The James Webb Space Telescope: its Commissioning and Technology

Bruce Dean, NASA Goddard Space Flight Center
Wavefront Sensing Group Leader

Takeaways

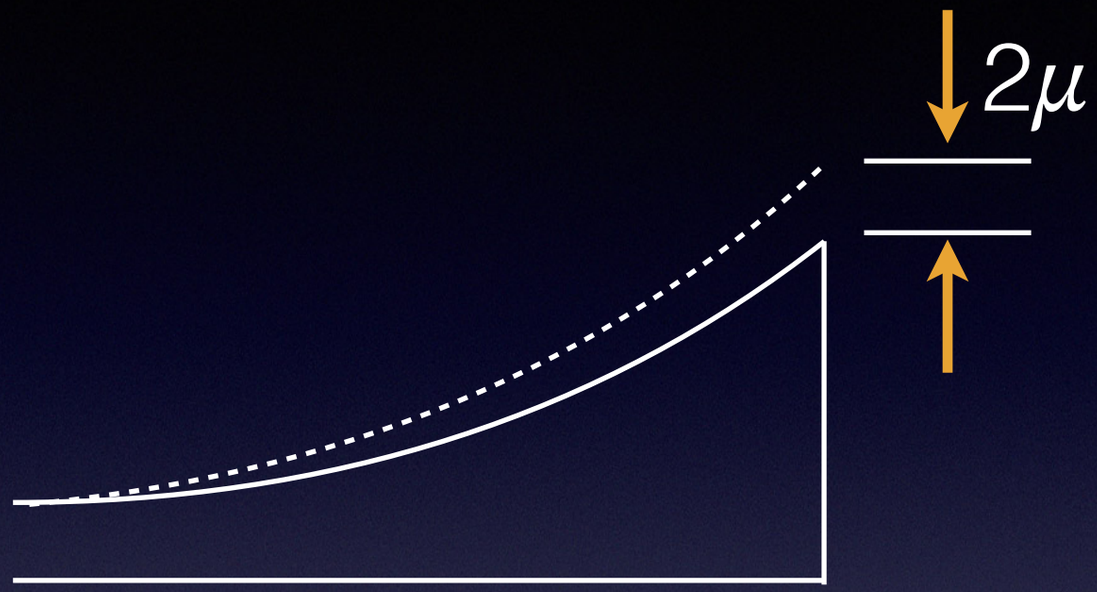
- Motivation

- Engineering, Optical Systems

- Commissioning

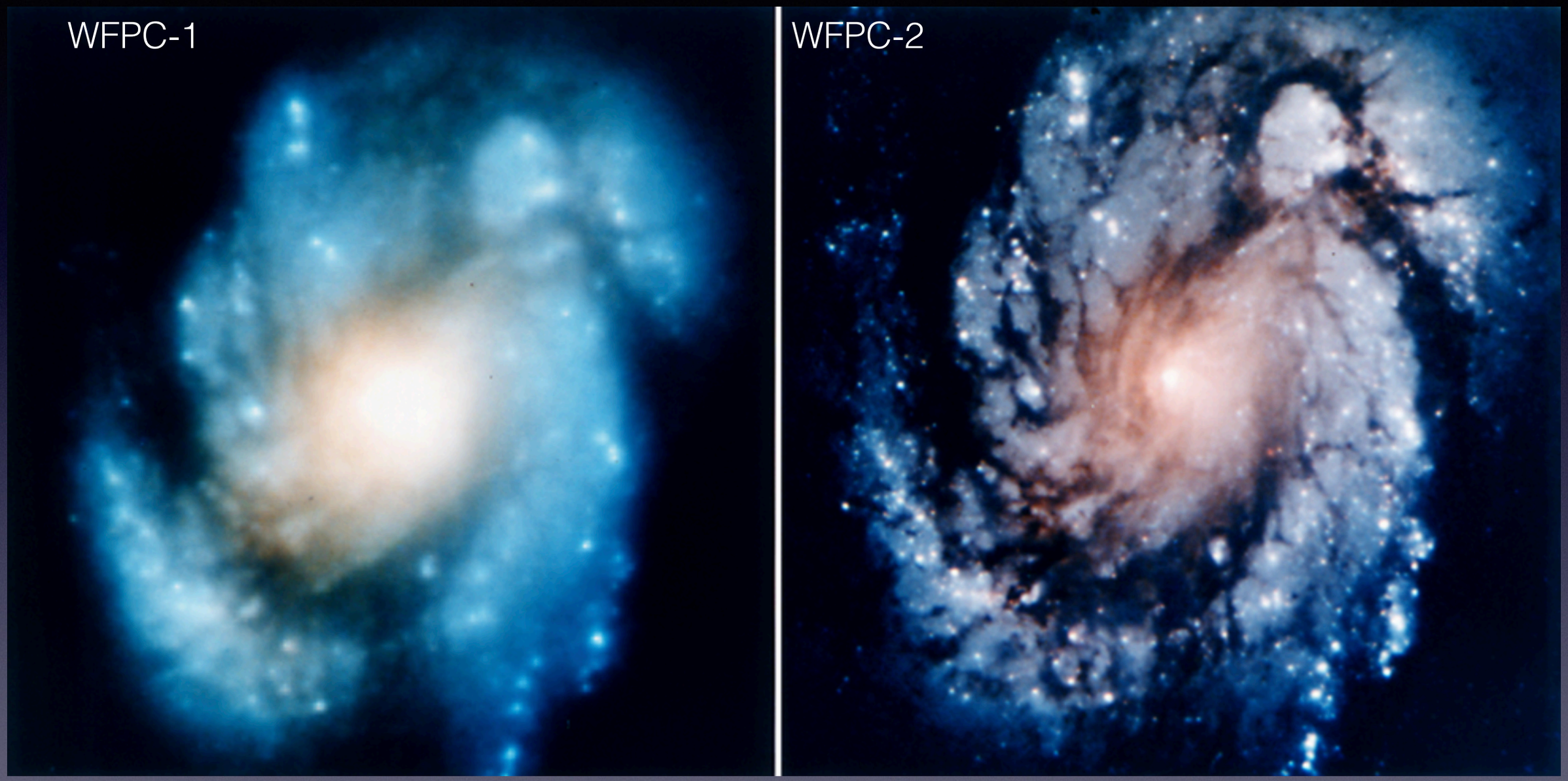
Reference:
Lee Feinberg, "*2022 Summer Series Seminar: Sharpening the View: Commissioning the JWST*," Aug. 9, 2022.

Background



1/35 diameter of a human hair

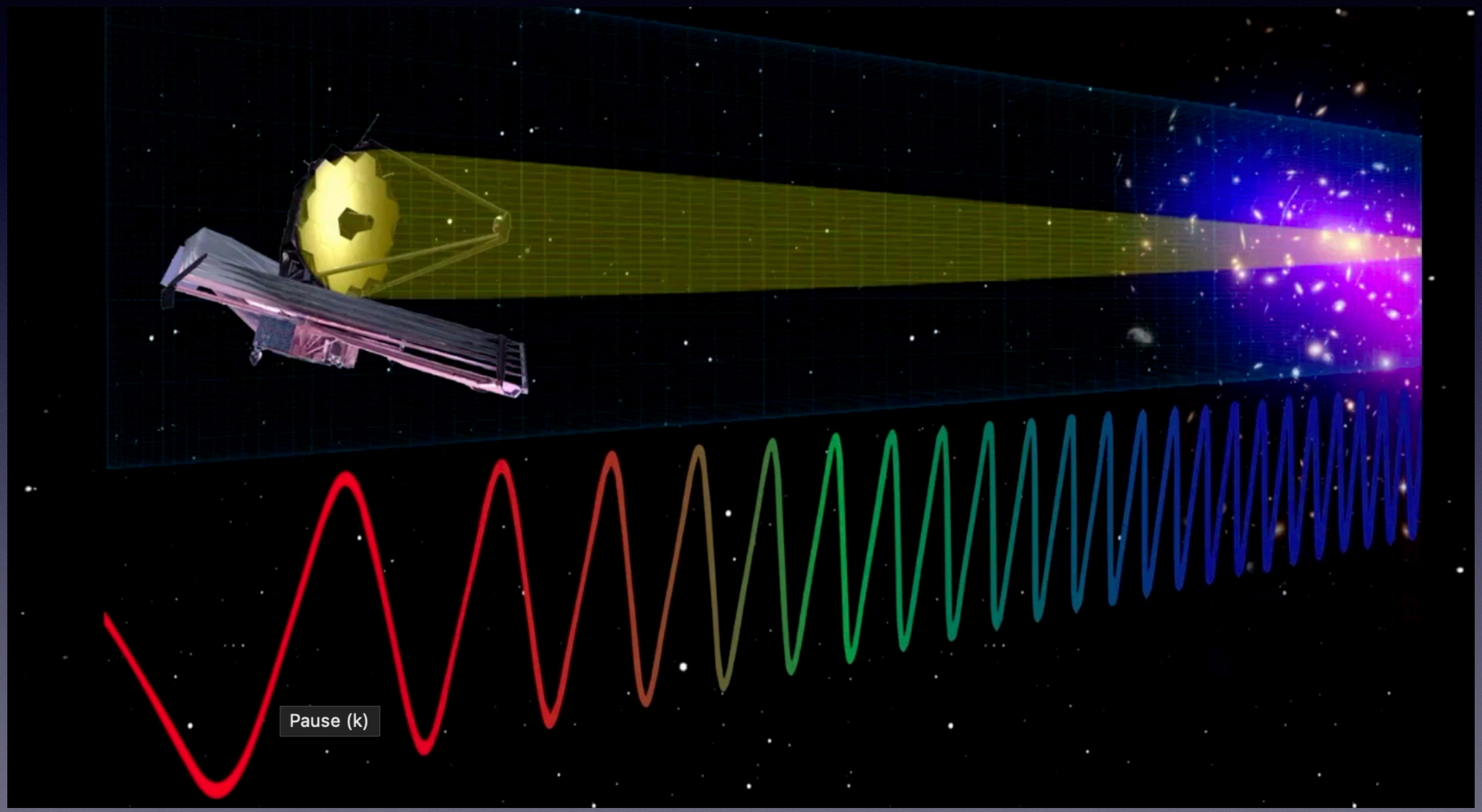
Hubble Space Telescope: before and after



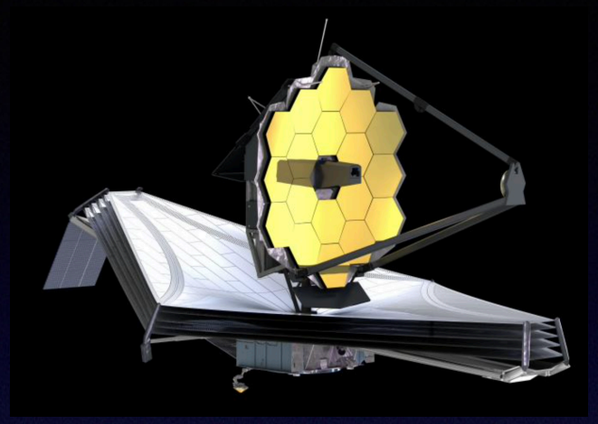
Galaxy M100: dramatic improvement in Hubble Space Telescope's view

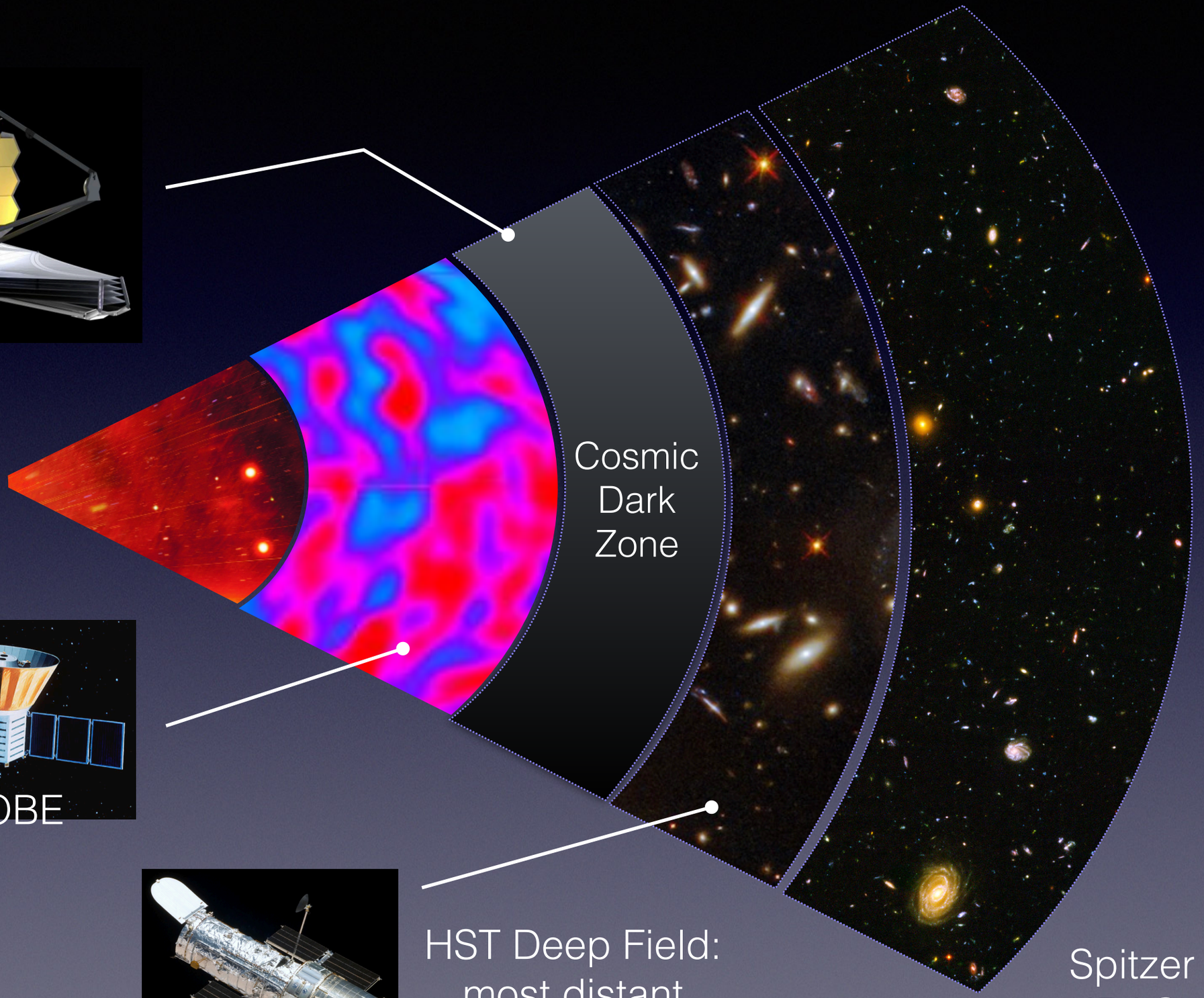
Hubble Deep Field, 1996

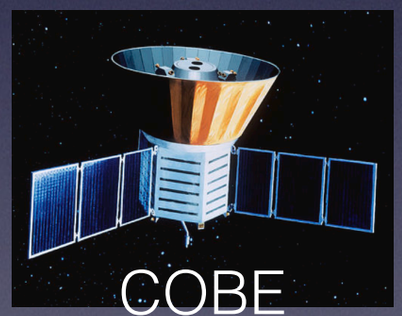
Motivation for a Next Generation Space Telescope (NGST)

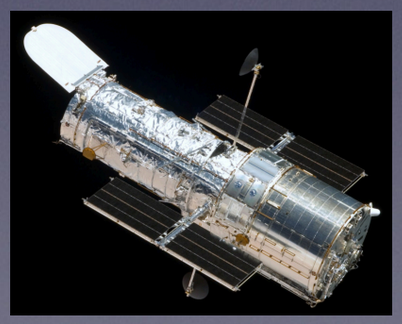


JWST Designed to See First Galaxies





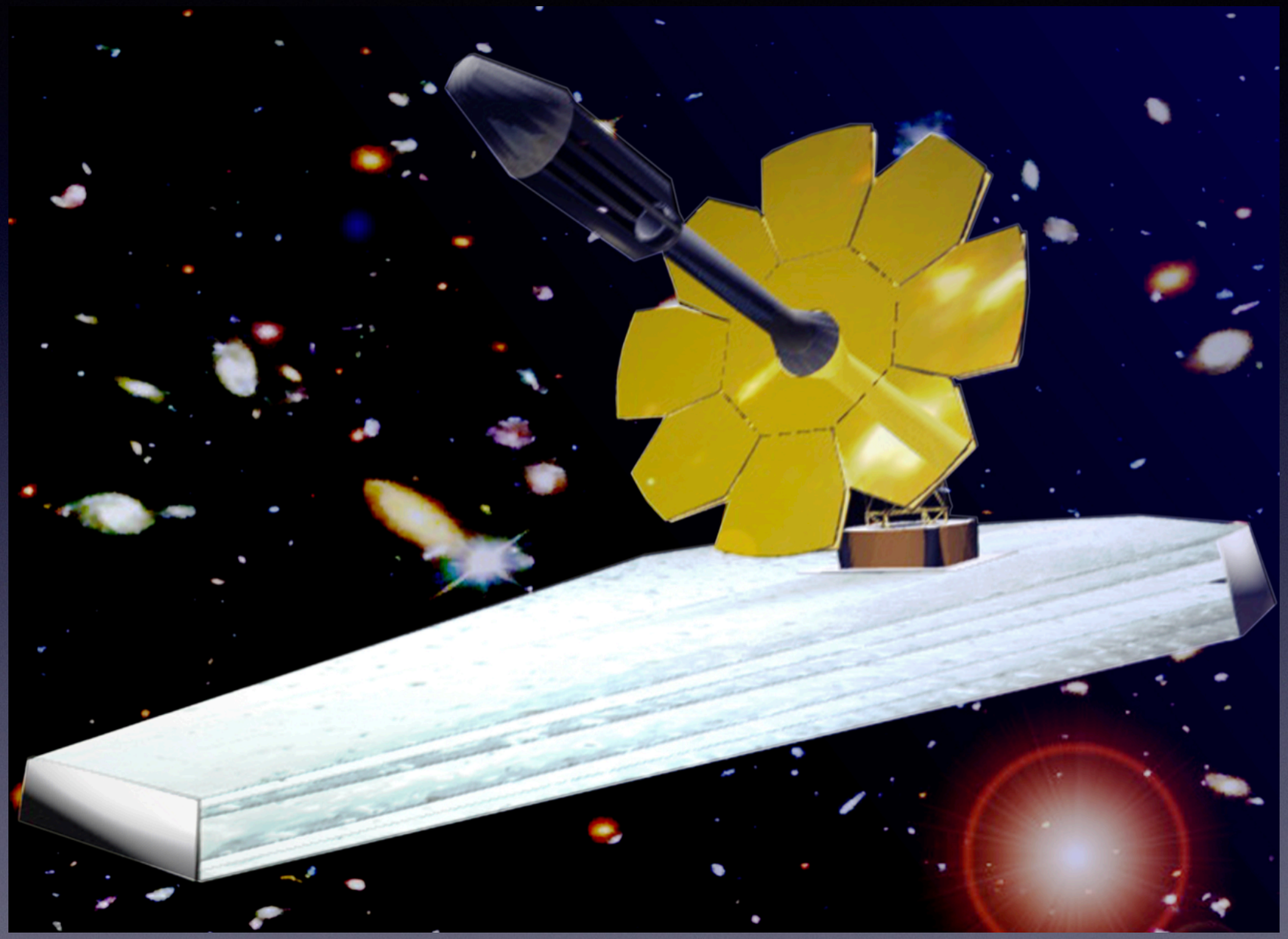




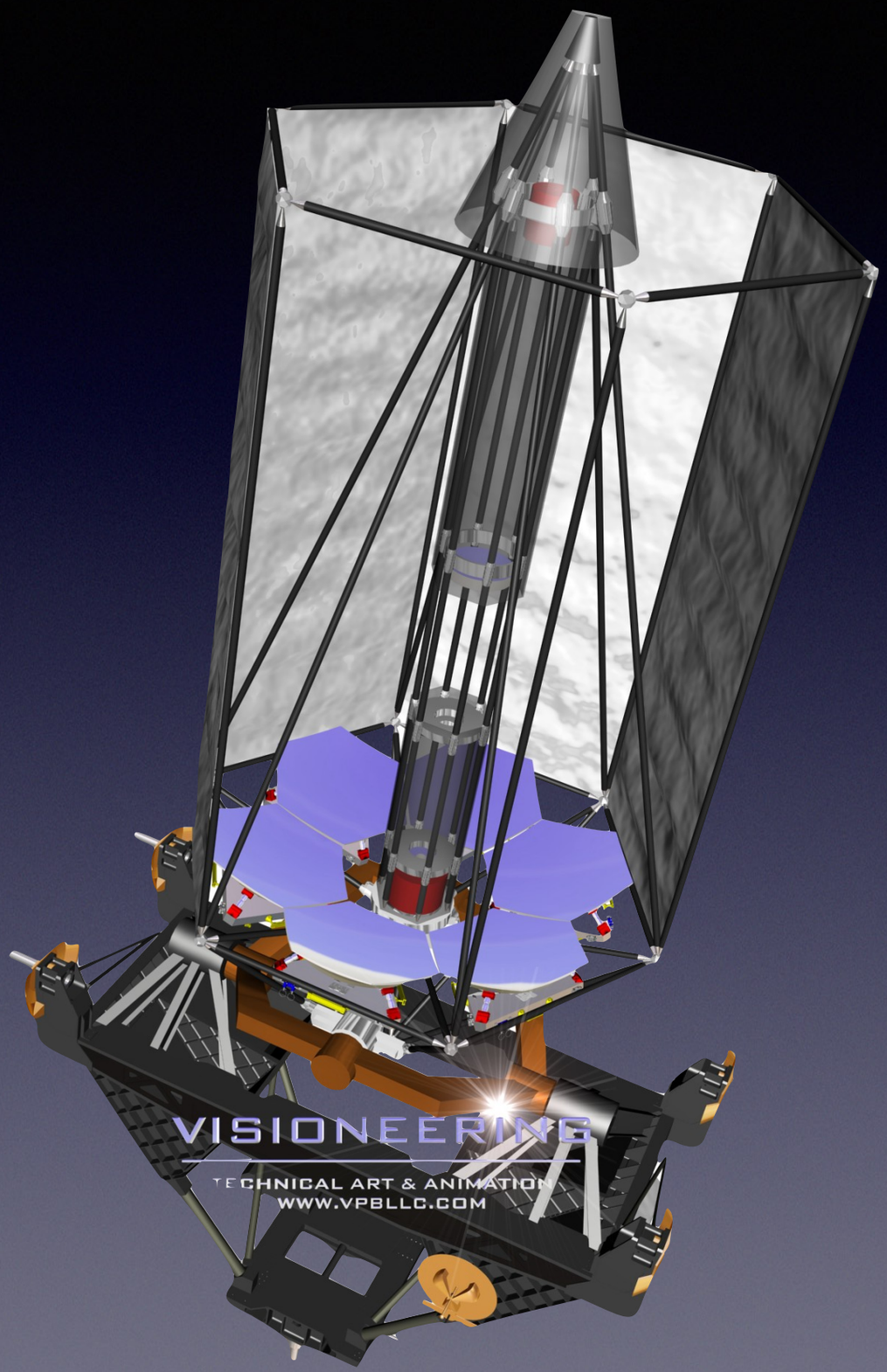
HST Deep Field:
most distant
objects yet

