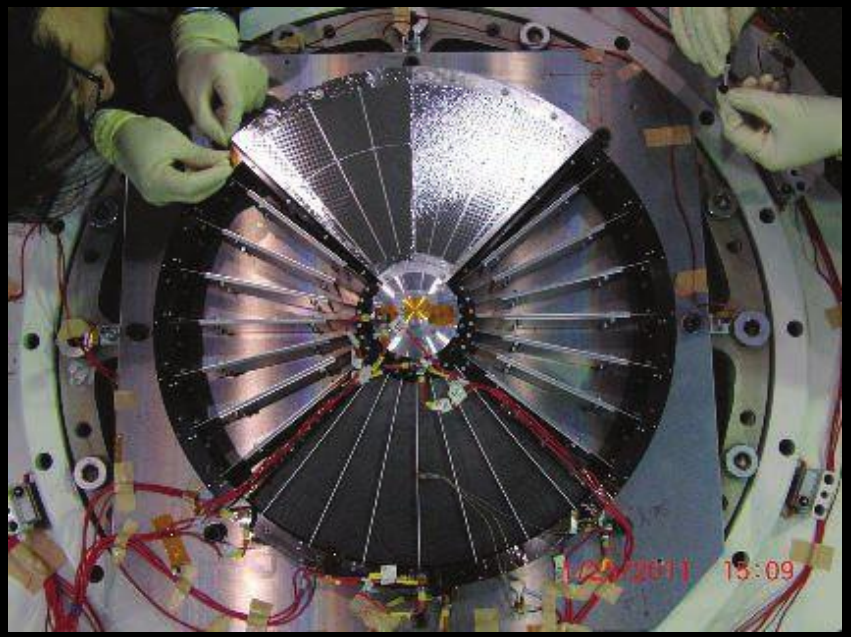
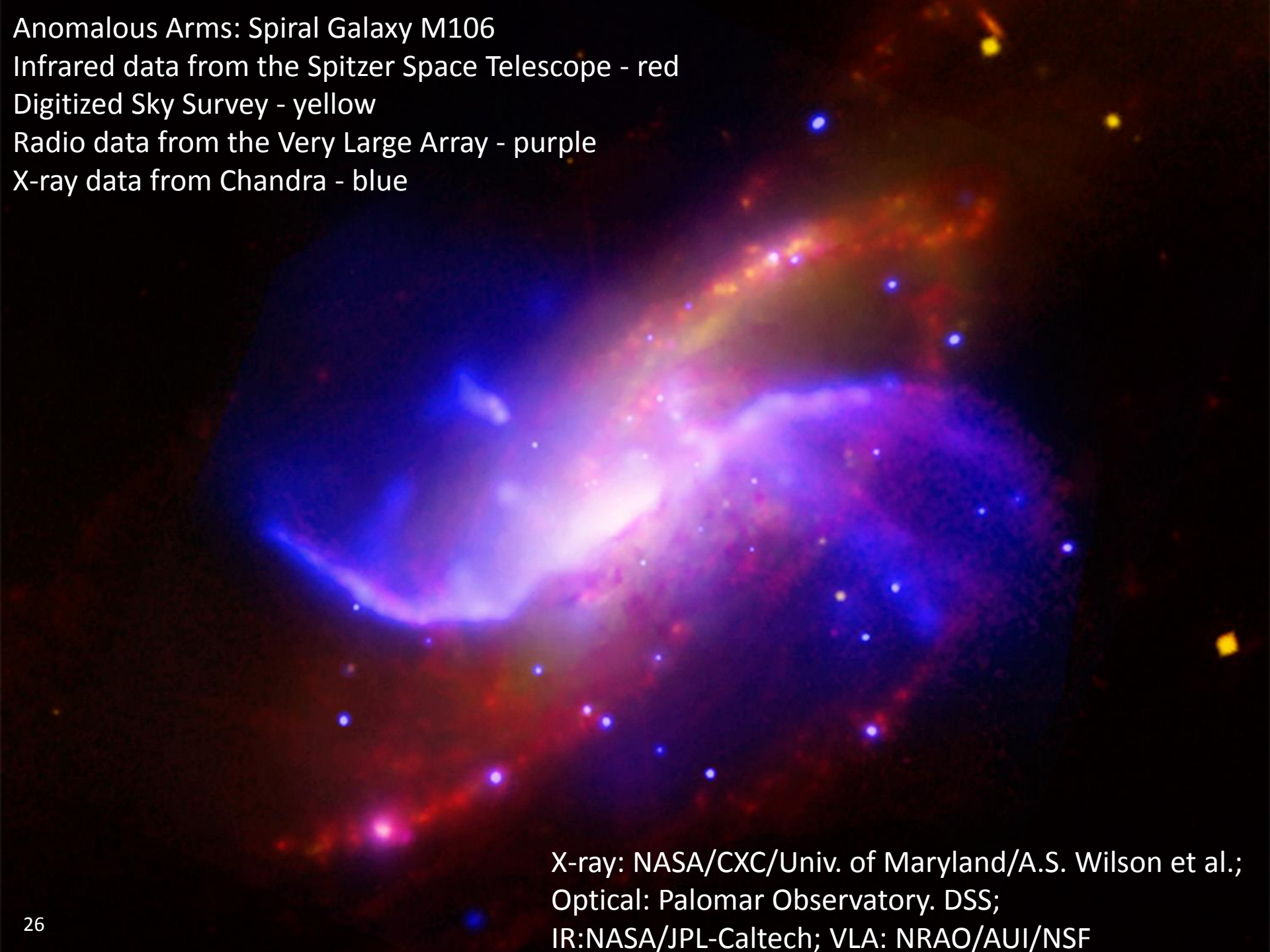
Past Production: Hitomi

- Labor intensive
- Vibration problems
- Foil bending/alignment mismatch



NASA/Hideyuki Mori, et al.,*


Anomalous Arms: Spiral Galaxy M106
Infrared data from the Spitzer Space Telescope - red
Digitized Sky Survey - yellow
Radio data from the Very Large Array - purple
X-ray data from Chandra - blue
X-ray: NASA/CXC/Univ. of Maryland/A.S. Wilson et al.;
Optical: Palomar Observatory. DSS;
IR:NASA/JPL-Caltech; VLA: NRAO/AUI/NSF

Tycho Supernova

X-ray: NASA/CXC/SAO,
Infrared: NASA/JPL-Caltech;
Optical: MPIA, Calar Alto, O.Krause et al.

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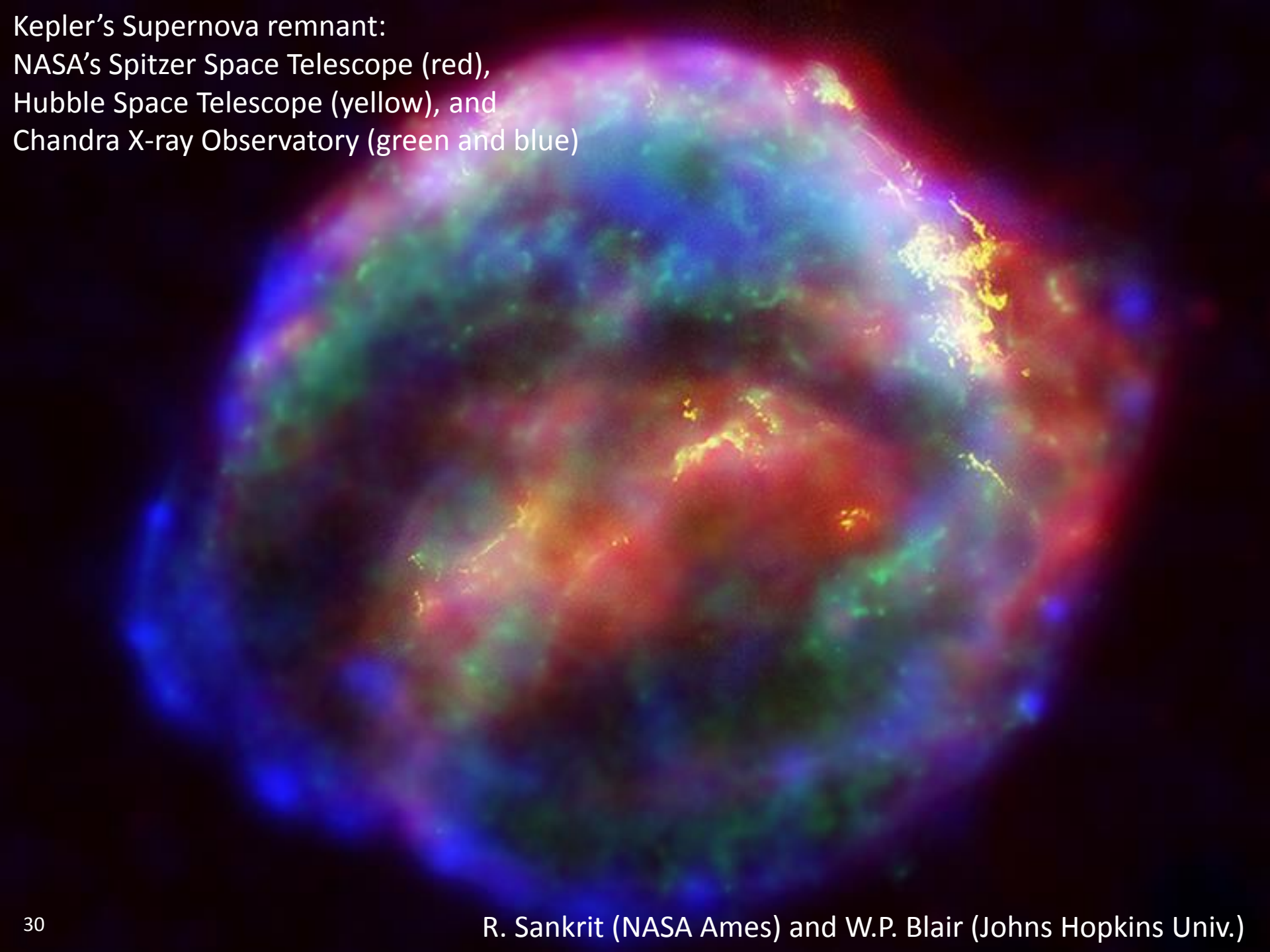
Giant Black Hole Kicked Out of Home Galaxy: CID-42

