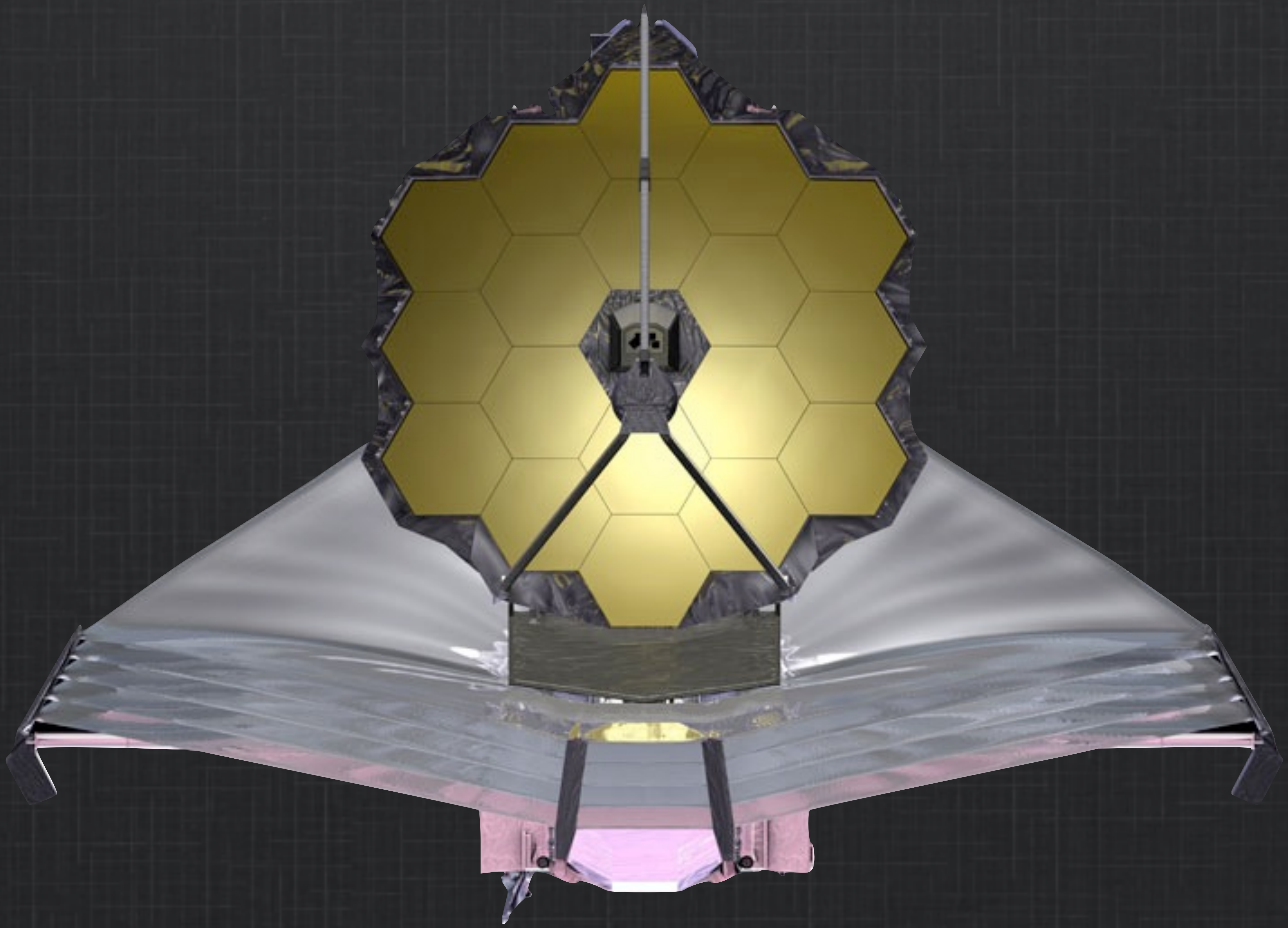
Preparing for the James Webb Space Telescope

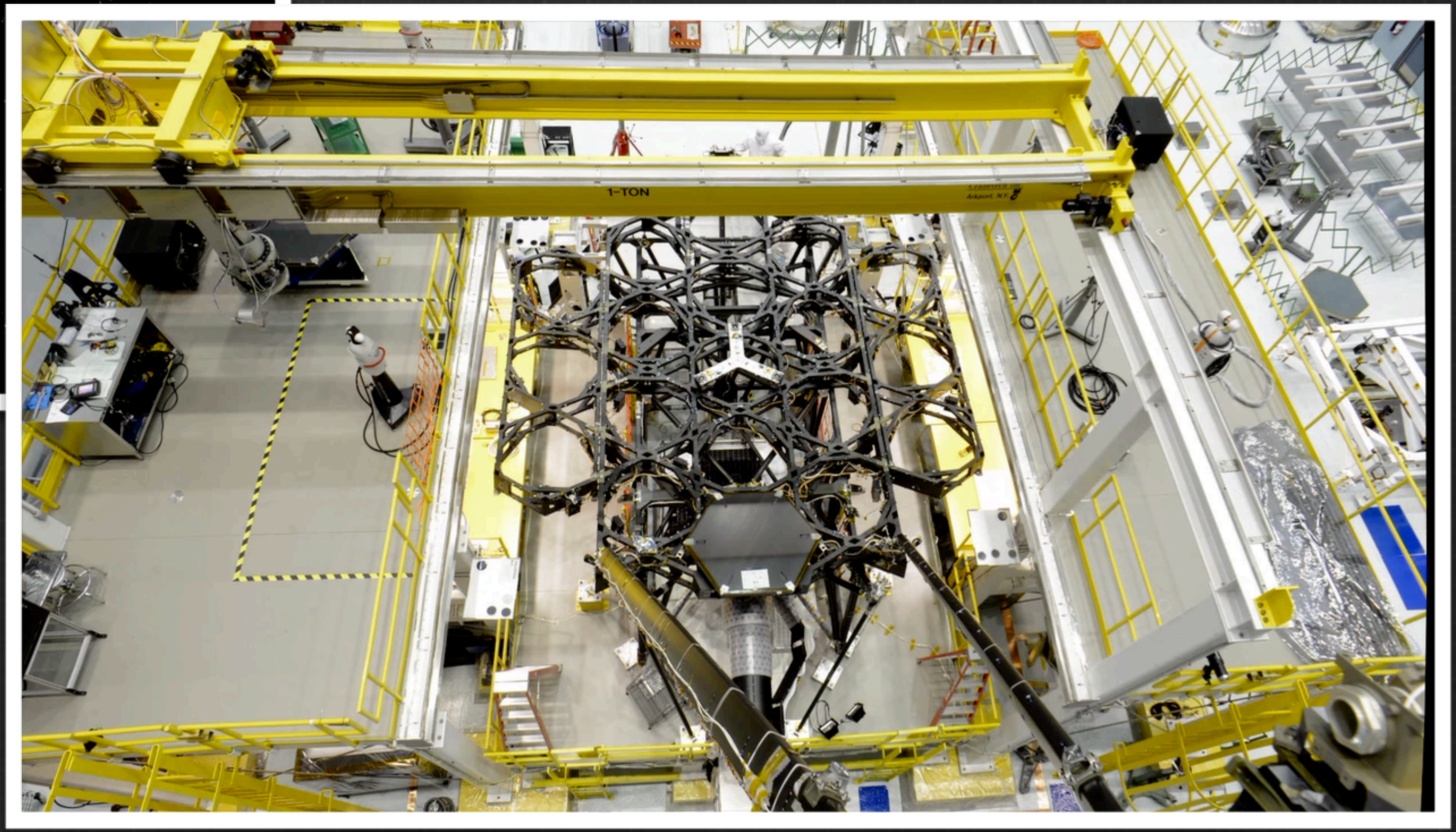


Jason Kalirai

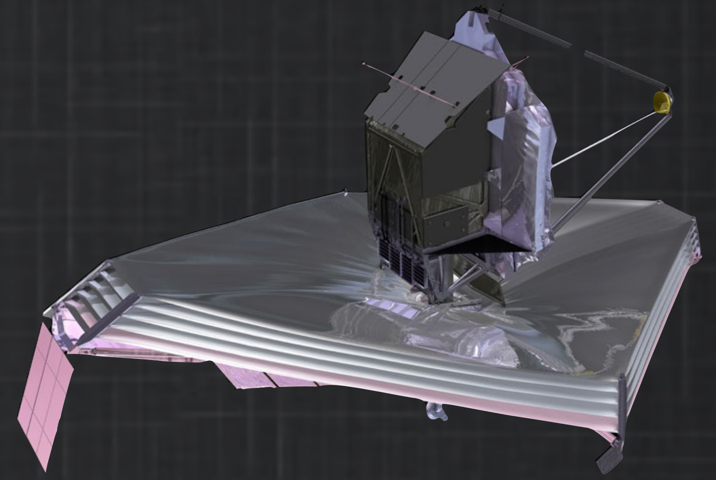
(Project Scientist for JWST at STScI)