Spitzer
IRAC
Ground Observatories

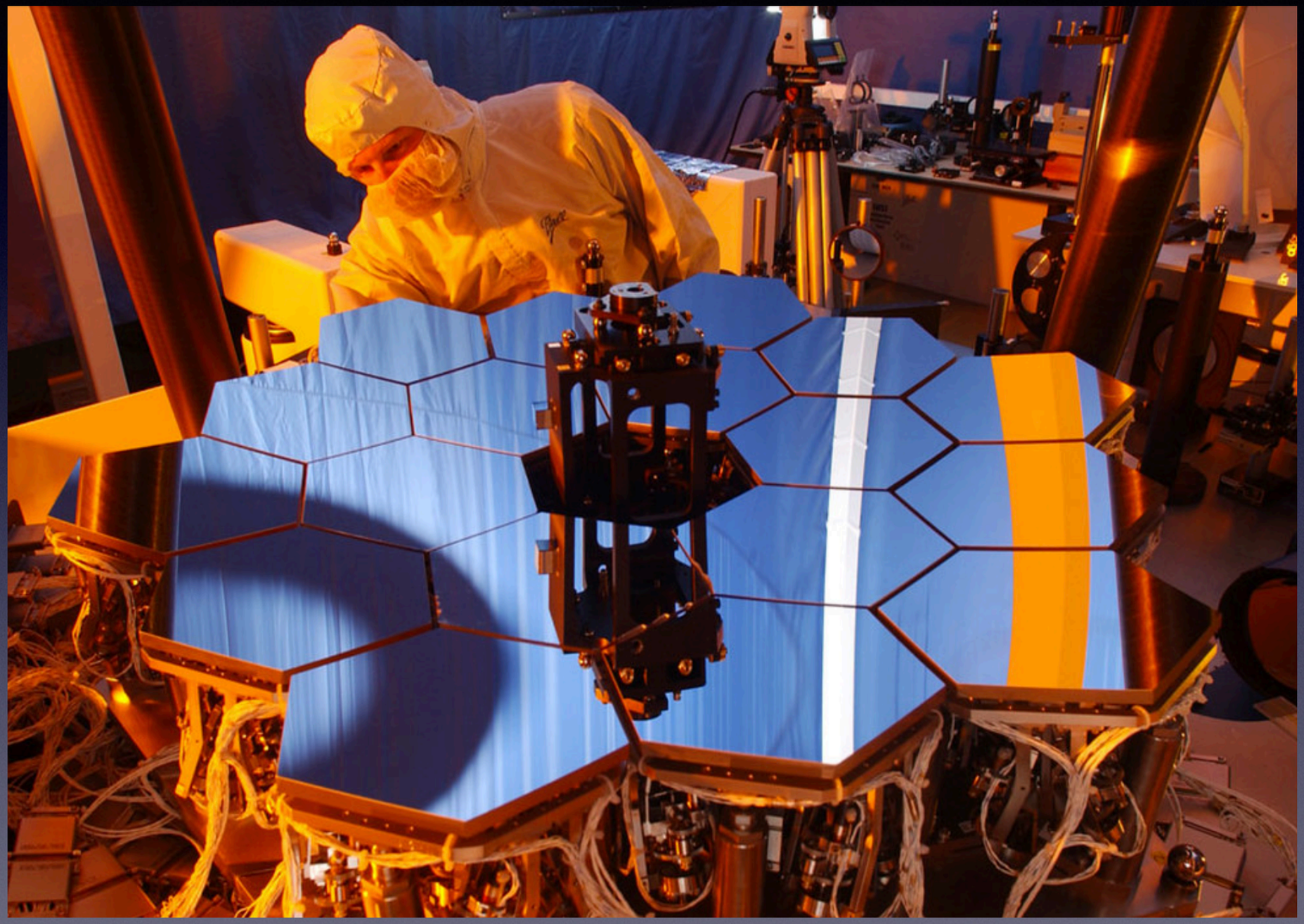
Side Note: Earlier Concept Designs



Pathfinder Mission: NEXUS



Technology Development: TRL-6, 2005



December 25th, 2021: French Guiana

December 25th, 2021: Baltimore, STScI

Nose Cone

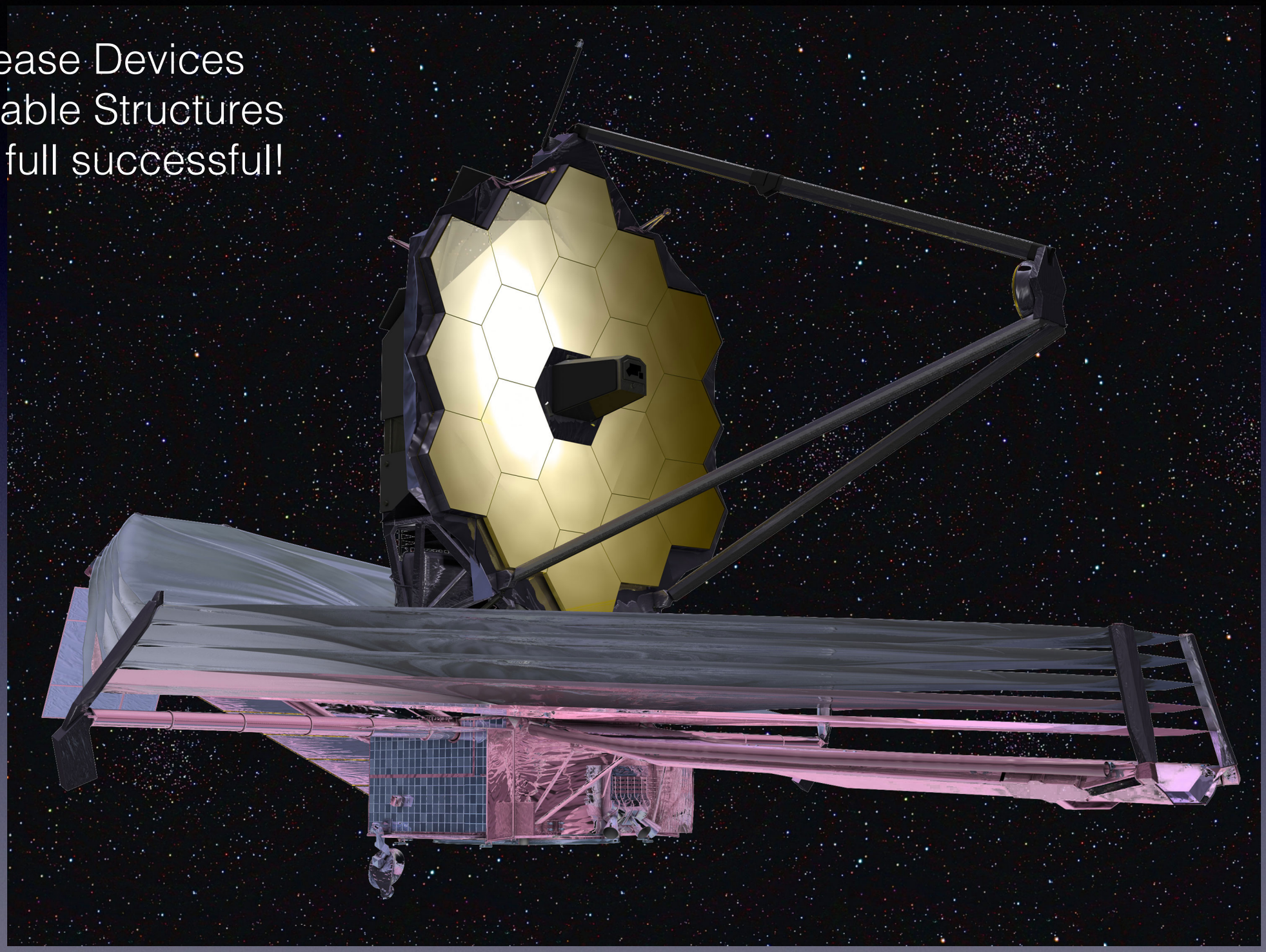
Stowed Configuration

Scale

View from the Ariane camera, Separation-2

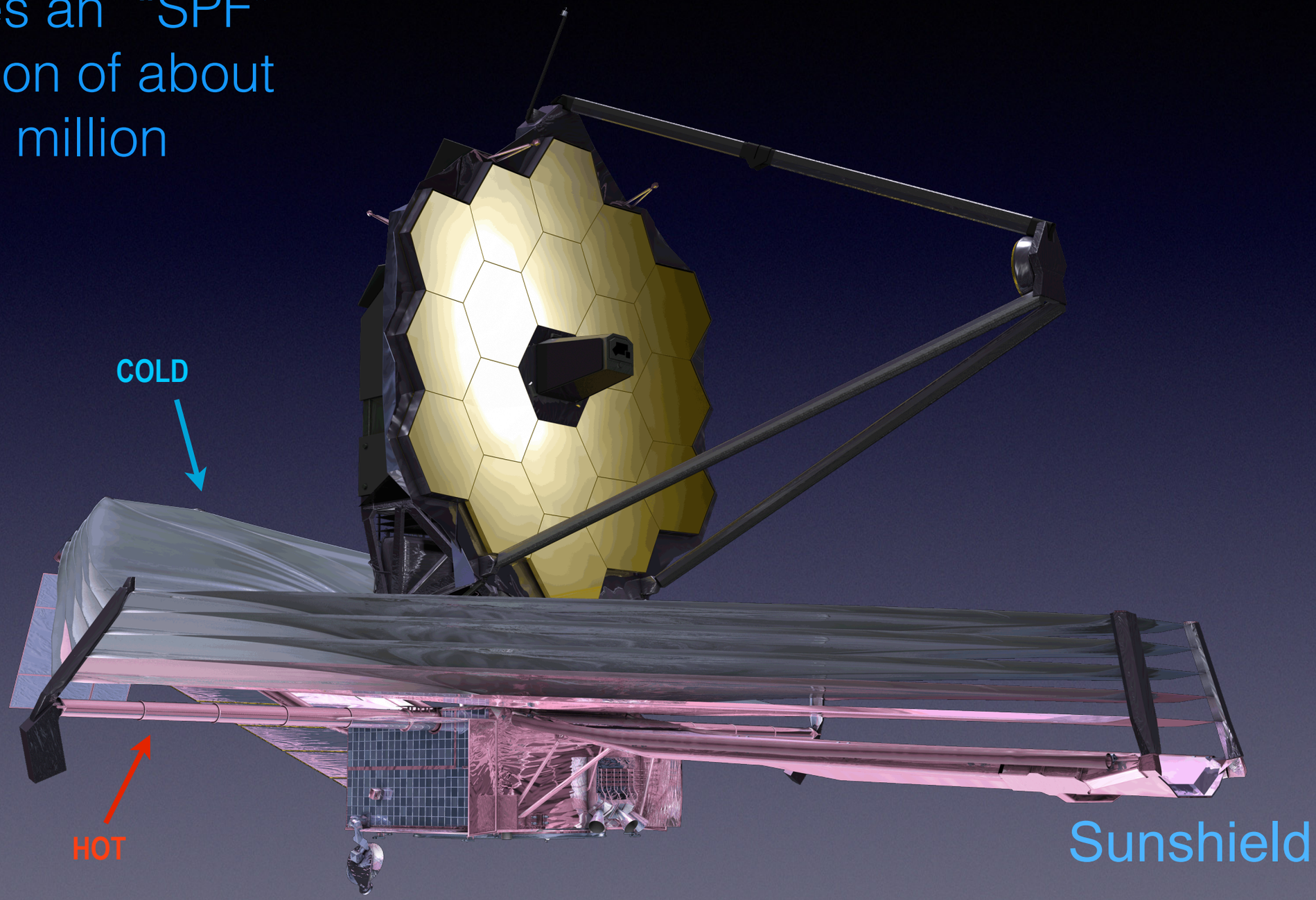
Overall Deployment

178 Release Devices
50 Deployable Structures
2 weeks – full successful!



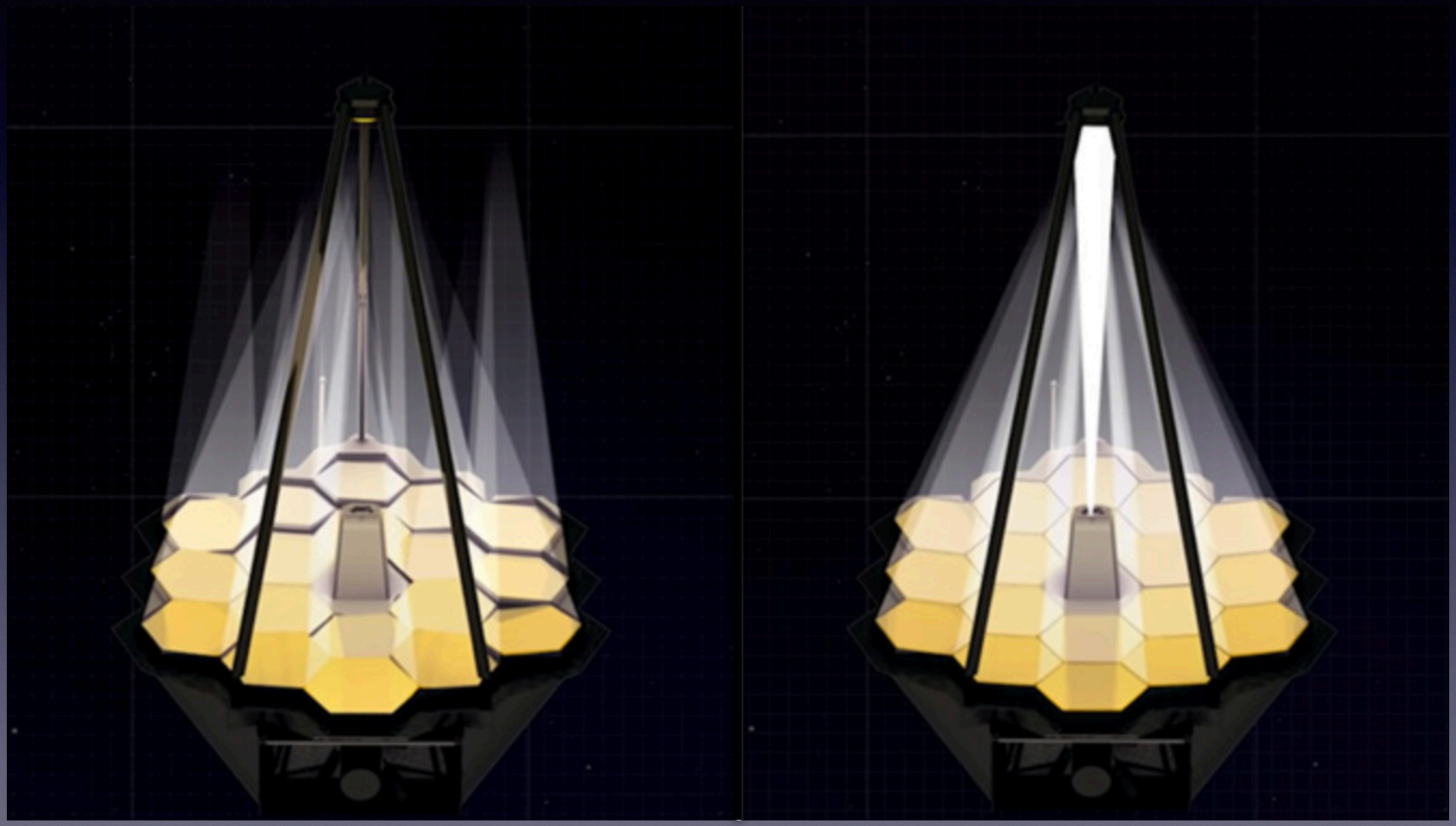
The Sunshield: Protection

Provides an "SPF" protection of about 1.2 million

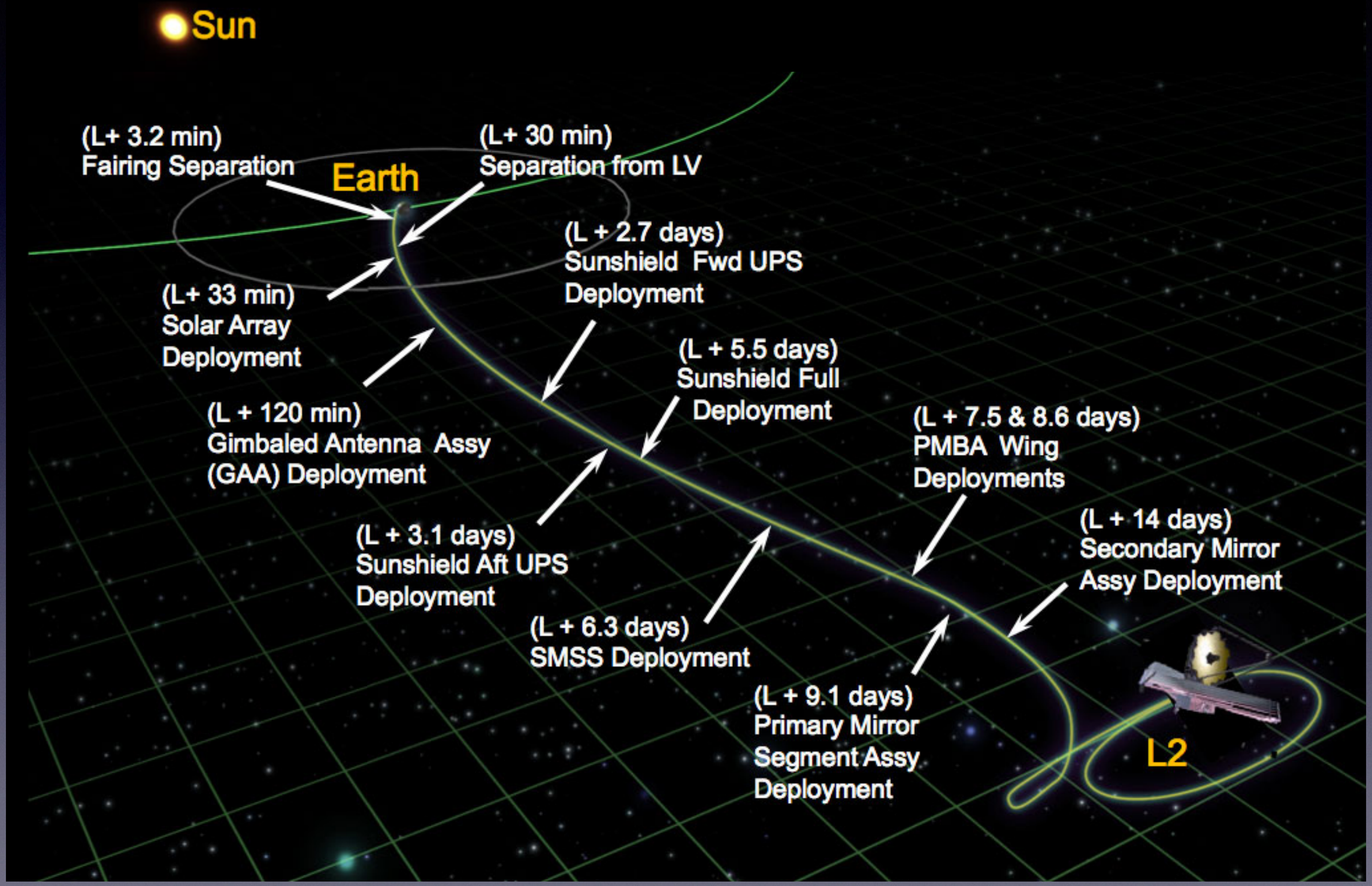


Nearly a 500 degree difference from the top & bottom of the sunshield

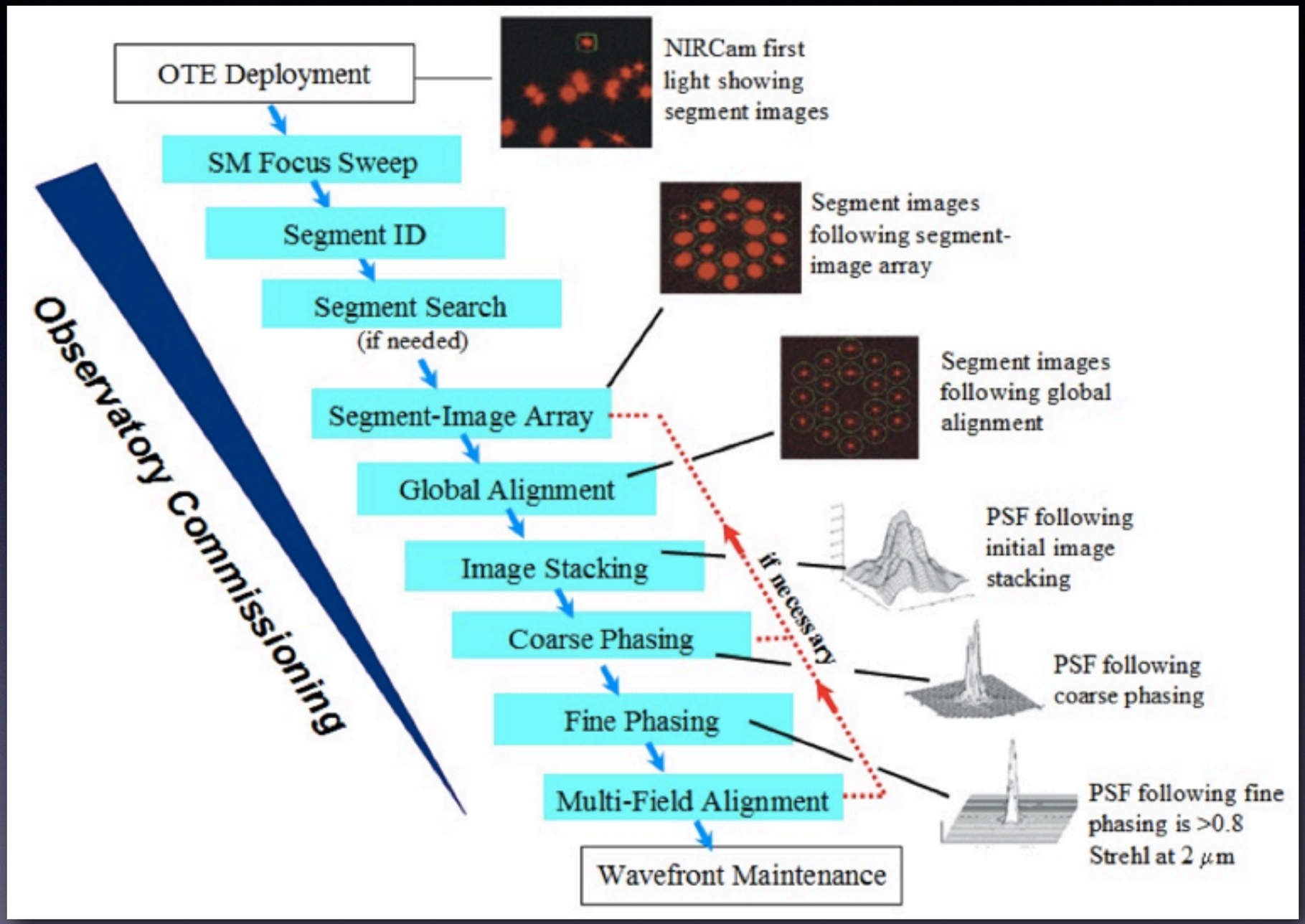
Telescope State



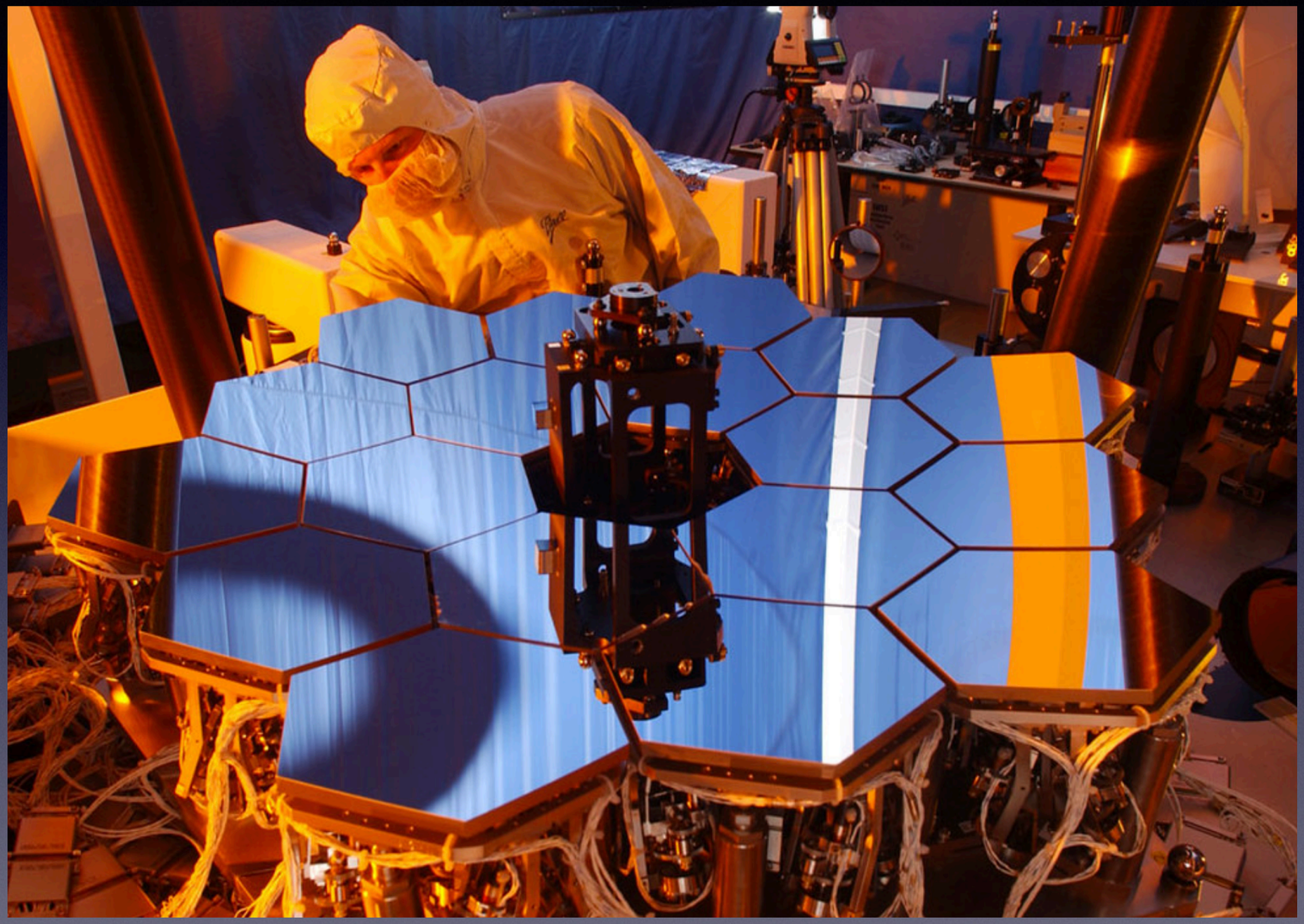
Overall Timeline



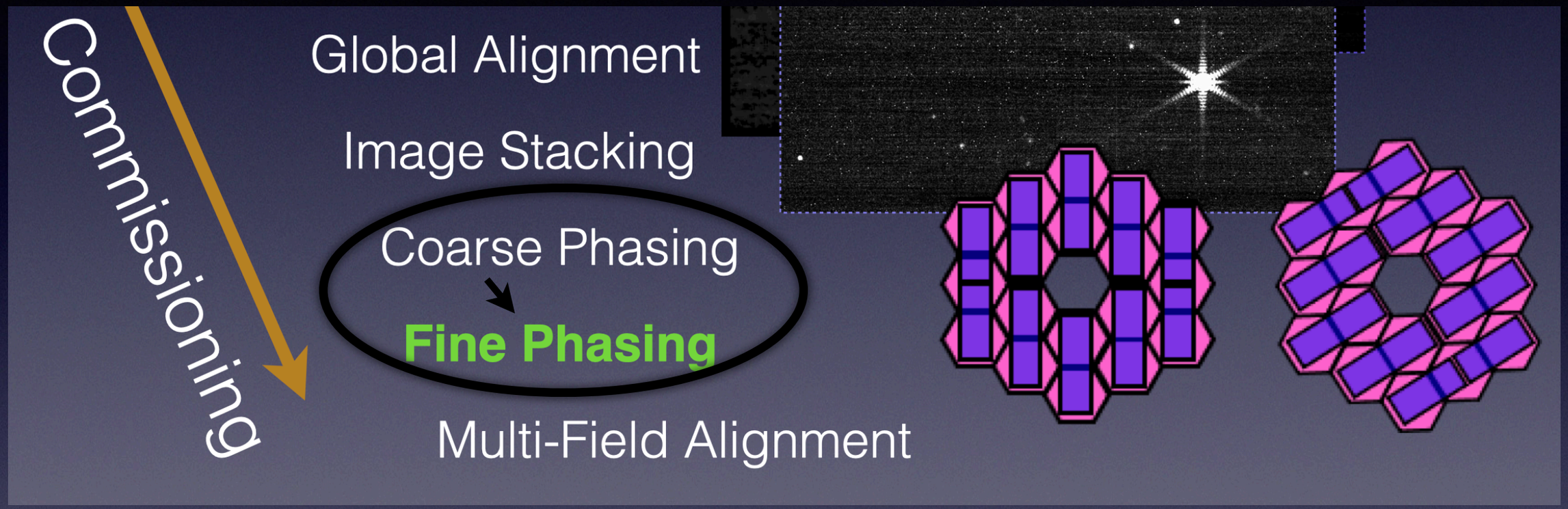
Waterfall - Overview of Commissioning Steps