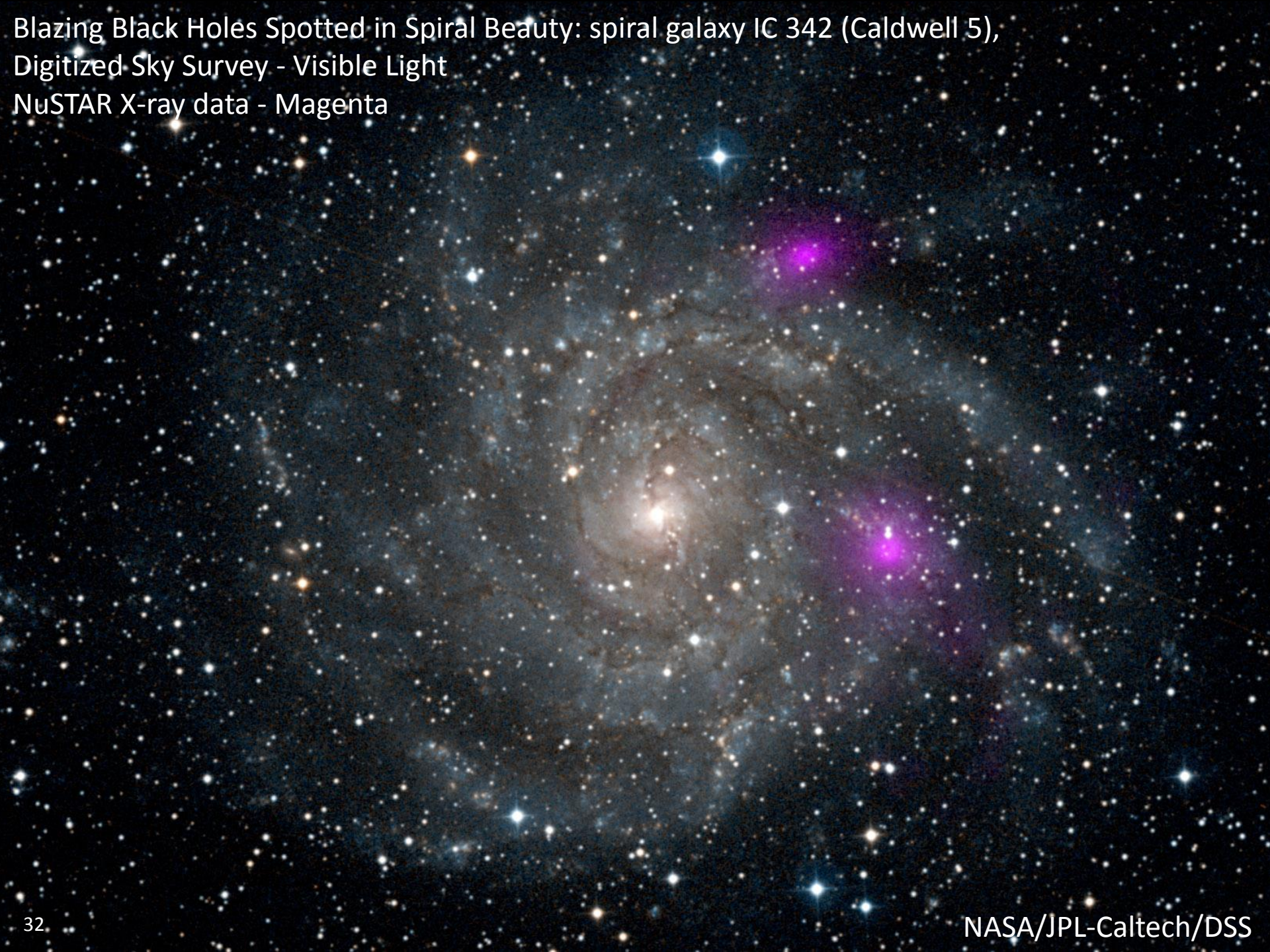
X-ray: NASA/CXC/SAO/F.Civano et al;
Optical: NASA/STScI;
Optical (wide field): CFHT, NASA/STScI

Tarantula Nebula

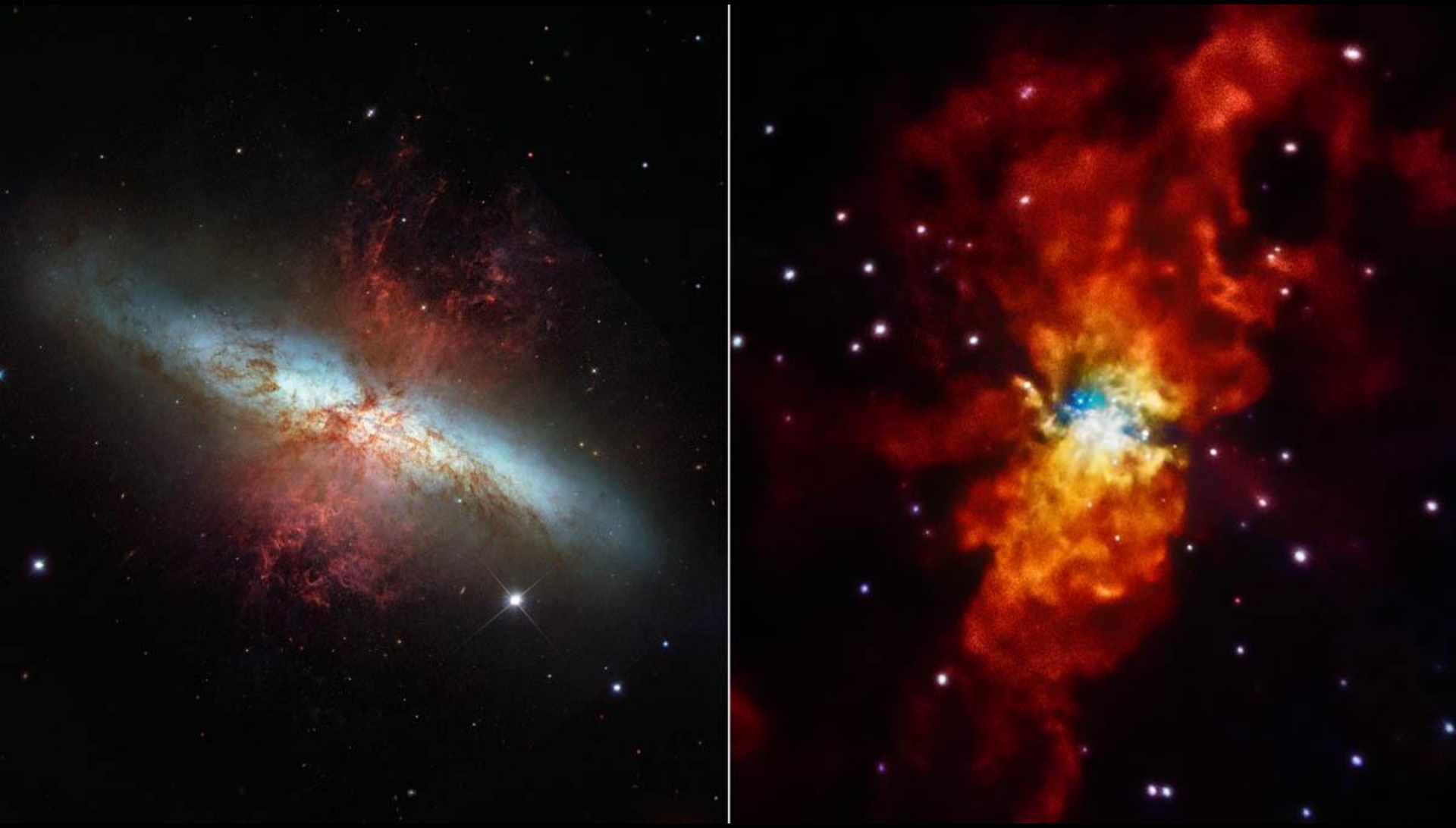
X-ray: NASA/CXC/PSU/L.Townsley et al.;
Infrared: NASA/JPL/PSU/L.Townsley et al.


Kepler’s Supernova remnant:
NASA’s Spitzer Space Telescope (red),
Hubble Space Telescope (yellow), and
Chandra X-ray Observatory (green and blue)
R. Sankrit (NASA Ames) and W.P. Blair (Johns Hopkins Univ.)


RCW 86 supernova remains
NASA's Spitzer and WISE Telescopes (red and orange),
NASA's Chandra X-ray Observatory (blue)
European Space Agency's XMM-Newton Observatory (green)
B. Williams (NASA GSFC)


Blazing Black Holes Spotted in Spiral Beauty: spiral galaxy IC 342 (Caldwell 5),
Digitized Sky Survey - Visible Light
NuSTAR X-ray data - Magenta
NASA/JPL-Caltech/DSS

Hubble & Chandra



Messier 82 (M82)

NASA

Overview

Precollimator

- Past
- Present
- Future

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Present

- Mindrum Precision
  - researching Precollimator since 2011

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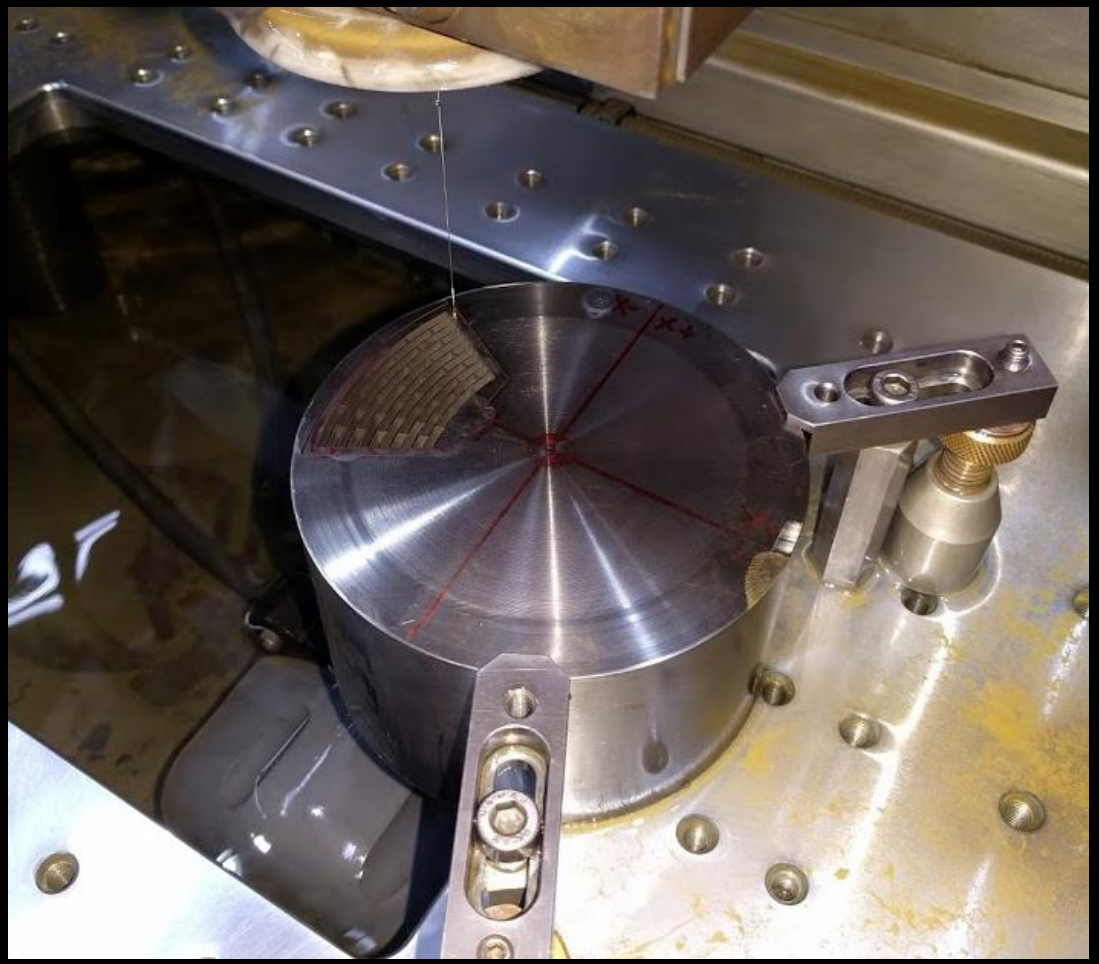
Present