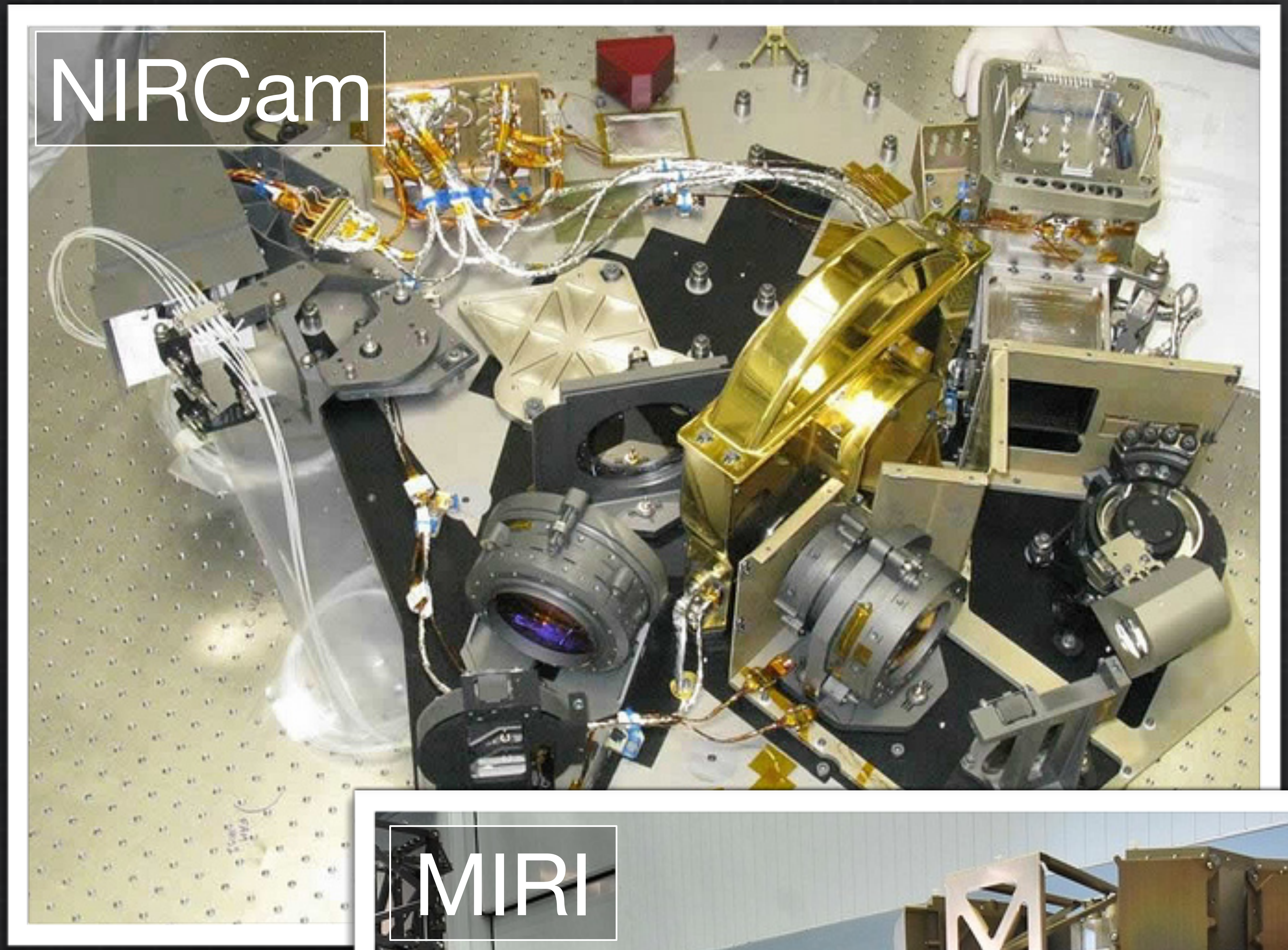
#JWST

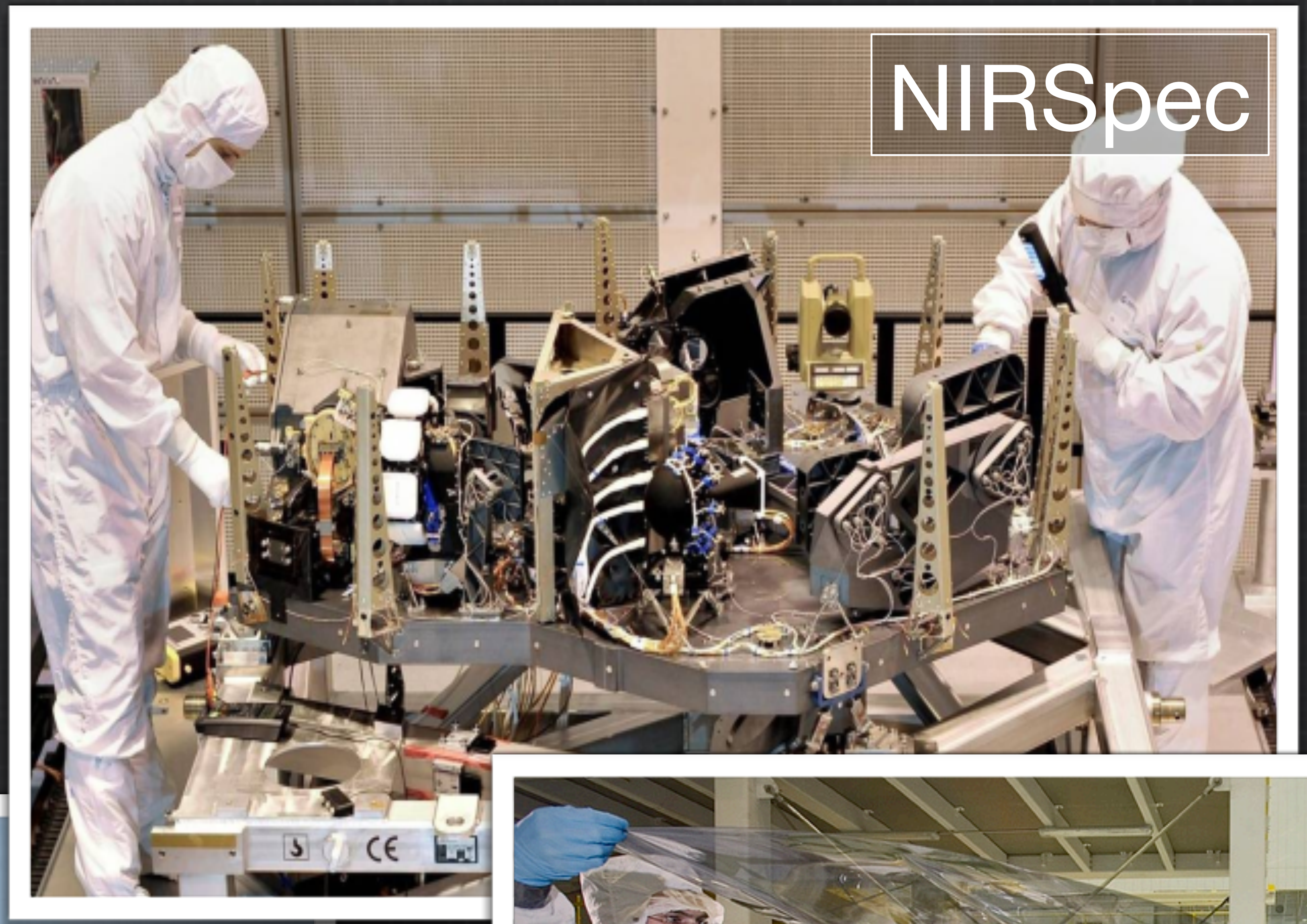
The James Webb Space Telescope

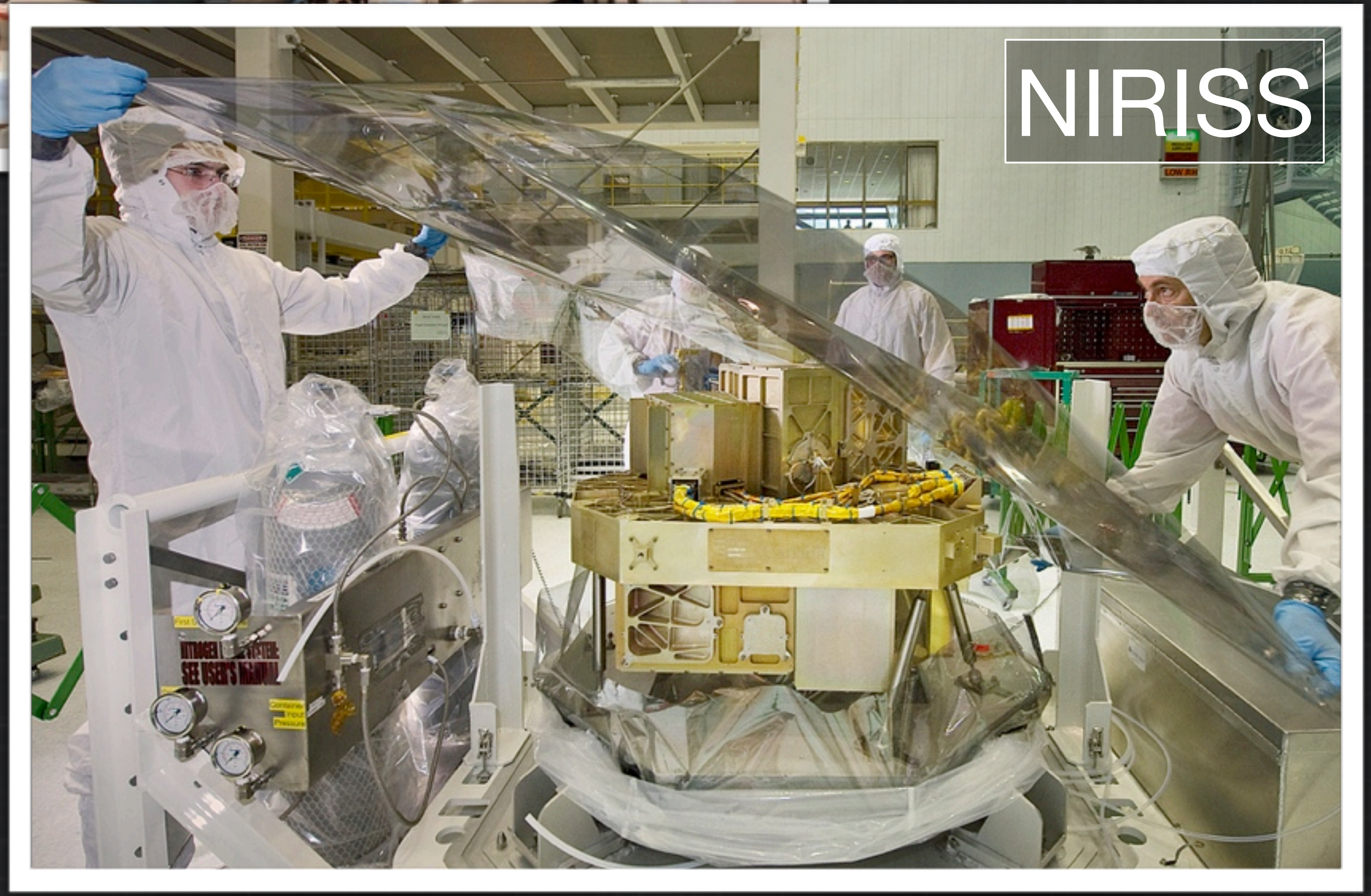


The JWST Instrument Suite





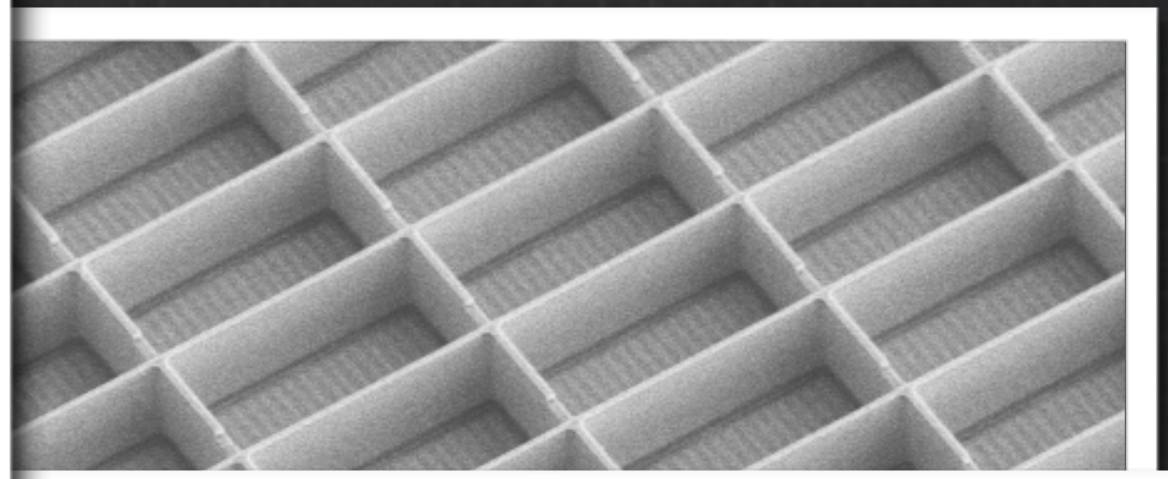





Ultra Sensitive and High Resolution Imaging
Mid IR IFUs
Single Object and Wide-Field Slitless Spectroscopy
Big Bang
Radiation Era
Dark Ages
Reionization era
First galaxies form
Present
m=1
m=2
m=3
Space Based MOS
Moving Target Support
Science Capabilities
Bright Object Modes
λ
JWST/NIRSpec 25 Transits
10x Earth mass (and hot)
Thick Atmosphere
Water & Methane
Water
Flux Ratio
Wavelength (Micron)
Near IR IFUs
0.8" ~ 5200 km
image at 0.94 microns (Cassini mission 2009)
exoplanet beta pictoris b
beta pictoris
NIR and MIR Coronagraphy

Multiplexed Spectroscopy in Crowded Environments

248,000 microshutters!