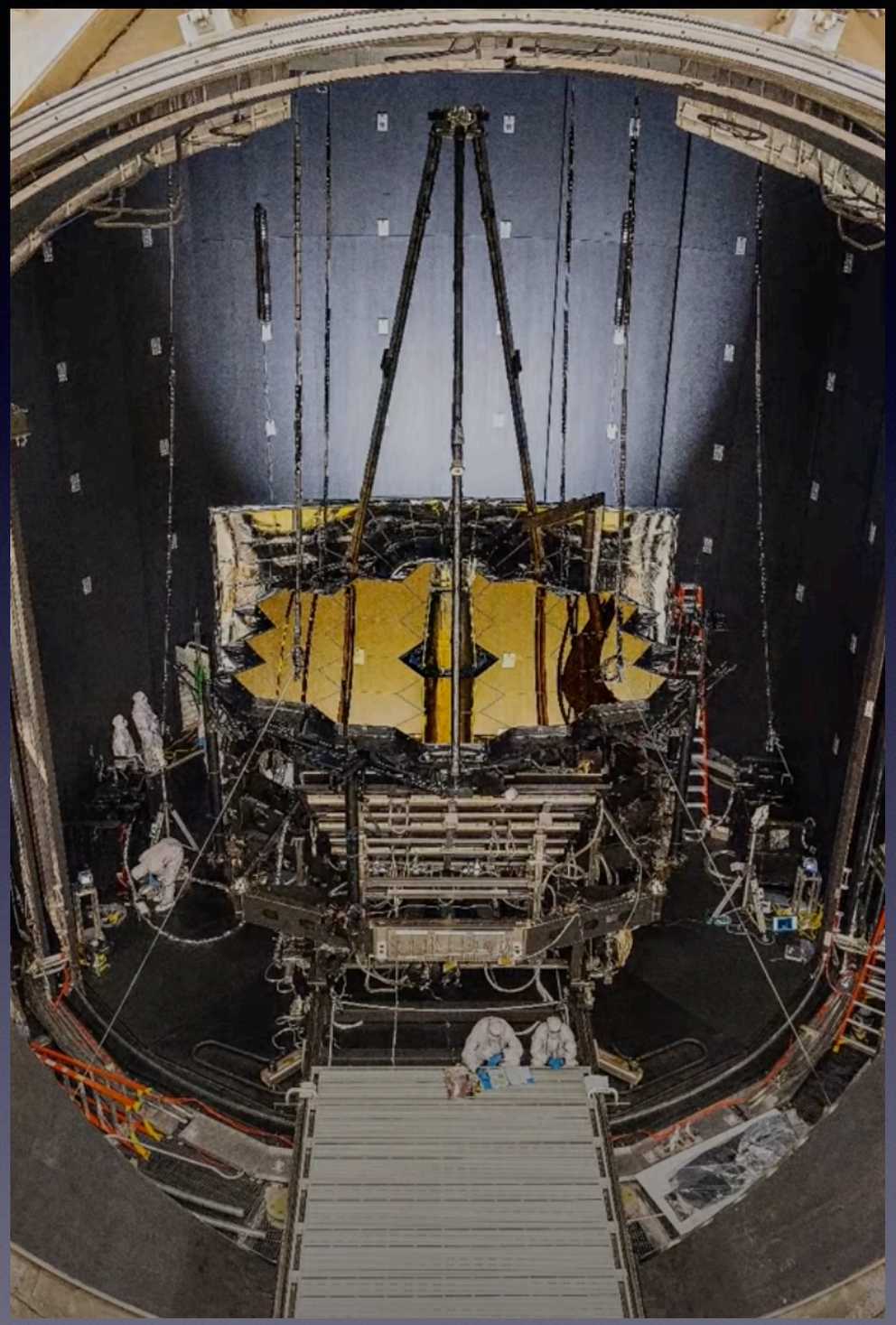
Technology Development: TRL-6, 2005

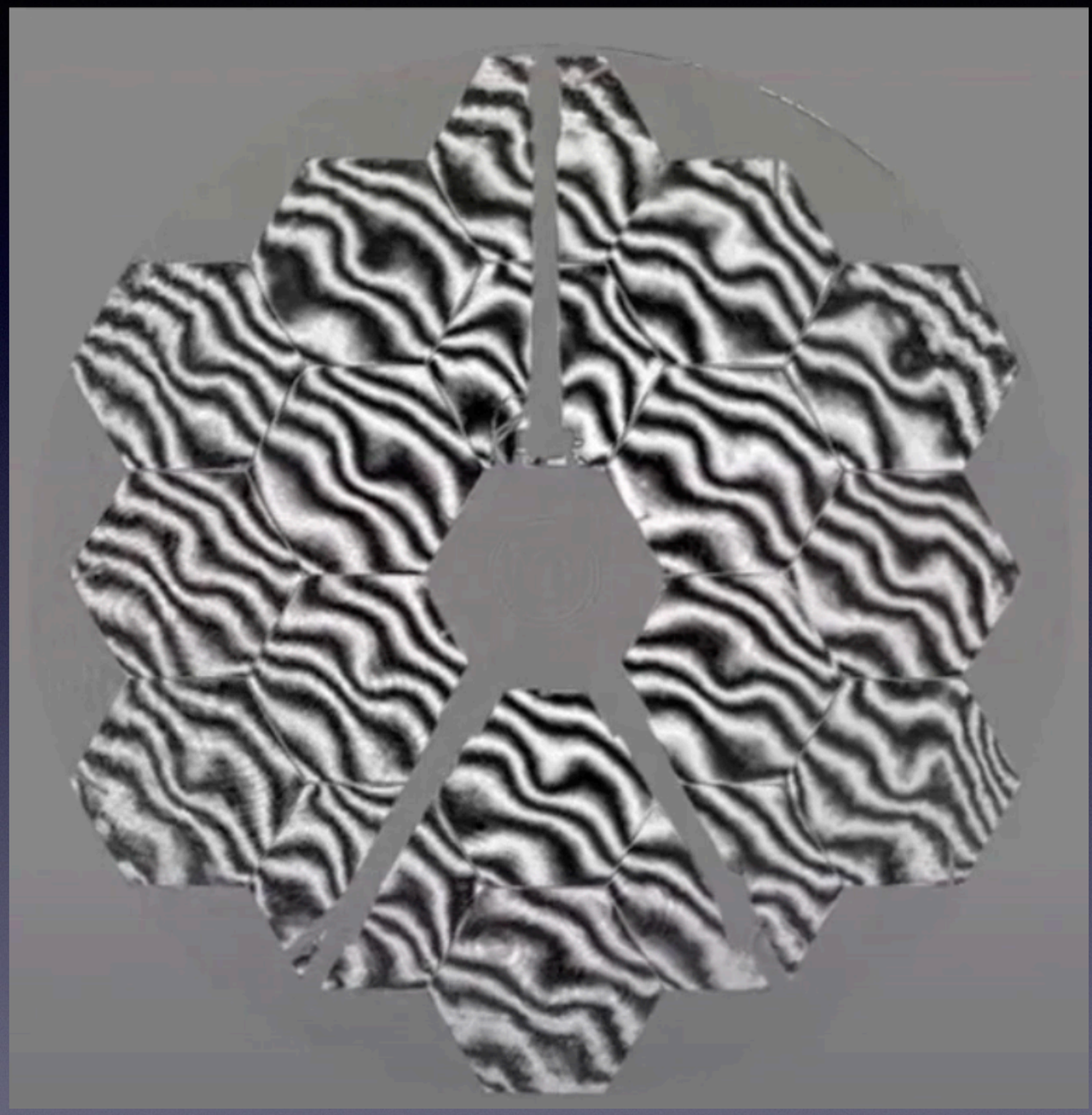


Handoff: Coarse to Fine Phasing

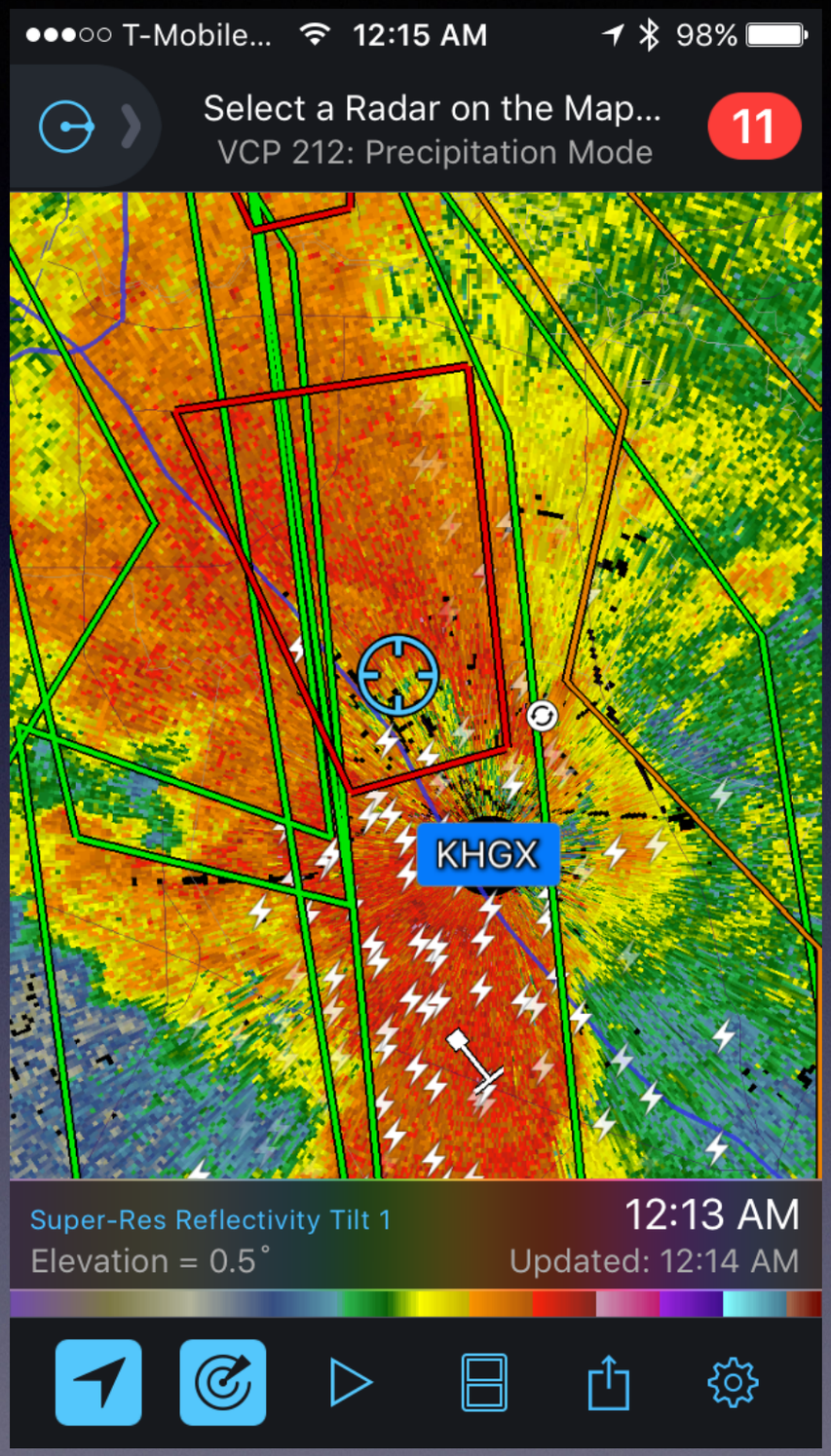


End-End Optical Testing, Summer 2017



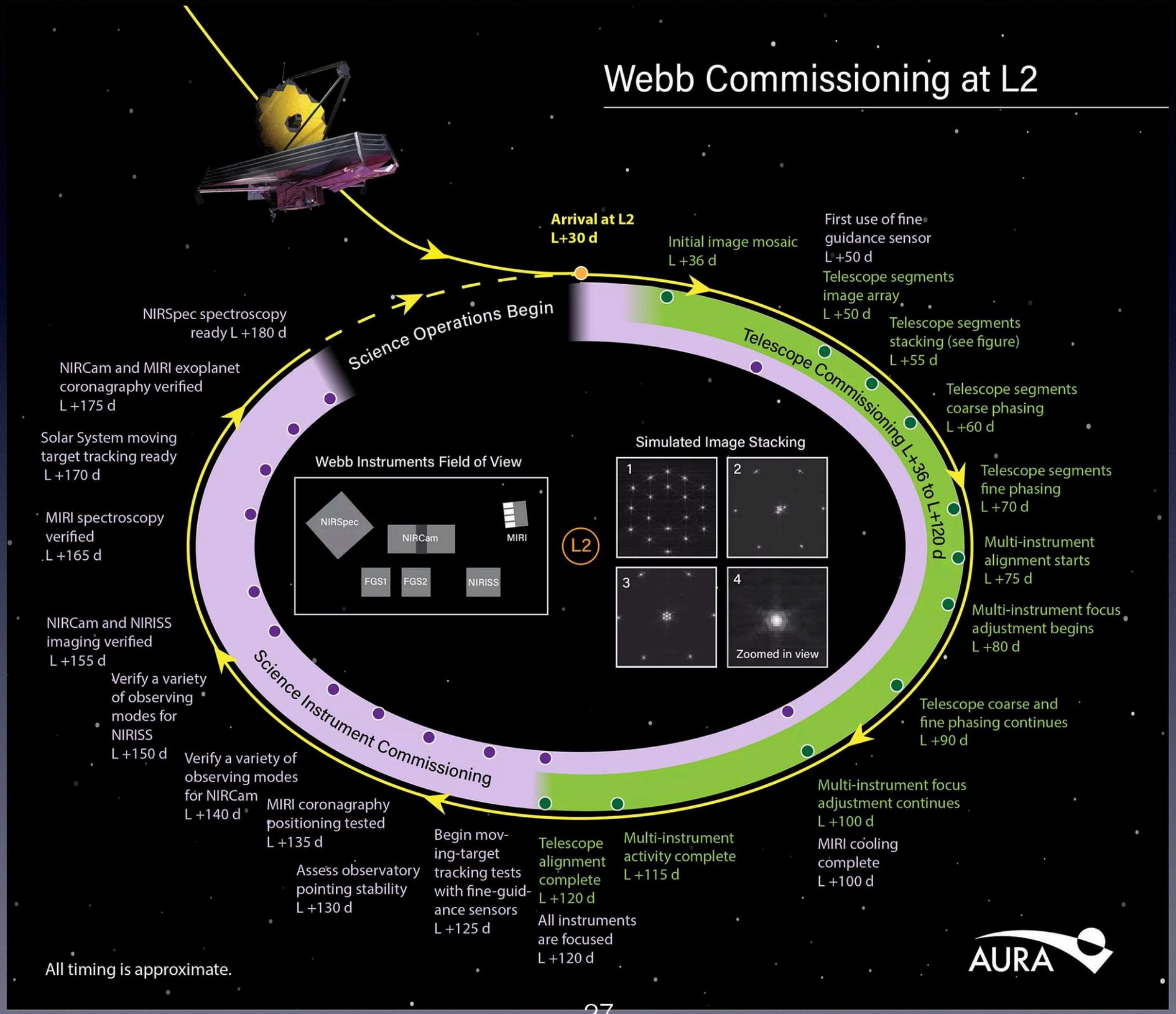


Hurricane Harvey



Hurricane Harvey

Optical Work Begins at L2



Alignment Work at the STScI

Wavefront Commissioning Team

BALL Aerospace

STScI

Goddard

WAS

Wavefront Analysis Software

Shadow

Wavefront Analysis Software

PRMS

Phase Retrieval Metrology System

View Inside the Wavefront Room

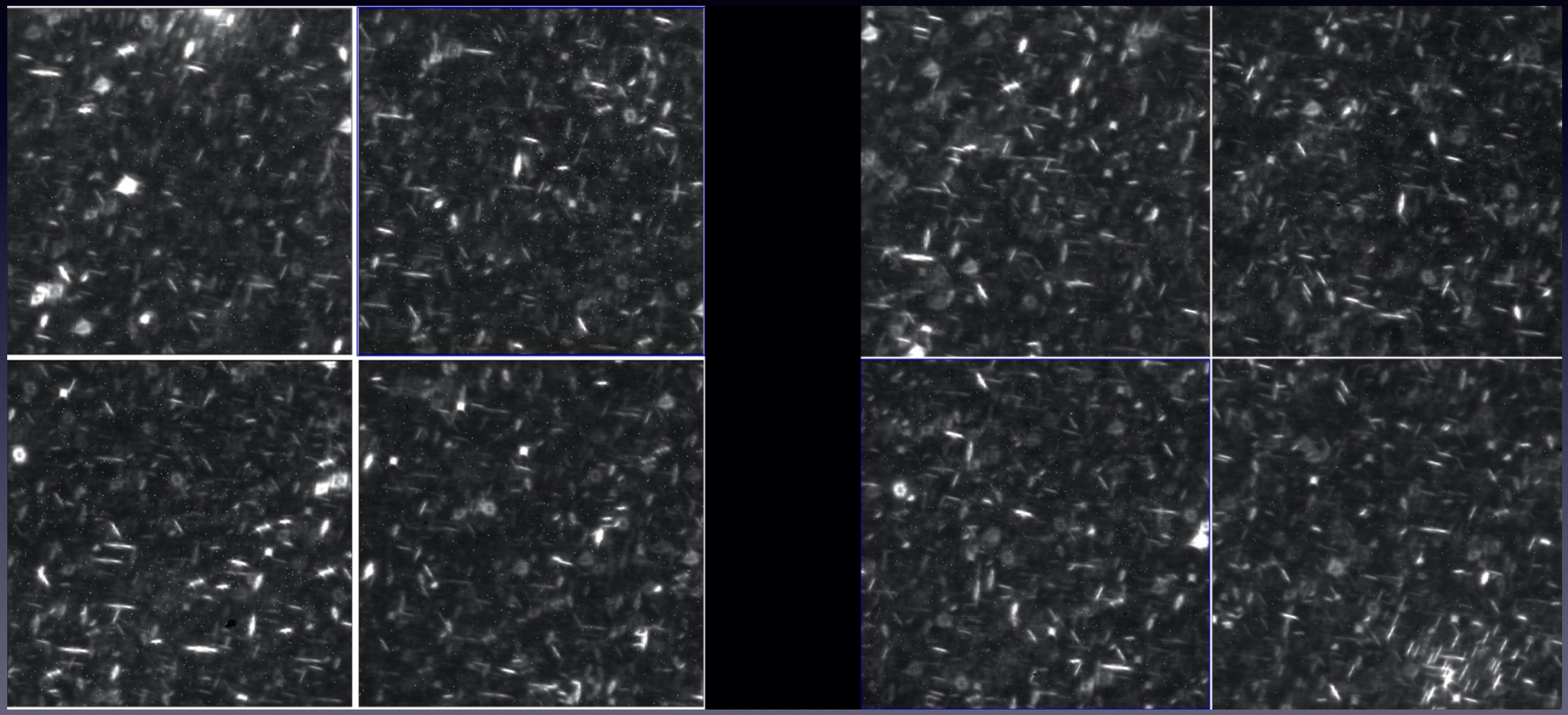
First Light: NIRCam Liveness Test

Team Meeting in Baltimore at the STScI MOC

Large Magellanic Cloud, February 2nd, 2022

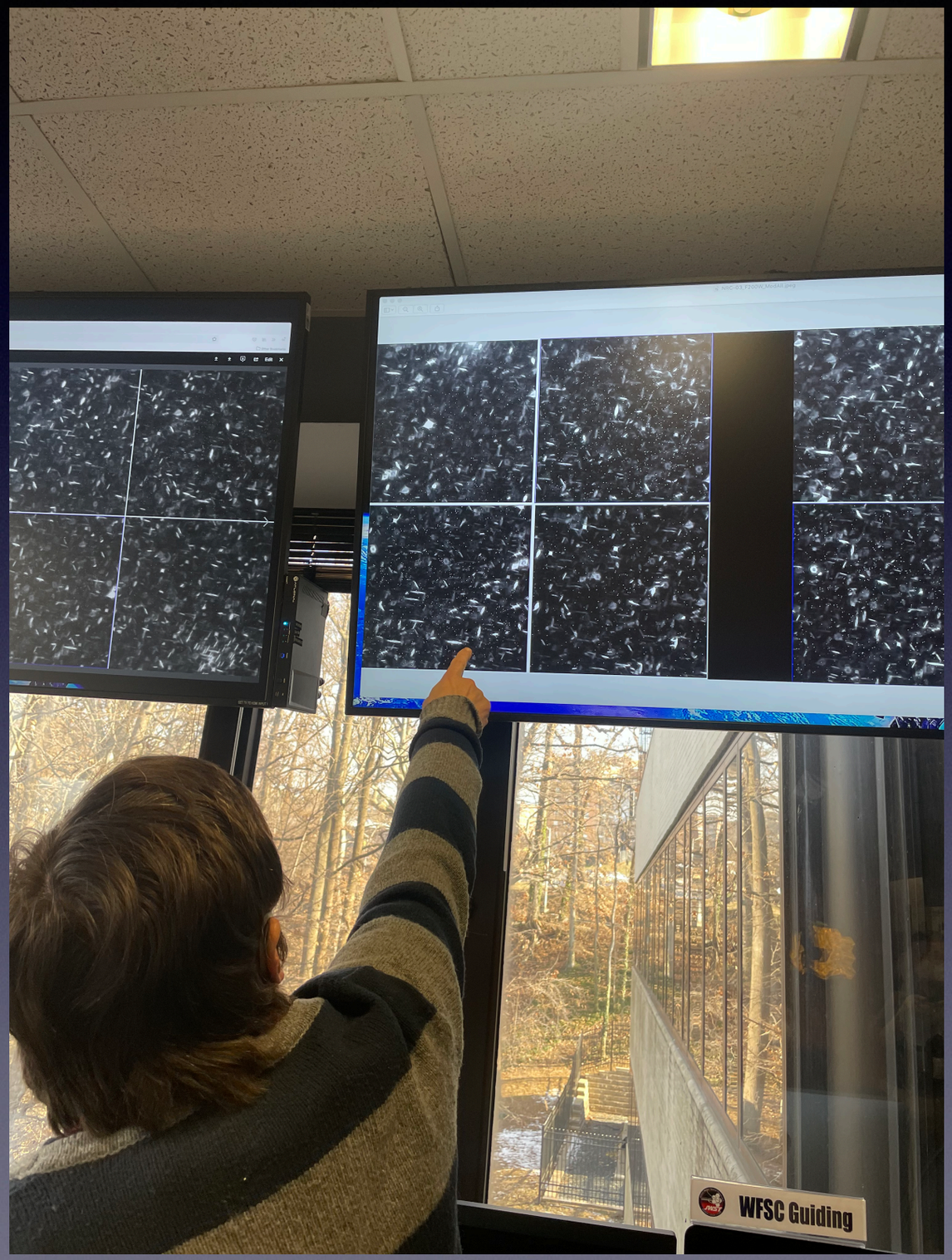
NIRCam-A

NIRCam-B

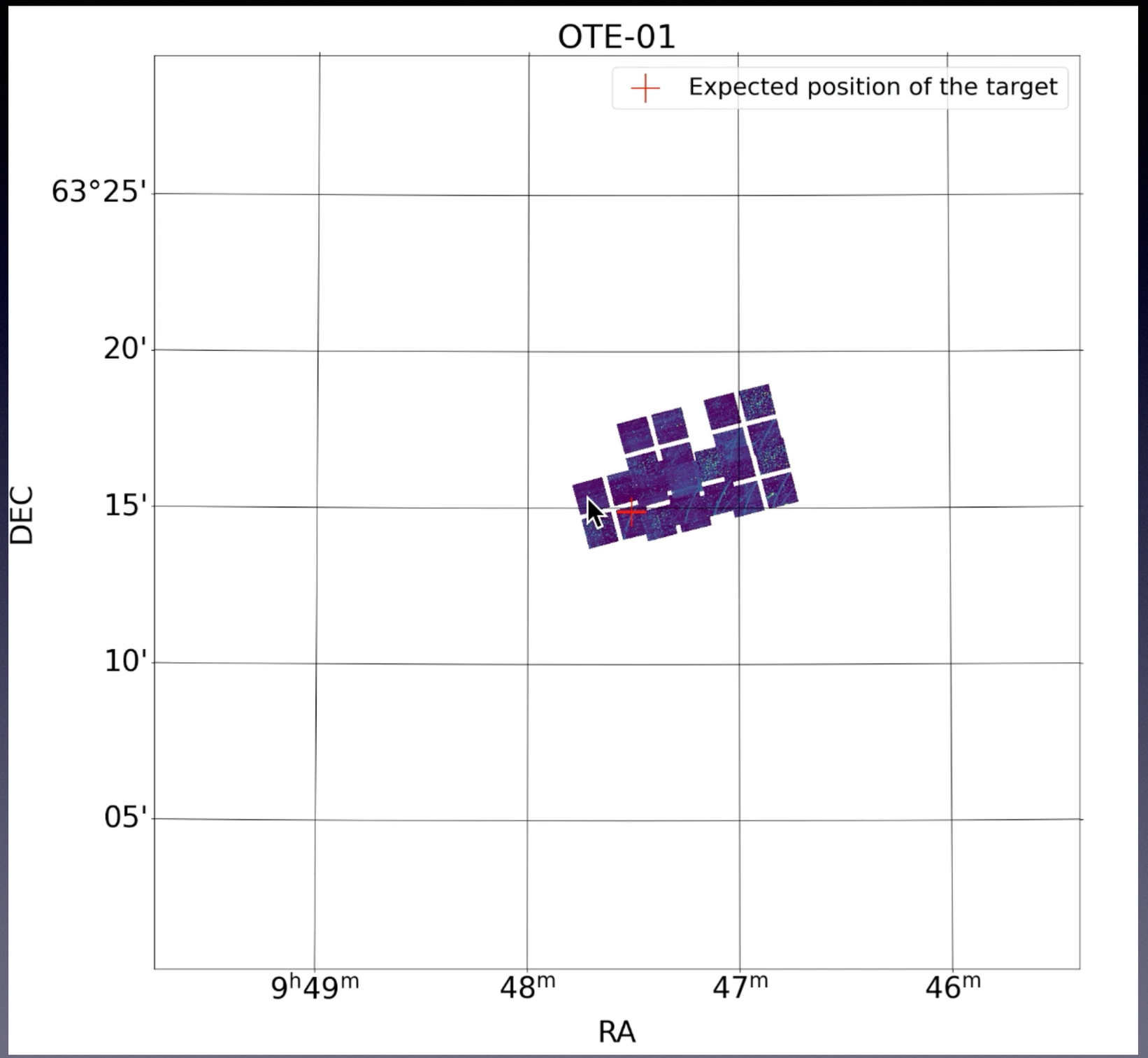


View from the Wavefront Room

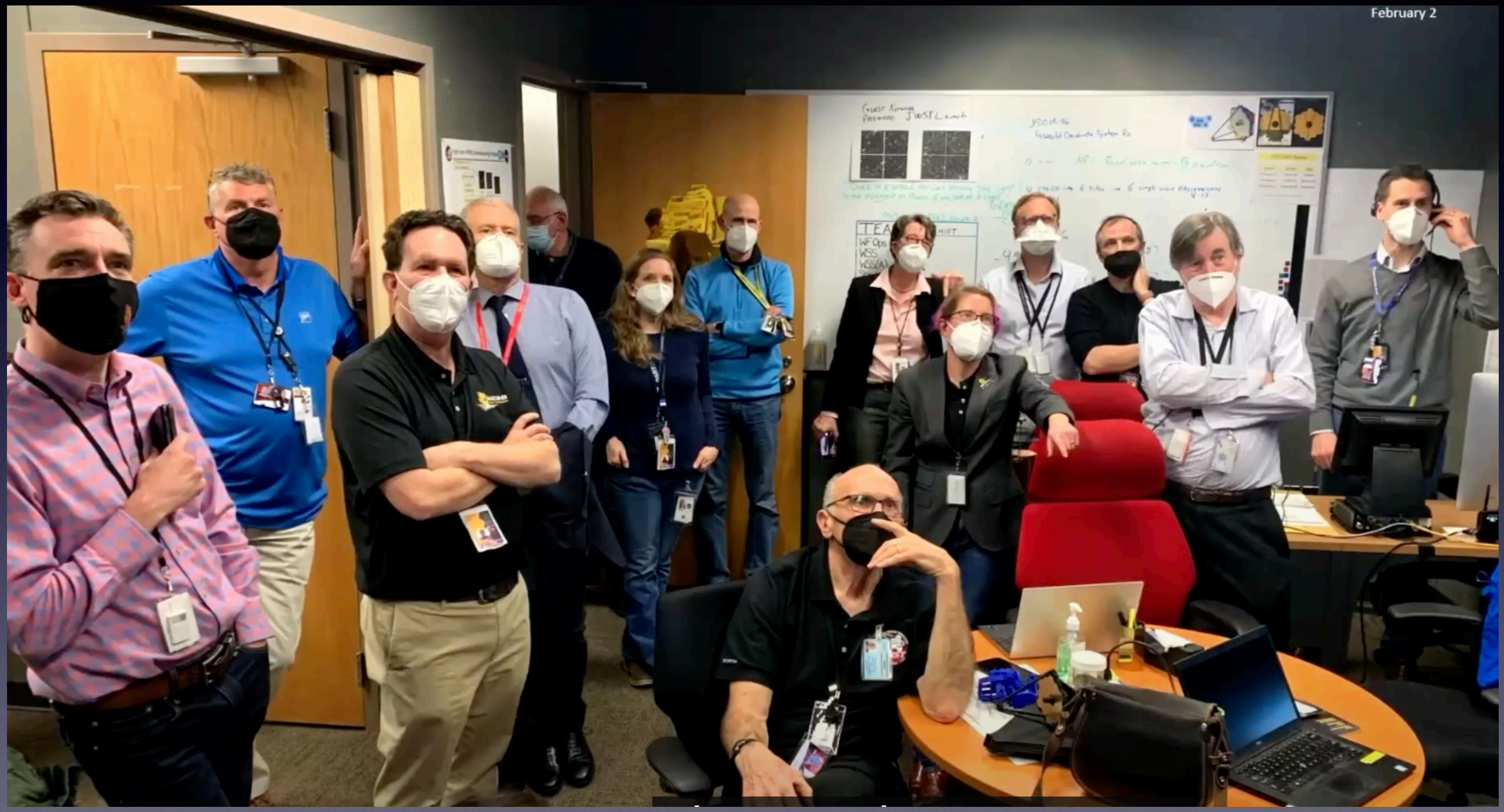
Large Magellanic Cloud, February 2nd, 2022