- Wire EDM
- Additive Manufacturing
- Chemical Milling



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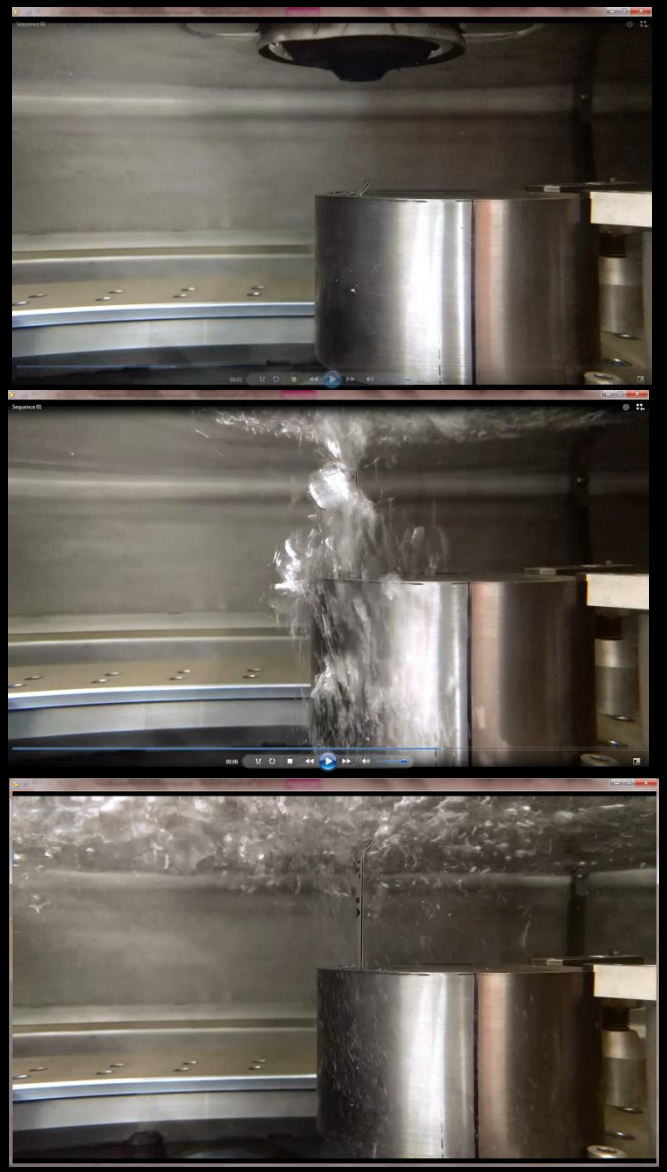
Present

- Wire EDM
  - Efficient cutting
  - Repetitive precision
  - Increased design flexibility



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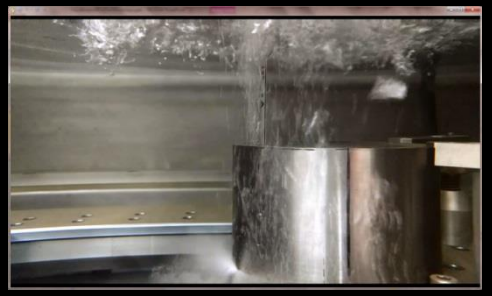
Video



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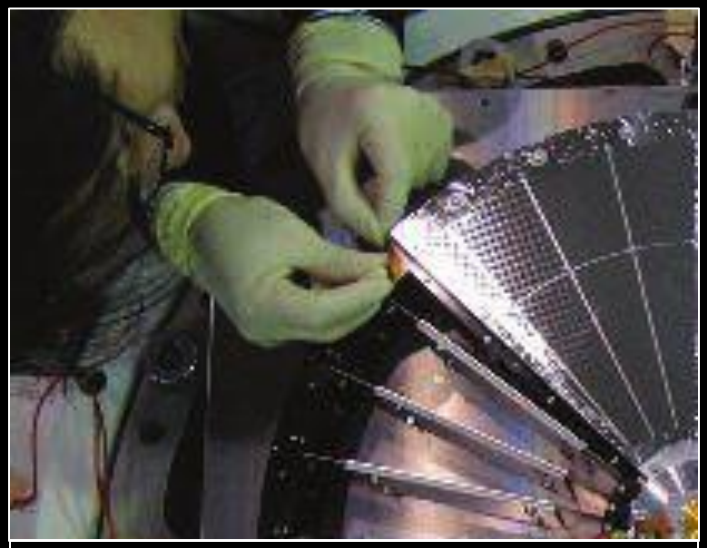
Present

- Monolithic/unibody design
  - Combined blades and support structure
  - Increased mechanical integrity/higher strength



NASA/ASTRO-H

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Present

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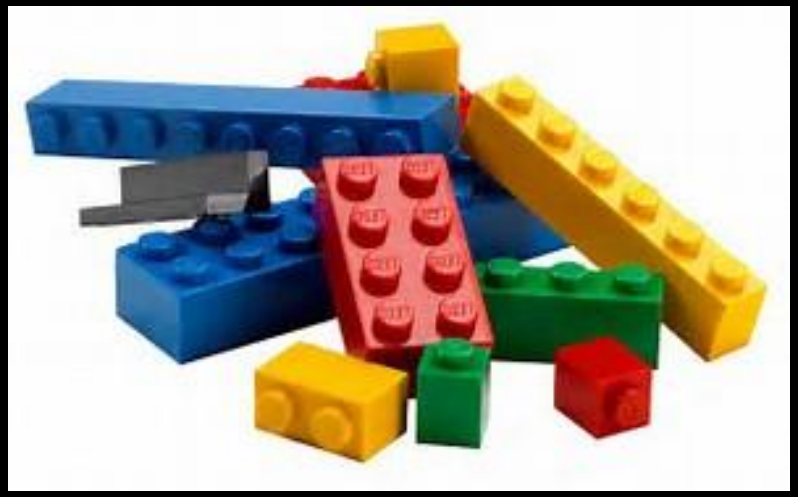

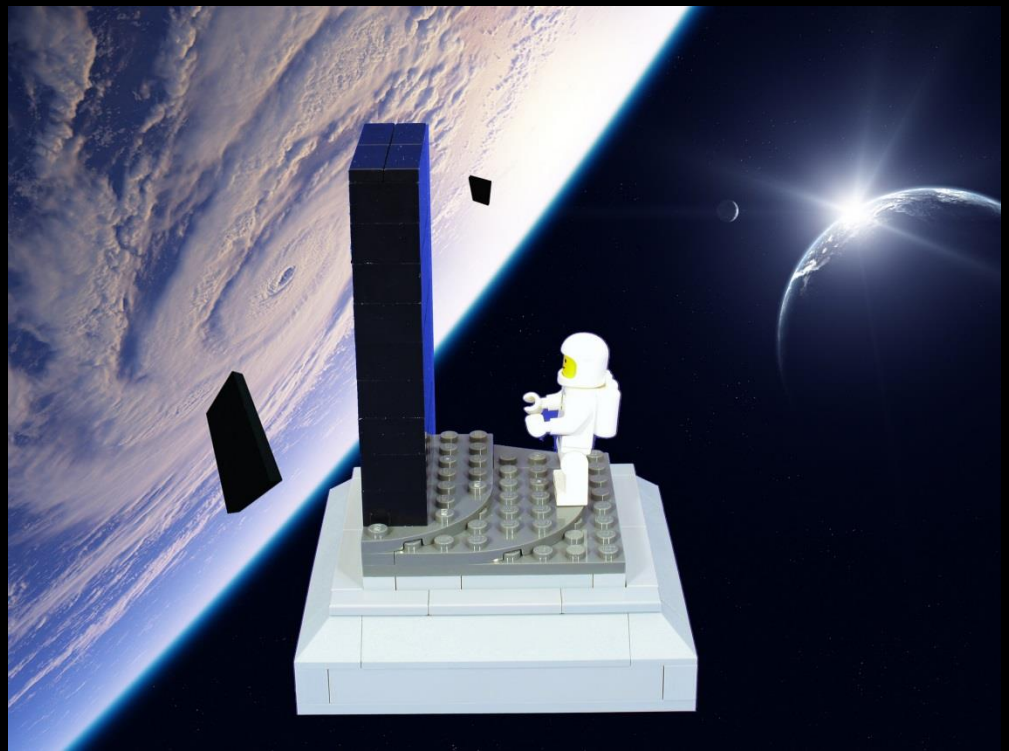

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Present

- Still need start hole
- Additive manufacturing investigated and rejected

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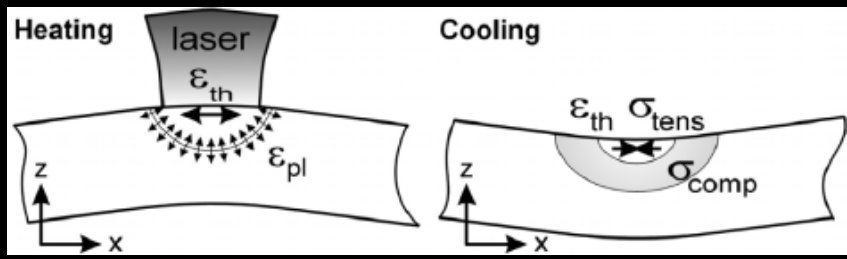
Present

- Additive Manufacturing
  - Electron Beam Melting
  - Laser Sintering



- Unable to hold tolerance
  - Curling of walls beyond 0.040” [1mm] thick
  - Unsuccessful kept adding support material
  - Better to start off with solid material