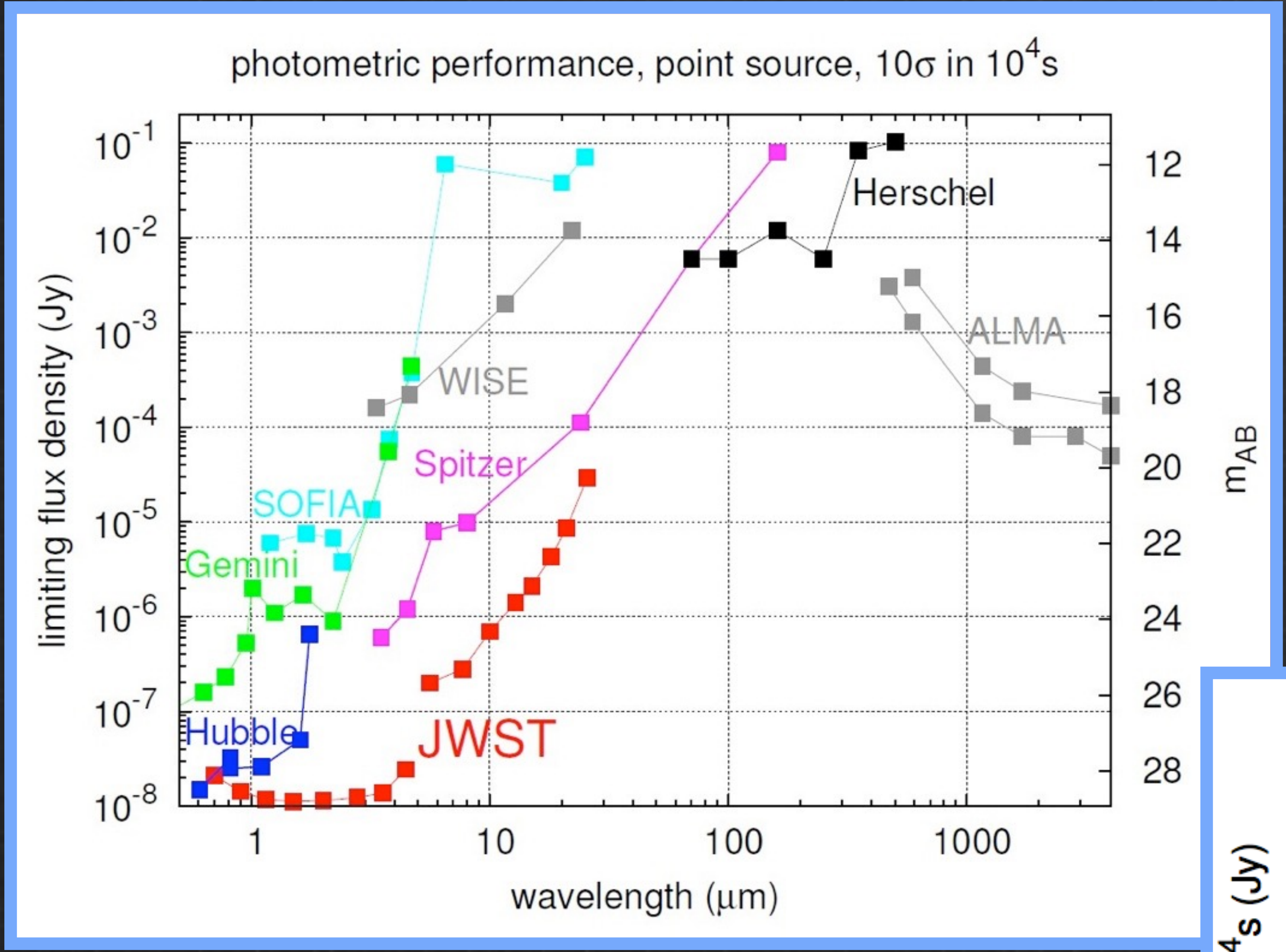


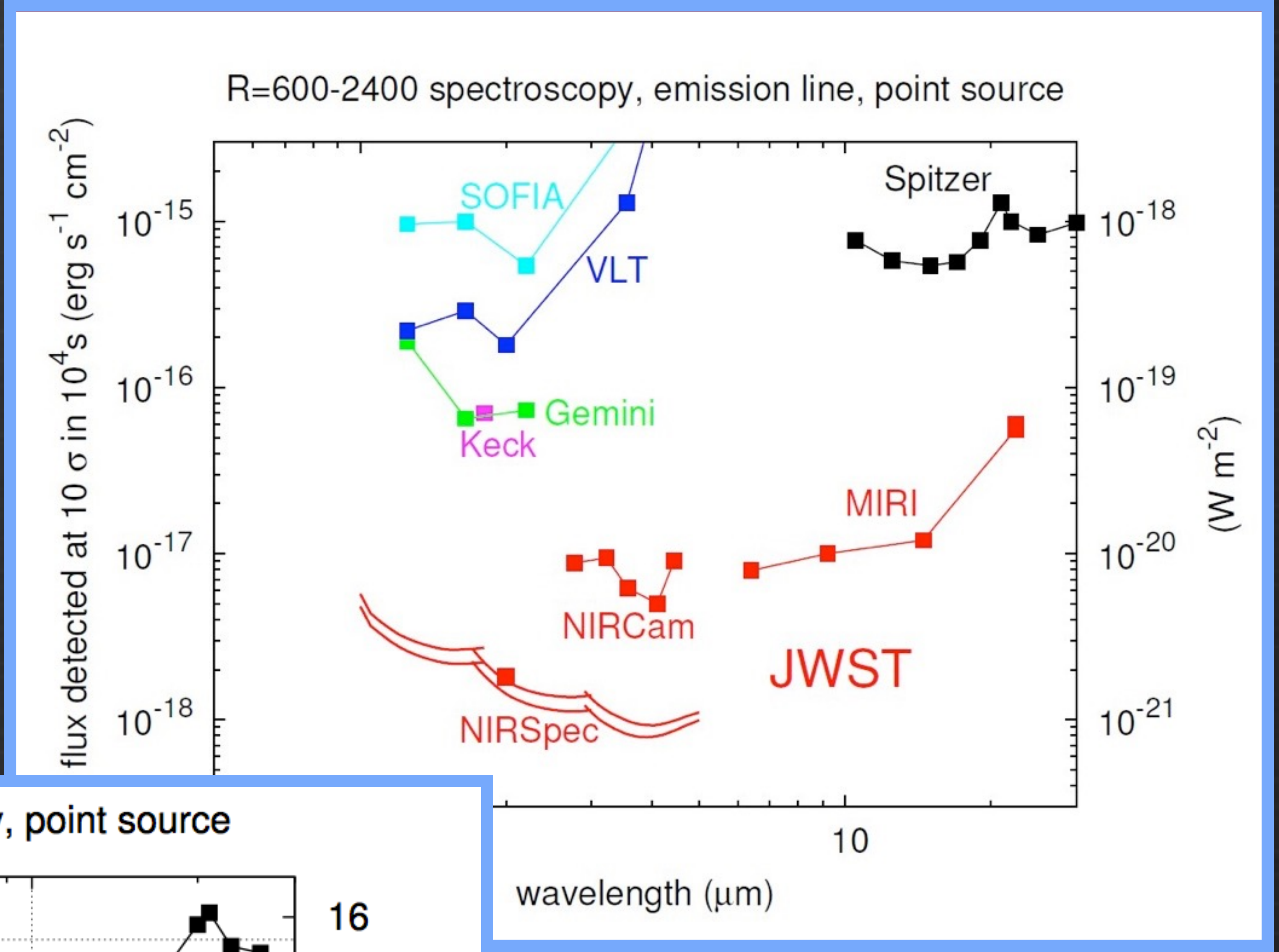
Multiplexed Spectroscopy in Crowded Environments

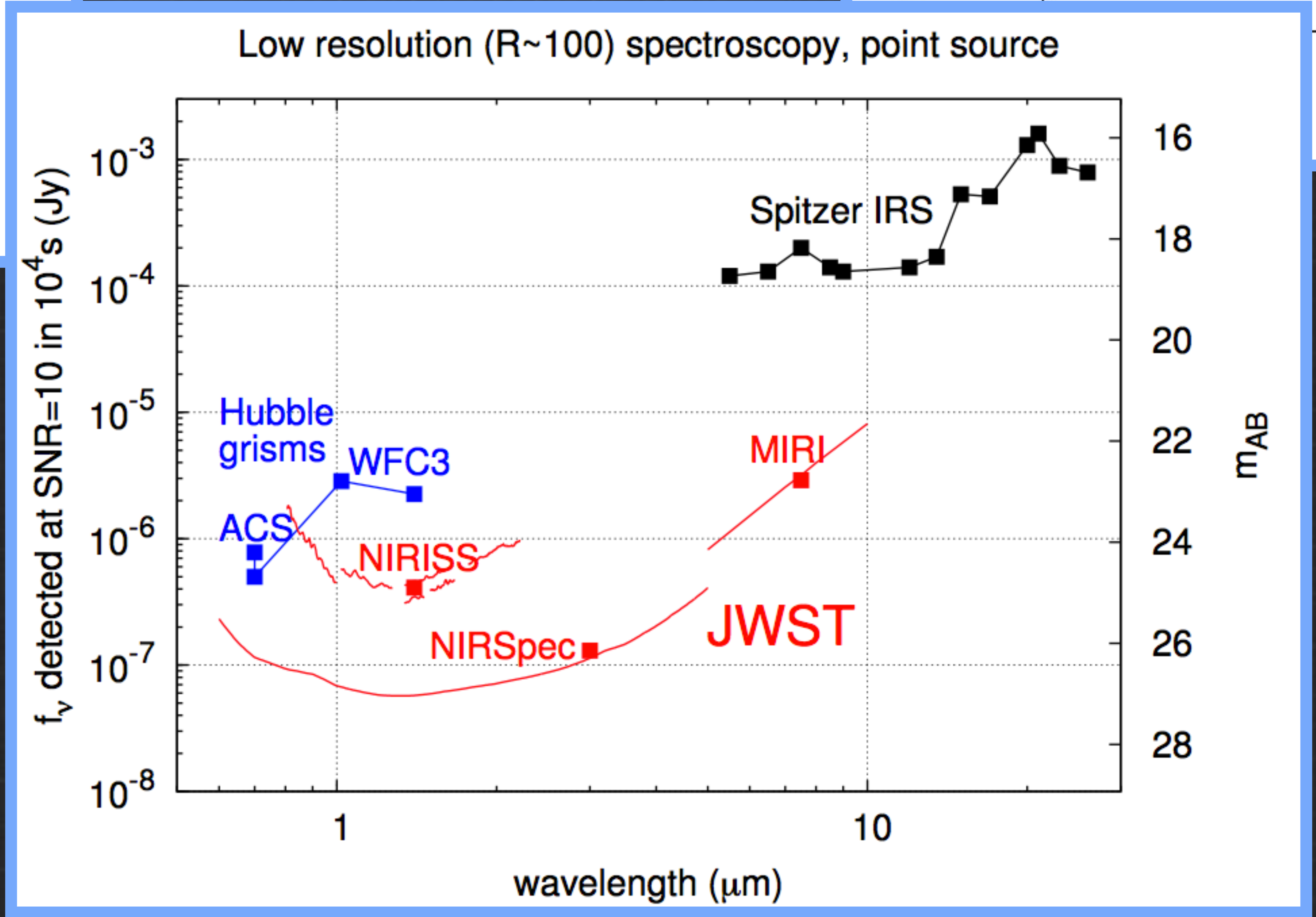
Multiplexed Spectroscopy in Crowded Environments

