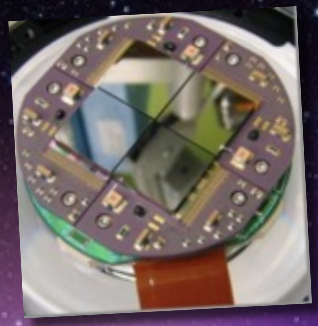
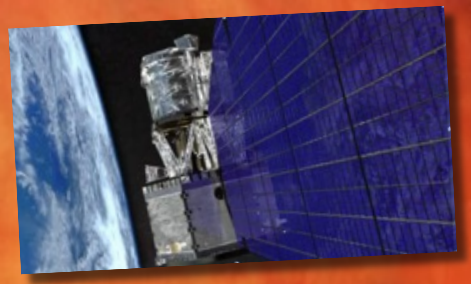
18th IACHEC meeting

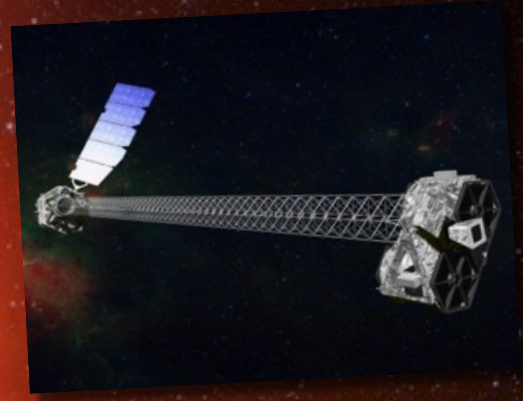
Pelham, Germany

April 20 – 23, 2026

NuSTAR Observatory Status



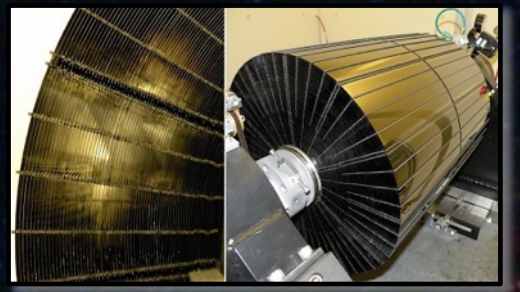




Hannah Earnshaw, for the NuSTAR SOC

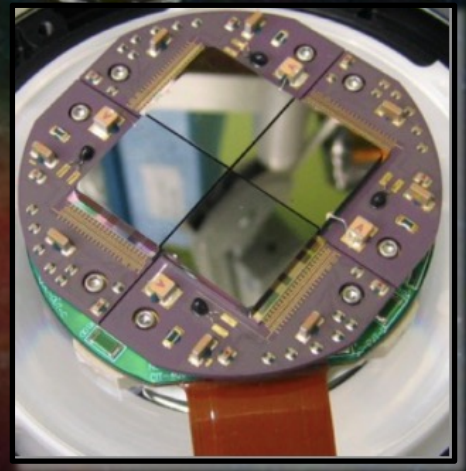
NuSTAR Observatory

NASA Small Explorer astrophysics mission
- PI Fiona Harrison (Caltech), Deputy PI Daniel Stern (JPL), PS Hannah Earnshaw (Caltech)
- Partners: ASI, SSDC, DTK, HEASARC, UCB-SSL
- Launched on June 13th, 2012, 620 km, 6° orbit
- Northrop Grumman LeoStar-2 spacecraft bus
- Science Operations at Caltech
- Mission Operations at UCB-SSL
- Archive and GOF at GSFC



2 Optics Modules
Conical Wolter-I approximation
133 shells (43 W/Si, 90 Pt/C)
HPD = 1 arcminute
FOV = 12′ x 12'

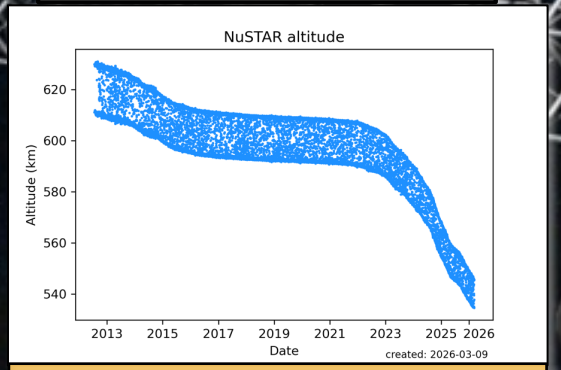
10.14m focal length deployed Mast



CdZnTe detectors
4x(32x32 pixels)

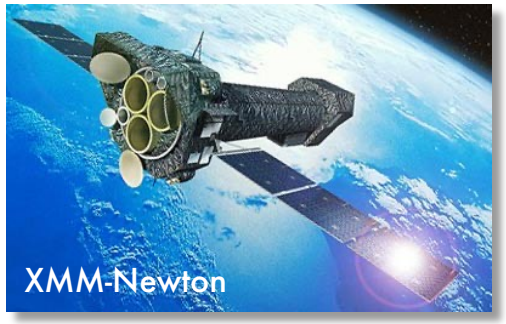
Resolution:
400 eV @ 6 keV
900 eV @ 60 keV
2 ms time resolution
60 μs with clock correction