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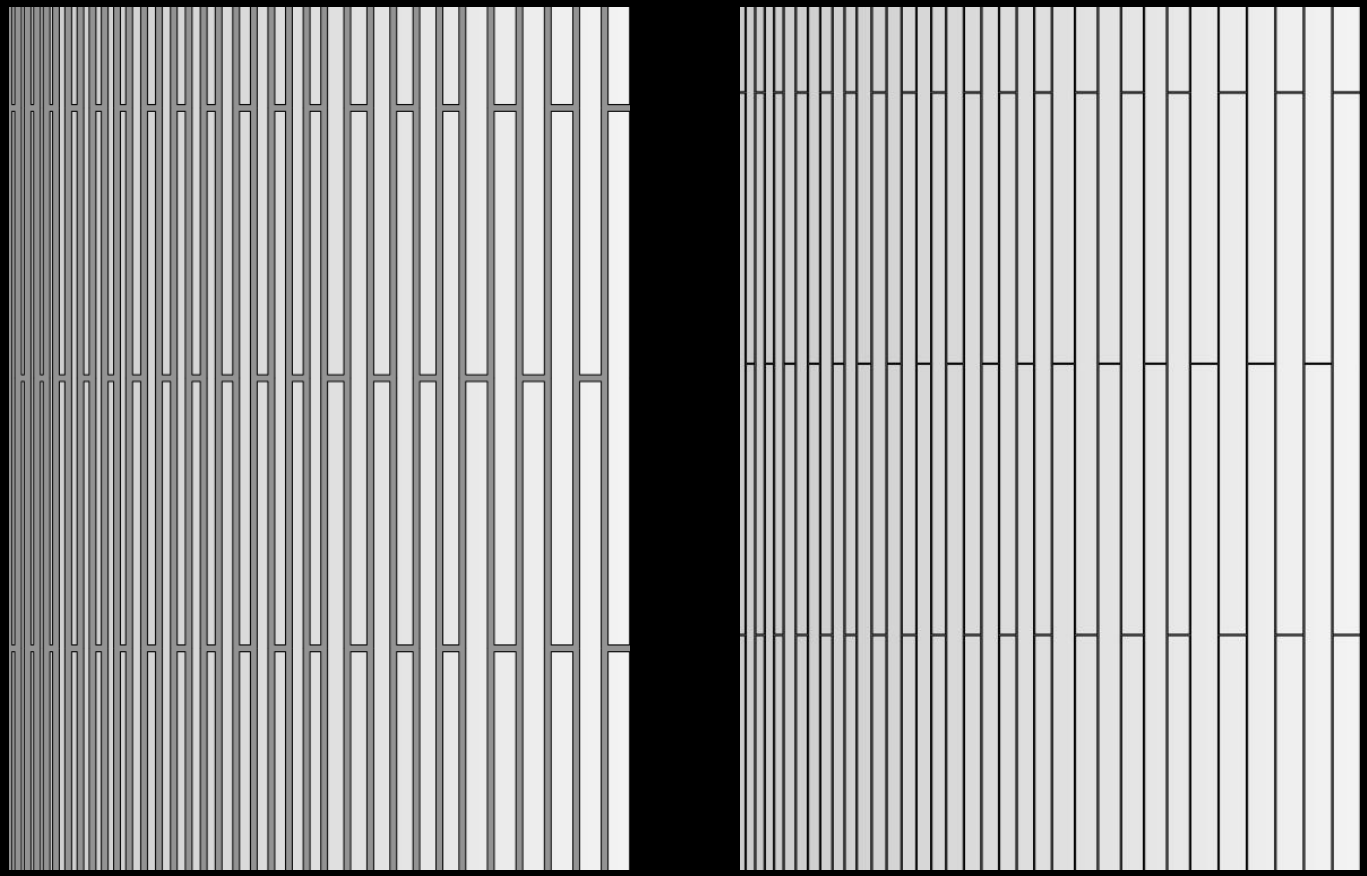
Present

- Reduce thickness/weight



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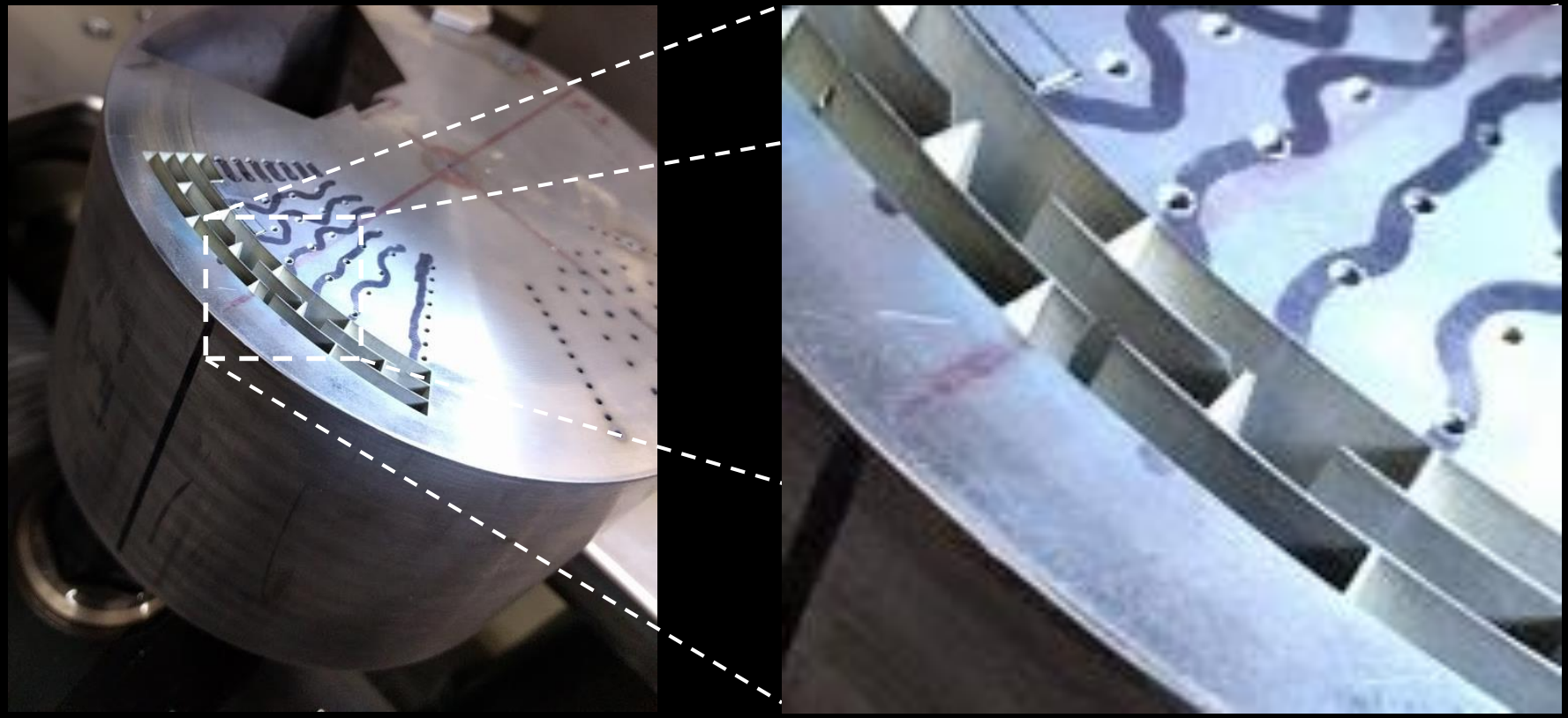
Present

- EDM unable to thin wall 0.004” [0.1mm]



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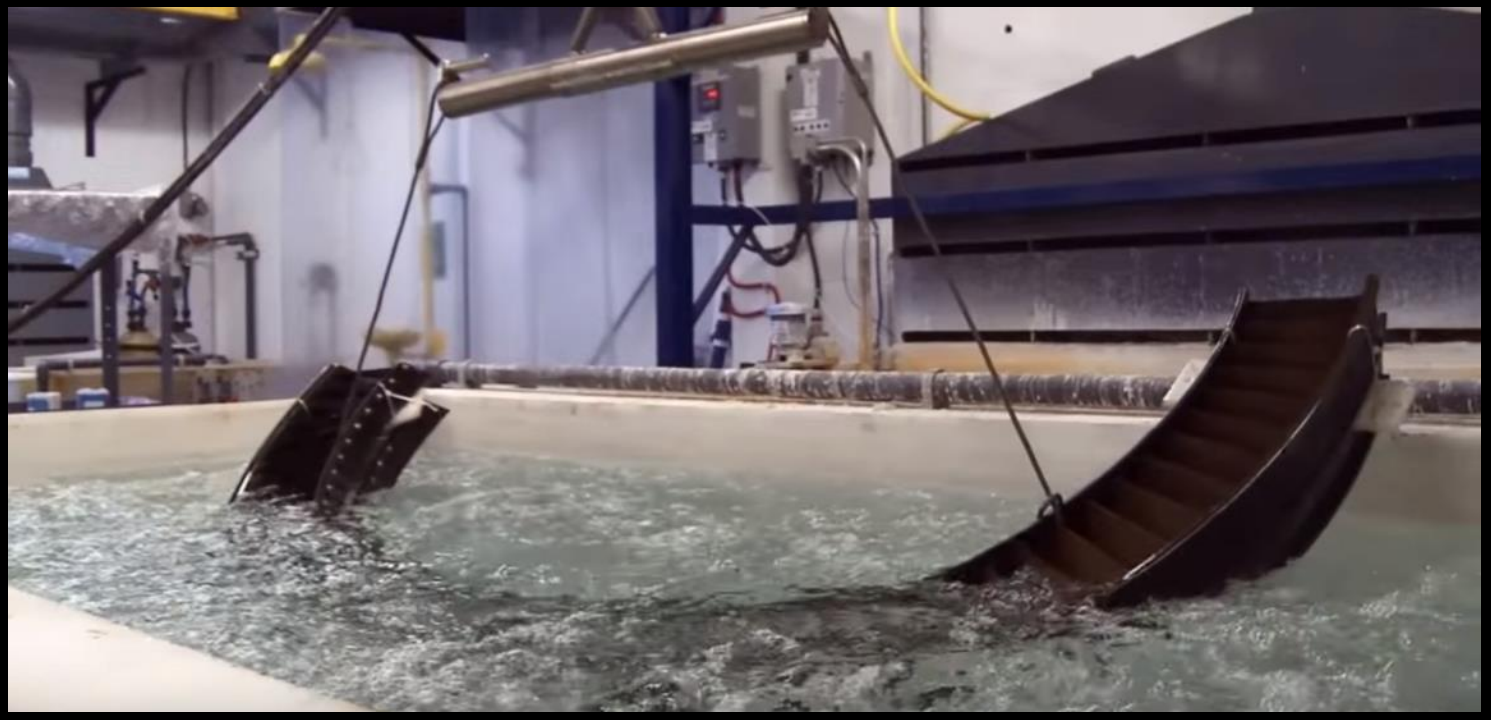
Present

- Chemical Milling
  - Uniform Removal of material
  - Known hydrogen embrittlement characteristics



Present

- Wire EDM with Chemical Milling
  - Hands off machining
  - Reduced cost
  - Faster production
  - Large, unique, diverse geometry
- Multiple prototypes for Engineering Models (EM)