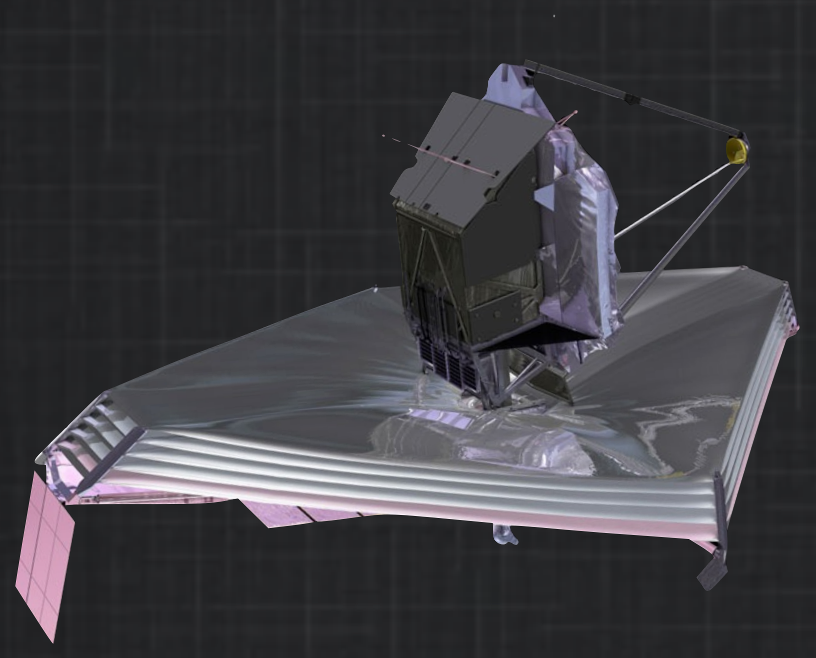
+ Targets in Operable Shutters
x Targets Outside Shutters

JWST Point Source Sensitivity

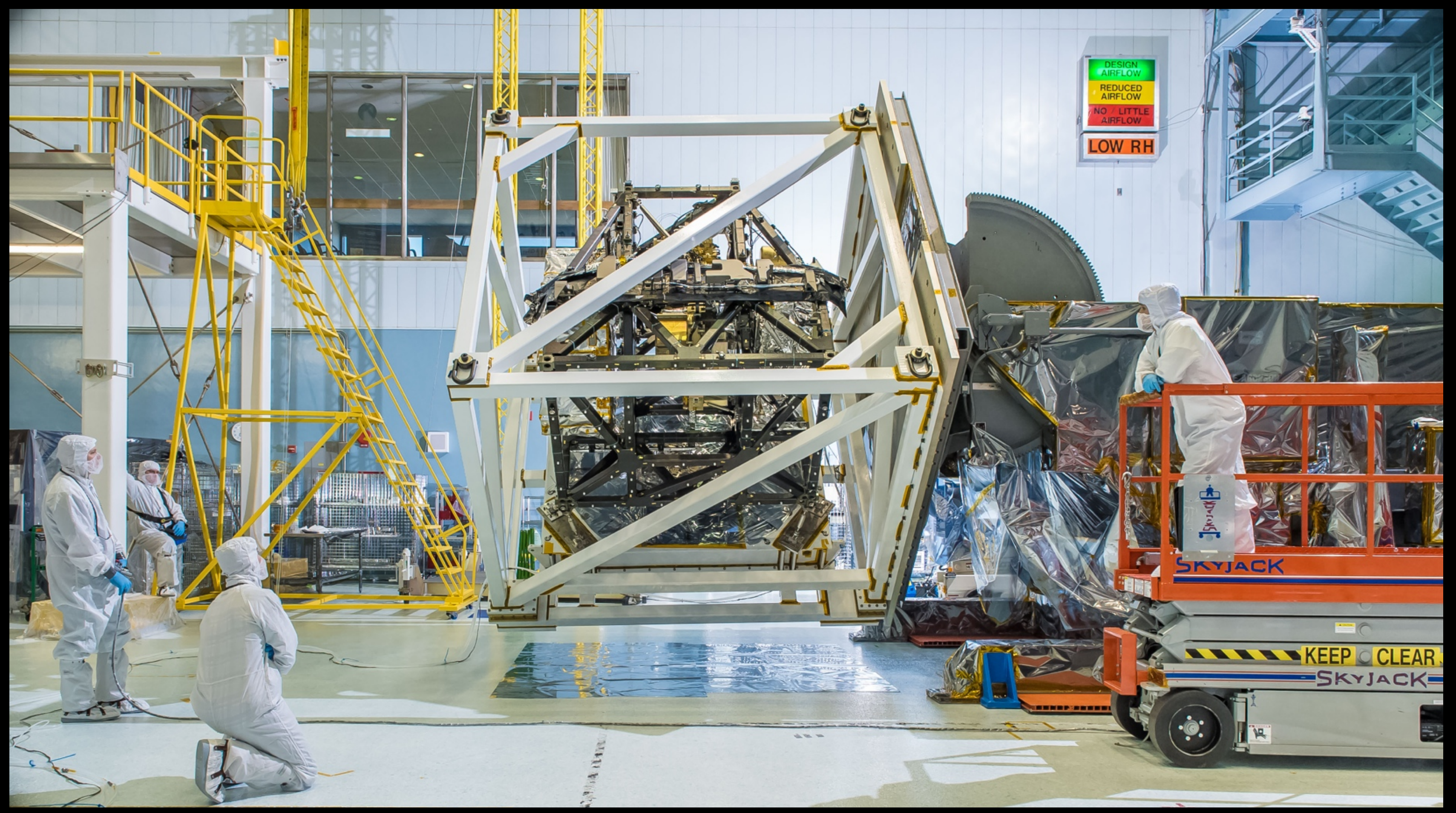


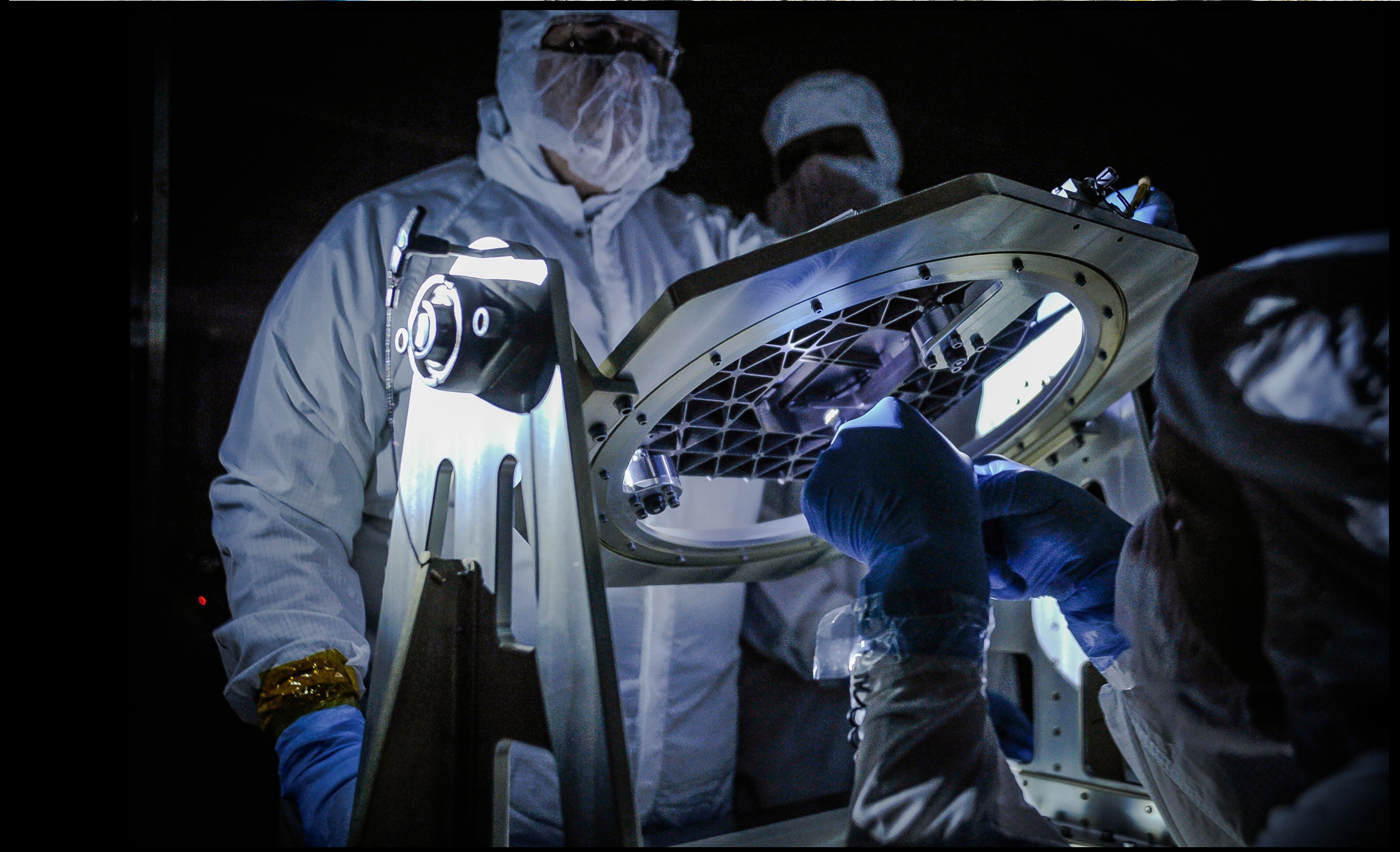
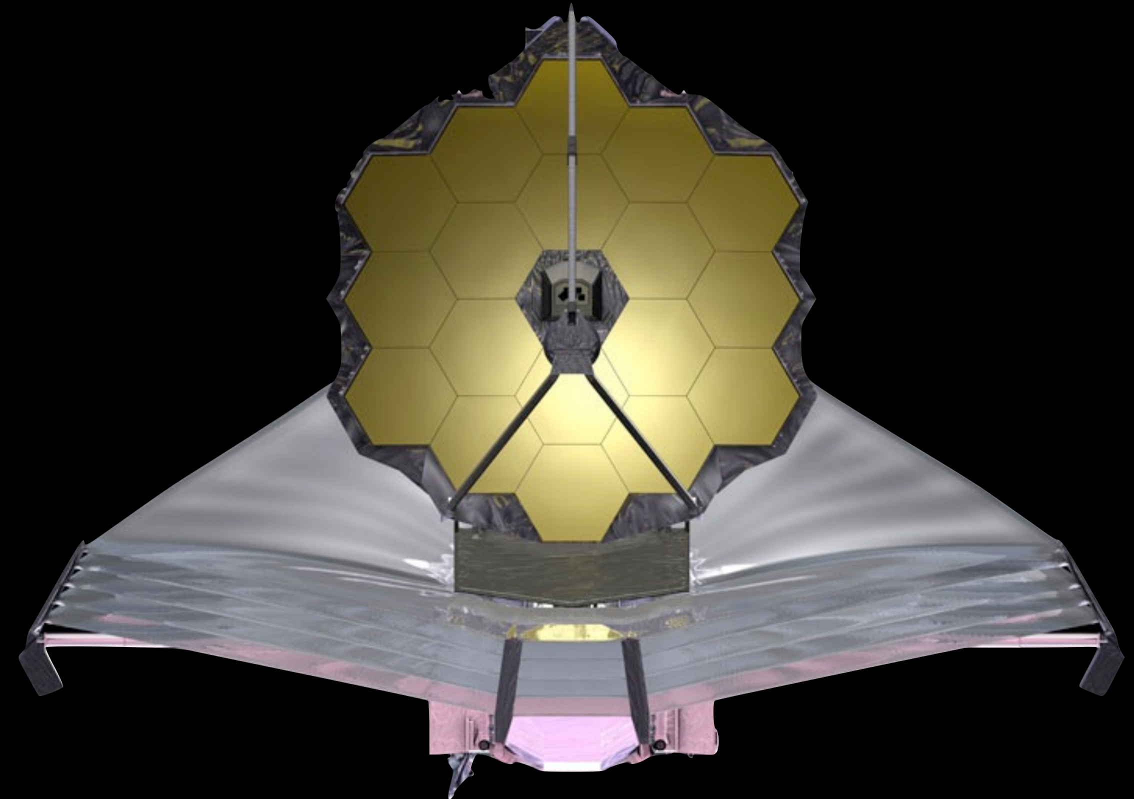