NuSTAR Orbit Altitude

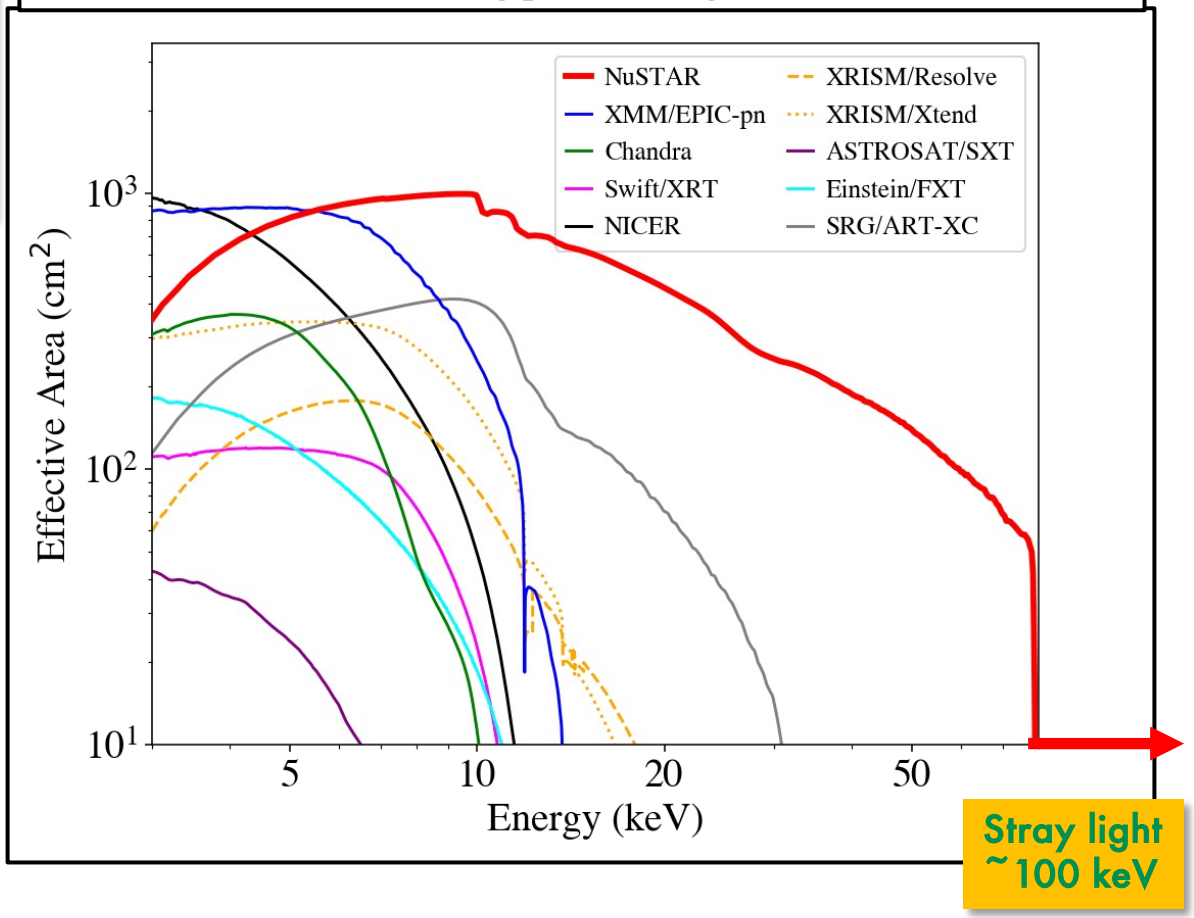


- No consumables
- Single string
- > 20 years orbit lifetime

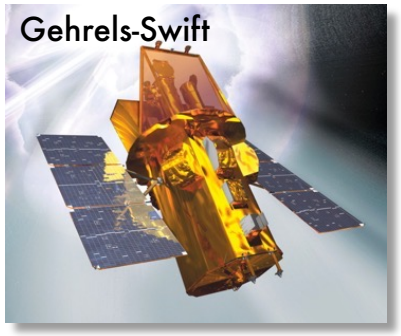
NuSTAR Synergies

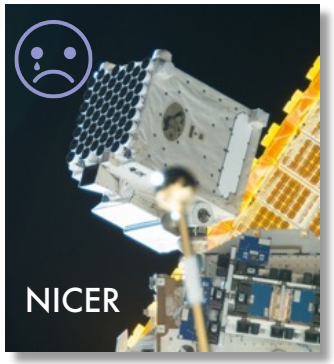


NuSTAR Energy Range 3–78 keV



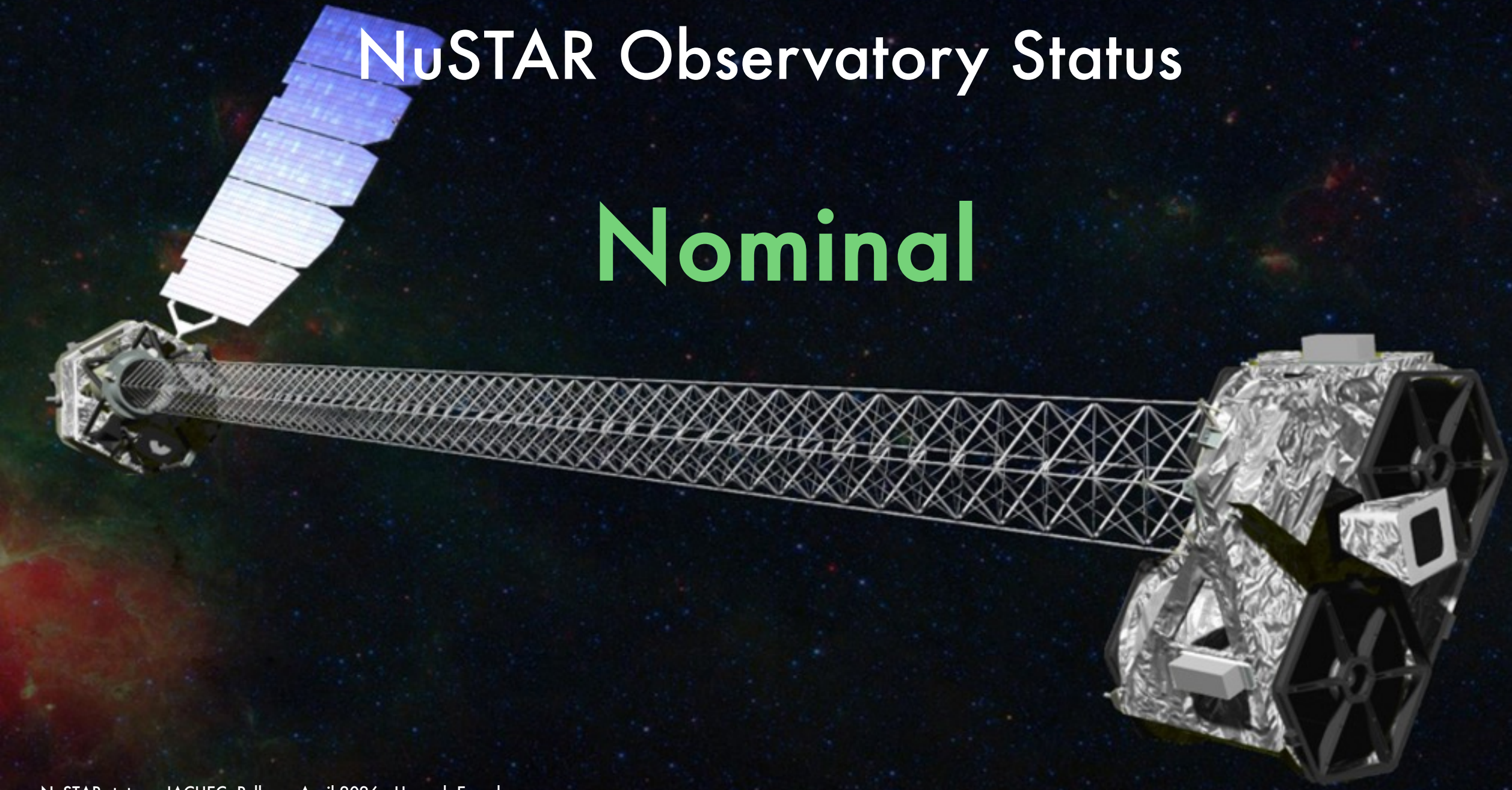
Stray light ~100 keV





NuSTAR Observatory Status

Nominal



Mission Update