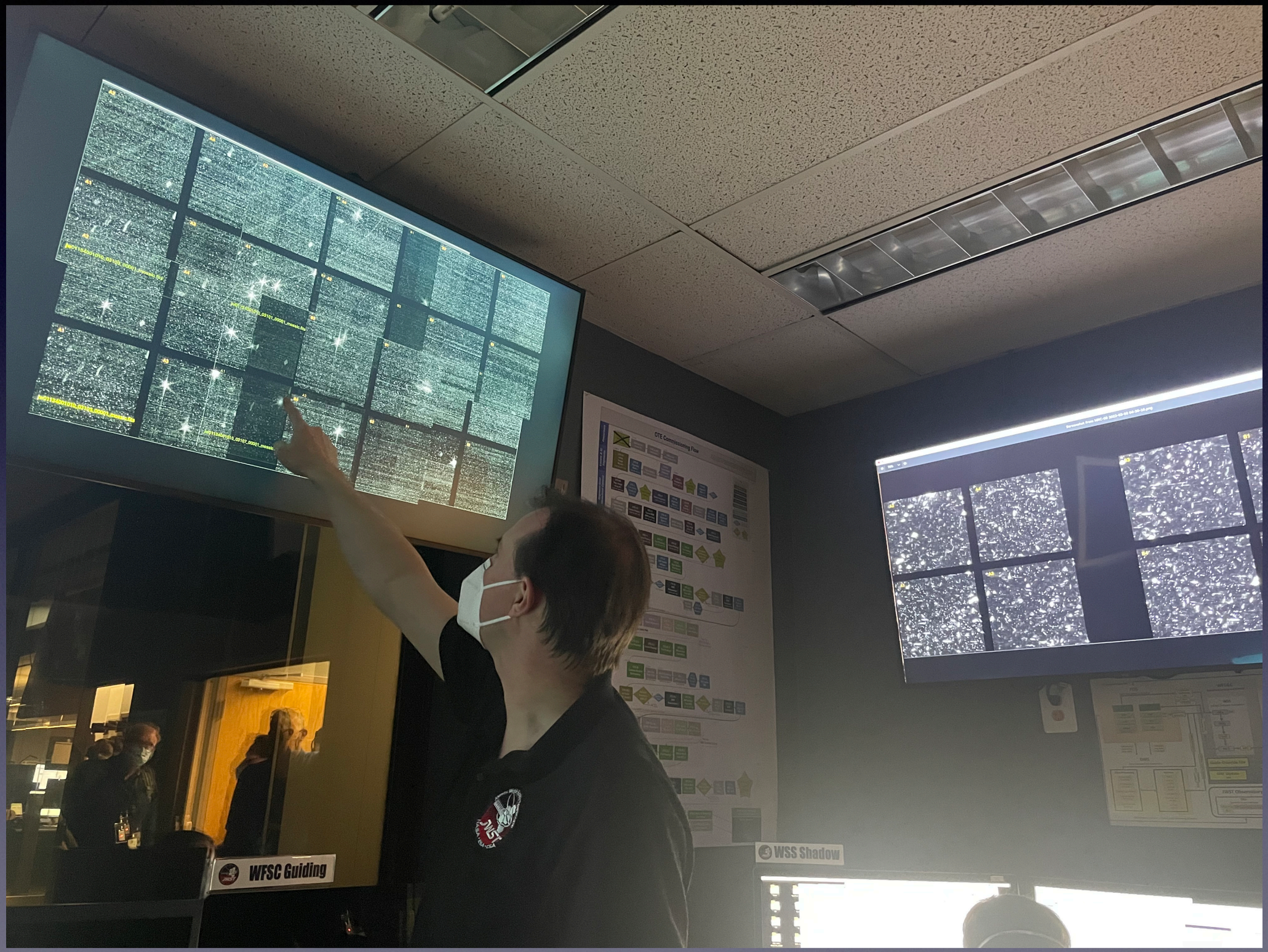
Next Step: Mosaic



Initial Data Comes In



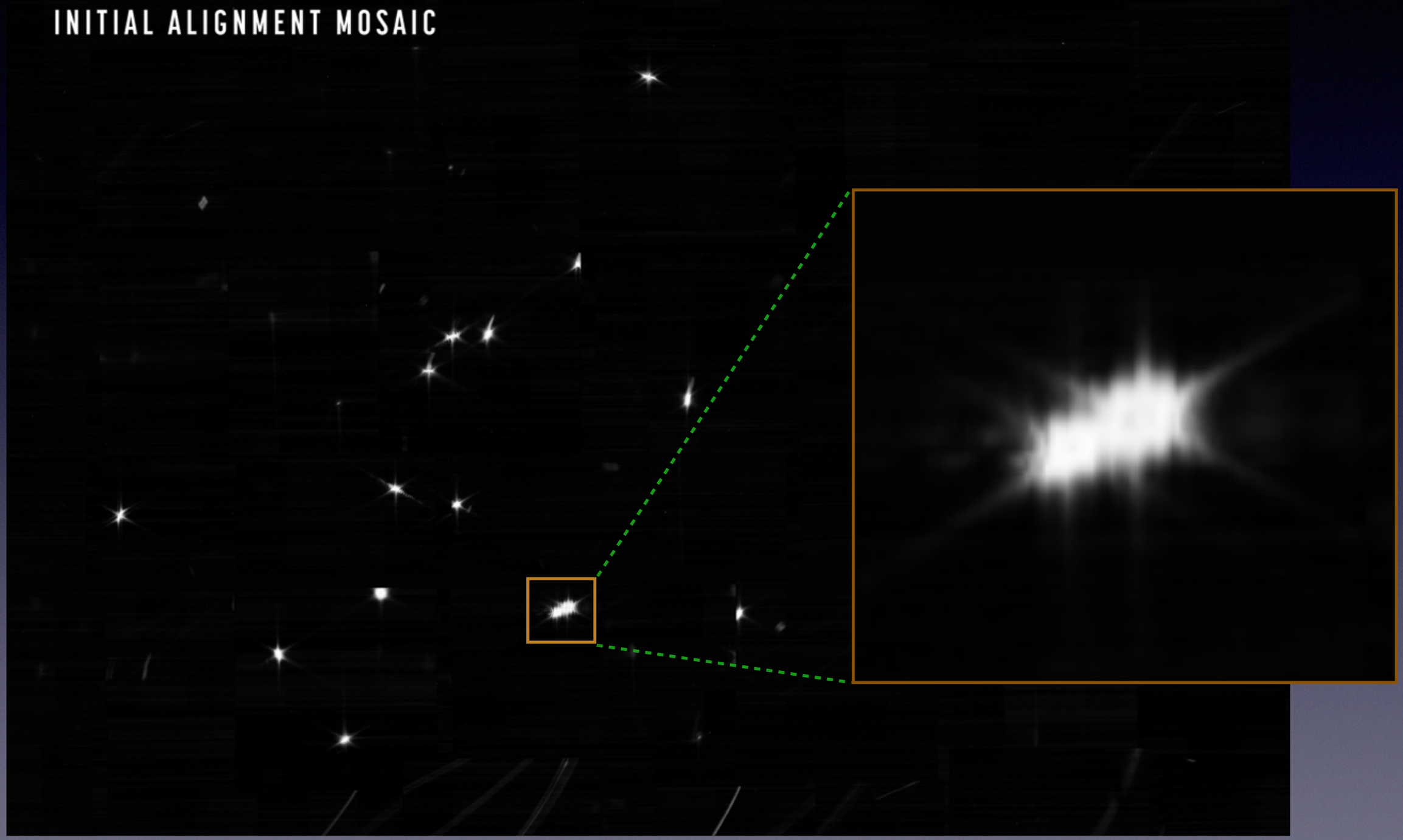
Excitement



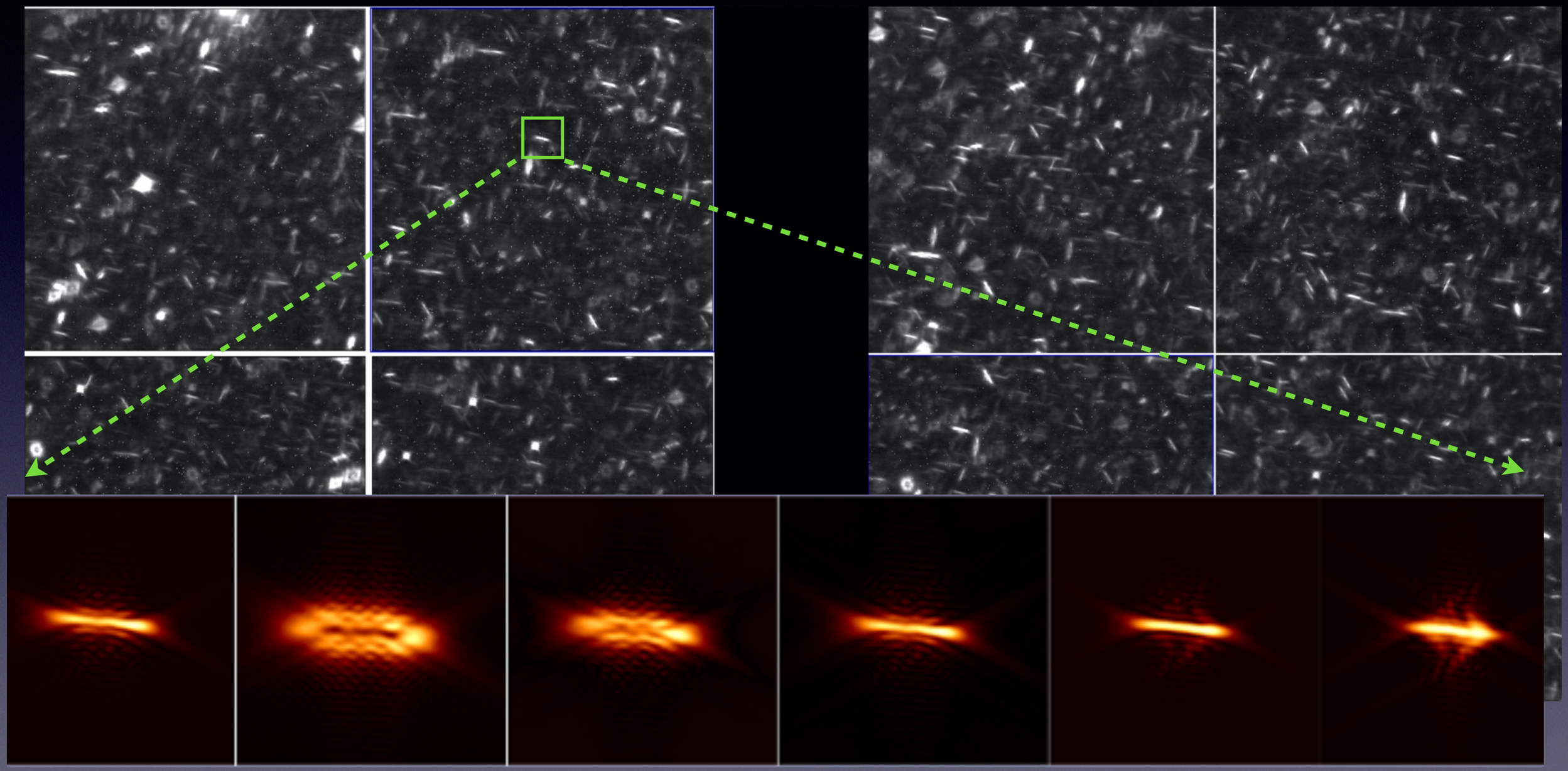
Initial Segment Annotations

Bright Star Repeated 18 Times

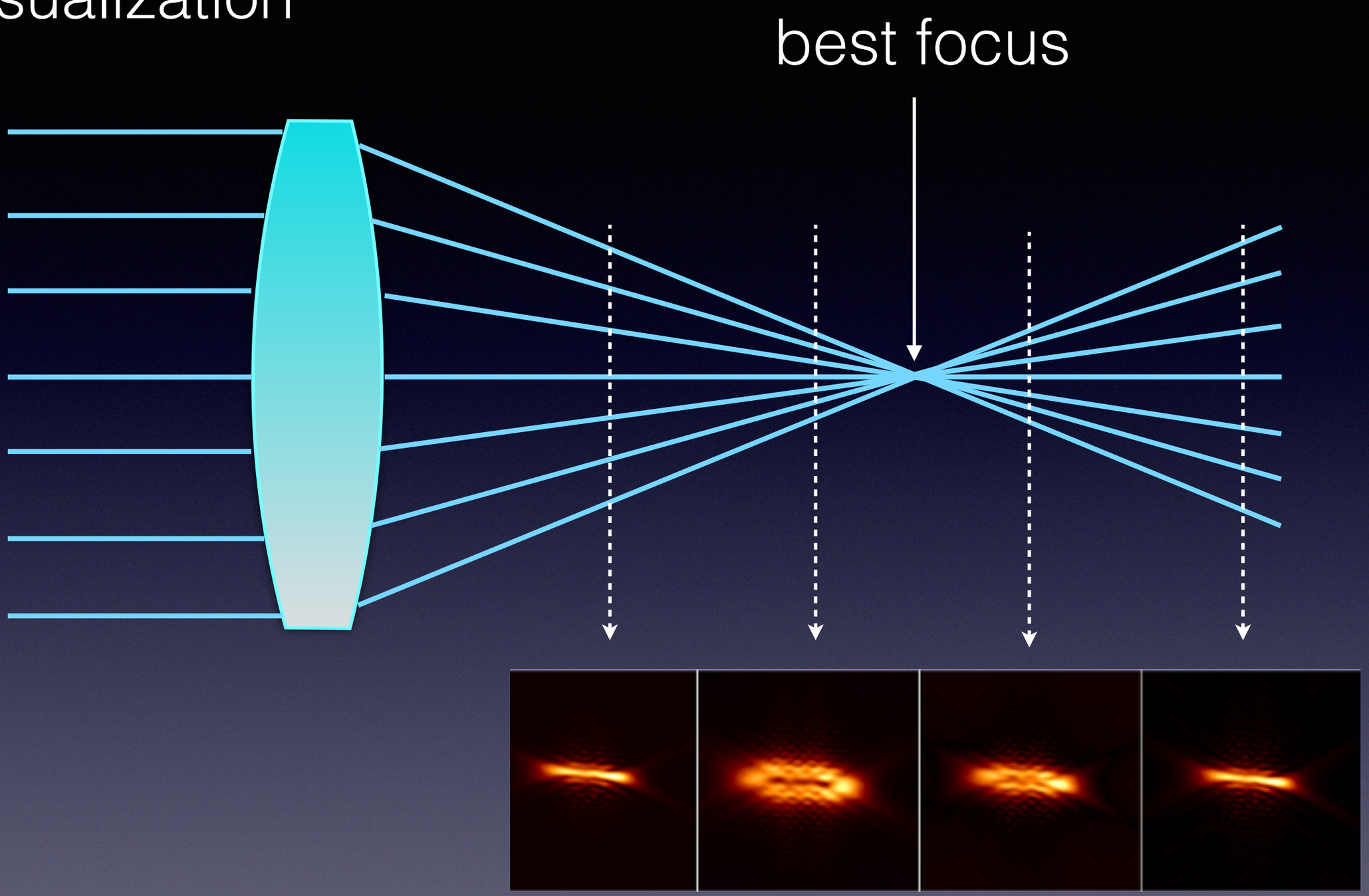
Segment Fringes



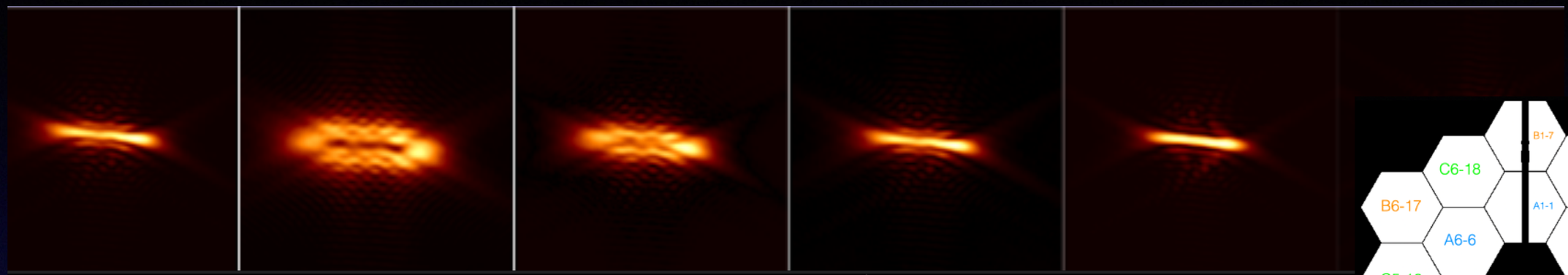
Early Secondary Mirror Focus Sweep

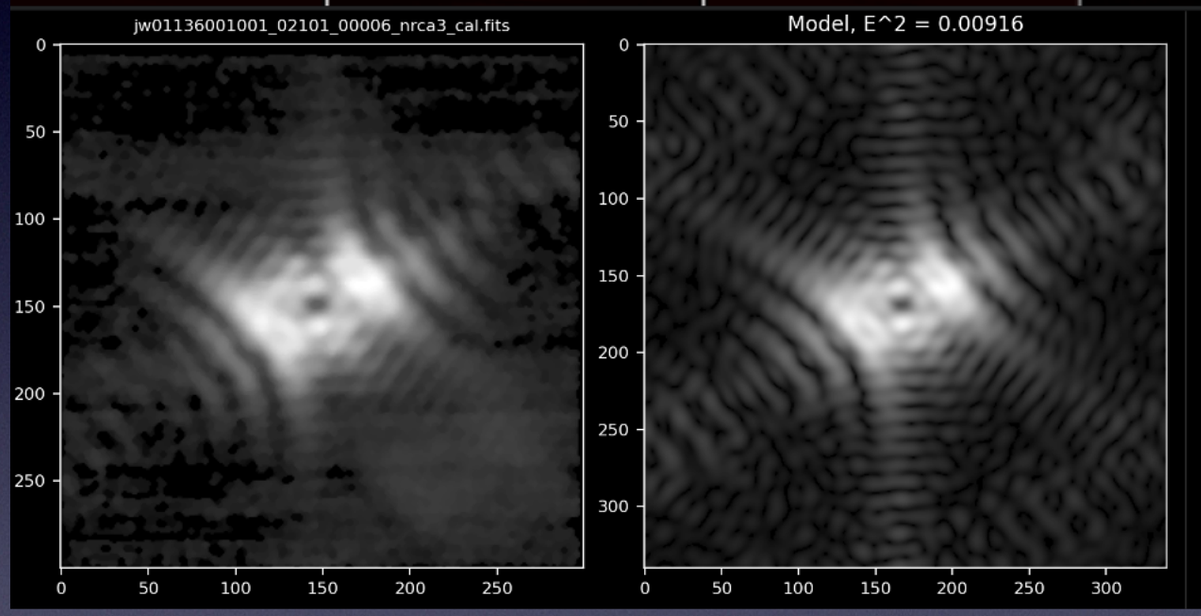


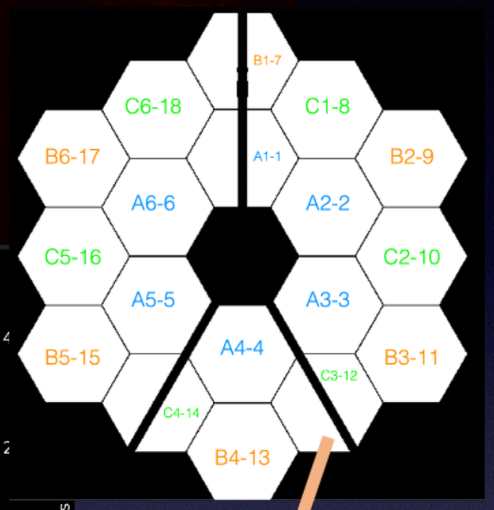
Visualization

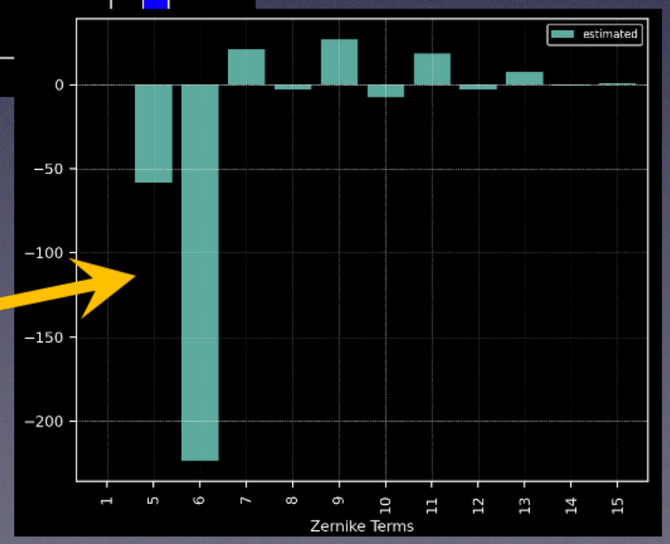


Initial Wavefront Sensing







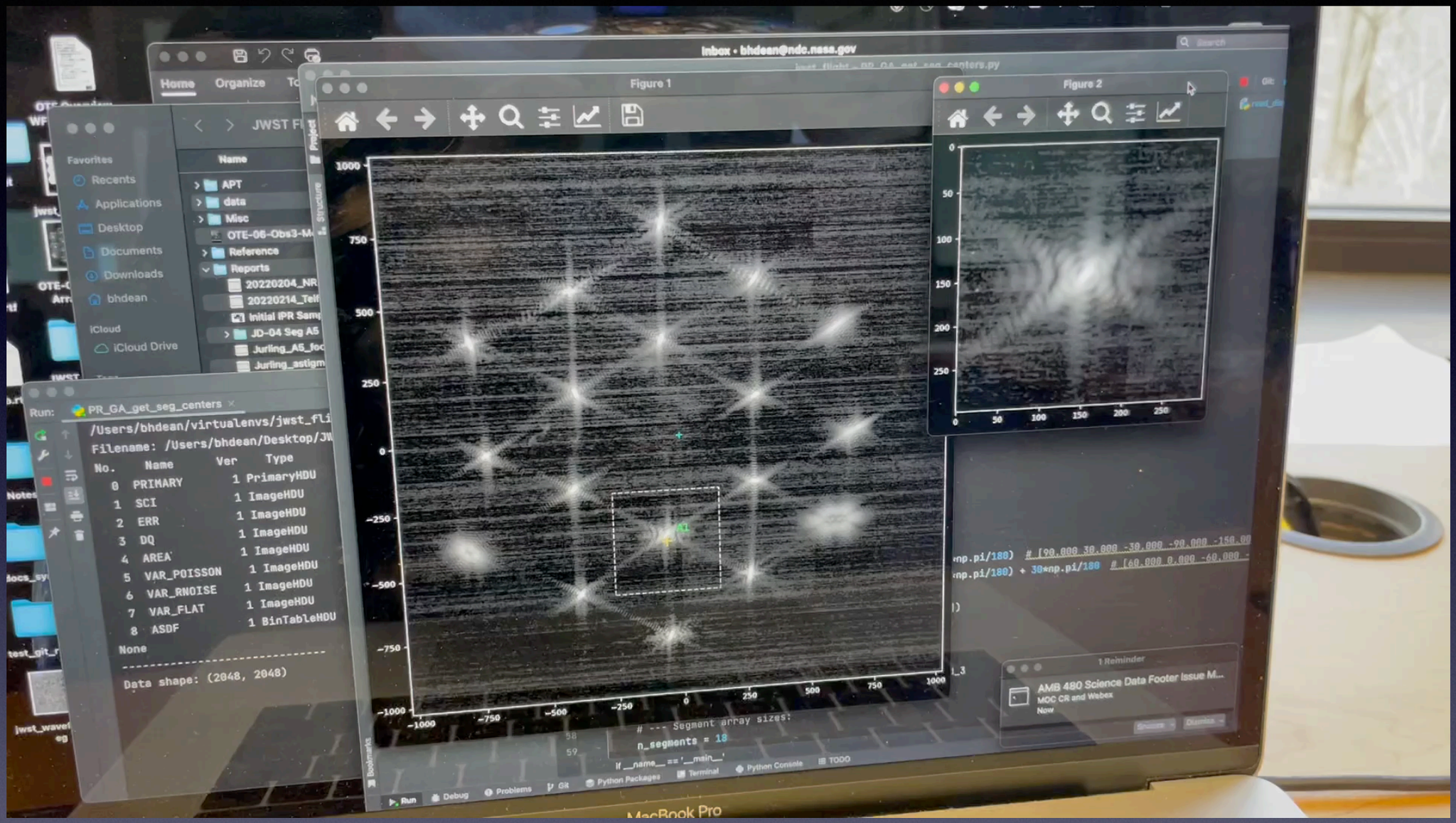


NASA GSFC, Feb 5, 2022

B. Dean / NASA GSFC

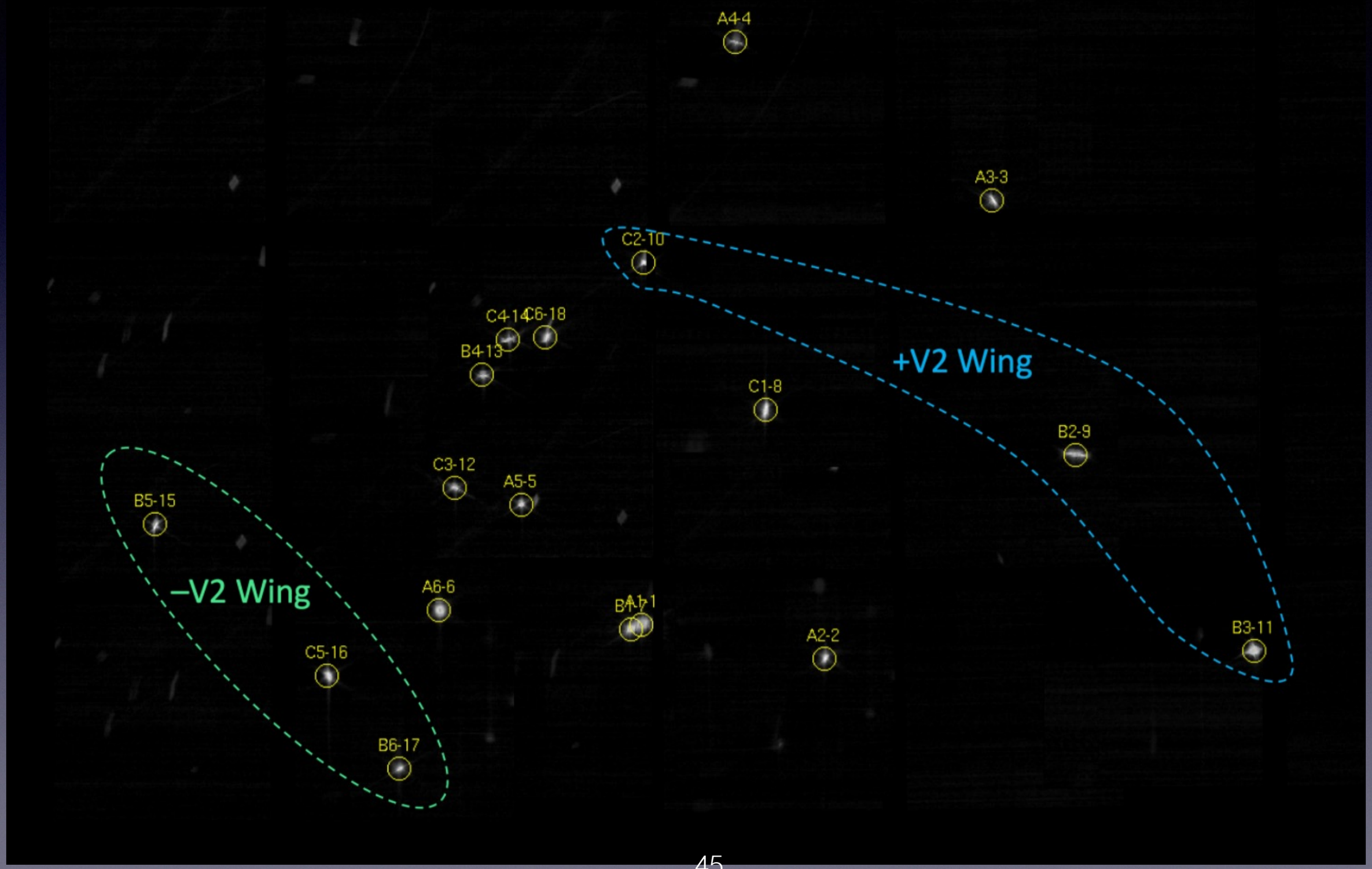
Signals used to drive hexapod actuators

One-by-One

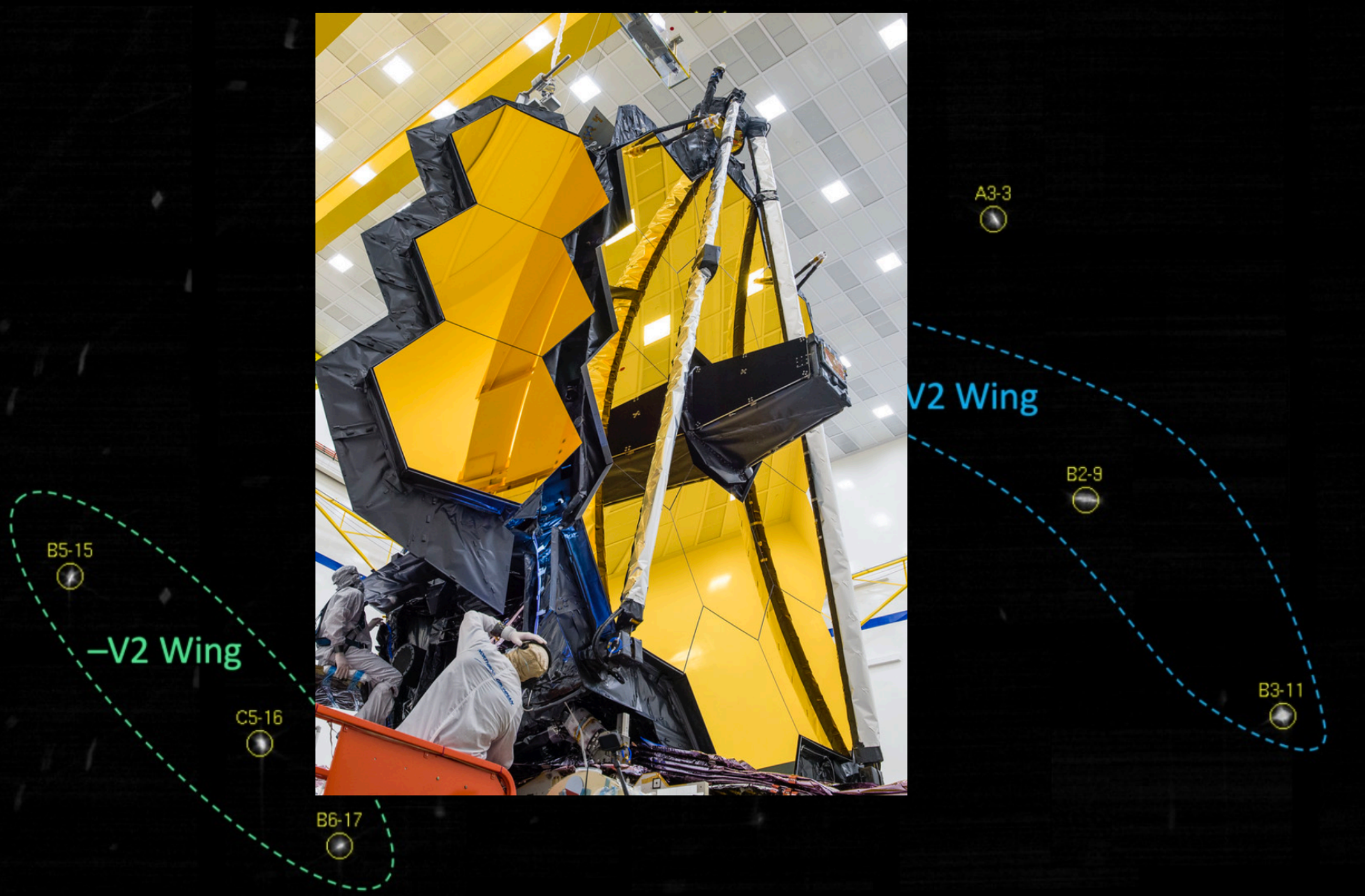

Inbox • bhdean@ndc.nasa.gov
Figure 1
Figure 2
Home
Organize
Favorites
Recents
Applications
Desktop
Documents
Downloads
bhdean
iCloud
iCloud Drive
Name
APT
data