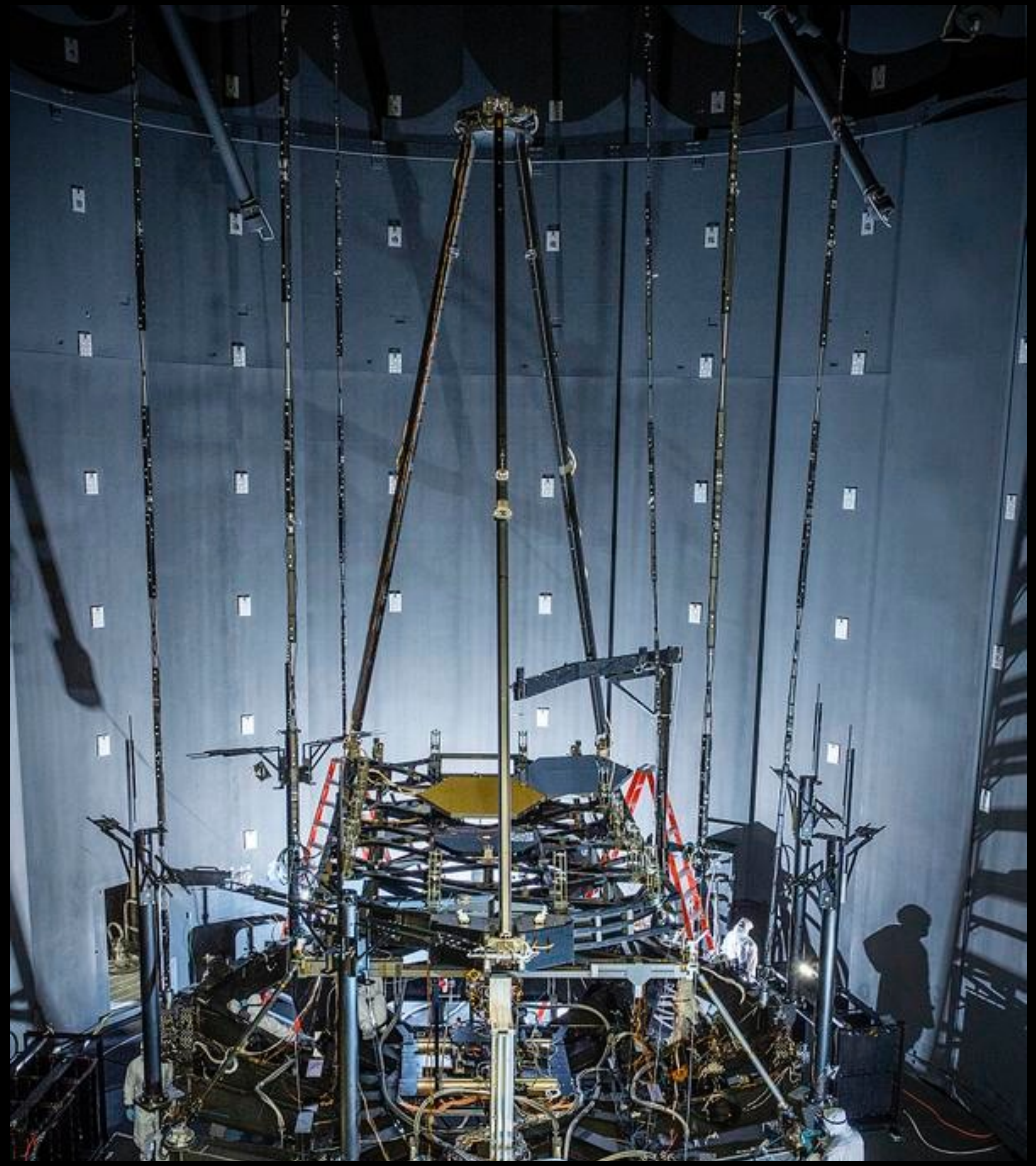


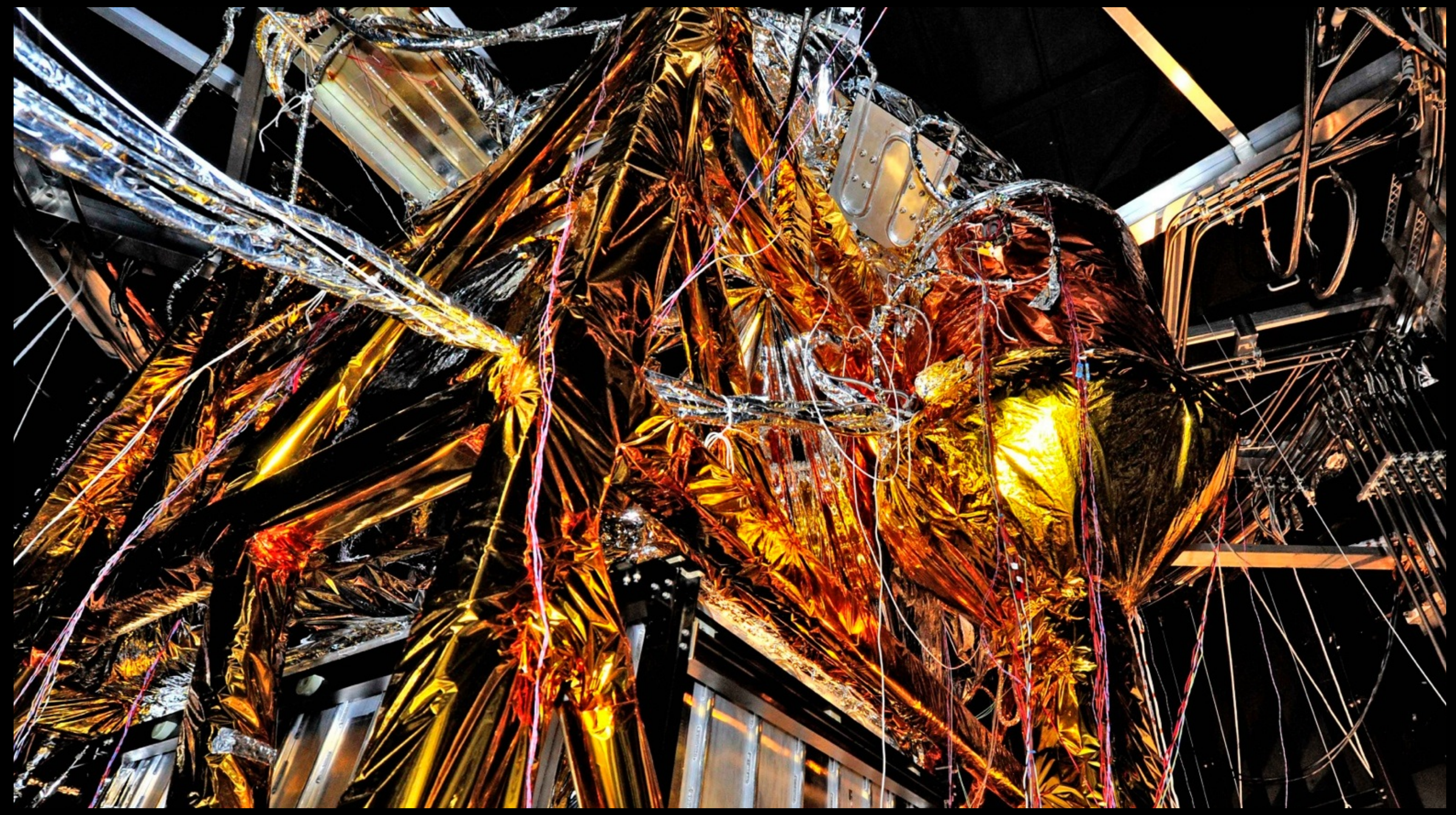




Technical Progress



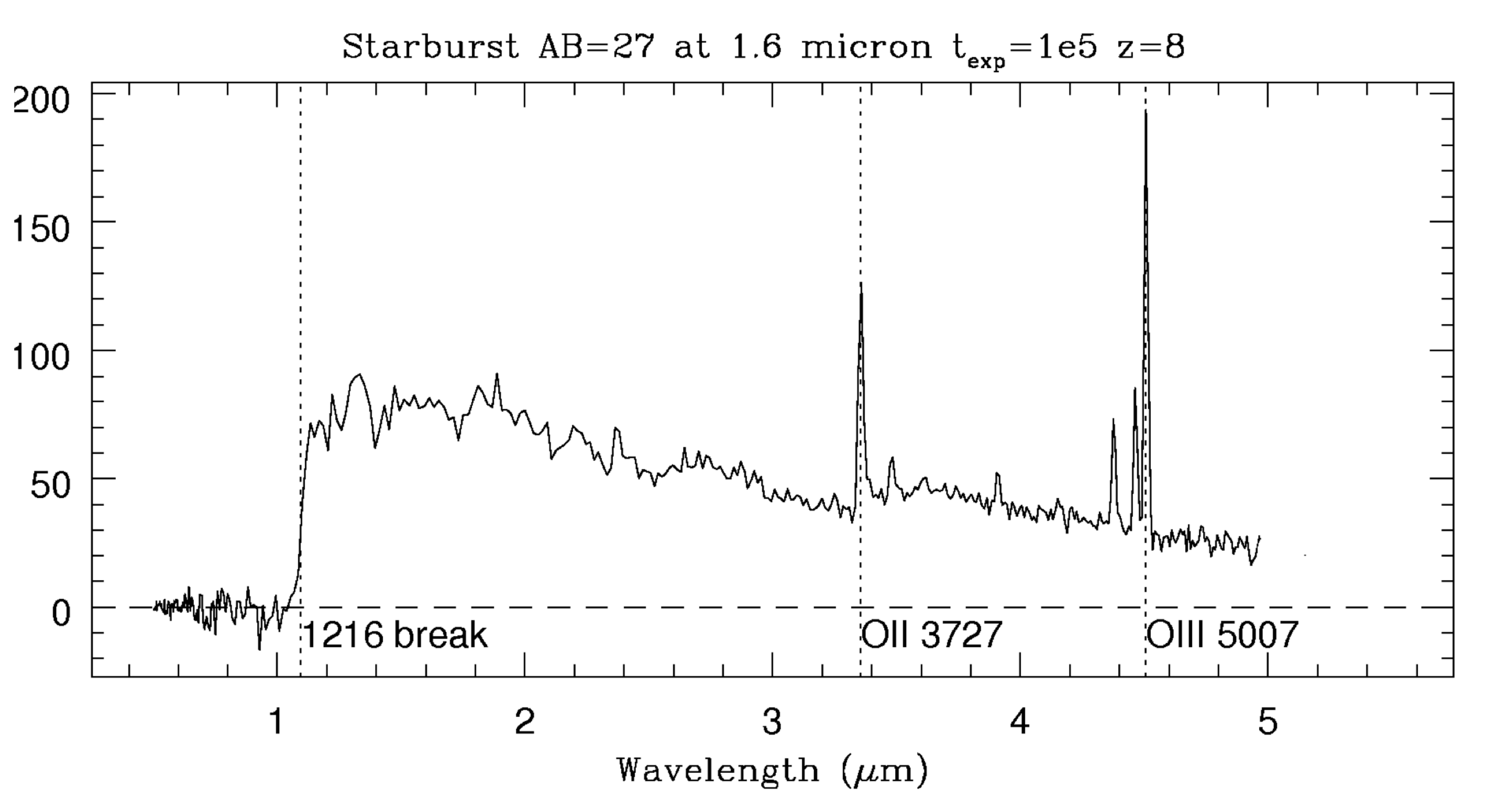



JWST is on schedule for its Oct 2018 LAUNCH!