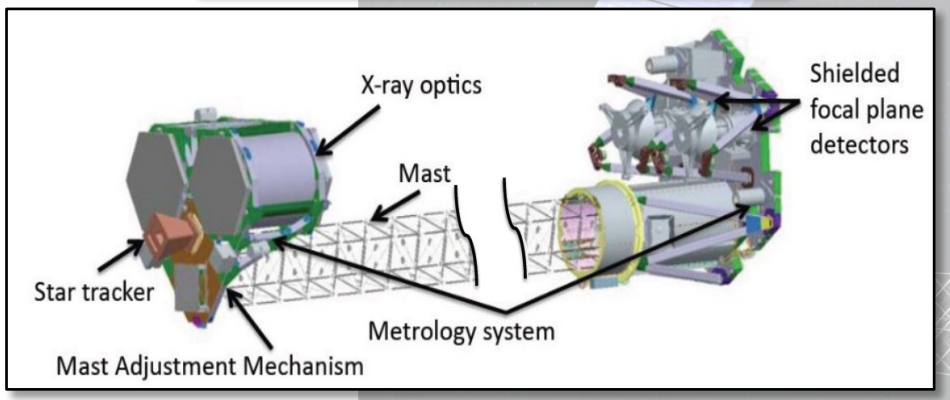
LeoSTAR-2 spacecraft bus has **no consumables**	
Solar Array and SADA, EPS	No concerns
Attitude Control System IRU*, Star trackers*, TAM, MTB, CSS, Reaction Wheels	No concerns
RF Communications	No concerns
Thermal control	No concerns
Electronics CEU, APE*	No concerns
Battery Evaluation of end of discharge voltage shows normal ageing *>20 years before any concerns*	No concerns