Misc
Reference
Reports
JD-04 Seg A5
Run:
PR_GA_get_seg_centers
/Users/bhdean/virtualenvs/jwst_fli
Filename: /Users/bhdean/Desktop/JW
No. Name Ver Type
0 PRIMARY 1 PrimaryHDU
1 SCI 1 ImageHDU
2 ERR 1 ImageHDU
3 DQ 1 ImageHDU
4 AREA 1 ImageHDU
5 VAR_POISSON 1 ImageHDU
6 VAR_RNOISE 1 ImageHDU
7 VAR_FLAT 1 ImageHDU
8 ASDF 1 BinTableHDU
None
Data shape: (2048, 2048)
# --- Segment array sizes:
n_segments = 18
if __name__ == '__main__'
1 Reminder
AMB 480 Science Data Footer Issue M...
MOC CR and Webex
Now
Run
Debug
Problems
Git
Python Packages
Terminal
Python Console
TODO
MacBook Pro

NASA Administrator Sees First Light Images

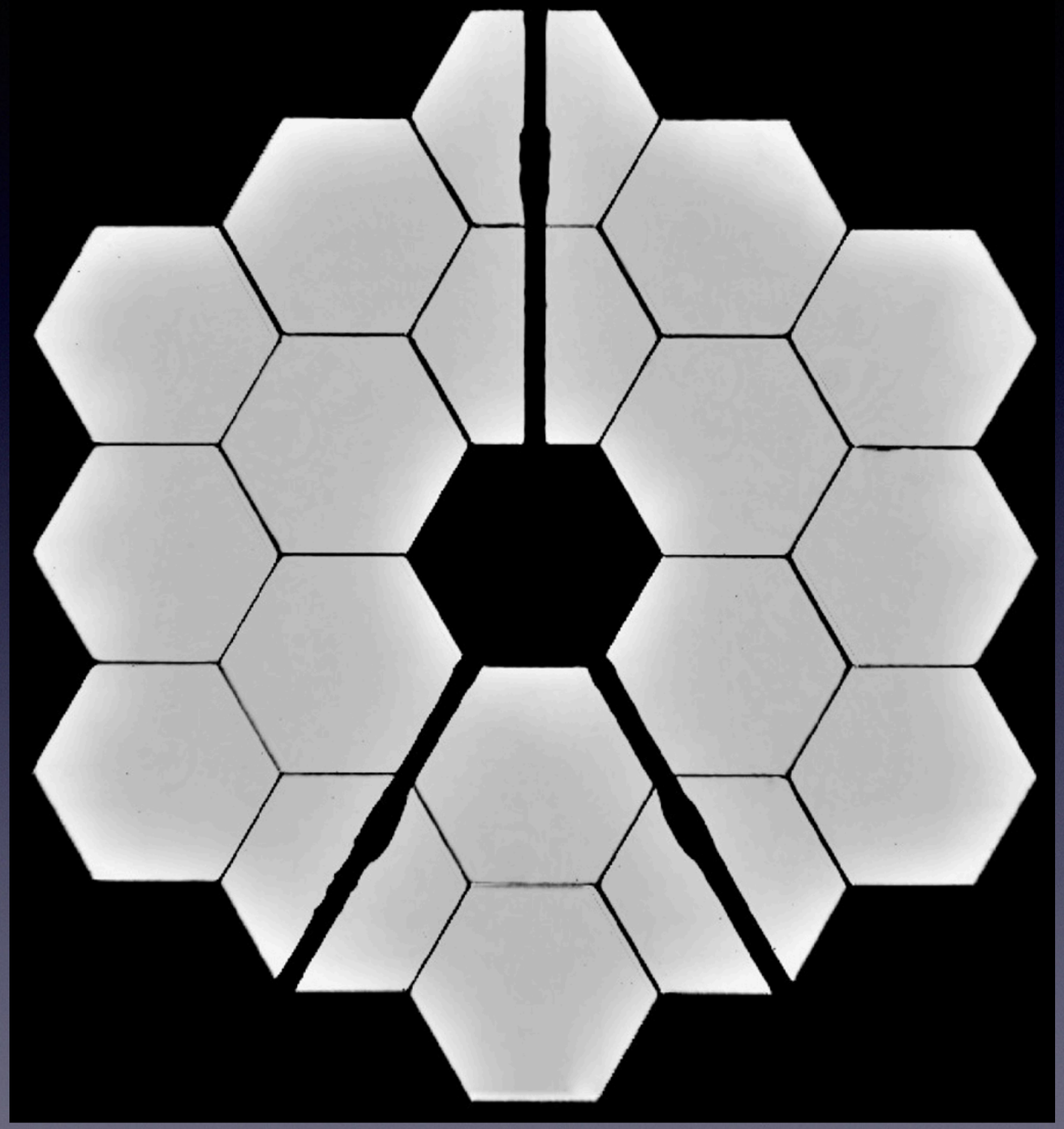
Results: Segment ID from Mosaic



Wings

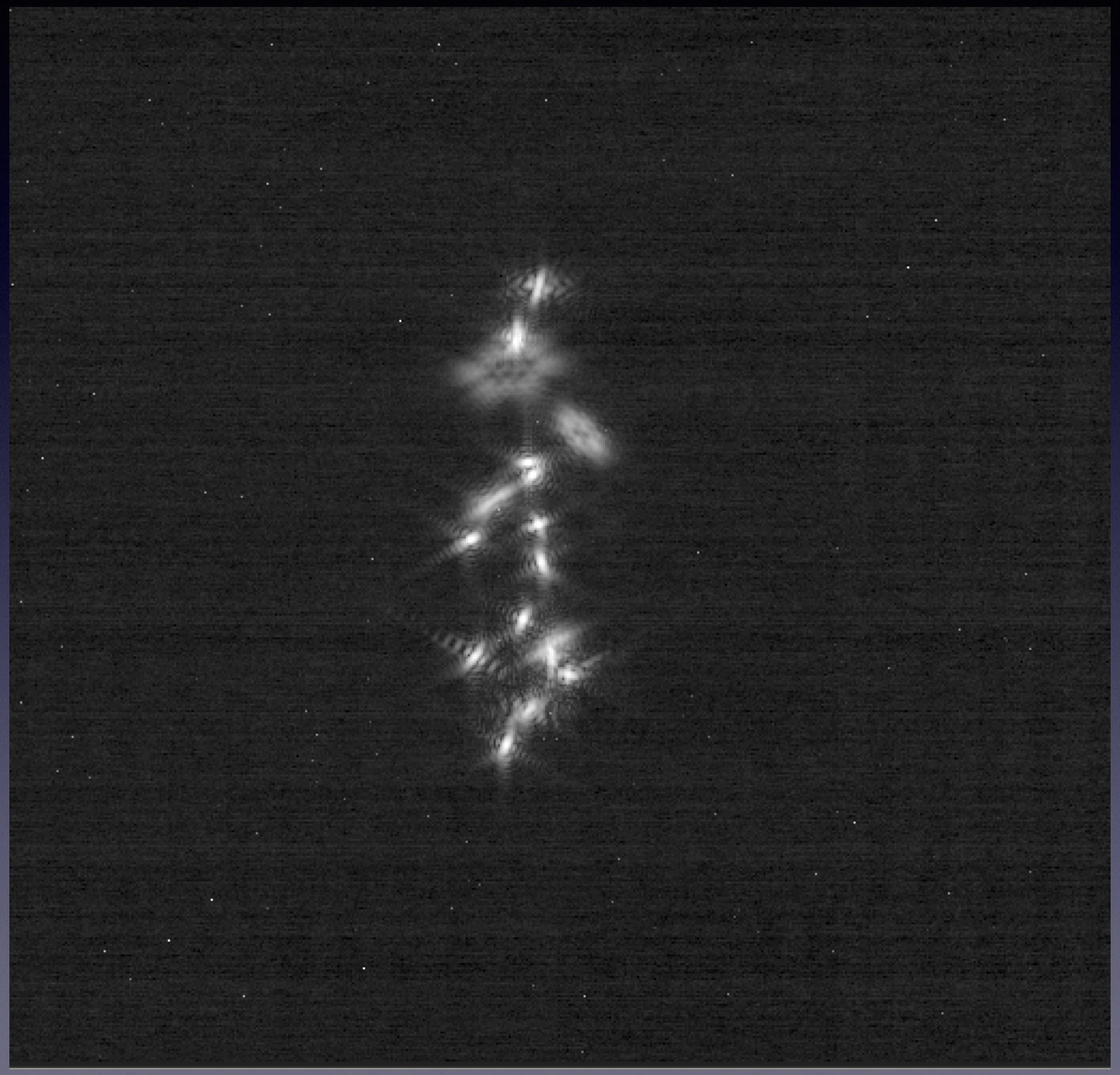


Pupil Image: NIRCam Alignment “Selfie”

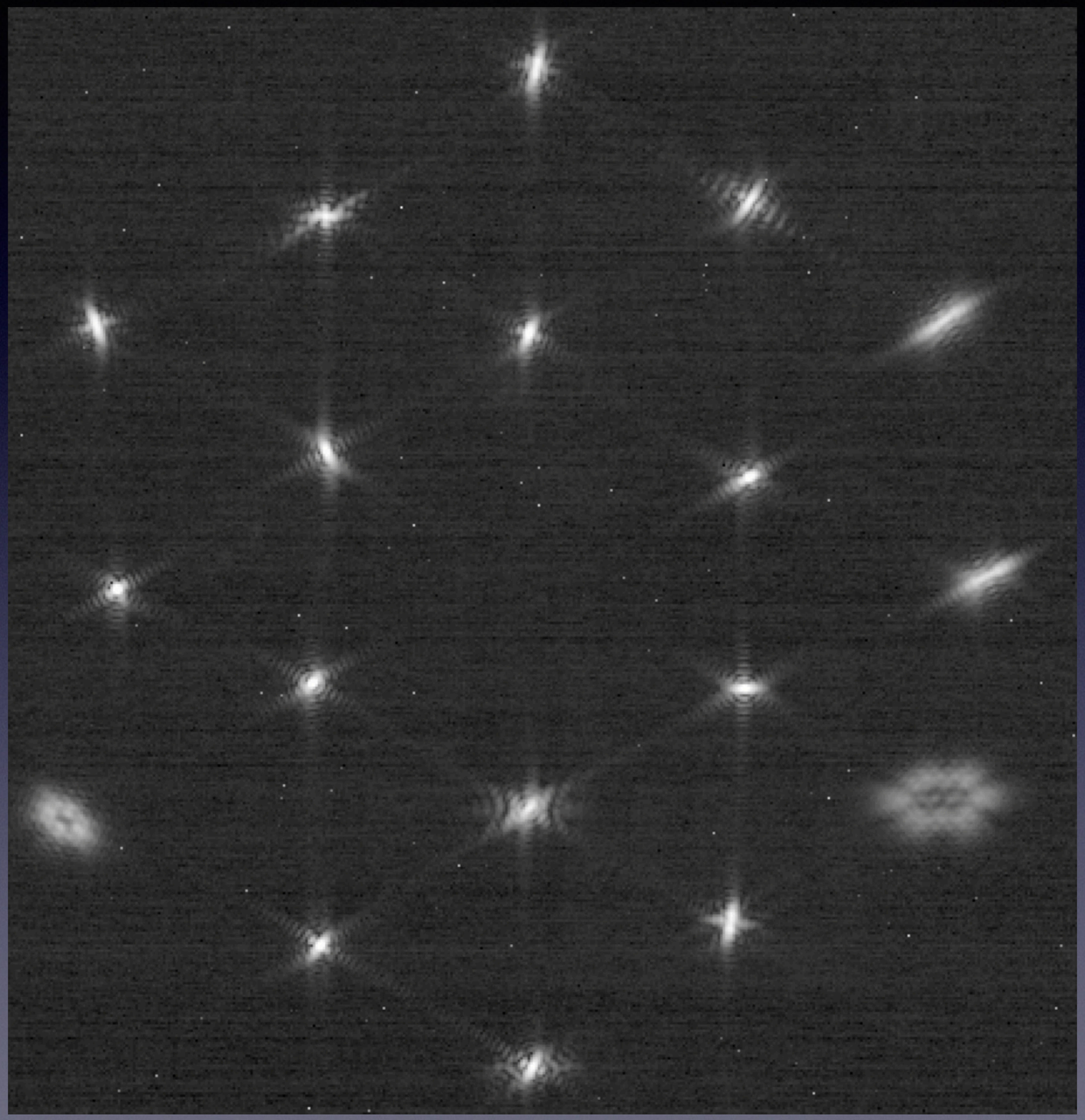


“pupil image” of the primary mirror. Edges show the primary mirror is aligned well with instrument.