A Better Snapshot of the Cycle 1 JWST Science Program

"Exploring the Universe with JWST"
Conference in ESTEC (Oct 12-16, 2015)

A More Complete Snapshot of Cycle 1 Science



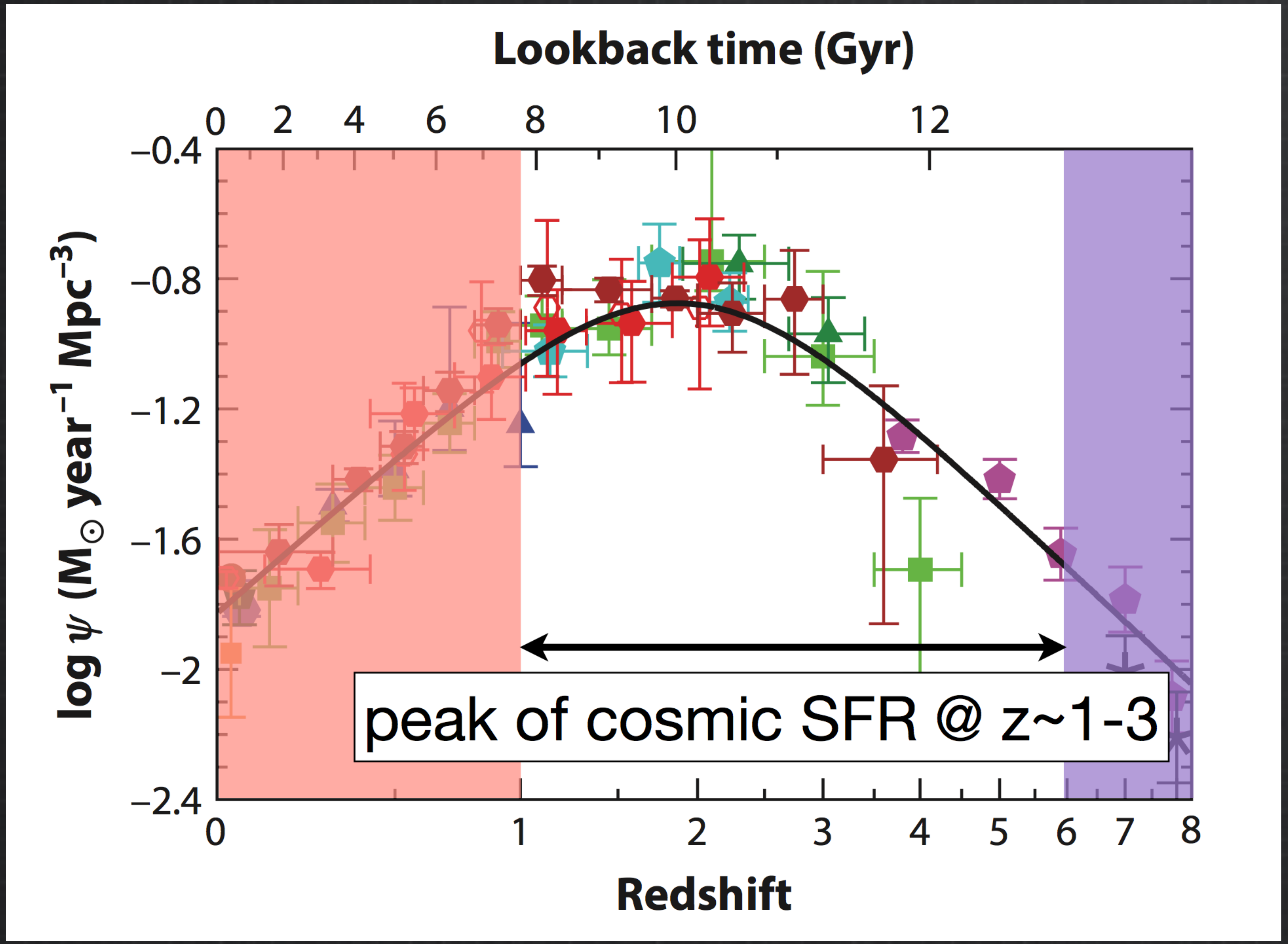
R. Ellis - z = 8 galaxy **spectra** w/ JWST

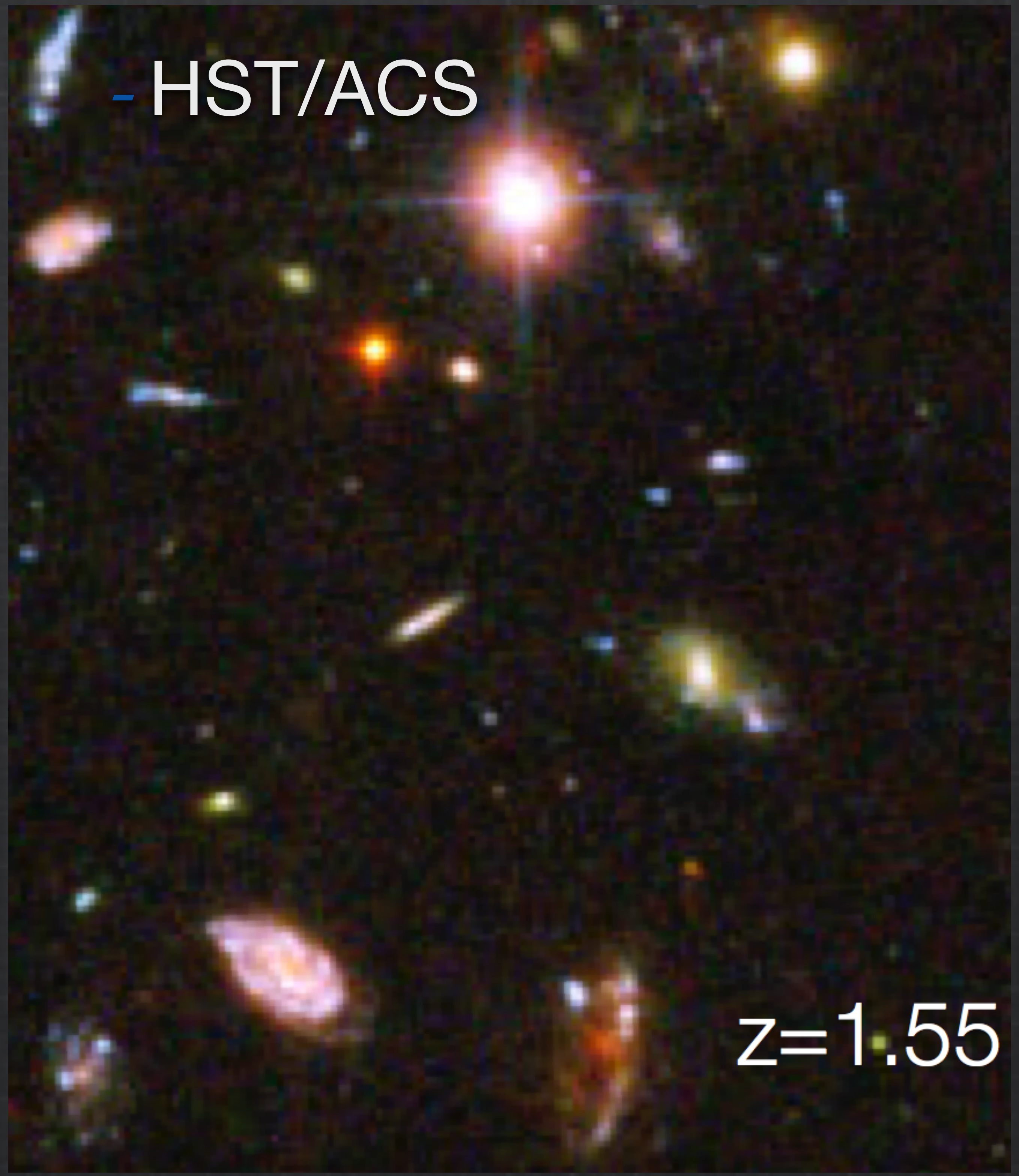
Hubble deep field imaging has contributed to demographics of early galaxies (#s, LFs, colors)

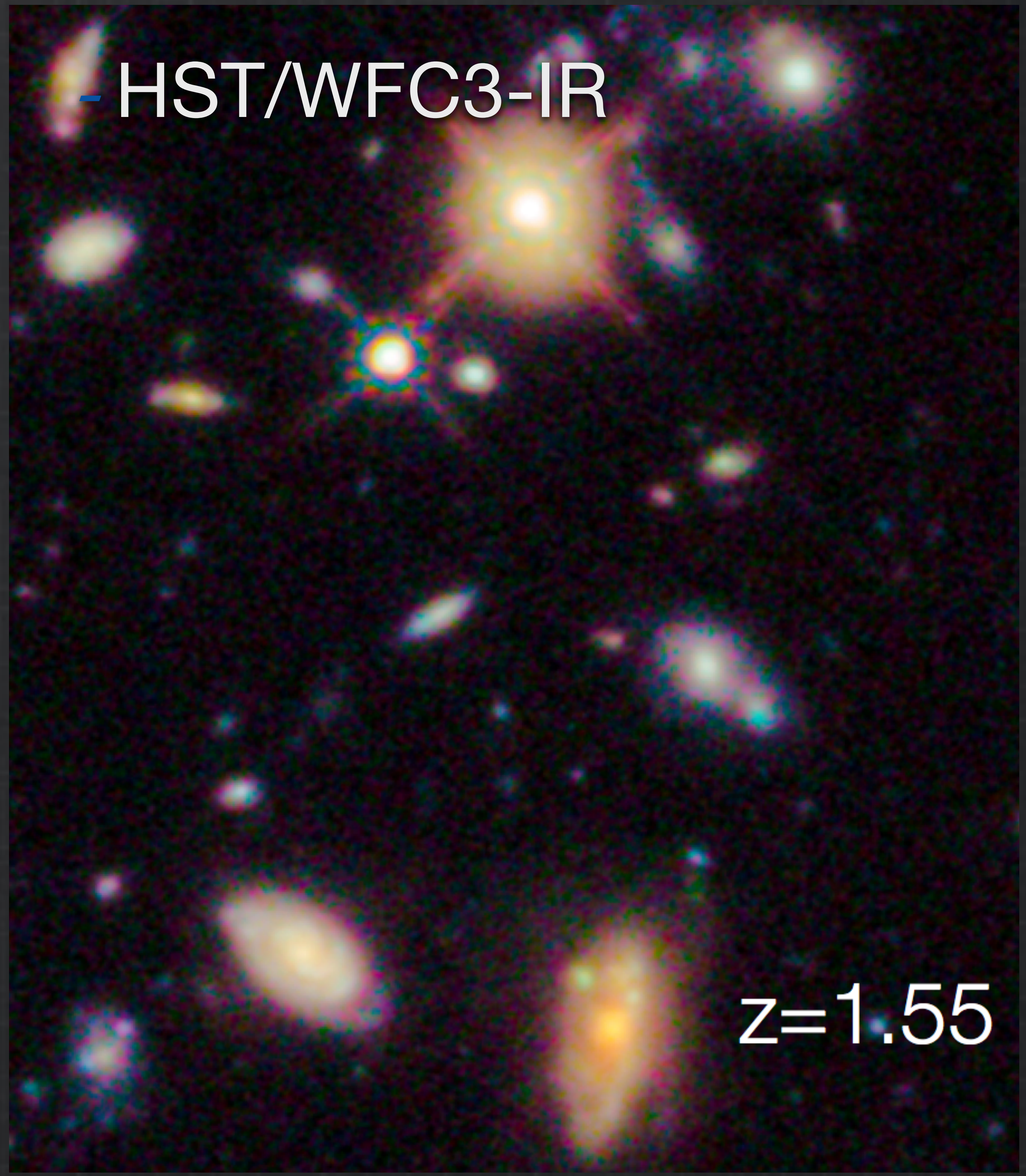
JWST spectroscopy will address detailed astrophysics