2024 Northrup Grumman review

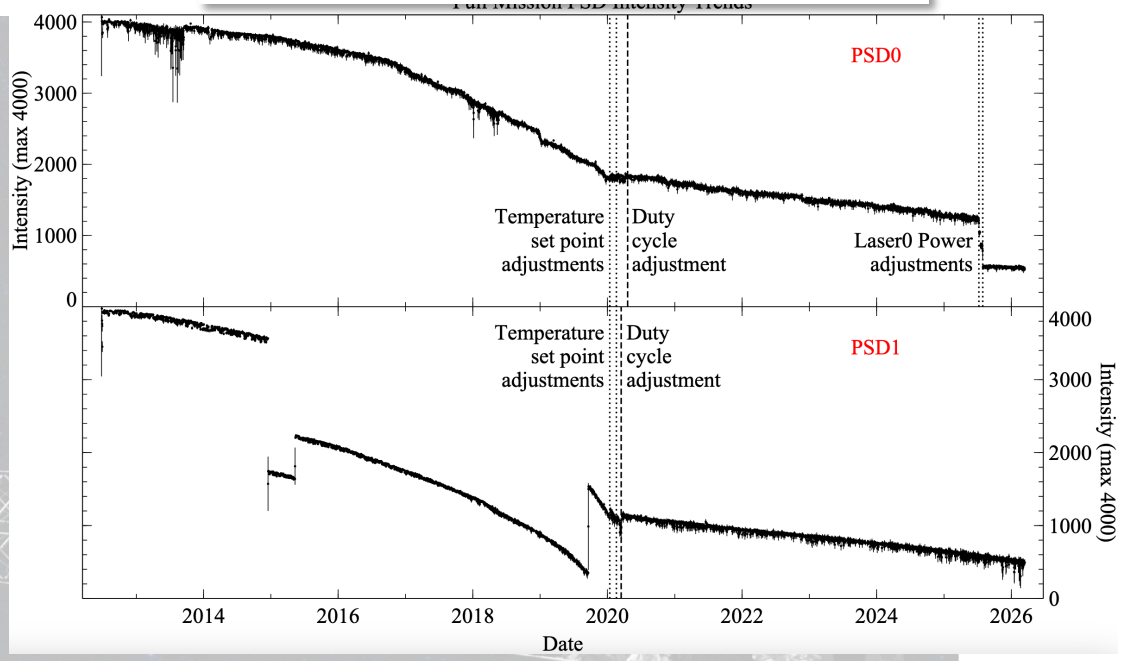
*rare resets occur as expected

Mission Update

Laser Metrology system stable

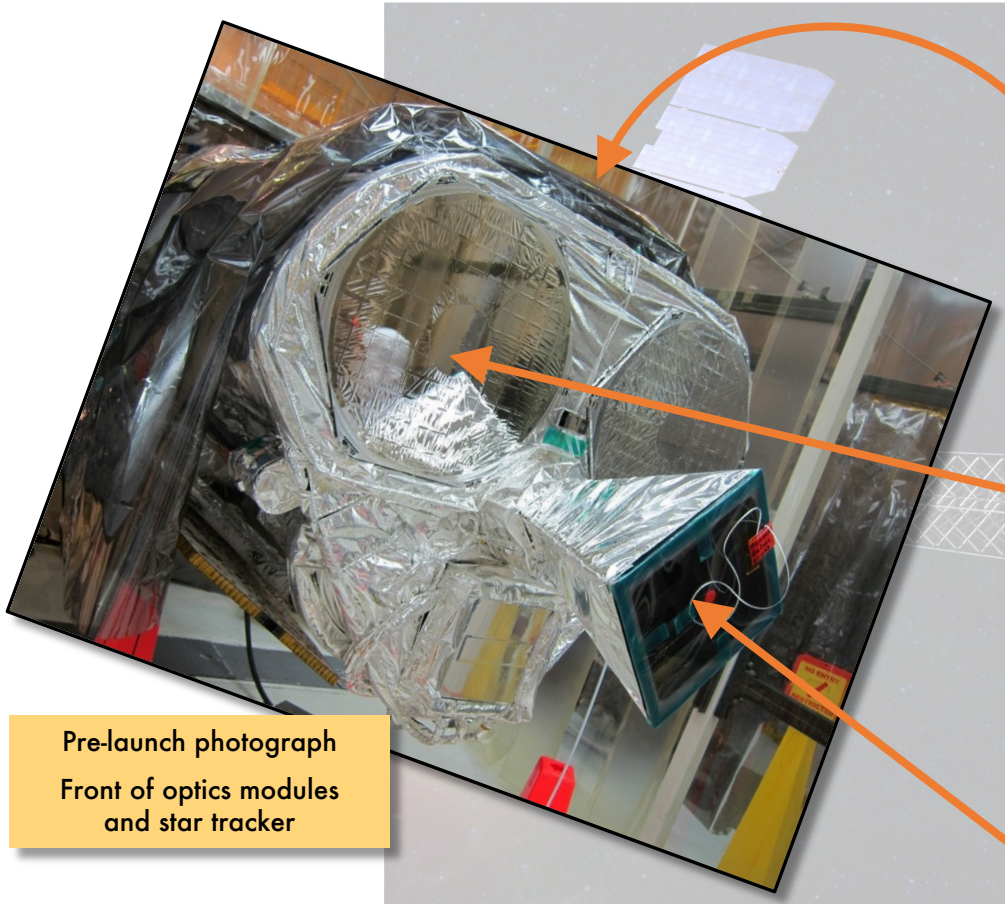


Metrology Laser Intensity over Time



- Metrology laser intensity continues to decline. Rate of decline for Laser0 has been slowed by a reduction in laser power
- Further duty cycle adjustment is planned for later this year
- Single-laser contingency remains an option, but we expect not to need to use it at this time

Mission Update



Pre-launch photograph
Front of optics modules and star tracker

Optic 0 Rear Tear

MLI tear in 2017
Rear of Optic-0 (FPMA)

High Optic-0 temperature for SAA > 145°

Recent increases to 37–40C at high SAA implying further tearing

Initial limit of 24-hr duration for observations at SAA > 130°

All observations with SAA > 130° now suspended

More on observing constraints at the Science Operations WG session

Optic 1 Front Tear

MLI tear in December 2024
Front of Optic-1 (FPMB)

High Optic-1 temperature for SAA < 60°
No recent change

Initial limit of 24-hr duration for observations at SAA < 60°

All observations with SAA < 60° now suspended

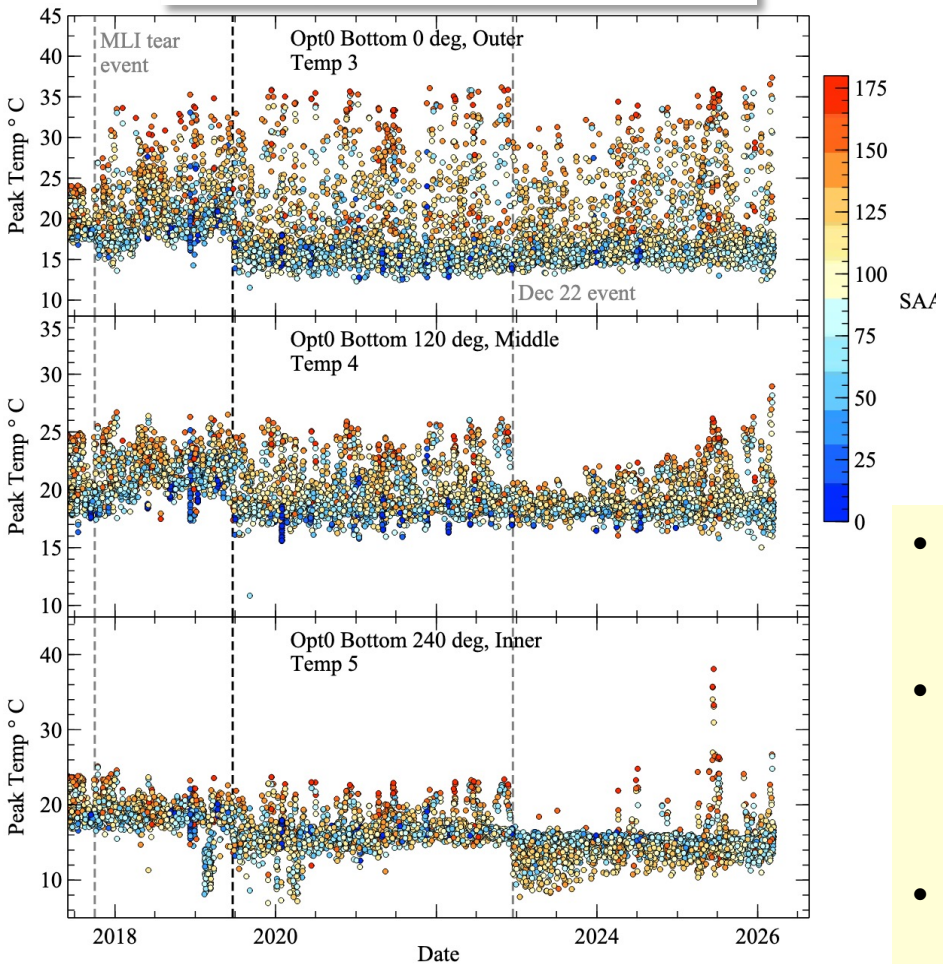
Astrometry Star Tracker (CHU4)