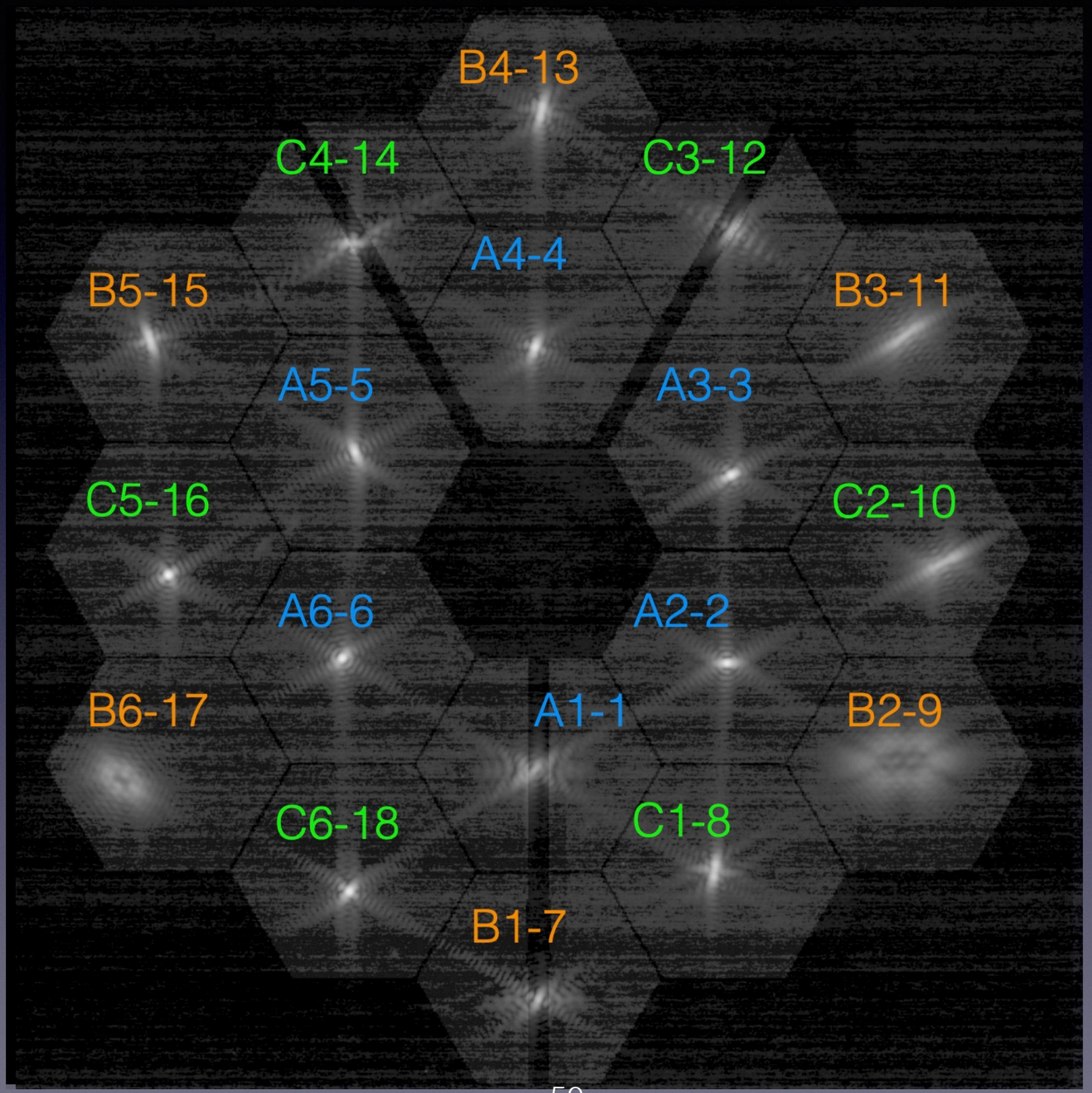
Image Array



Initial Image Array - Starting Point

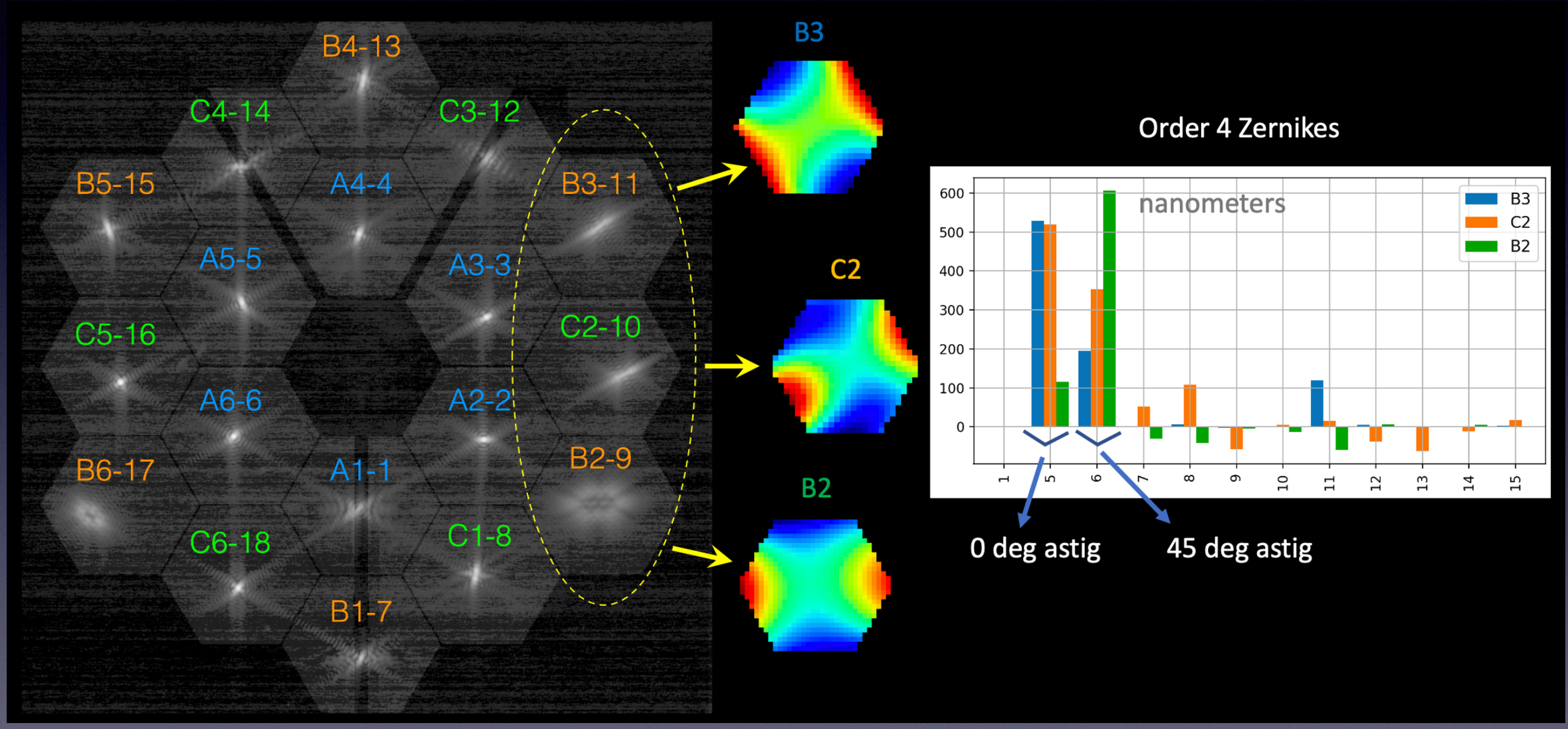


Visualization: Segment IDs

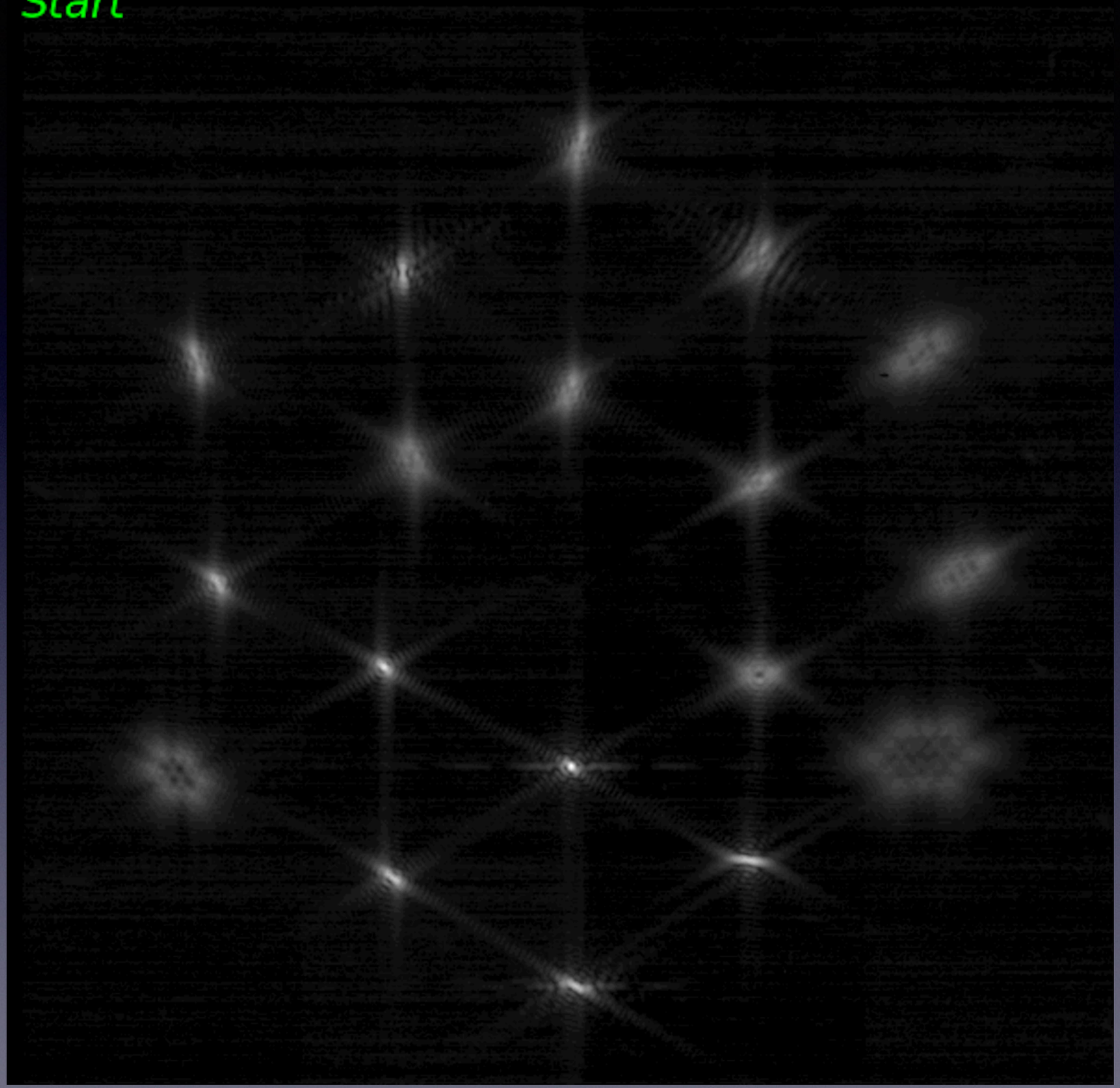


Initial Assessments

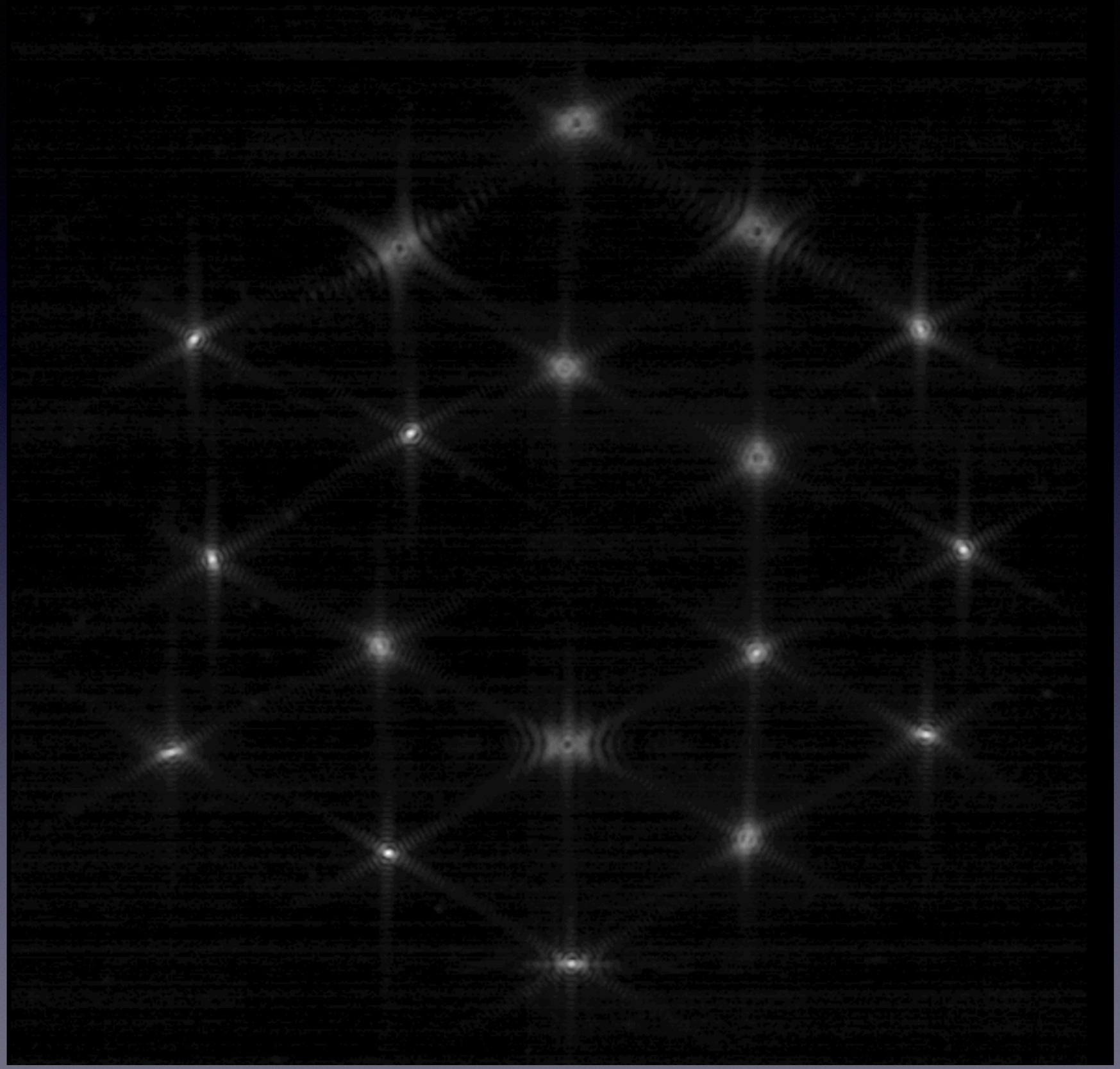
February 13, 2022



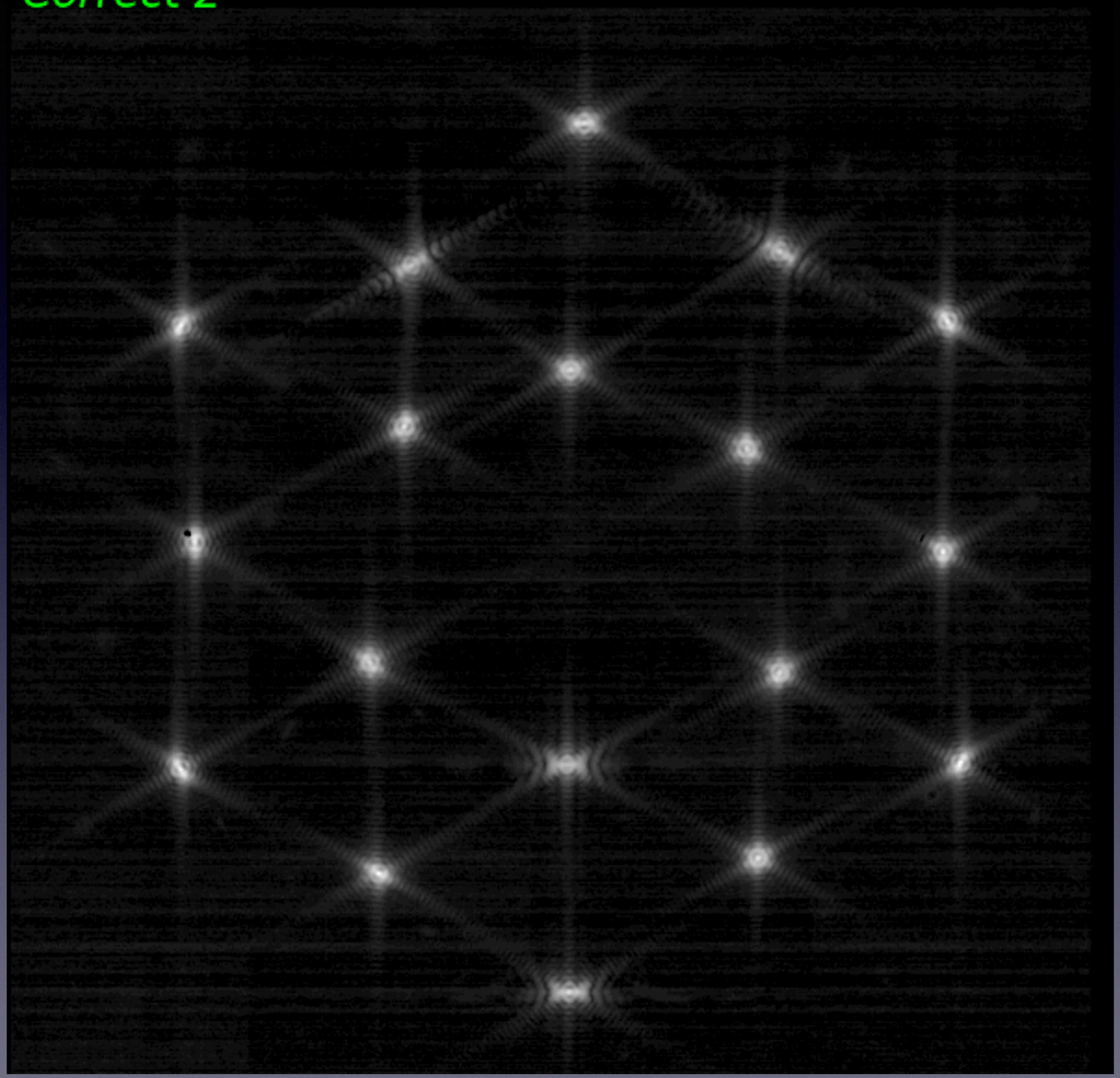
Start



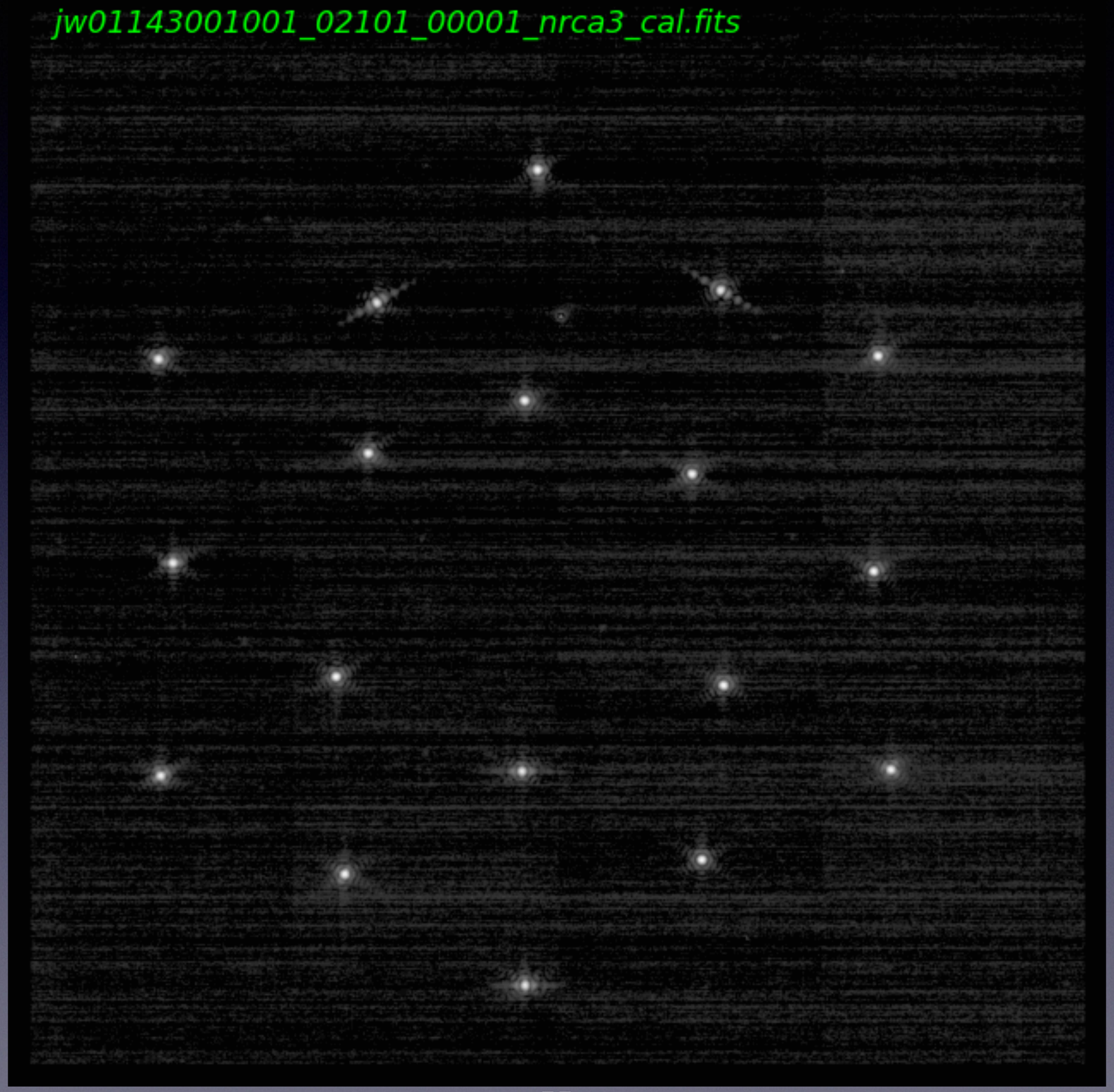
Correct 1



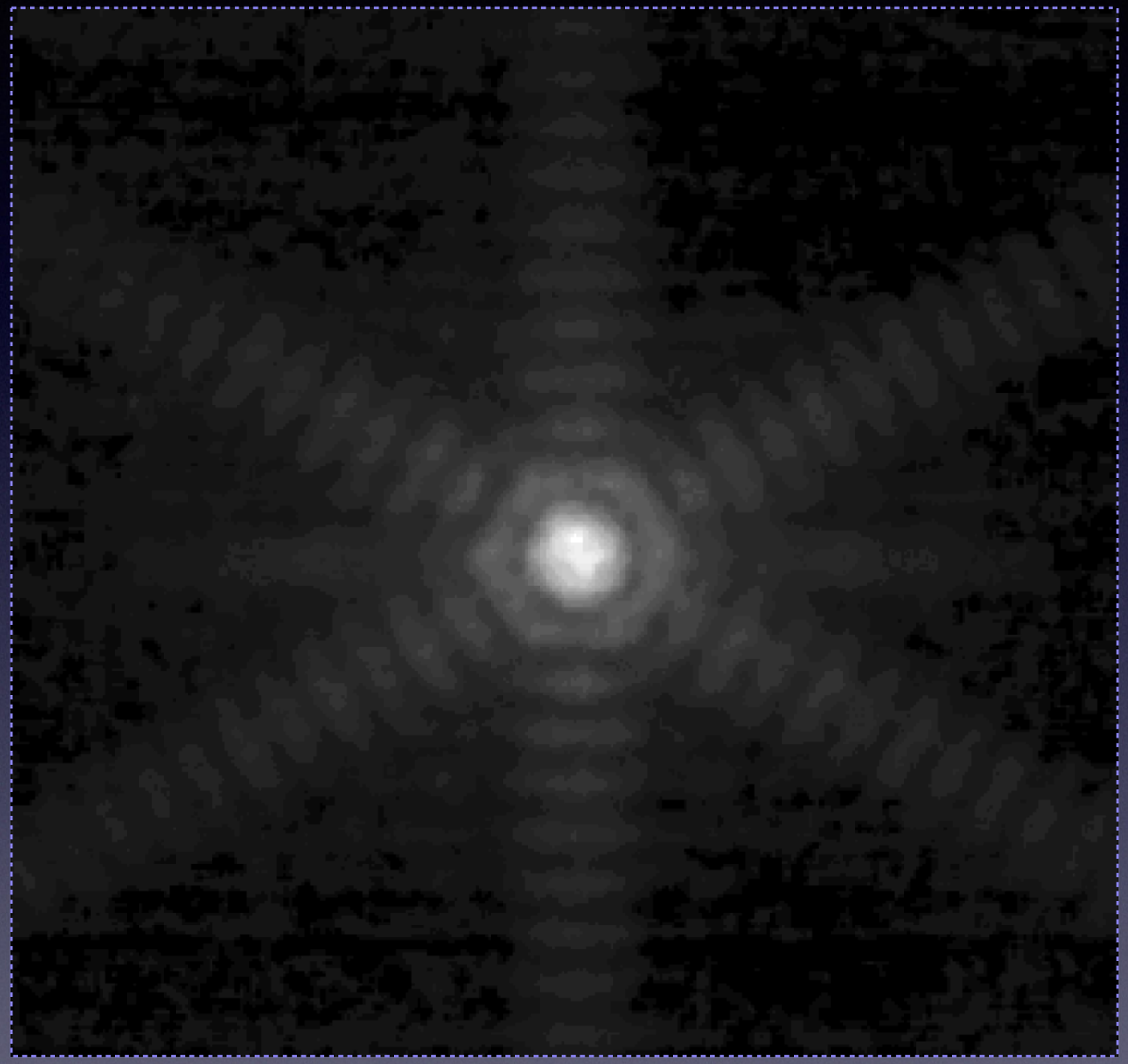
Correct 2



Segment Stacking



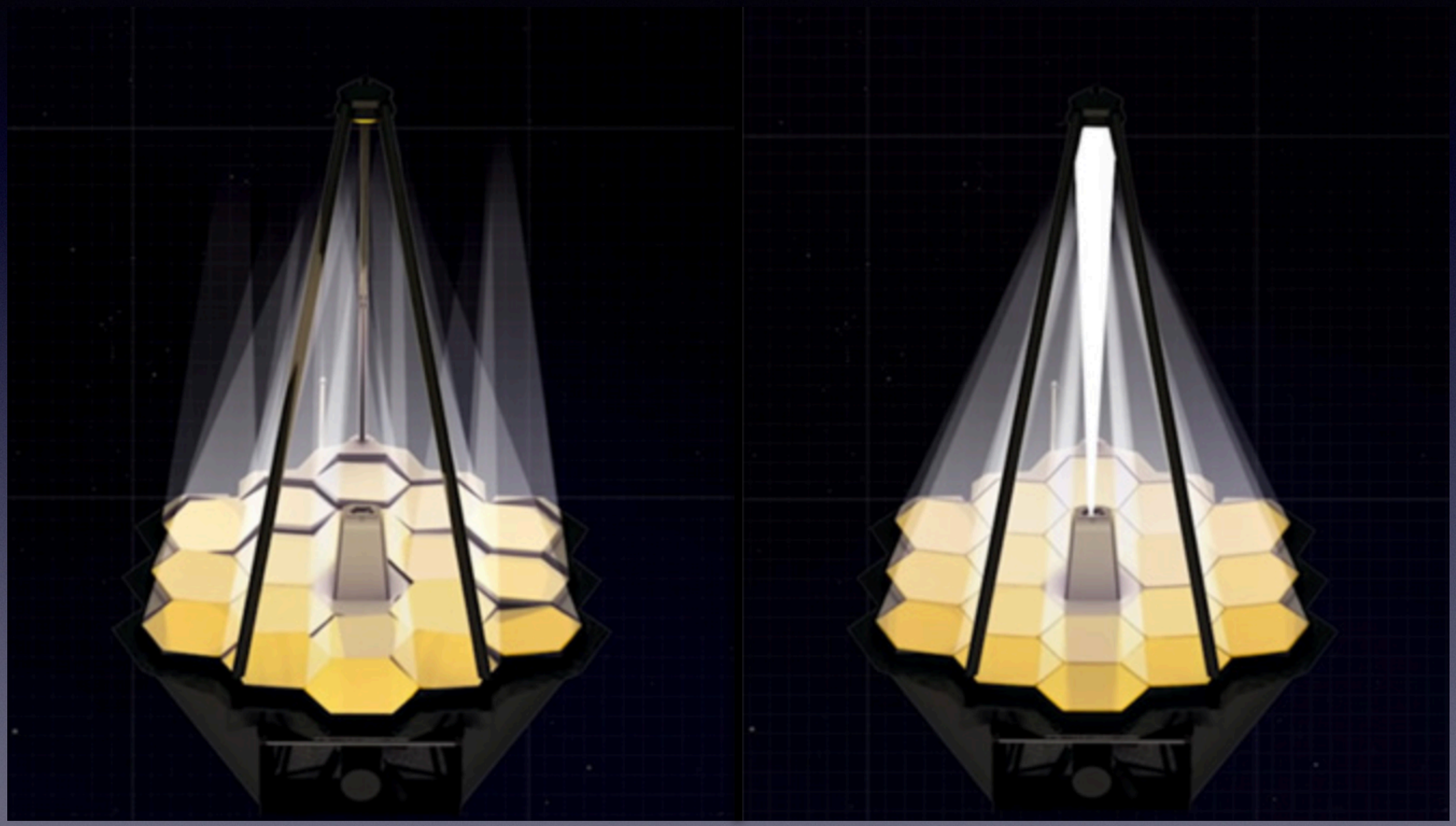
Initial Stacked Results



First Stacked Image but alignment not complete

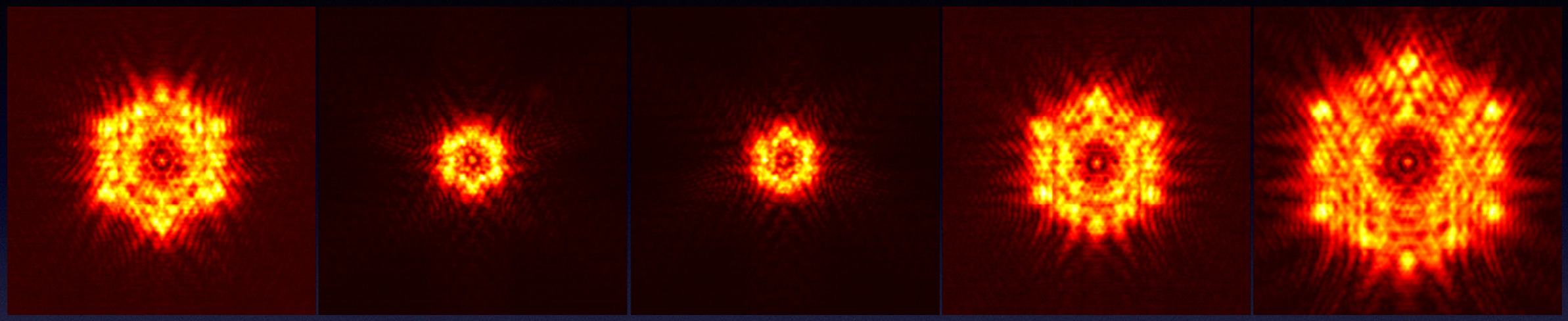
Feb 22, 2022

Remember: still have work to do

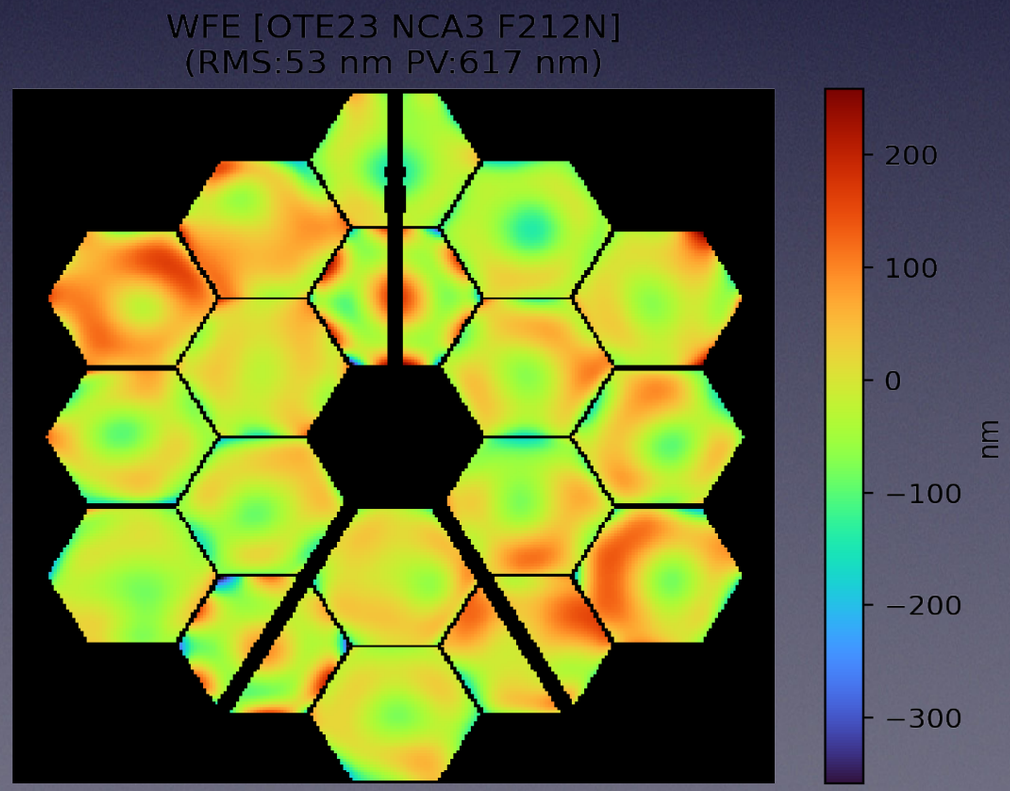


Example Phase Retrieval

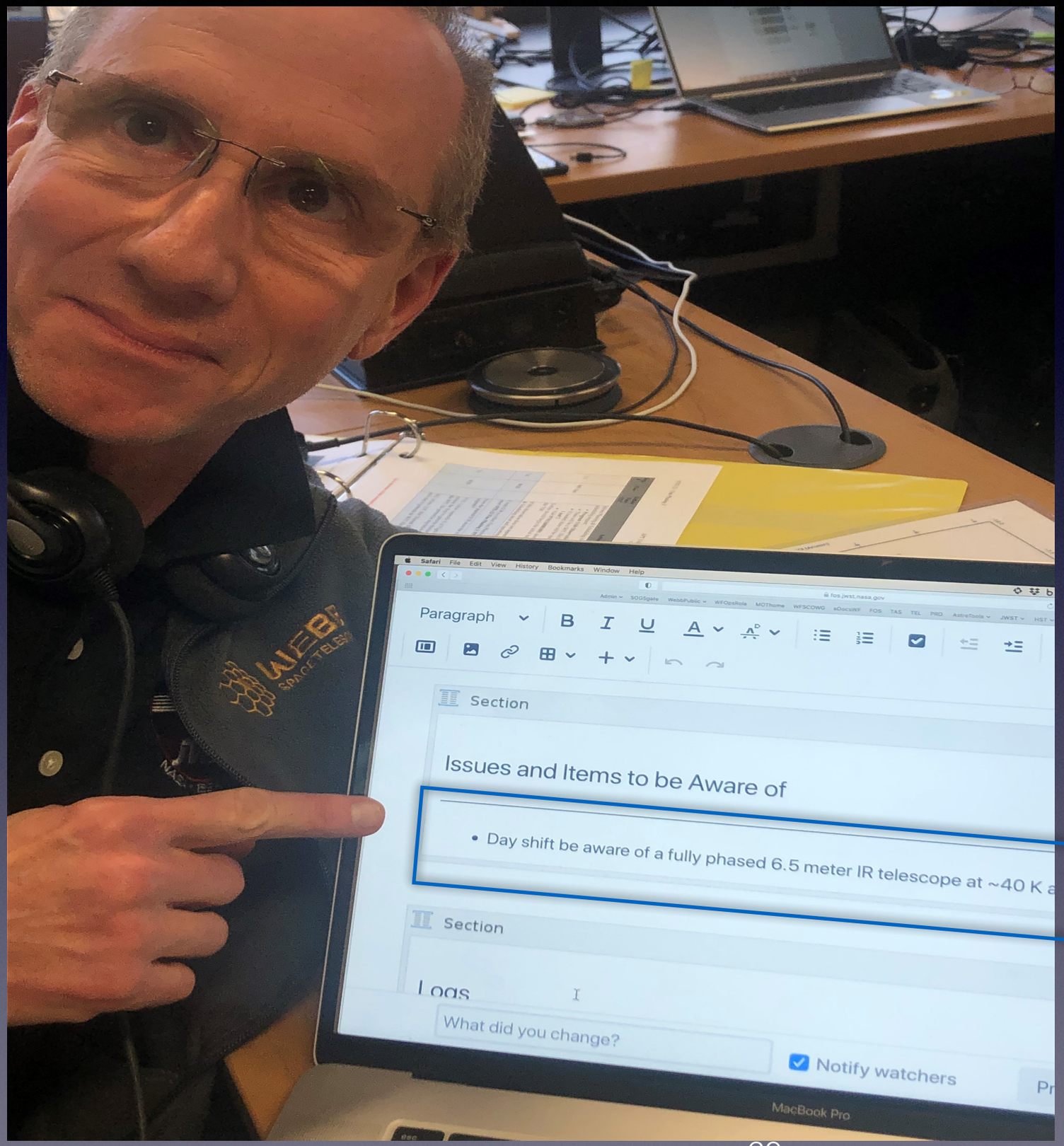
-8 λ -4 λ +4 λ +8 λ +12 λ