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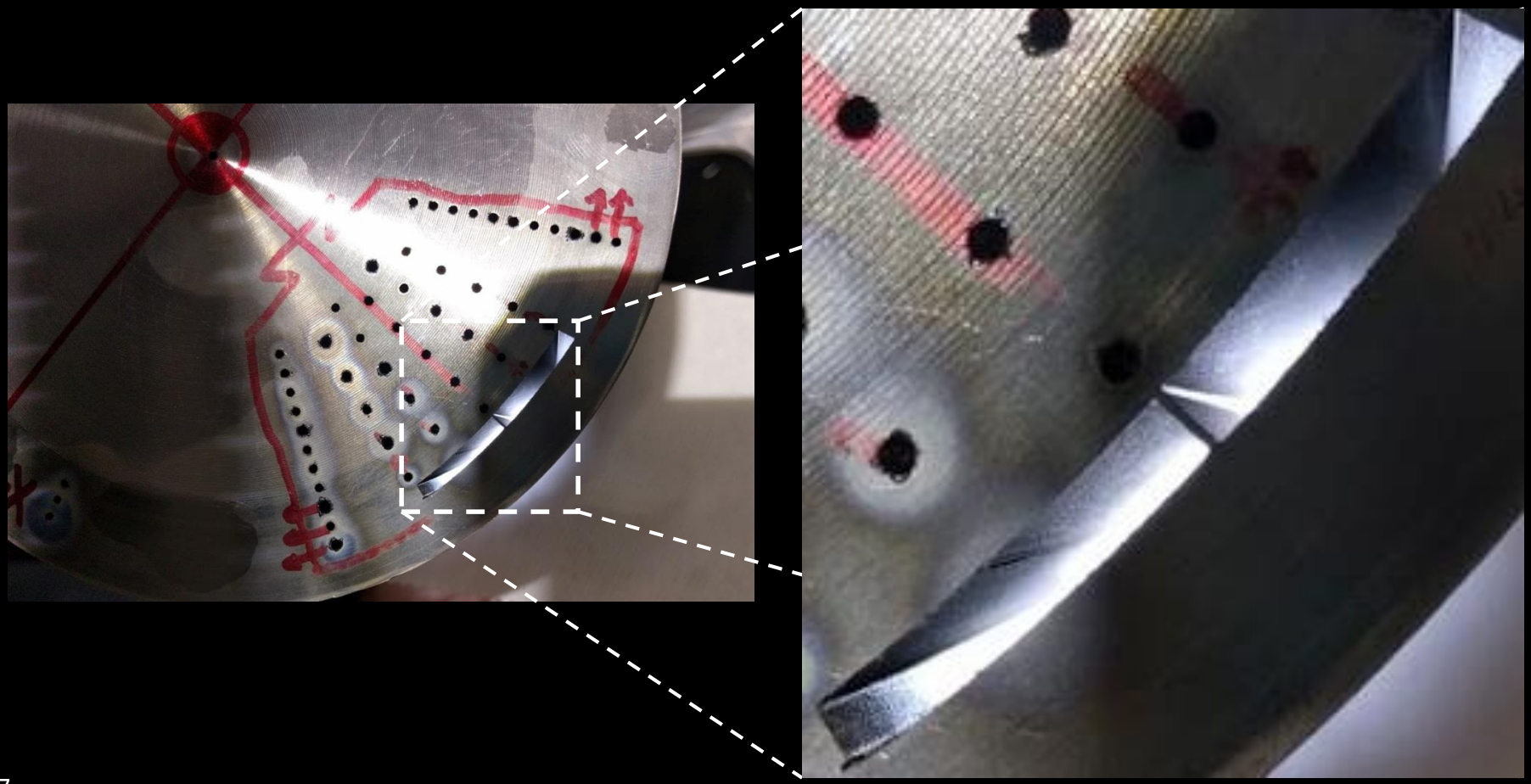
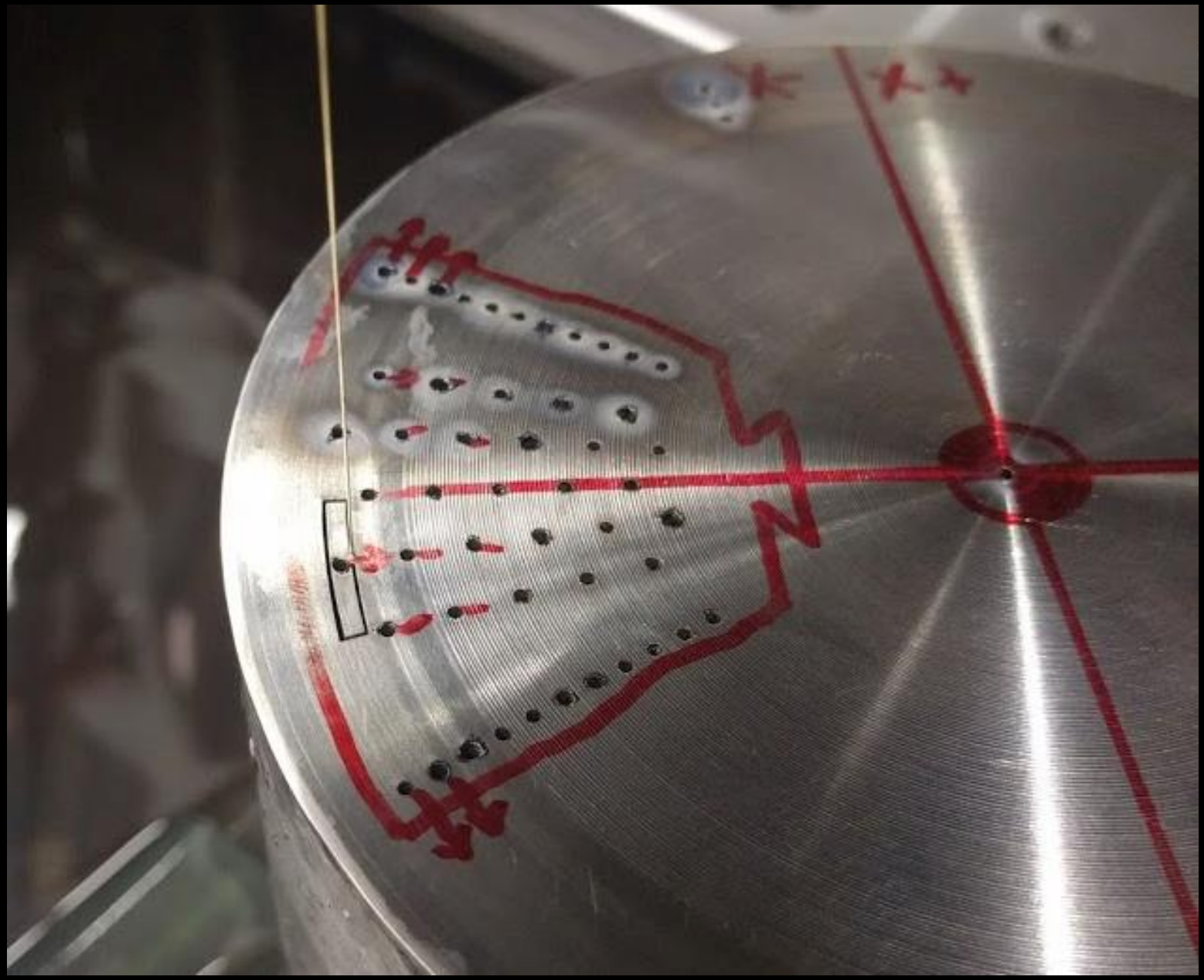
Present

- Rough or smooth surface finish





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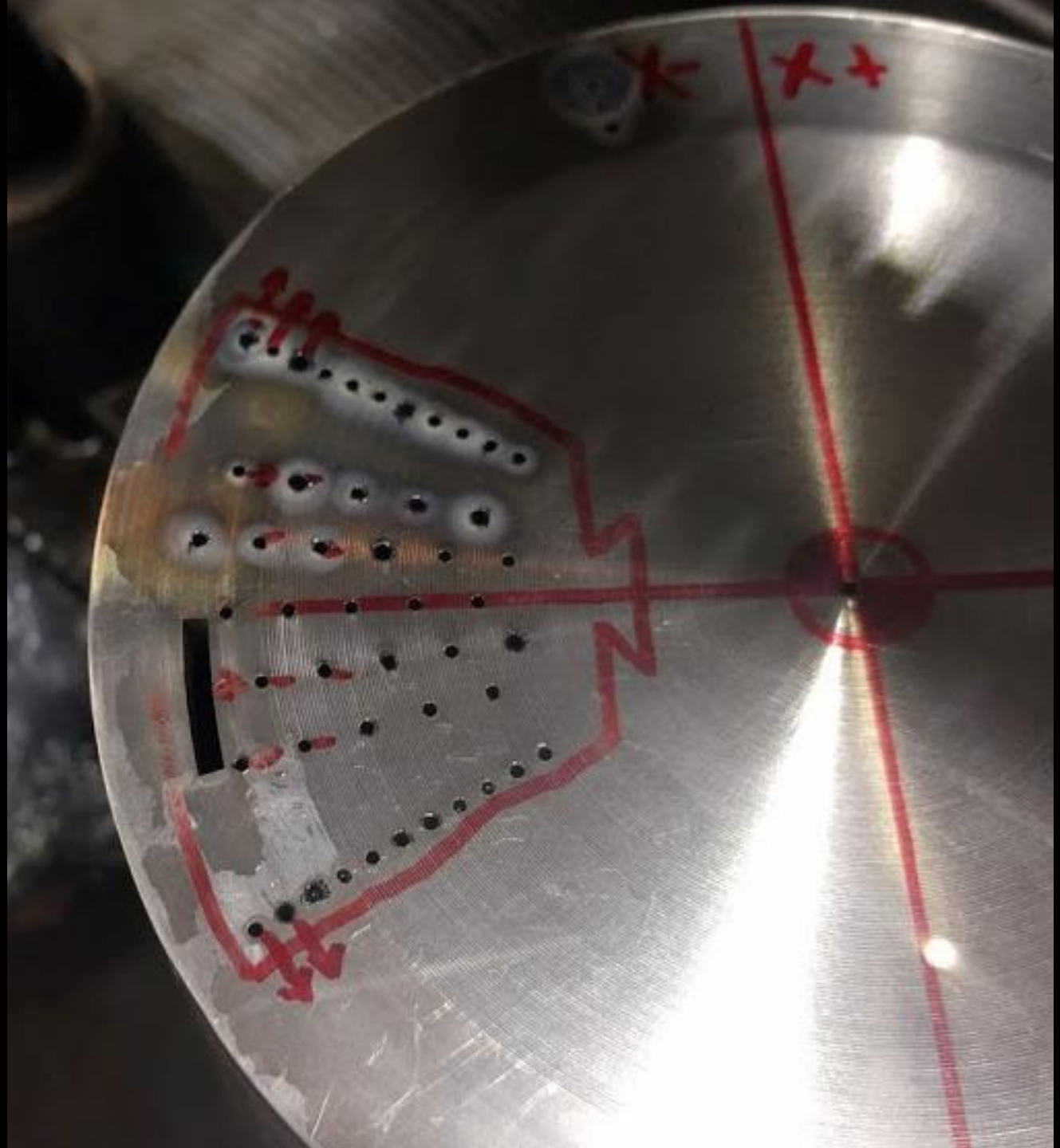