Low gain area in central 1° of 20° field of view

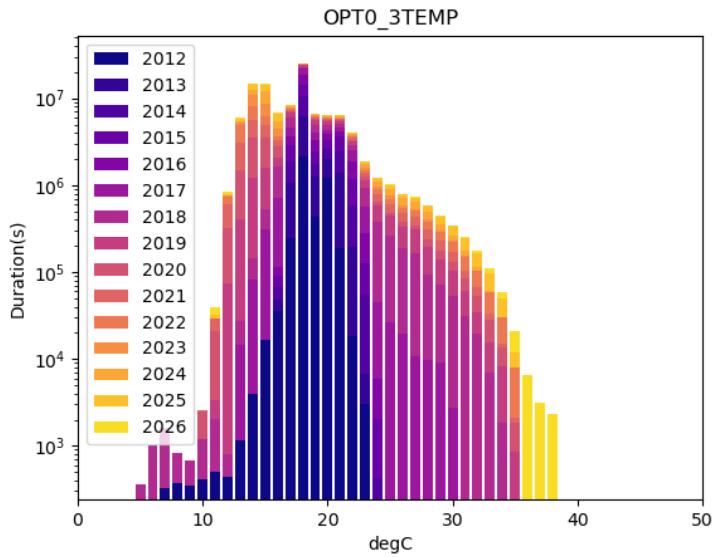
Further degradation not expected now that Solar observations are suspended

Mission Update

Optic 0 temperatures



High temperature duration



- Epoxy not expected to slump below 50C
  - However, thermistors only measure locational temperature, not across entire optics
- Epoxy creep expected to be a function of cumulative thermal input
  - Time spent close to 40C in 2026 would have equivalent effect to entire mission prior to 2026
- No PSF degradation from optics deformation observed yet

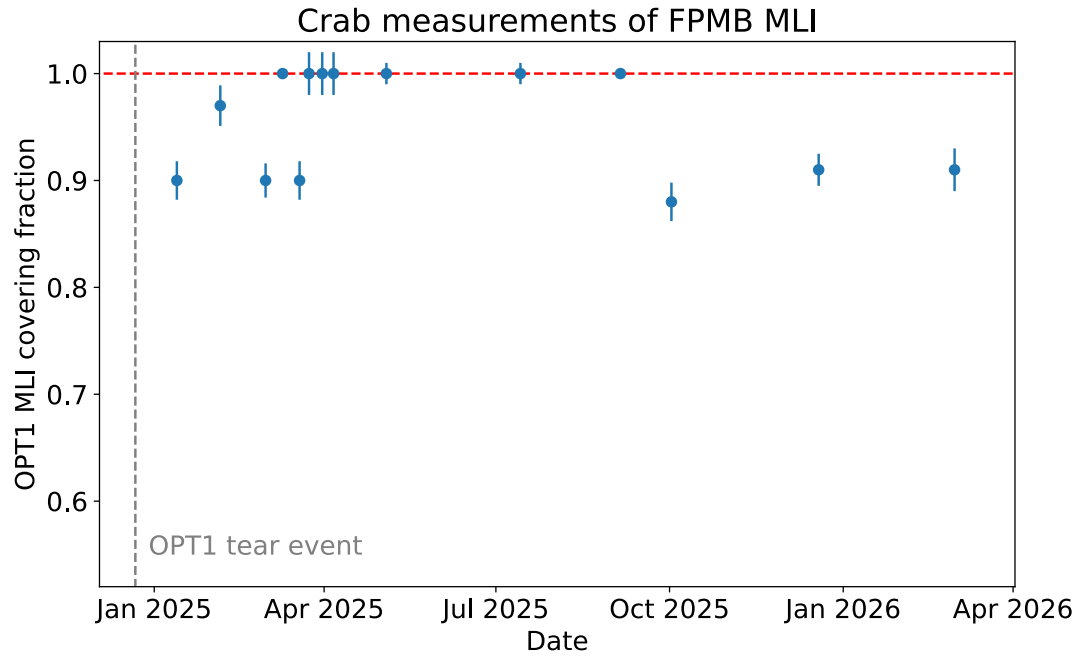
Mission Update

MLI tear throughput monitoring

- Tears present on opposite ends of both optics modules
- FPMB can no longer be considered as the baseline for the FPMA MLI correction
  - FPMA ARF has remained steady since 2024, even since recent temperature increases
  - Accounted for in current CALDB
- Regular observations of the Crab are being performed to characterize the behavior of changing ARF
- CALDB update not planned for FPMB unless its behavior stabilizes
- Observations of bright sources may require an additional mtable to the model
  - for energies 3 to 7 keV
  - adjustments are at ~few % to ARF
- Detailed instructions available on NuSTAR SOC MLI webpage:

nustarsoc.caltech.edu/NuSTAR_Public/NuSTAROperationSite/mli.php

Fractional coverage of OPT1 MLI



Mission Update

Gain update

- We review detector gain every ~6 months
- Since 2012, we have used ~105 keV internal background line as part of these NuSTAR gain checks (in addition to observations of Kepler)
- The past year has showed a dramatic reduction in the line strength (all activation lines)
  - Likely connected to the change in the NuSTAR altitude / radiation environment
- Can no longer use the 105 keV line (too faint), so switching to a ~88 keV activation line to supplement the Kepler observations
- No issues seen at present and no gain drift seen in the last year. Will continue to monitor and plan a supplementary paper to Grefenstette et al. (2022) on the changing background

Feel free to ask Brian about this!

Calibration History

Date	Description
2013-08-14	Initial CALDB public release
2013-11-25	ARF adjustment (-15% NuSTAR flux)
2014-01-17	VIGN adjustment
2014-07-01	Gain calibration improvement
2015-03-20	Full mission gain adjustment
2016-06-06	Update gain, effective area, line of sight absorption
2019-12-13/19	Update long-term gain tracking
2020-05-06	High resolution clock correction
2020-08-13	Temperature-dependent ARF implemented for FPMA
2021-02-23	Observatory alignment update
2021-10-26	Observatory calibration update based on 9 years of Crab observations
2022-05-10	FPMA DET2 long-term gain adjustment
2024-03-11	FPMA DET0 long-term gain adjustment; remove temperature dependent ARF capability for FPMA
2025-02-24	FPMA ARF MLI correction adjusted for observations after 2018
2025-03-31	New temperature model for clock correction

Clock correction software modernization nearly complete!