T. Zielinski, NASA GSFC



Shift Report



Fine Phasing 3 Graveyard Shift Report

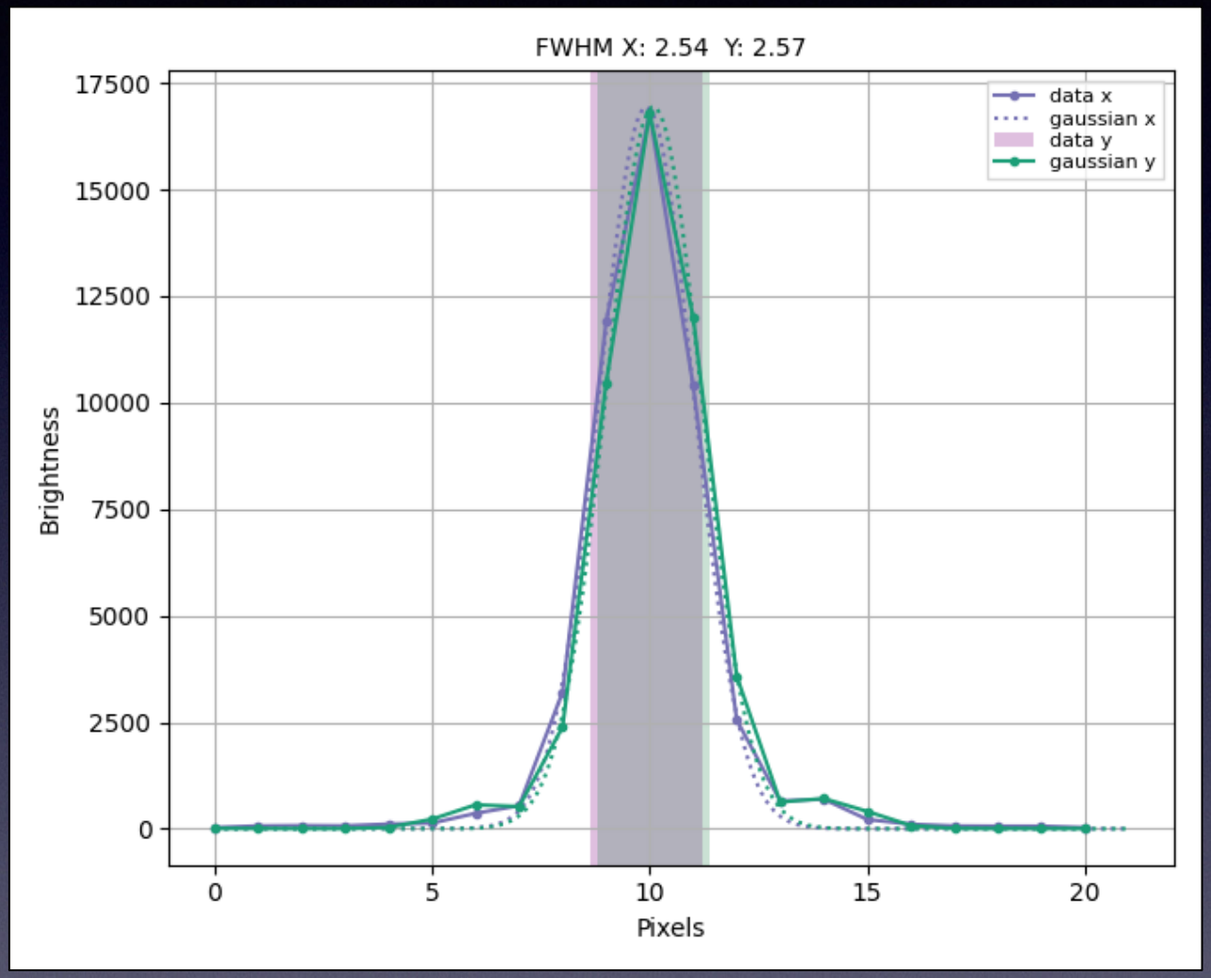
Initial Galaxies

Excitement


The SM is currently at BEST FOCUS
High Level WFSC Commissioning Process
ALL PURPOSE

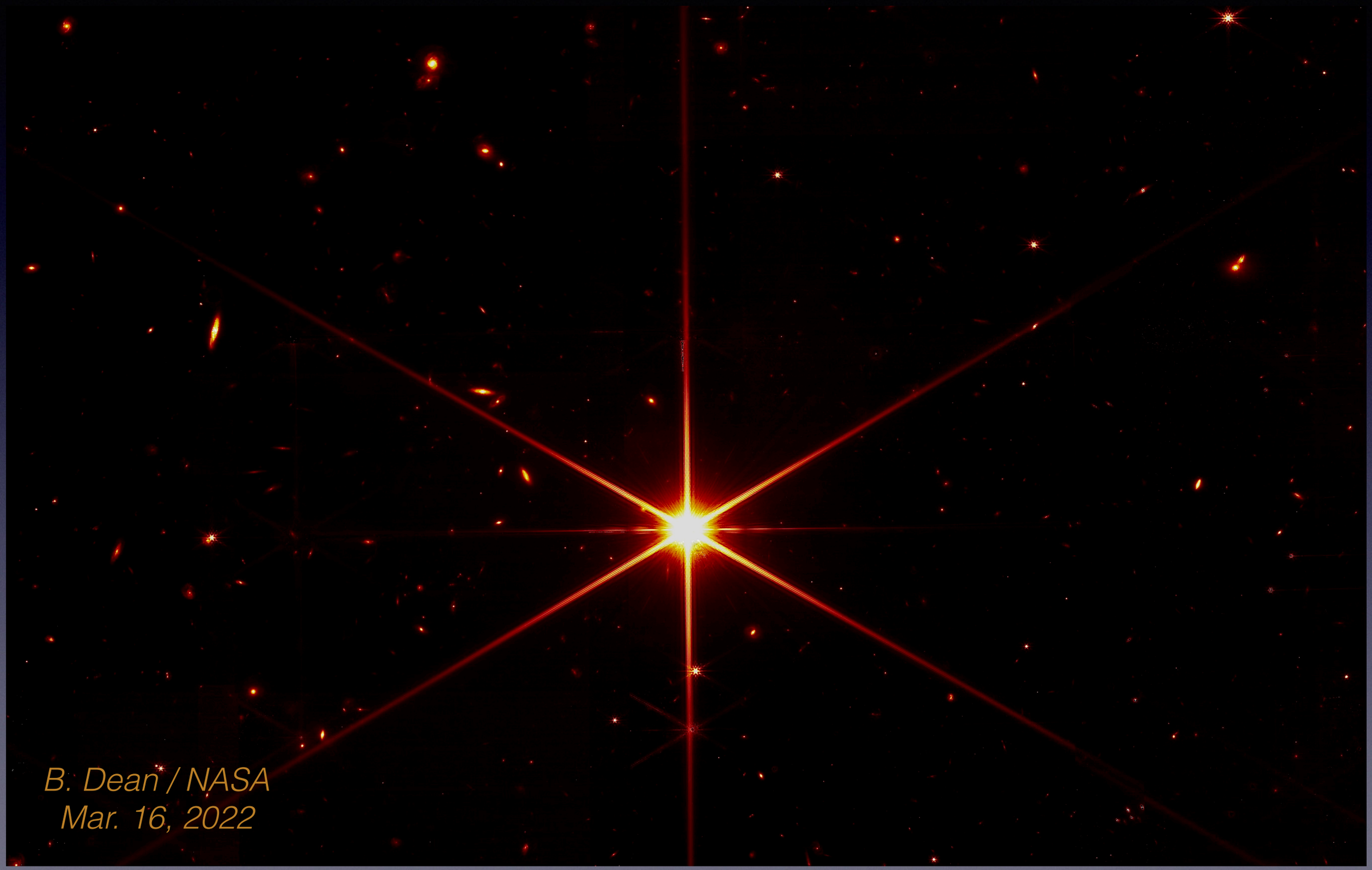
First Fine Phase Images in the MOC Conference Room

FWHM Assessment (most stars look this way)



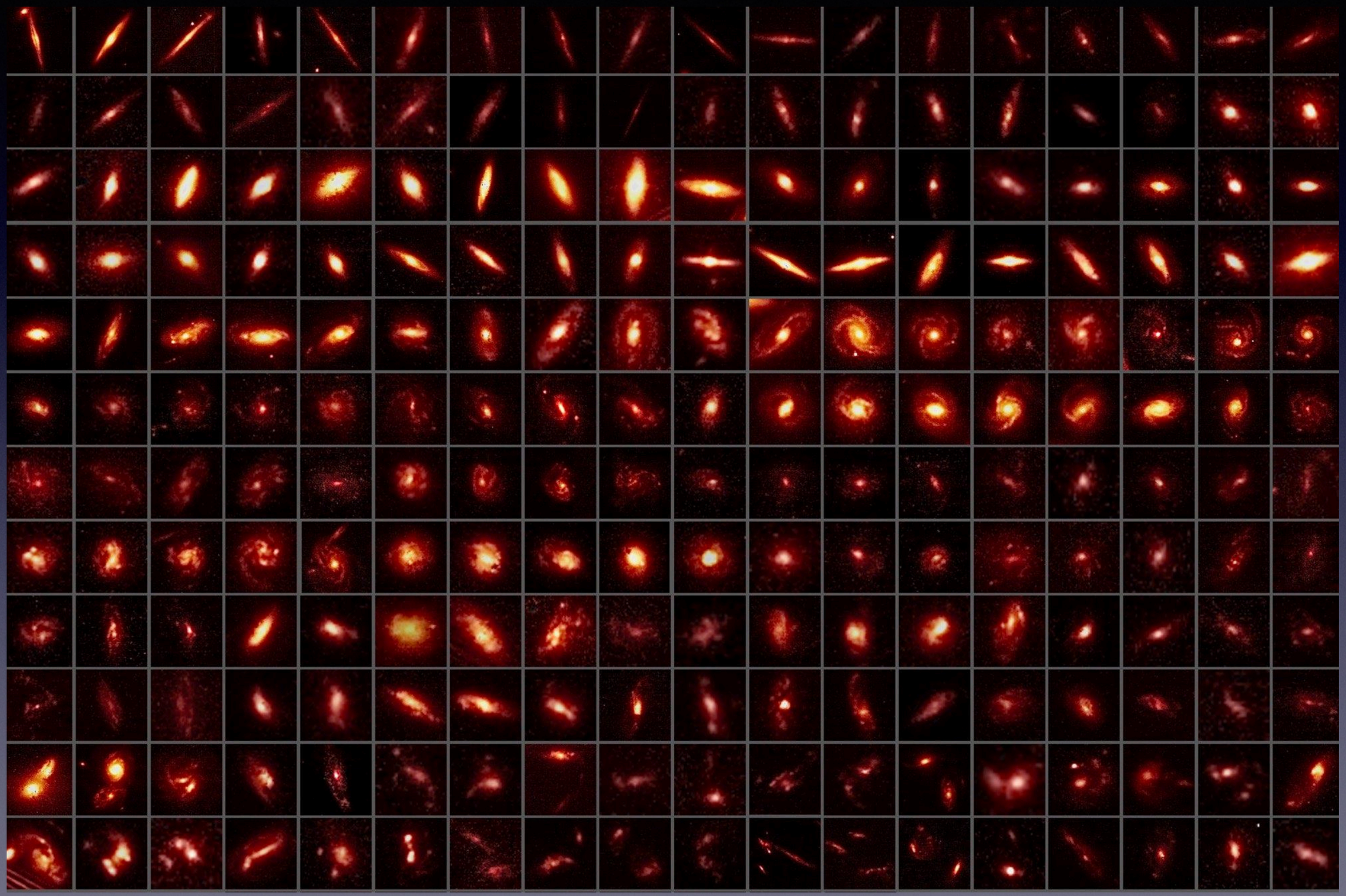
Star is 77 milli-arcseconds wide

Engineering Test Image Released

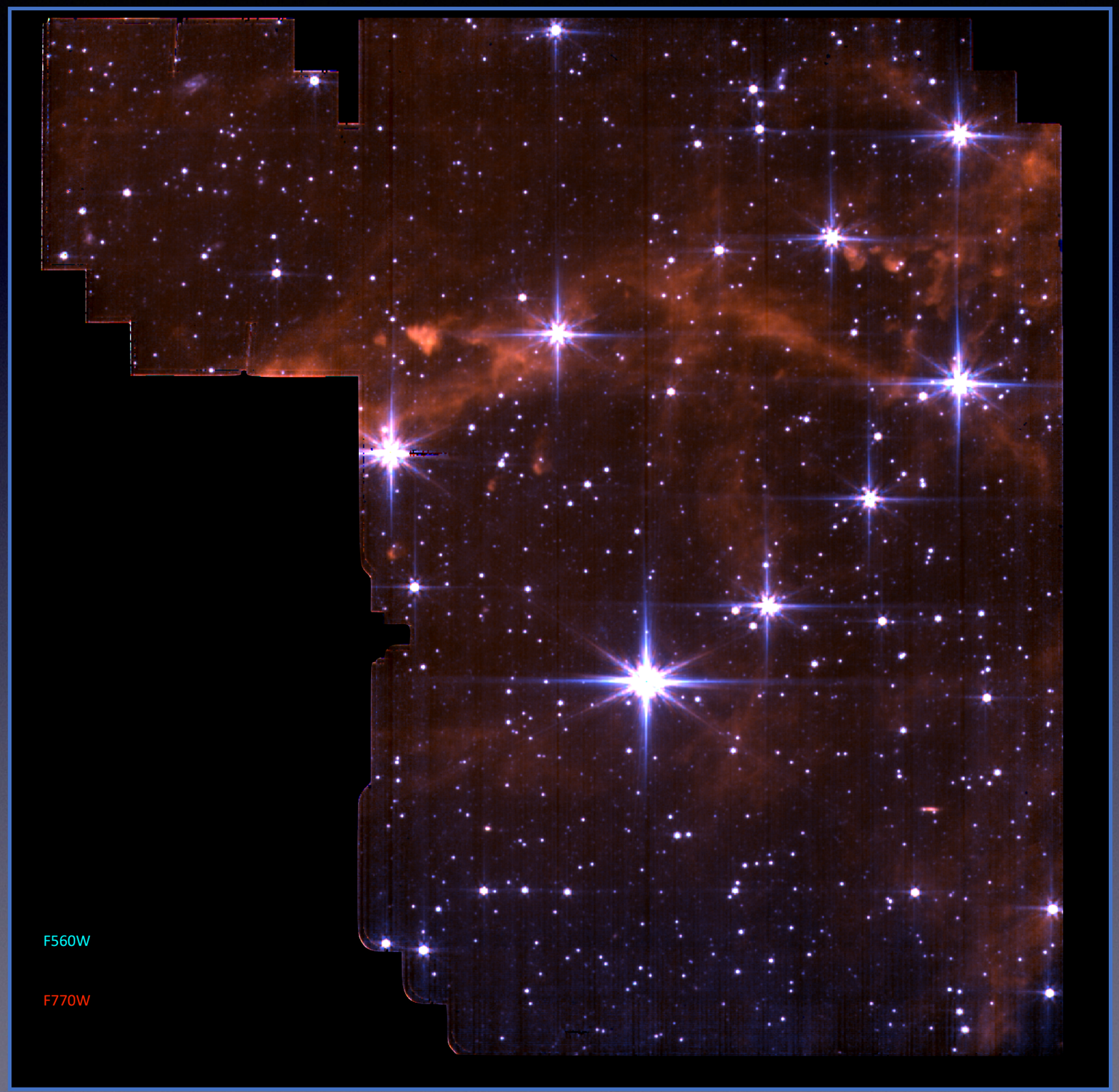


B. Dean / NASA
Mar. 16, 2022

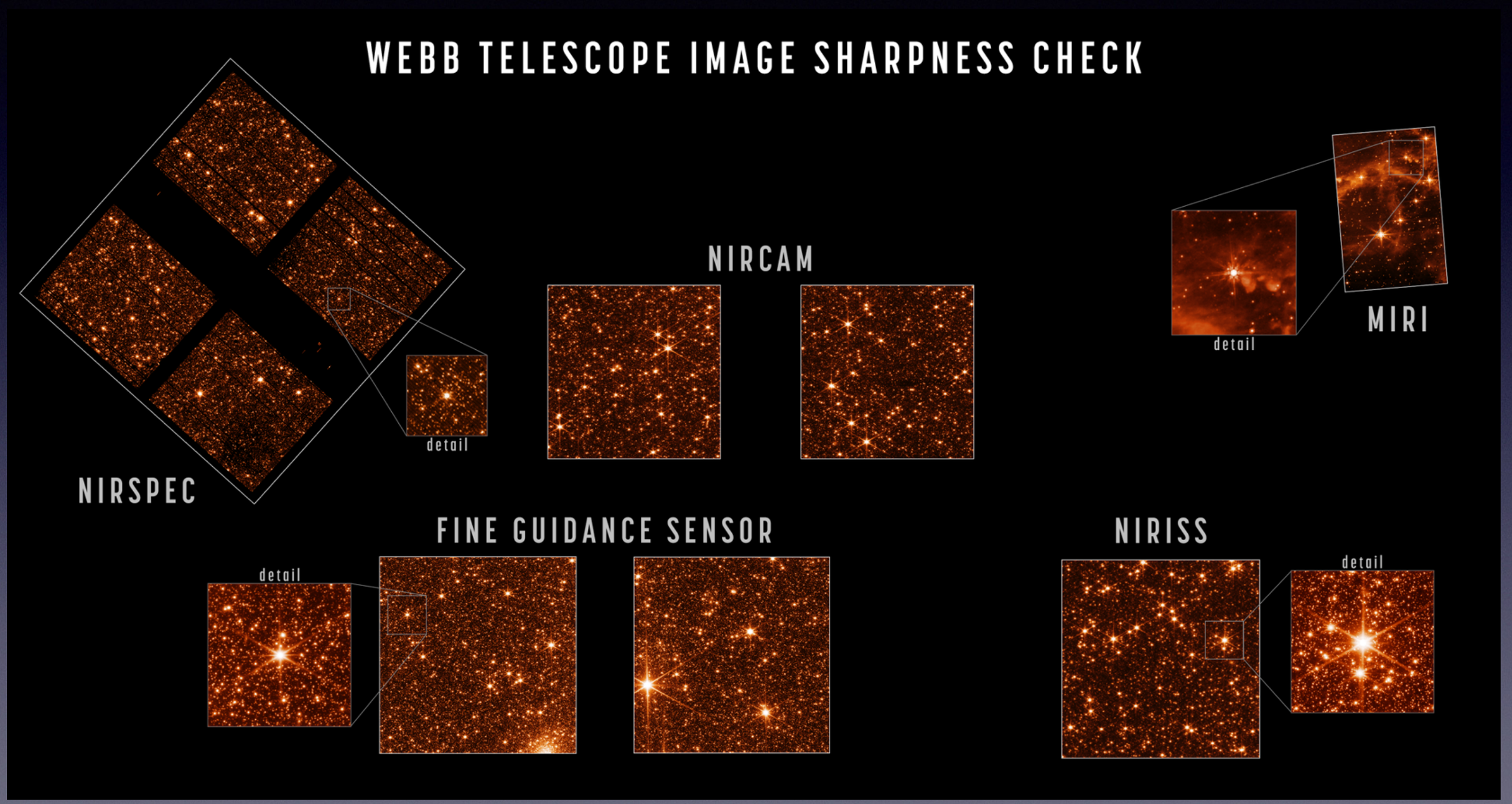
Galaxies in a Test Image



Turning on and operating the MIRI Cryocooler (mid-April)



Additional Science Instruments

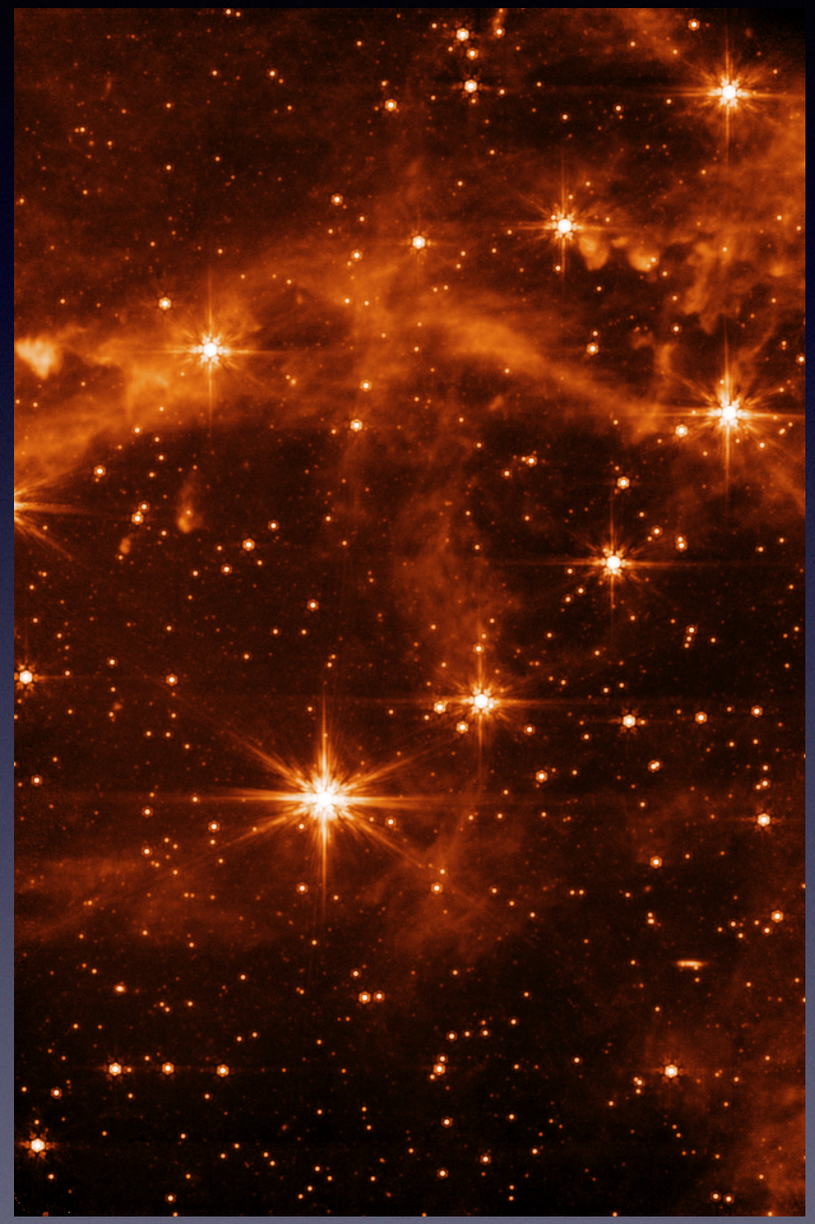


How well is it performing?