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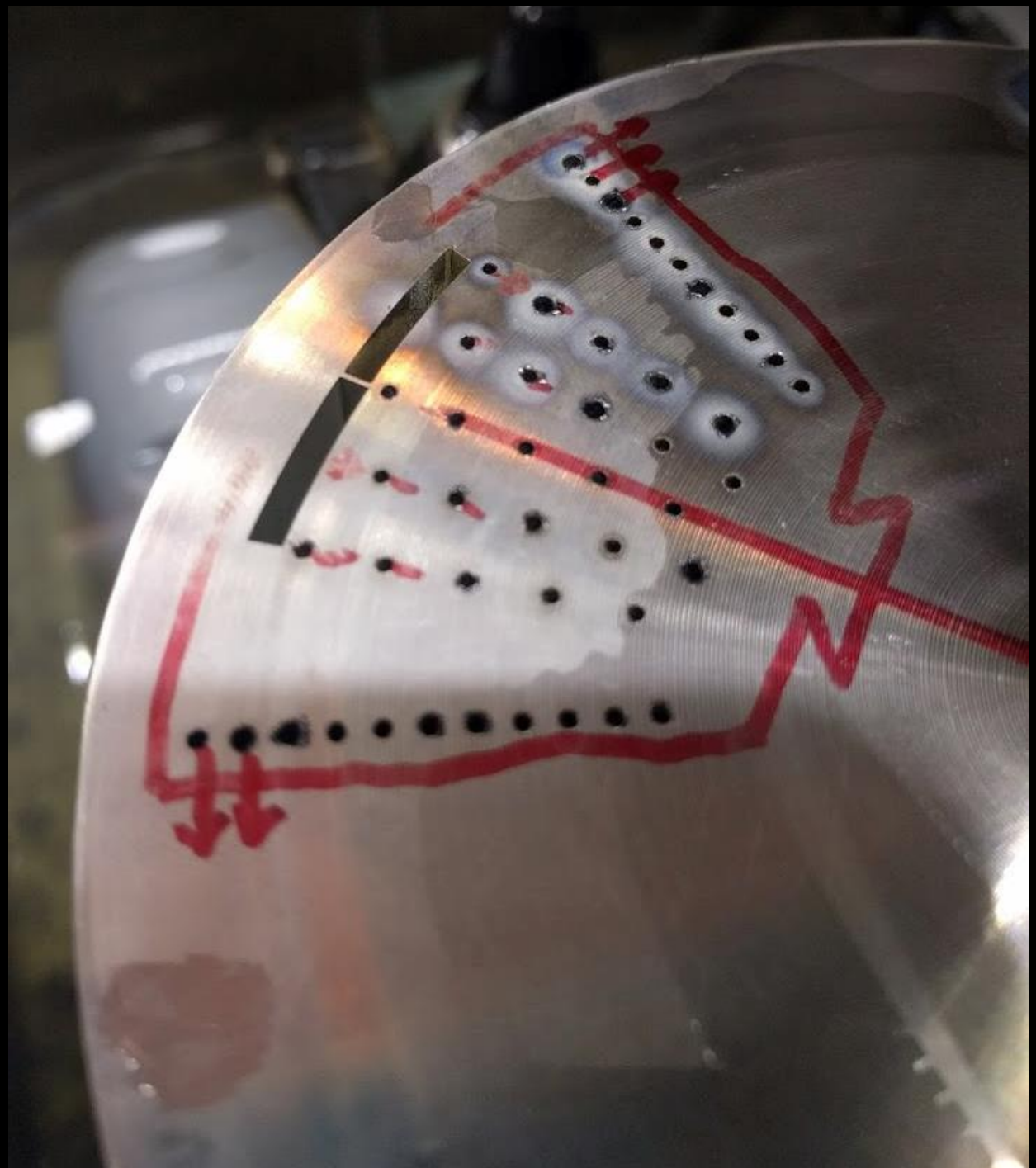

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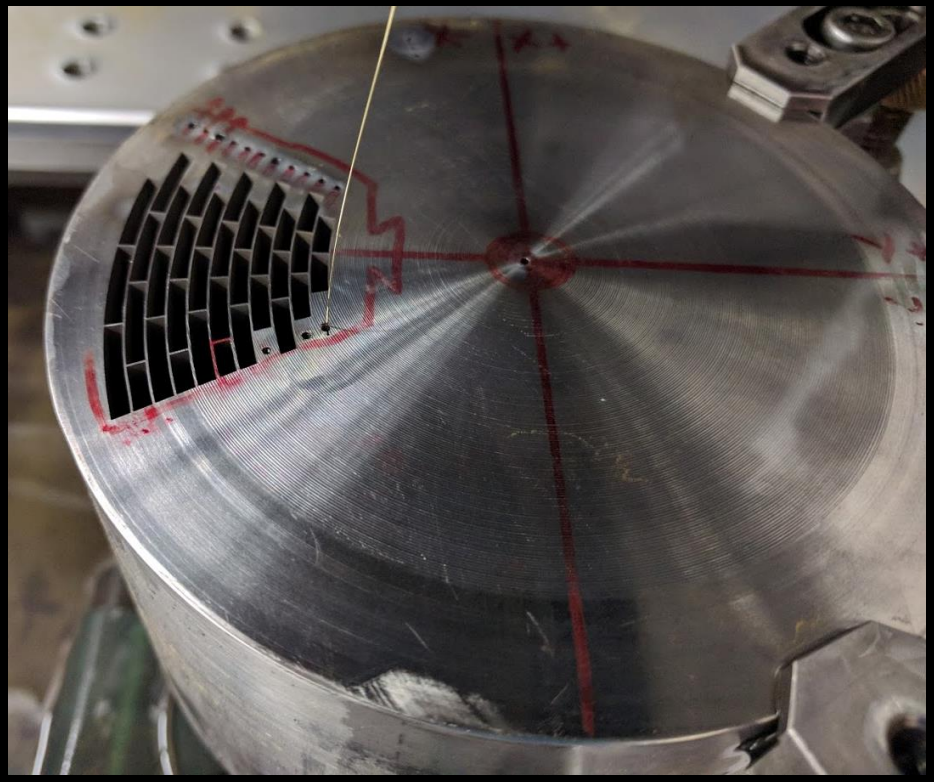

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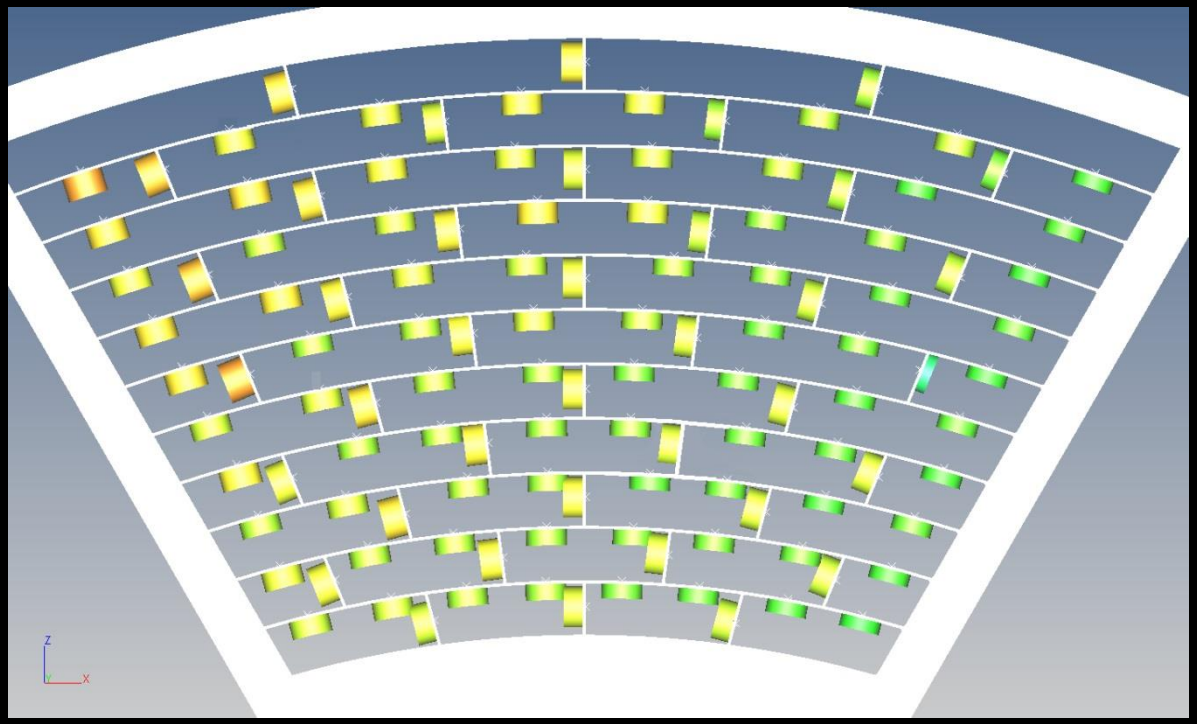
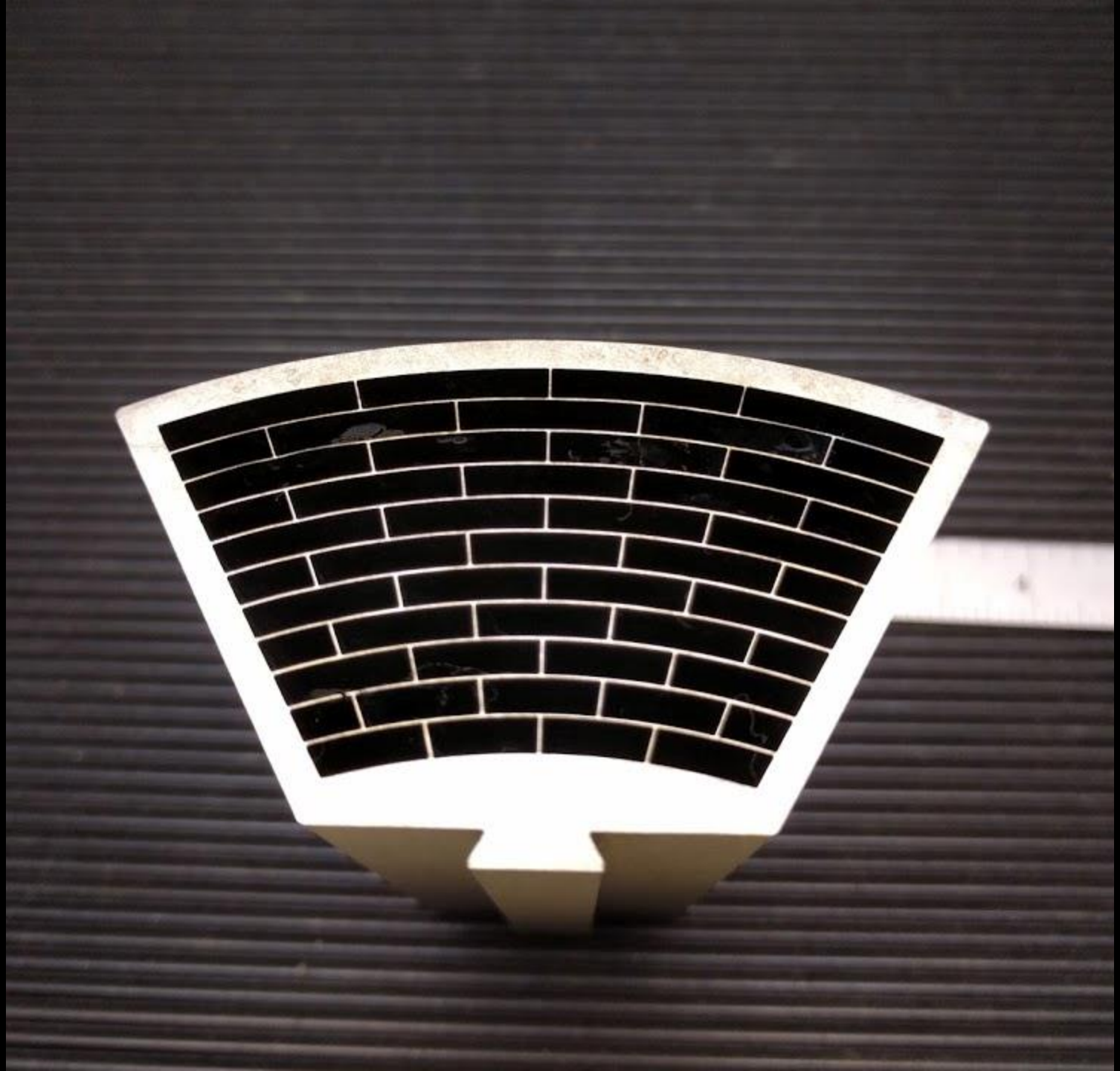
- Optically or mechanically measured for
  - Thickness
  - True position alignment