NuSTAR Summary

Observatory status is green

- Observatory lifetime is expected to extend into late 2020's
  - Expanding synergies with addition of IXPE and XRISM joint programs
  - Increased support for ToO triggers from ZTF -> LSST, LIGO/Virgo, IceCube

2026 and beyond…

NuSTAR is a community-driven observatory, a key part of the NASA astrophysics portfolio

- *Proposed to NASA Senior Review for a three-year extension of operations*
  - *Operations extended to 2028*
- *Automated rapid ToO response*

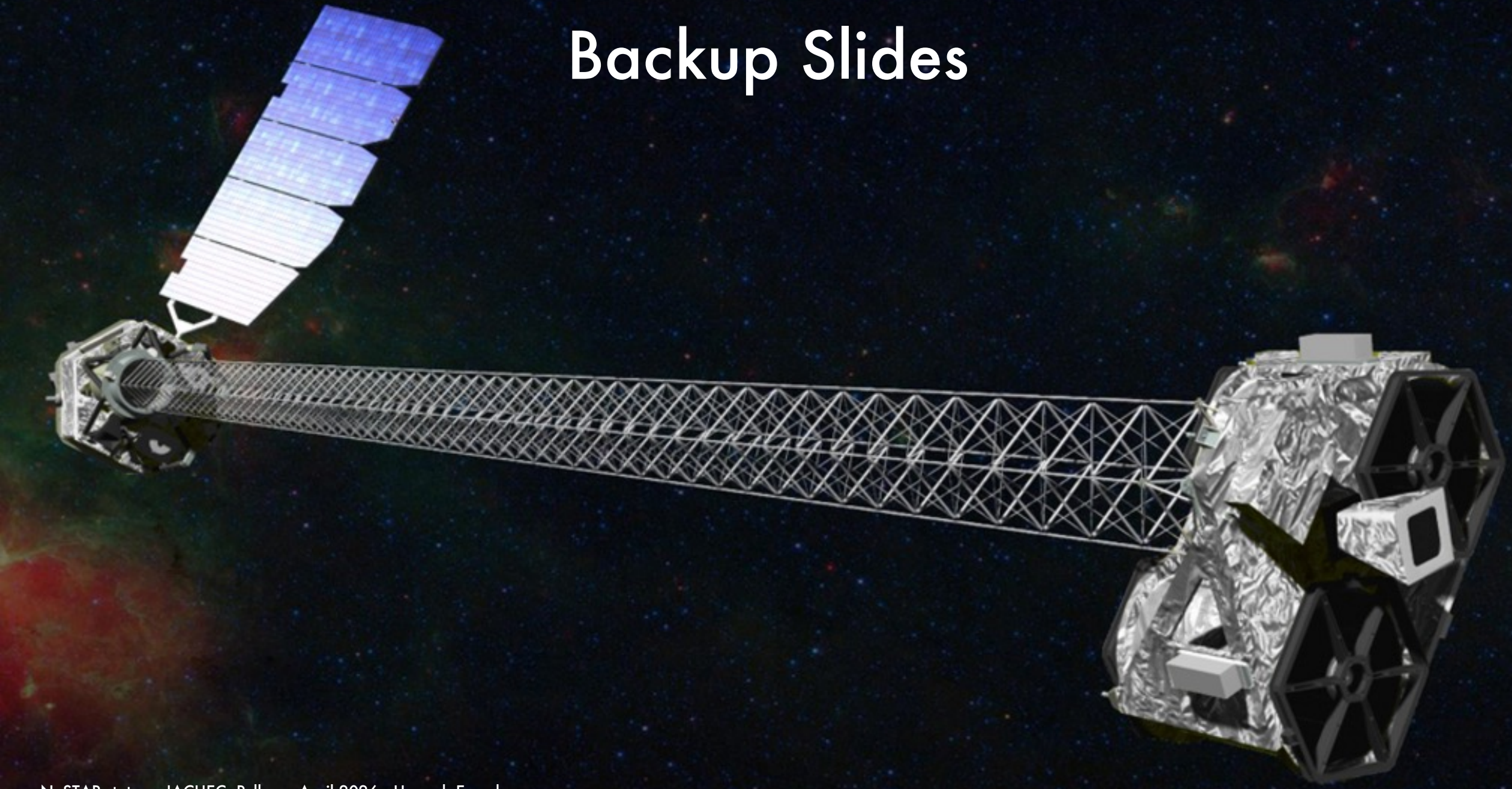
More on that at the Science Operations WG session!

We continue to have access to a scientific instrument that is…

- *stable*
- *well calibrated*
- *operationally efficient*
- *highly productive*
- *with unique capabilities*