- nature of star formation: regular or burst-like (feedback)
- ionizing spectrum (stellar pops, role of AGN)
- escape fraction of Lyman limit photons
- chemical composition: O/H, C/O ratios (early nucleosynthesis)
- is there dust?

A More Complete Snapshot of Cycle 1 Science







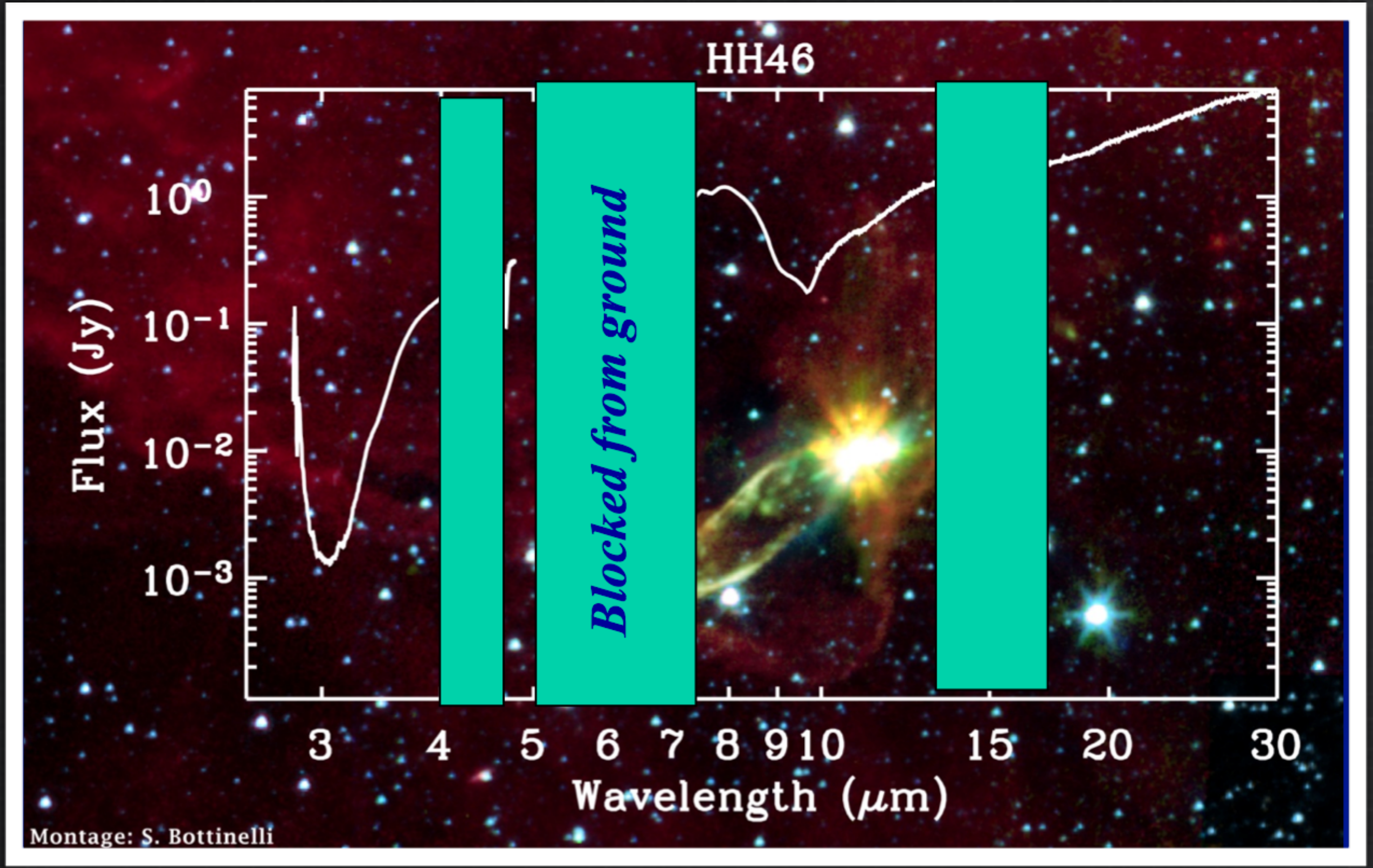
J. Lotz - Unveiling the Peak of Galaxy Assembly w/ JWST

Tremendous progress in understanding $1 < z < 6$ galaxies, where 75% of the Universe's stars formed

JWST's resolution and sensitivity in the near IR will be a game changer, and answer these questions

- how much hidden star-formation at $z > 3$?
- what are we missing? red galaxies - dusty and/or old?
- galaxy structures at $z > 3$? where are the mergers? where are metals and gas outflows at high z?
- super massive black holes/AGNs at $z > 1$? what is the role of (dusty) AGN in galaxy assembly?
- what is the role of environment?

A More Complete Snapshot of Cycle 1 Science



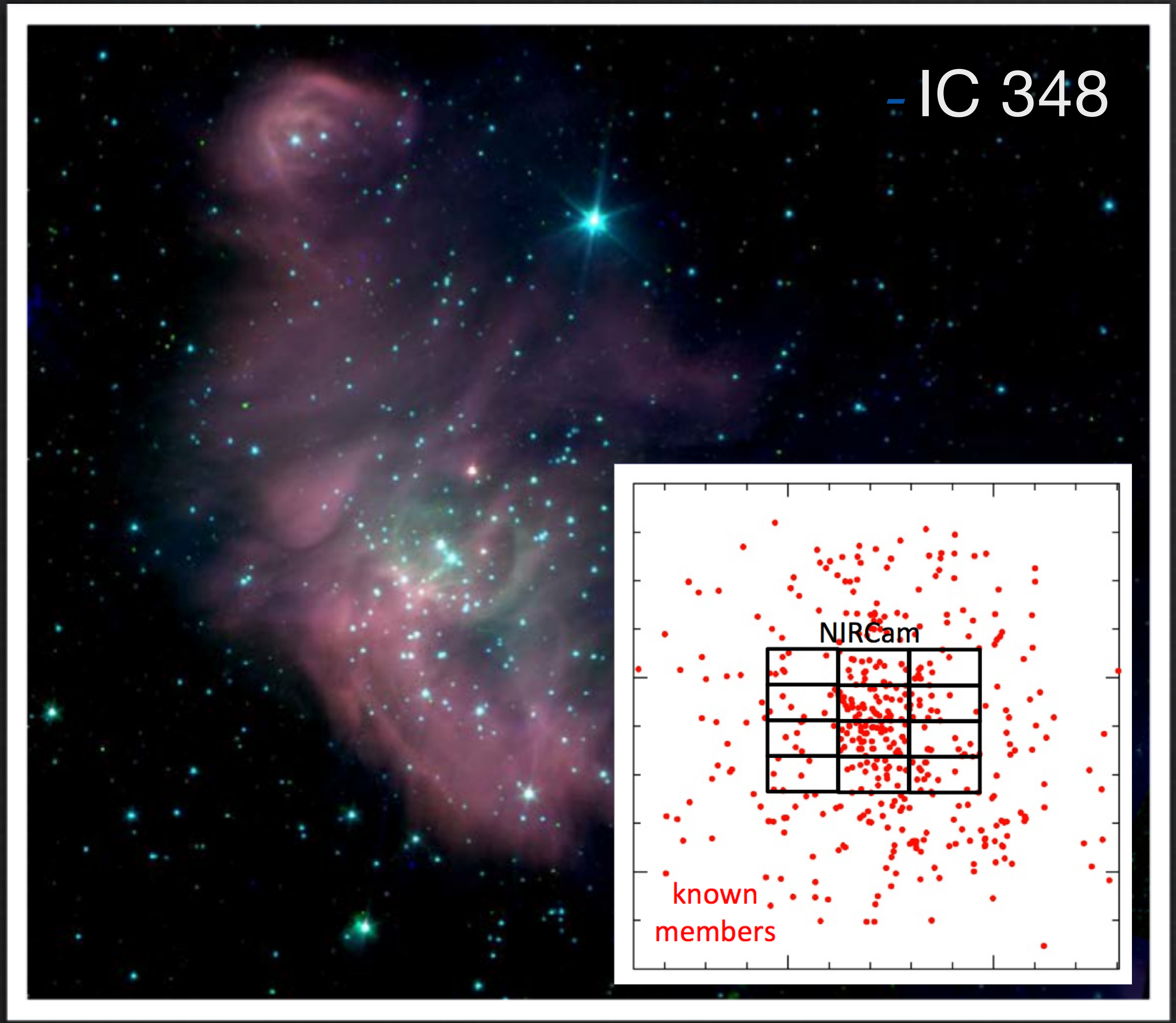
E. van Dischoeck - Embedded Phase of Star Formation w/ JWST