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Overview

Precollimator

- Past
- Present
- Future

Future Input Requested

- Blade
  - Height
  - Length
  - Thickness: thinner than mirror 90 - 150 µm
- Alignment Geometry: Blade - mirror
- Gap between mirror and blade features
- Material Needs

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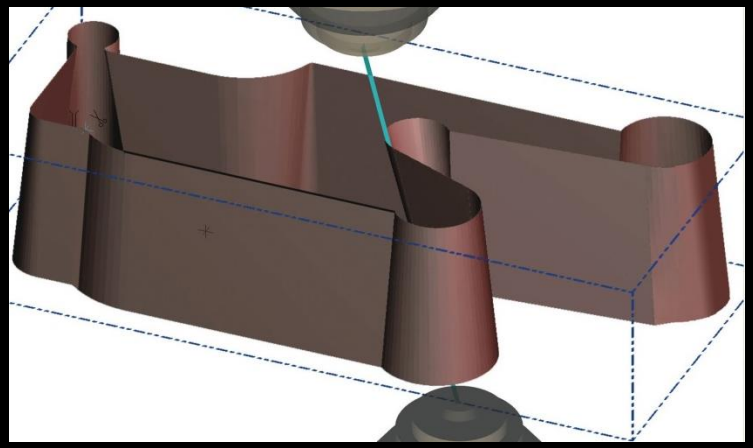
Future

- Possible capabilities
  - Tapered walls or notches
  - Multi layer assemblies
  - Coatings
  - Integrated Mounting clamps
- Call for telescope needs (Diameter, Gap width, Rib width, weight restriction, Height)



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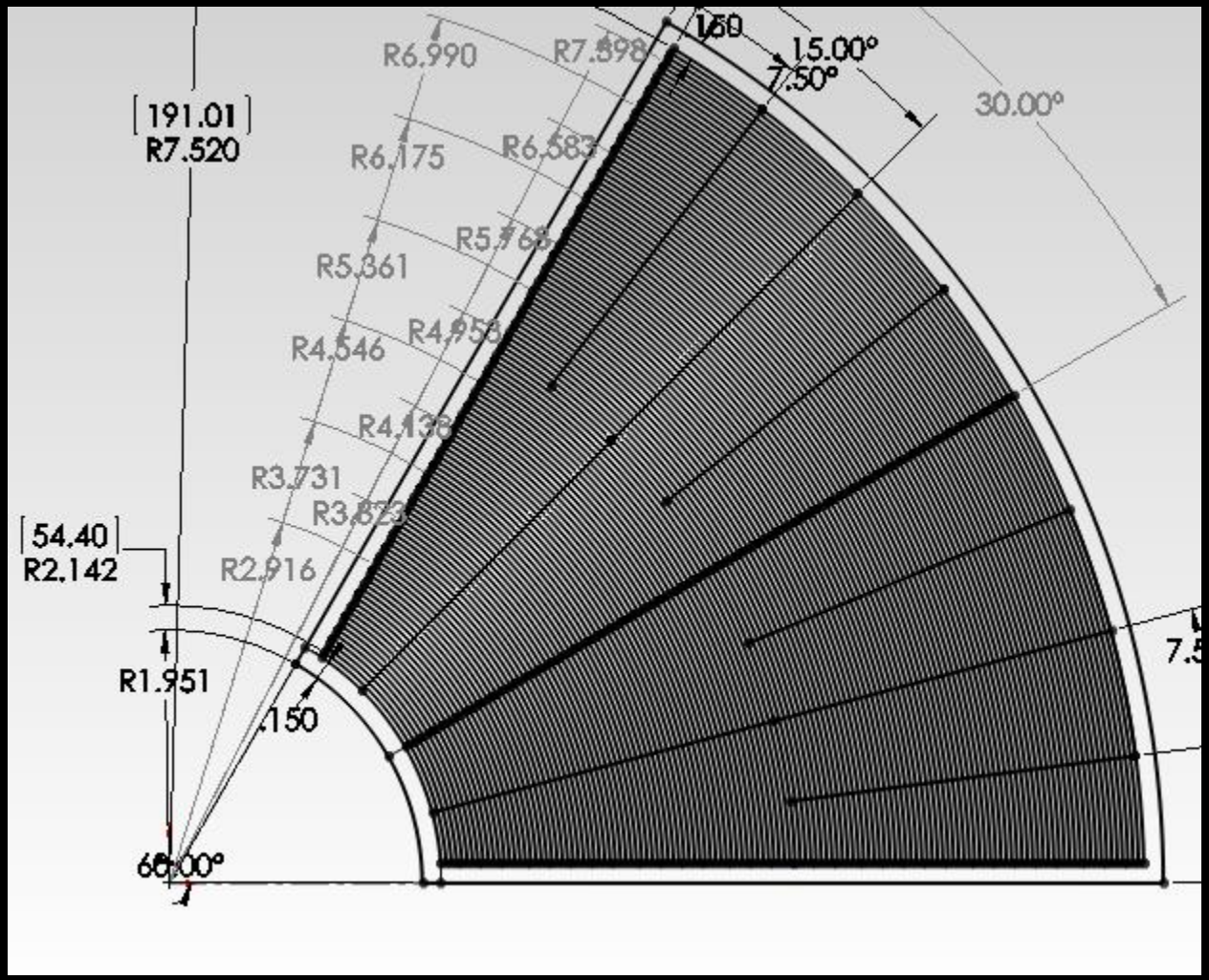
Future

- NuSTAR
  - 133 blades
  - Section pattern
  - Irregularities



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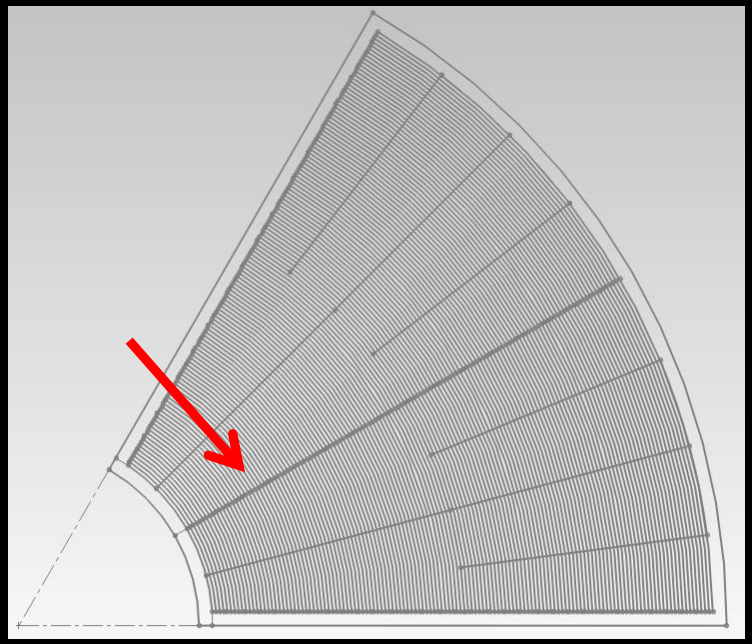
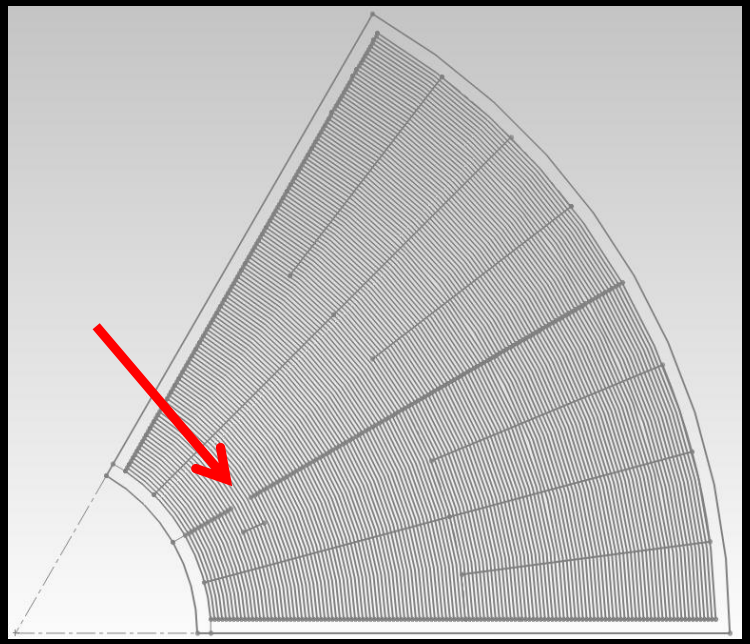
Future: Mindrum Improvement

- Patterned for mirror irregularity
- Fully customized support structure
- Increased precollimator/mirror alignment