…and responsive to the needs of the community

Backup Slides

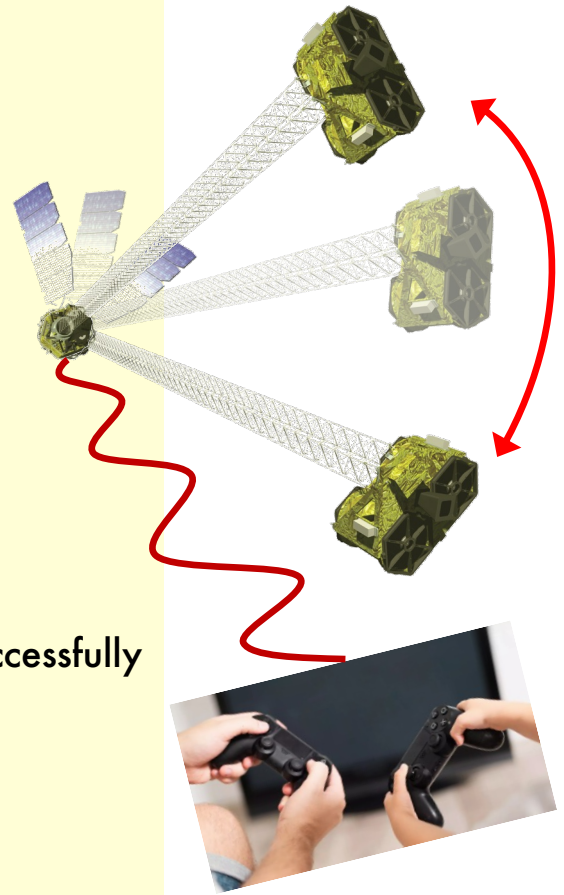


Mission Update

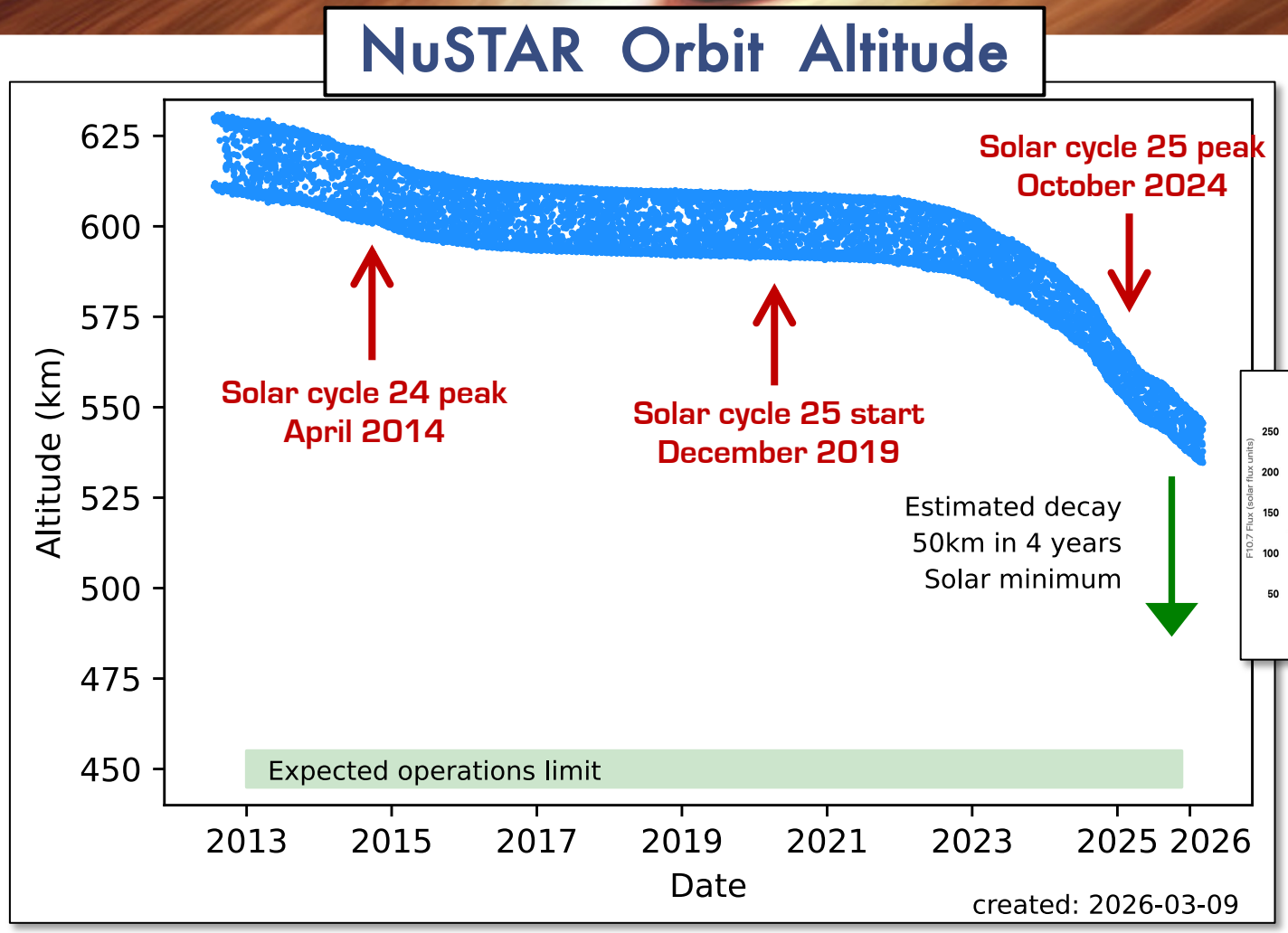
Automated ToO rapid response system

Goal: reduce standard ToO response times to < 24 hrs

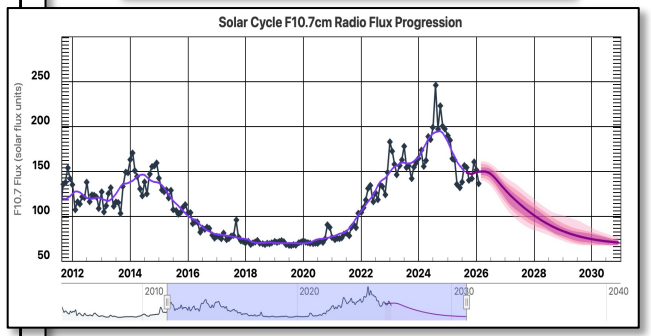
- Currently < 48 hrs best effort
  - Manual scheduling and command sequence upload
  - Operators required to drive into the UCB-SSL mission operations center
- Automated systems undergoing final testing
  - Automated observation scheduling
    - Slew time set to be after next schedule contact, 5 contacts scheduled per day
  - Automated command sequence generation at SOC
  - Automated delivery of command sequence to MOC
  - Automated command validation and upload to spacecraft on next contact
- No operator required to be in the MOC (remote monitoring)
- PIs of ToO proposals requesting rapid response will need to provide a code to successfully submit a trigger to automated system
  - Messaging system alerts teams to triggering of rapid response ToO
  - Follow up scheduling by SOC and MOC to return to regular programming
    - Minimum exposure time for ToOs is 20 ks ~12-hour duration
- System went live in November 2025 – no triggers yet…