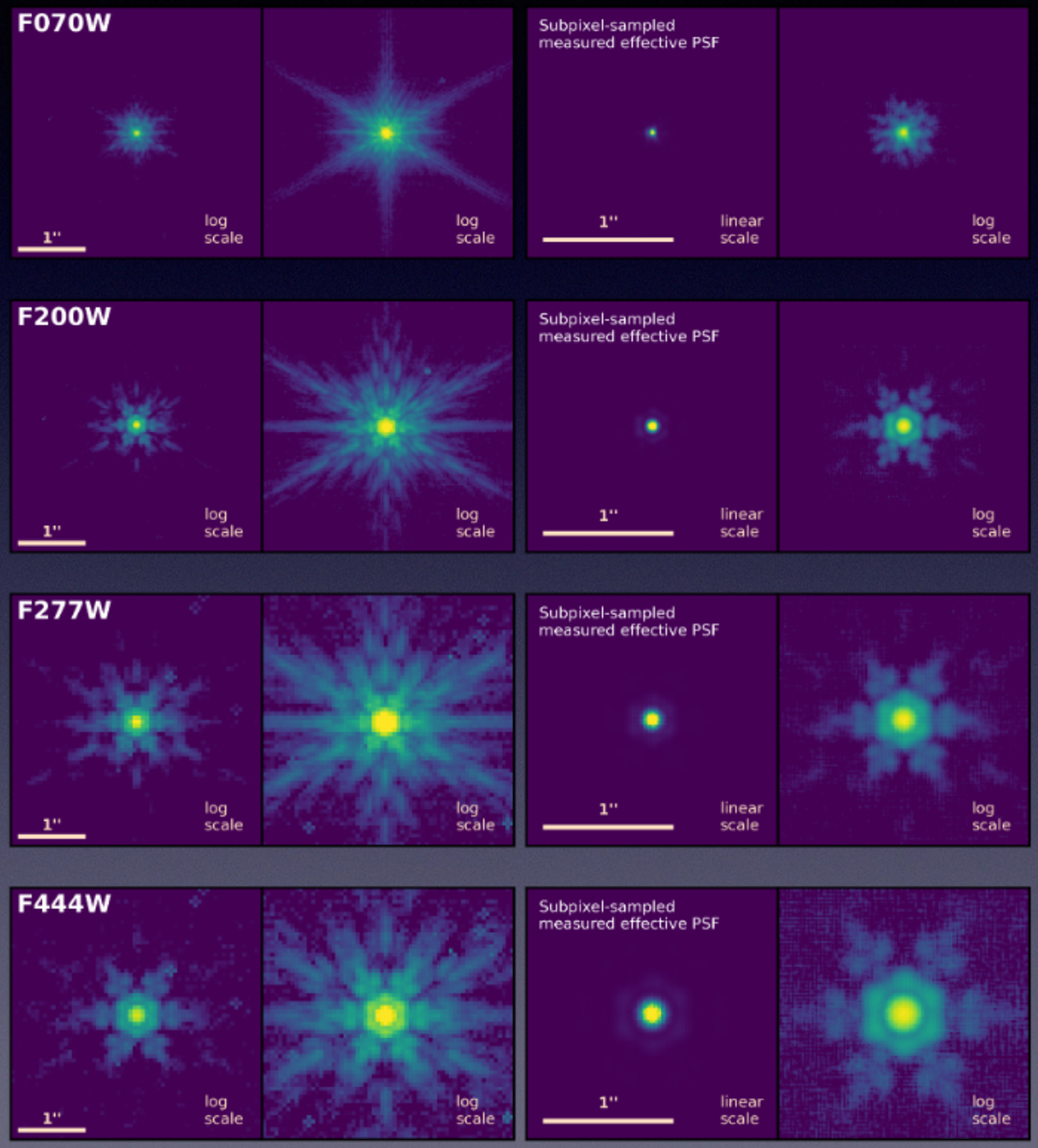
Diffraction limited at 1.1um

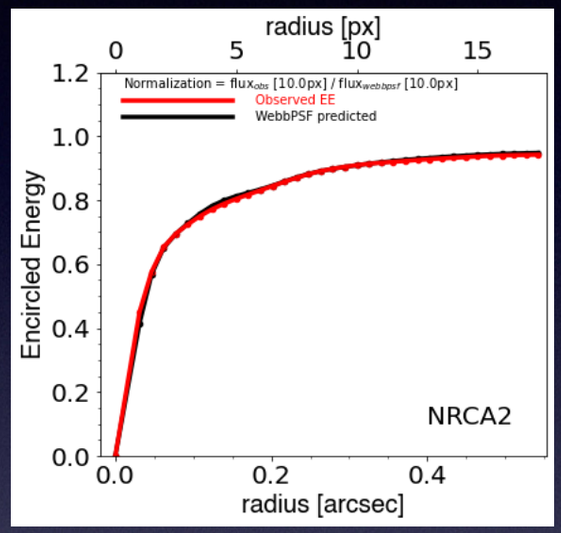
Image Quality: Wavefront Error

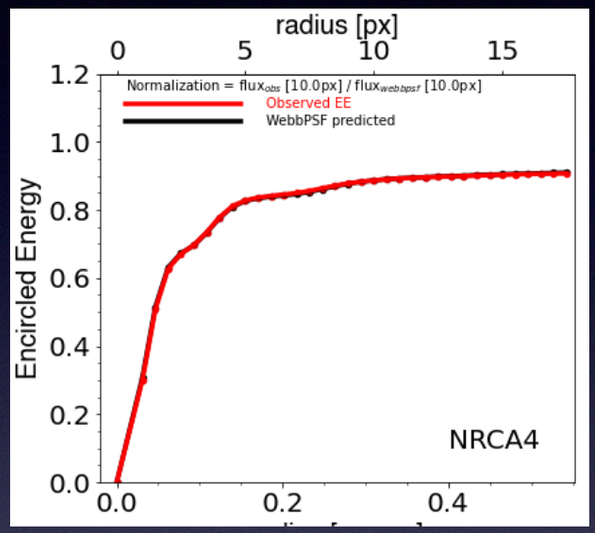
	OTE WFE Mid /Hi	OBS Static measurement	OTE stability	Image Motion	Obs BOL	Obs Reqt	Obs margin
NIRCAM A SW	37	65	13	18	79	150	128
NIRCAM B SW	37	85	13	18	96	150	115
NIRCAM A LW	37	100	13	18	110	301	281
NIRCAM B LW	37	119	13	18	127	301	273
NIRISS	37	85	13	18	96	180	152
FGS 1	37	95	13	11	104	186	155
FGS 2	37	85	13	11	95	186	161
MIRI	37	132	13	18	140	421	397
NIRspec Sq Ap	37	106	13	18	115	238	209

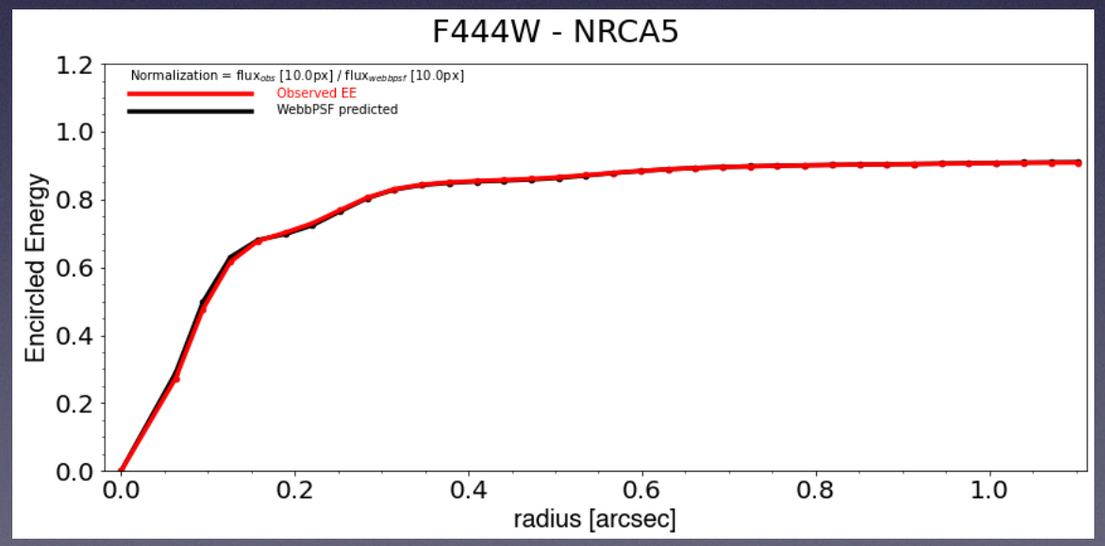


Point Spread Functions are precisely as Fourier Optics predicts

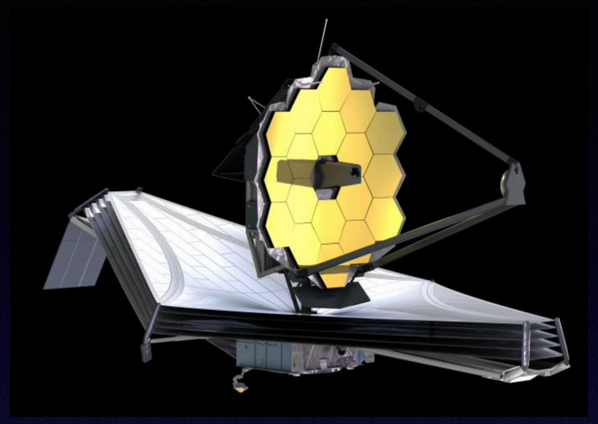


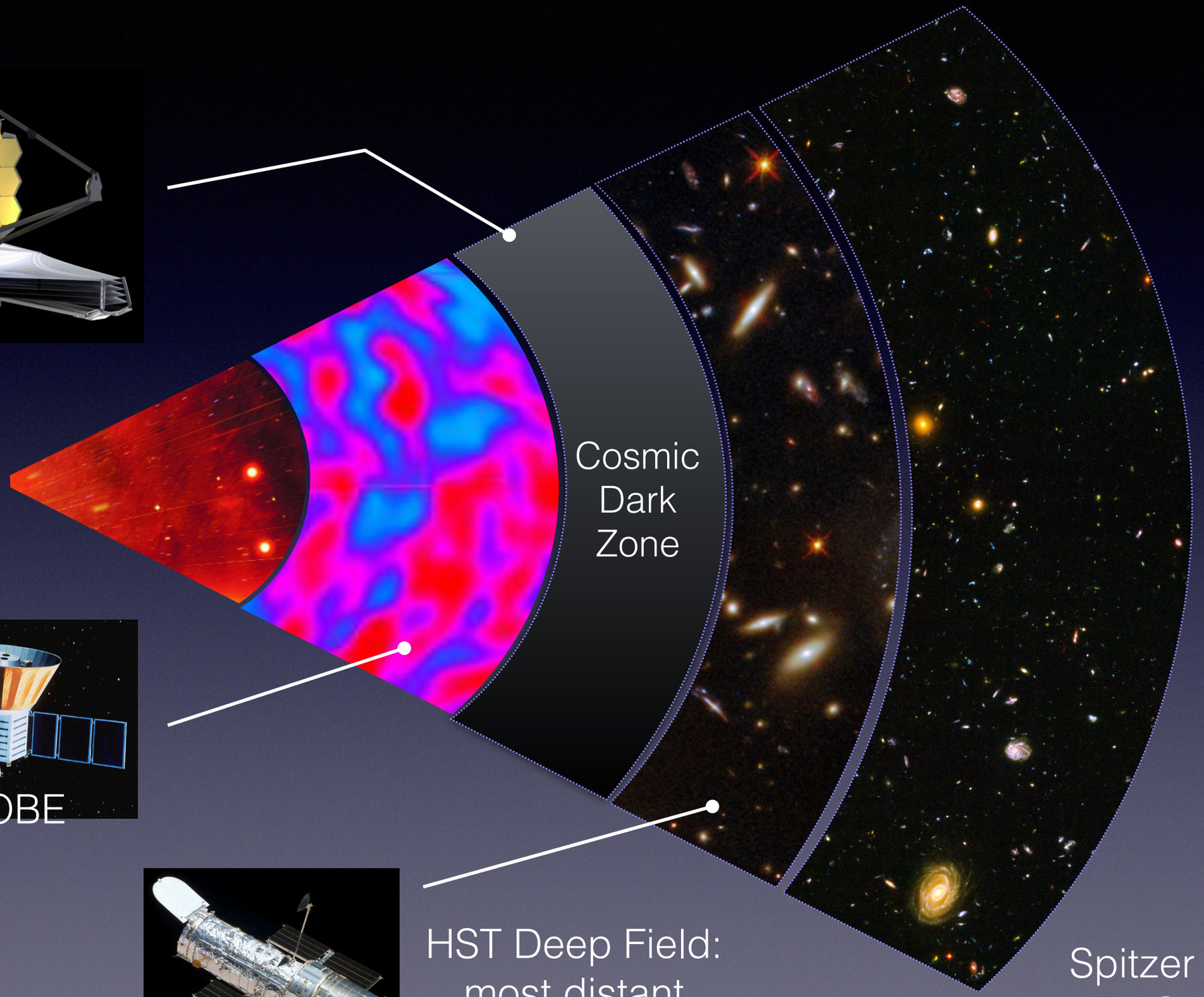


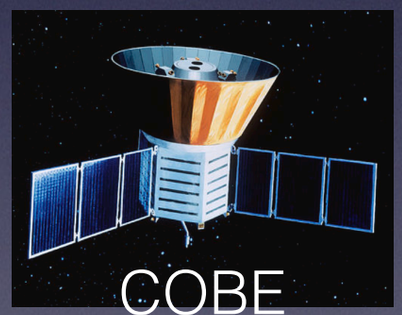


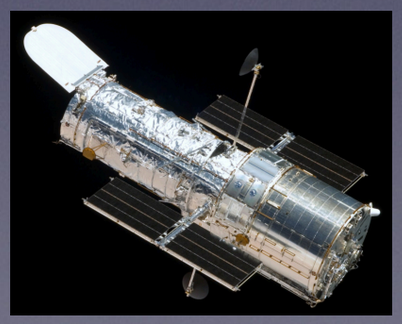


Lets go back





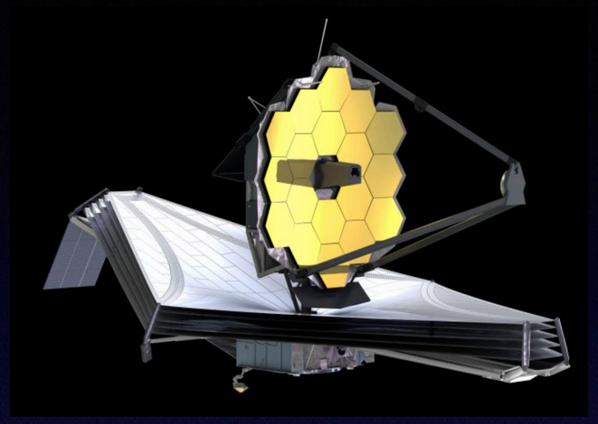


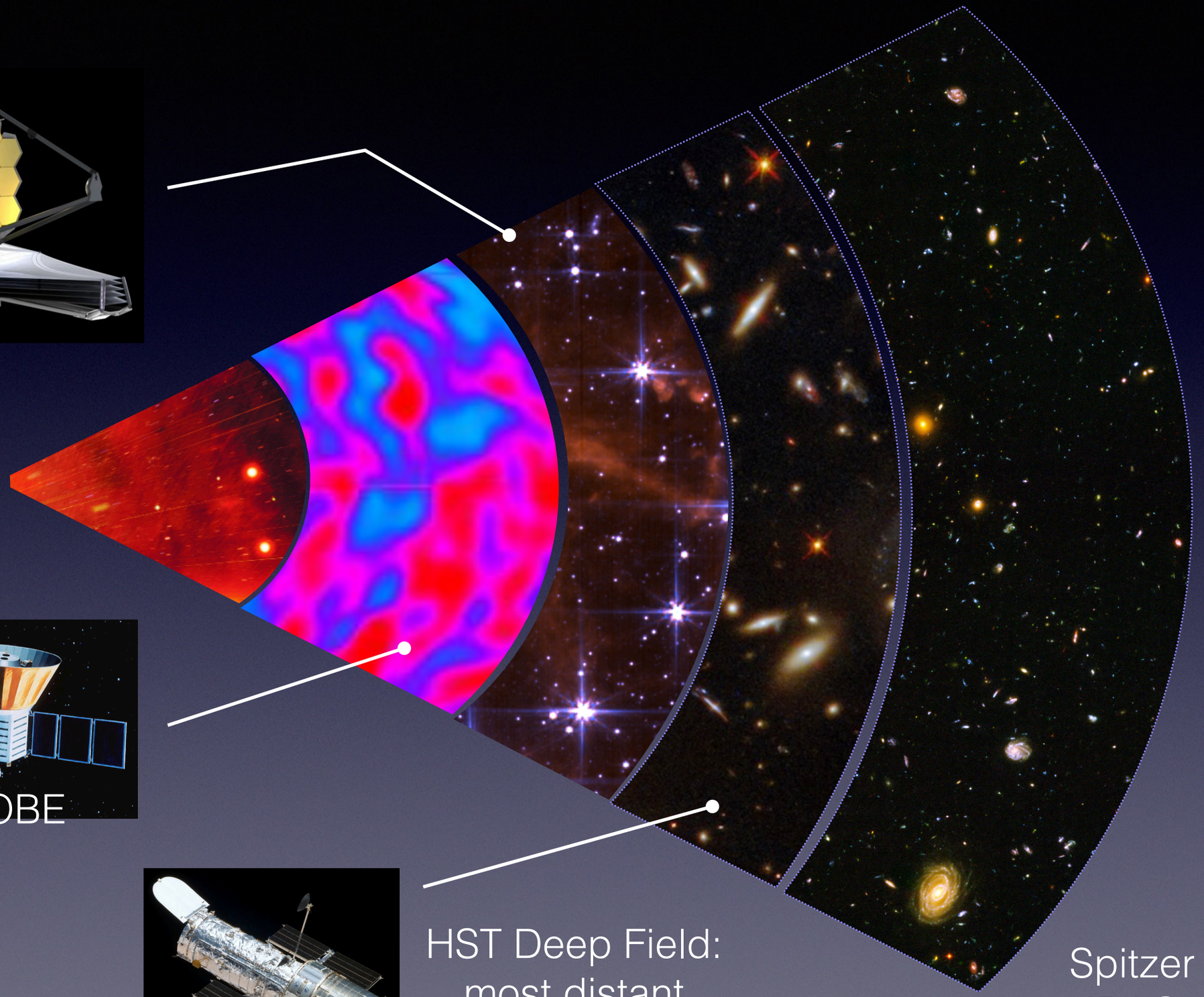


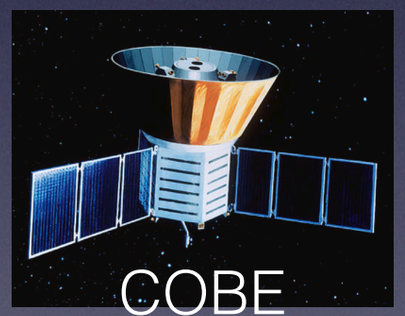
HST Deep Field:
most distant
objects yet

Spitzer
IRAC
Ground Observatories

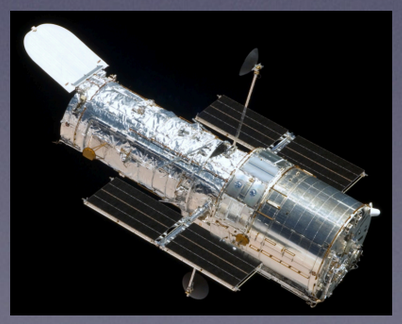
Where we are at now







COBE



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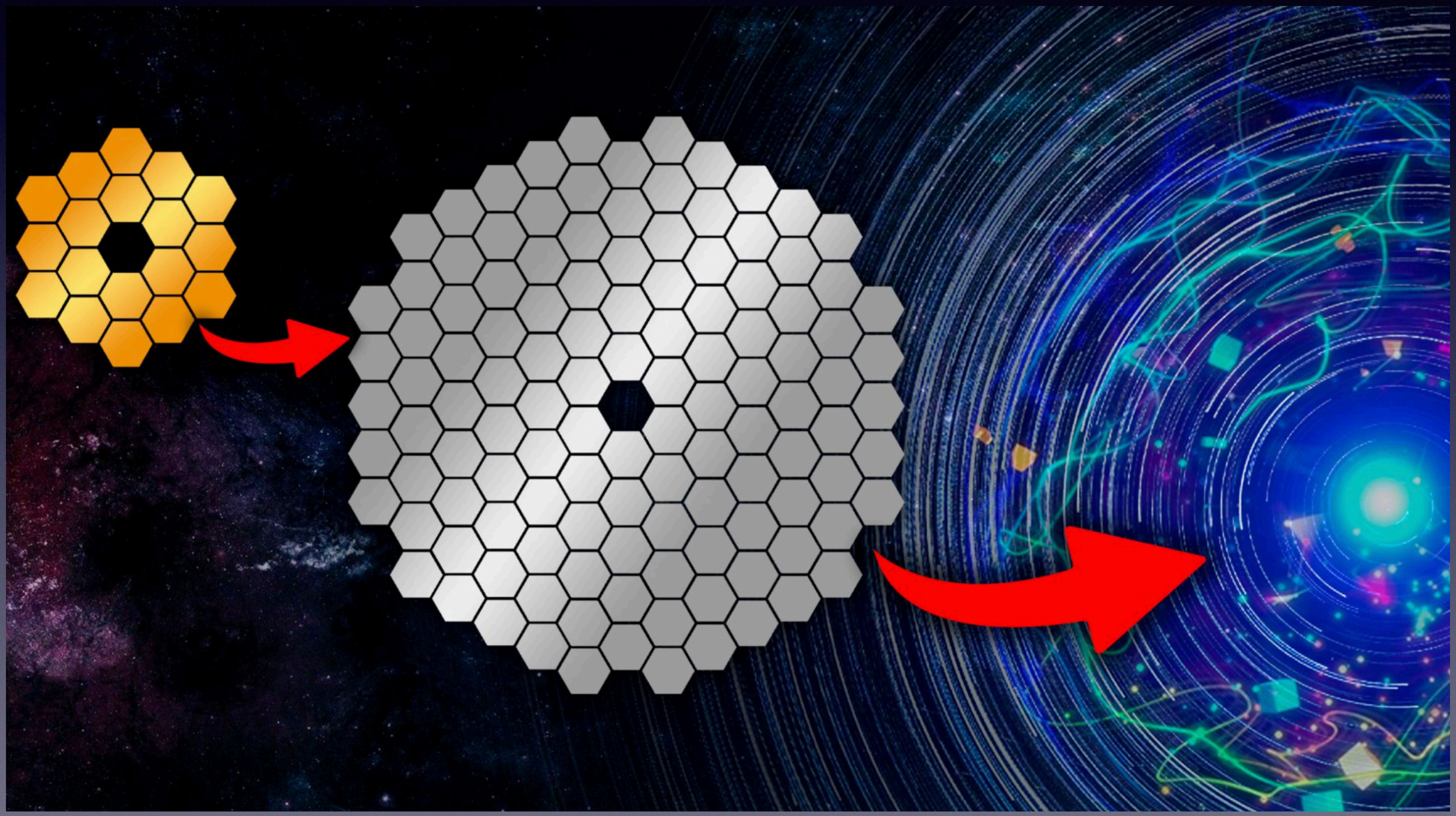
Where we are going: Habitable Worlds Explorer

- Earlier Telescopes: structure of the Universe
- Next: The search for Life



Commissioning Team

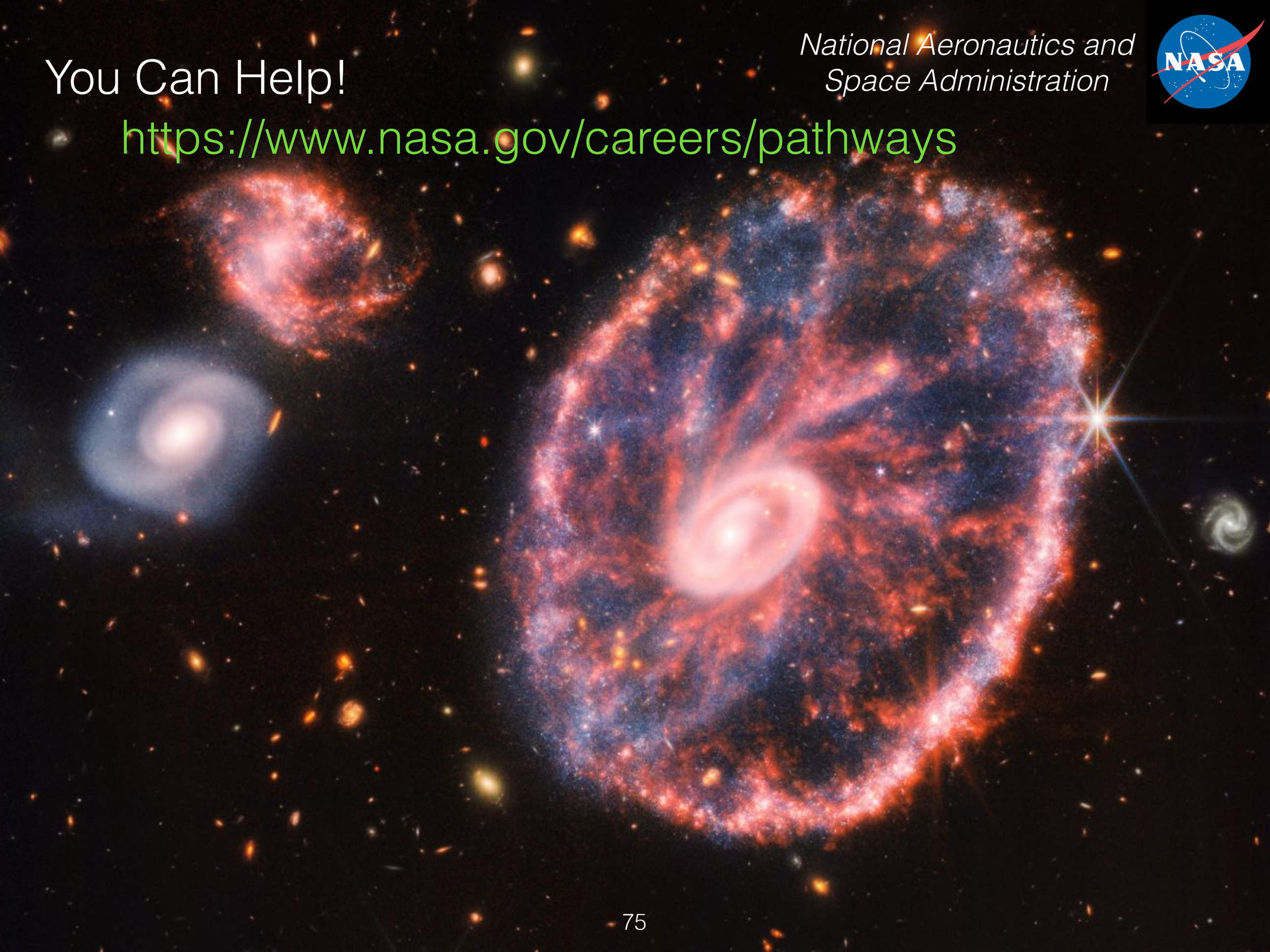
Latest: the telescope and observatory are working remarkably well

OTE Commissioning took tremendous teamwork - thanks to all who supported.

You Can Help!

https://www.nasa.gov/careers/pathways

National Aeronautics and Space Administration



Initial Science Images Released

President Biden July 11, 2022: "*We can see possibilities no one has ever seen before. We can go places no one has ever gone before.*"