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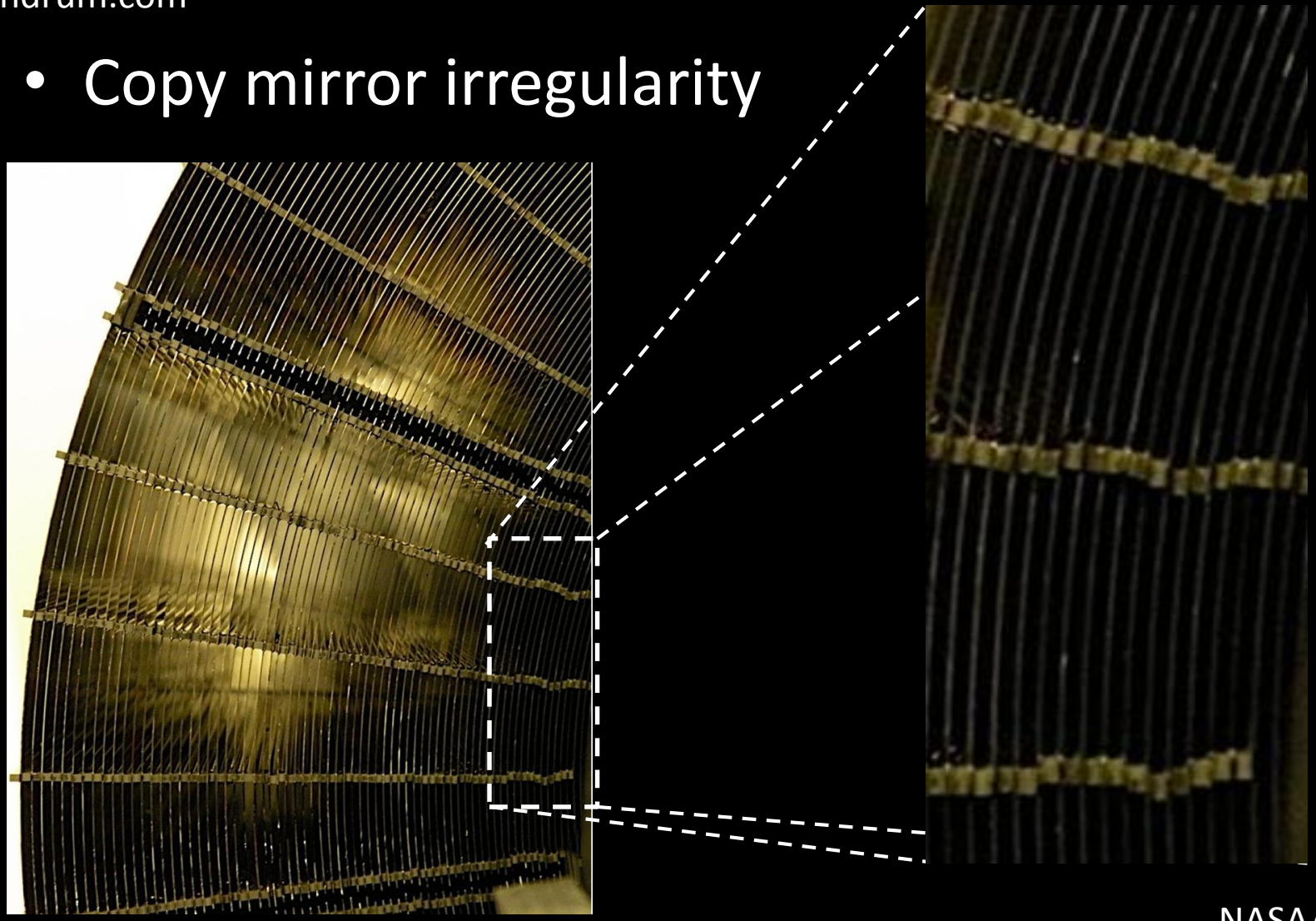
Future

- Copy mirror irregularity



NASA/JPL-Caltech

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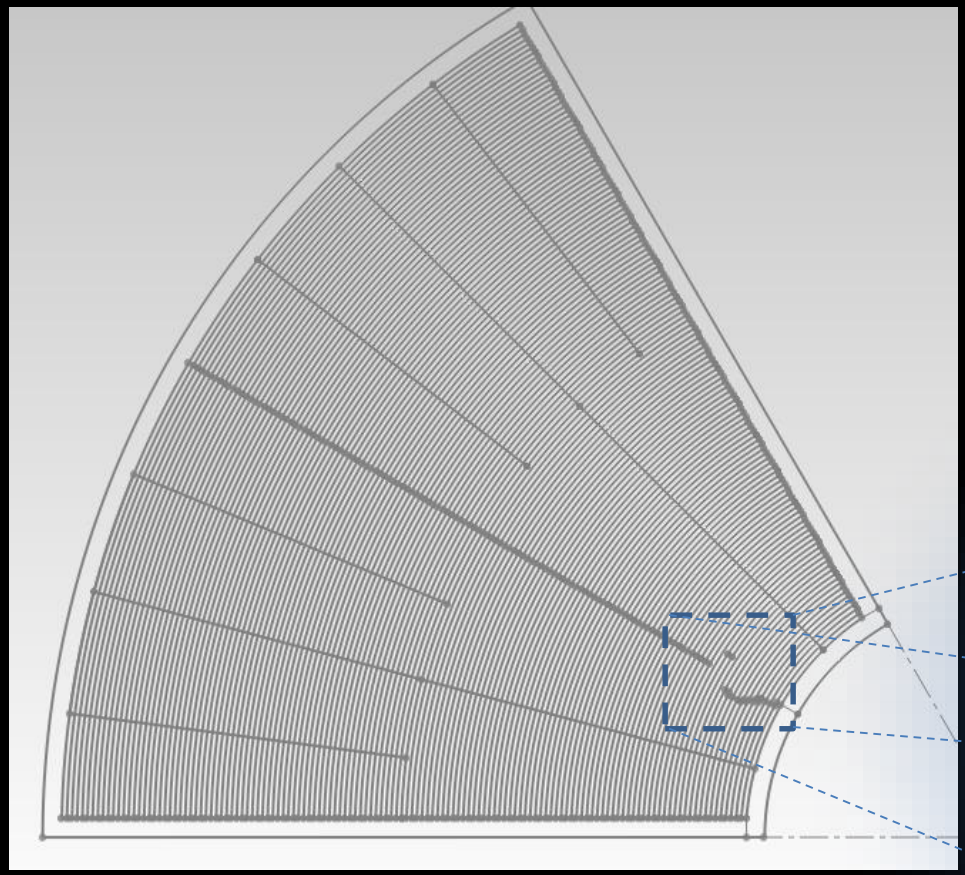
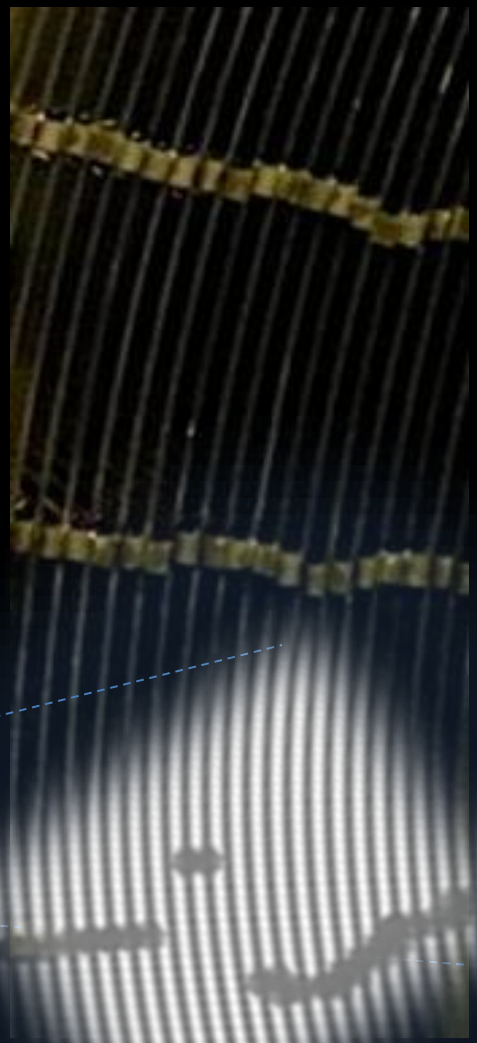
Future

- Copy mirror irregularity





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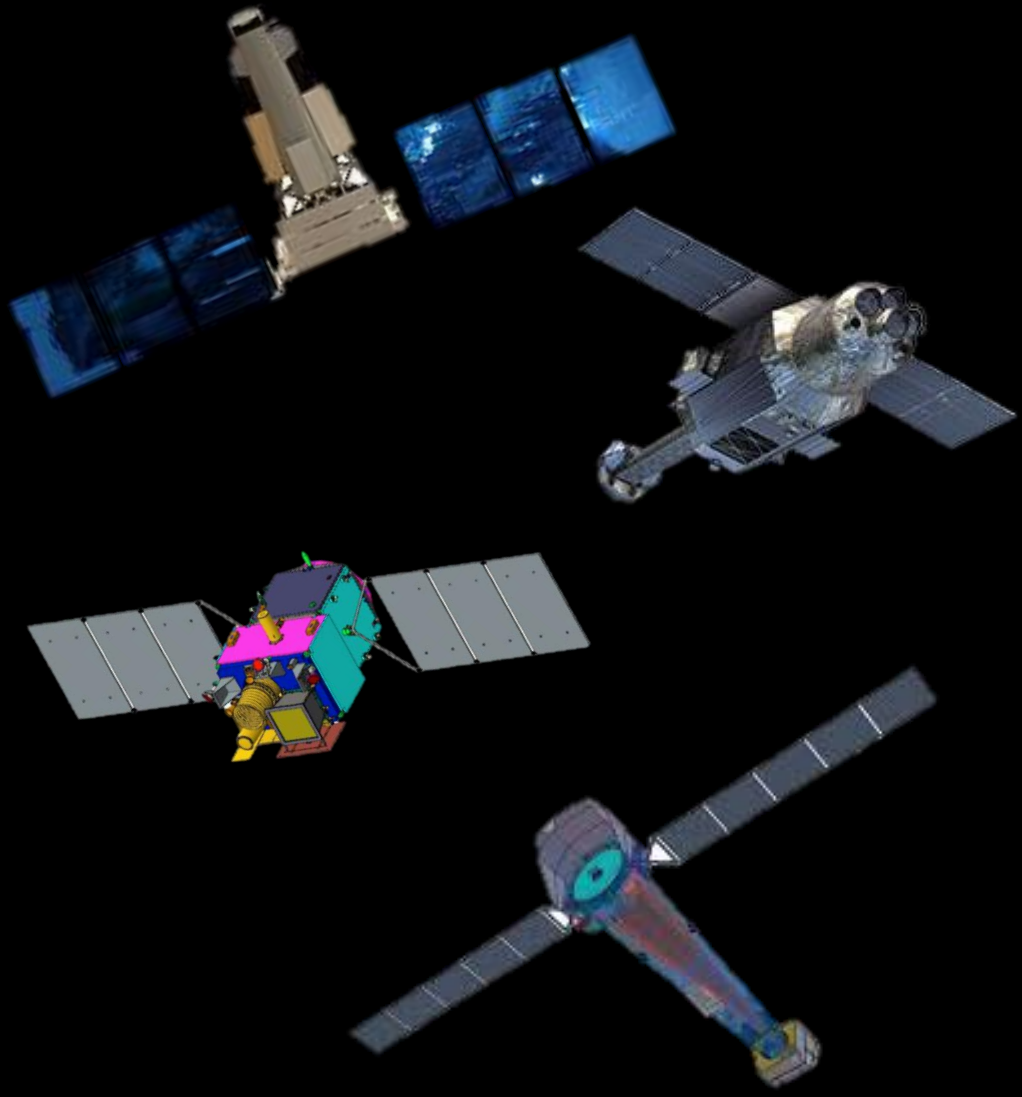
Future

- Spektr-RG 2018
- XARM (Astro-H 2) 2020
- SVOM 2021
- ATHENA 2028



Future

- Capable of growth for new XRT demands
  - Larger detection area (>2 m^2 at 1 keV, 0.25 ath 6 keV)
  - Broader energy range
  - Diverse field of view (Narrow-5’ / Wide-40’x40’)
  - Angular resolution lower than 5”
  - a time resolution < 10μs
  - high count rate capability

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Future

- Requires new precollimator shapes
- Mindrum Precision create new geometry
  - Create lighter structures
  - Unique shapes
  - Engineering Model (EM) variants
  - Prove increased capability/calibration
  - Integrate solid body alignment with optic mirrors

Overview

Precollimator

- Past XRT work
- Present Precollimator
- Future Growth