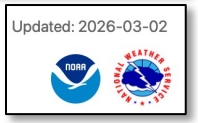


NuSTAR Observatory



Expect nominal operations through Solar minimum

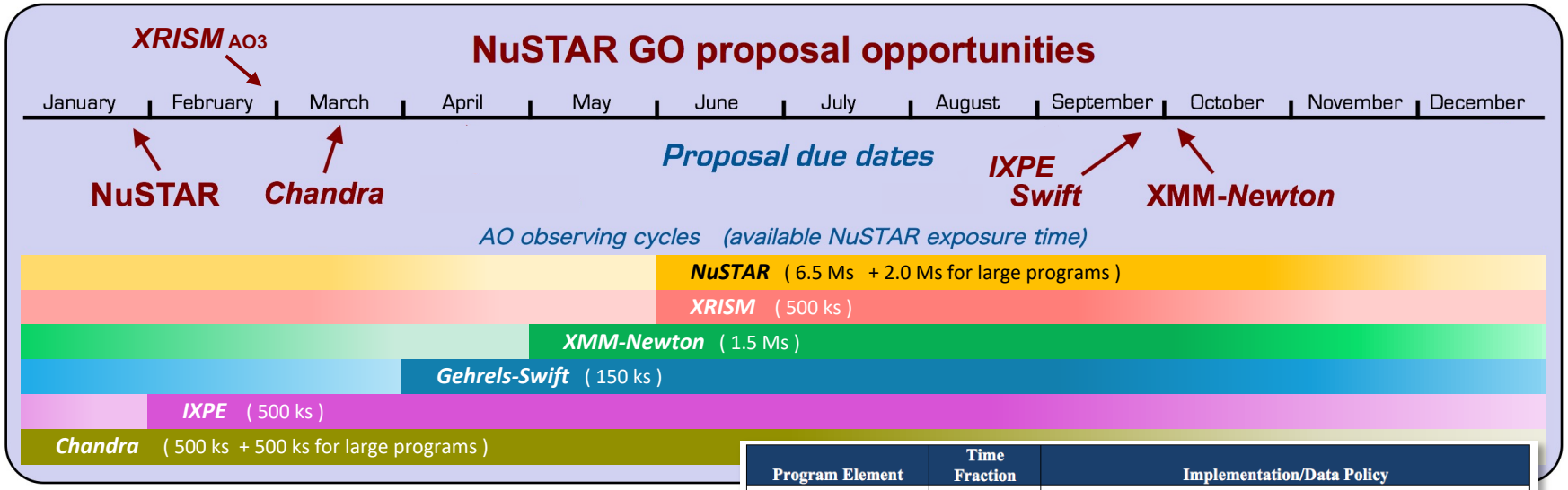




GO Program

Proposals requesting NuSTAR observing time may be submitted to six GO programs

- Due dates spread throughout the year



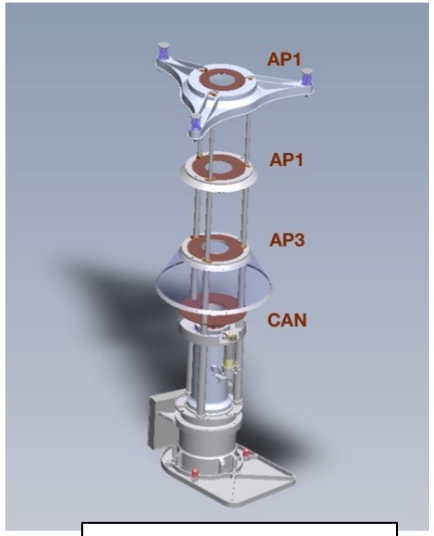
Executing about 100 proposals / year

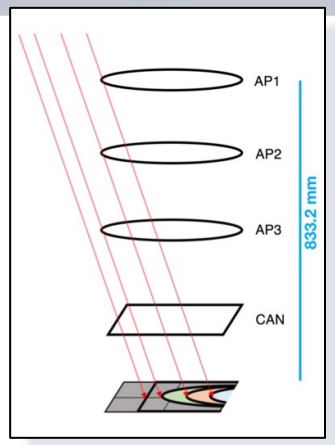
= 70% of observing time

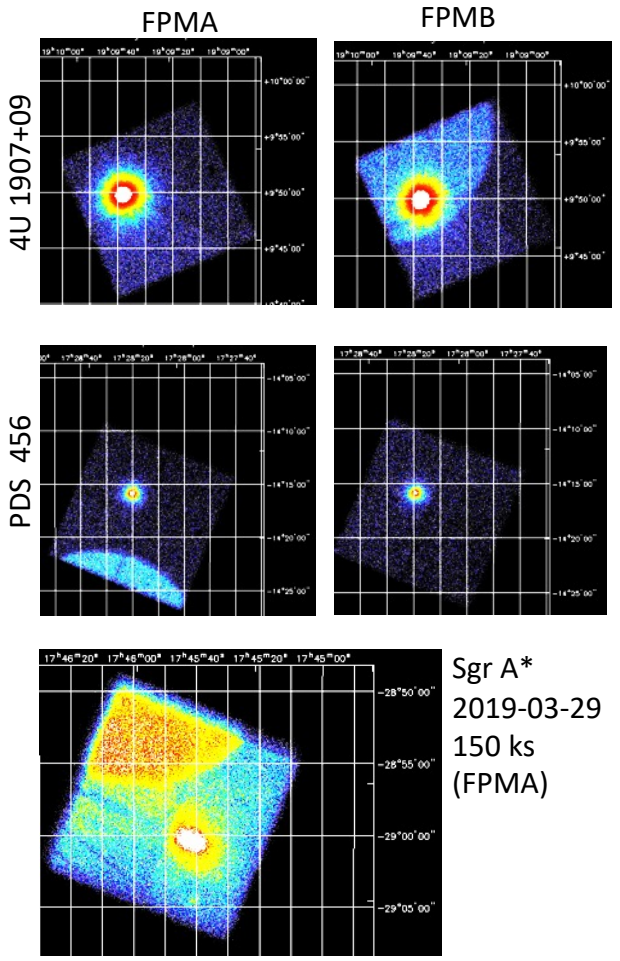
- >50% observations coordinated with other observatories
- >75% observations have time constraints

Program Element	Time Fraction	Implementation/Data Policy
Guest Observer Program	70%	Annual open call for proposals with time offered through *XMM-Newton, Chandra, Gehrels-Swift, IXPE,* and *XRISM* TACs for joint observations. 6-month limited-use period.
Legacy Surveys	3%	*Swift-BAT* AGN survey (20 ks exposures). No exclusive-use period.
PI Discretionary Time	17%	Unanticipated ToOs open to community. No exclusive-use period.
Program Reserve	10%	Reserve for calibration, engineering and unanticipated operational issues. Calibration data has no limited-use period.

Stray Light Calibration







Sgr A*
2019-03-29
150 ks
(FPMA)

- Stray light observations may extend NuSTAR science past **100 keV**
  - High energy limit of 79 keV determined by optics response
- Annual Stray light observations of the Crab used for calibration
  - Bypasses optics, based on well understood detector response
  - Accurate measurement of Crab flux allows absolute calibration to 4% precision

  Measurement of the Absolute Crab Flux with NuSTAR, Madsen et al. (2017)
- Adjustment to cross calibration with other observatories
  - (XMM-pn calibration update)
- Originally a nuisance, now stray light observations are used to:
  - Harvest transient light curves and spectra from Galactic center region
  - Minimize data loss during observations of bright sources
    - Allowing uninterrupted observations – avoiding overwrite of on-board storage buffer
- StrayCats on github

  Grefenstette *et al.* (2021) ApJ 909, 30 and Ludlam et al (2022) ApJ 934 59

  https://nustarstraycats.github.io/straycats/
- Extended SMC X-1 spin and orbit analysis
  - Brumback *et al.* (2022) ApJ 296, 187

StrayCats