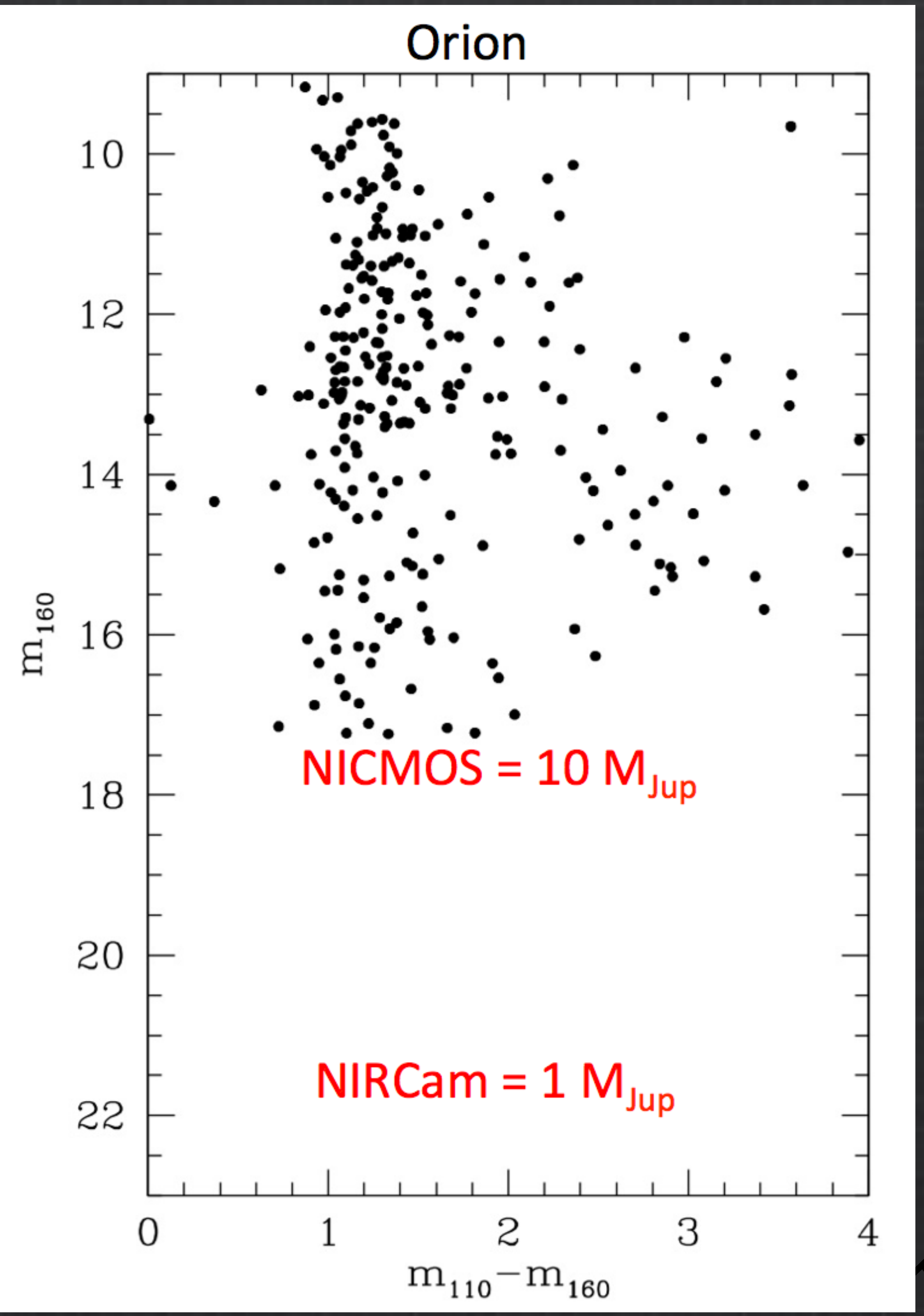
Spitzer, Herschel, WISE, and ground submm have built complete inventories of protostars out to a few kpc

JWST IFU spectroscopy will now characterize physics and chemistry on 10 - 1000 AU scales

- lots of IR diagnostics to use, each giving insights on the disk, accretion, shock, UV, high energy, etc.
- need modeling tools and lab data!
- JWST spatial resolution will resolve disks and envelopes.
- Physical structure of warm dust, geometry, earliest stages of massive star formation, variability, where does matter enter disk, fragmentation, resolve accretion from outflow shocks, water transport from clouds.

A More Complete Snapshot of Cycle 1 Science





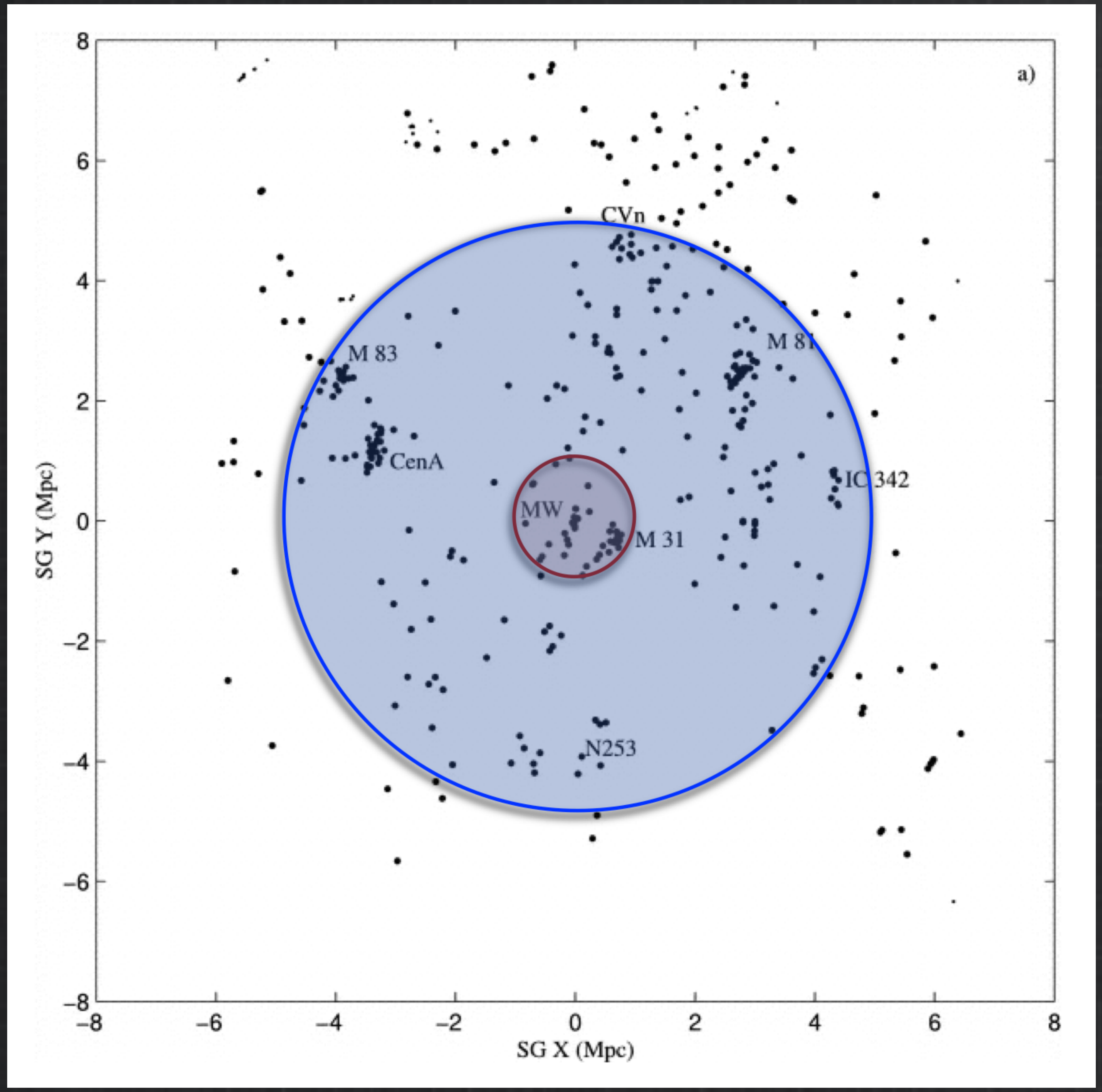
K. Luhman - Pre Main Sequence Stars and the IMF w/ JWST

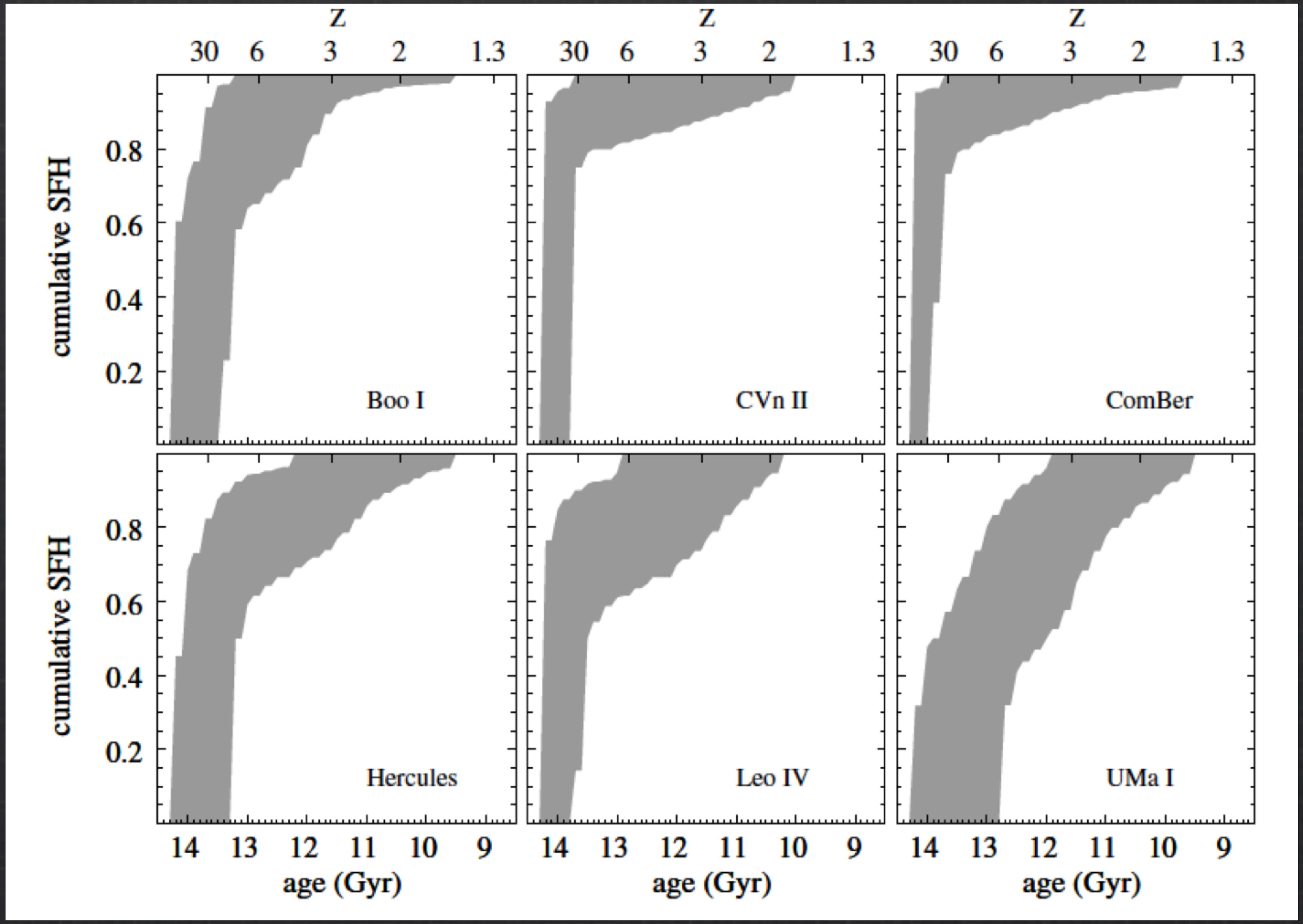
Space based IR observations have uncovered the substellar regime

JWST NIR and MIR imaging will measure complete stellar-planetary census in star forming regions

- JWST will see free floating Jupiter mass objects in Orion
- thousands of circumstellar disks in a variety of environments and evolutionary states
- unbiassed IMF over a complete mass distribution, and its variation with environment (e.g., spatial)
- spectra of 1-10 M_{JUP} objects in clusters to help interpret spectra of young planets

A More Complete Snapshot of Cycle 1 Science





Brown et al. (2014)

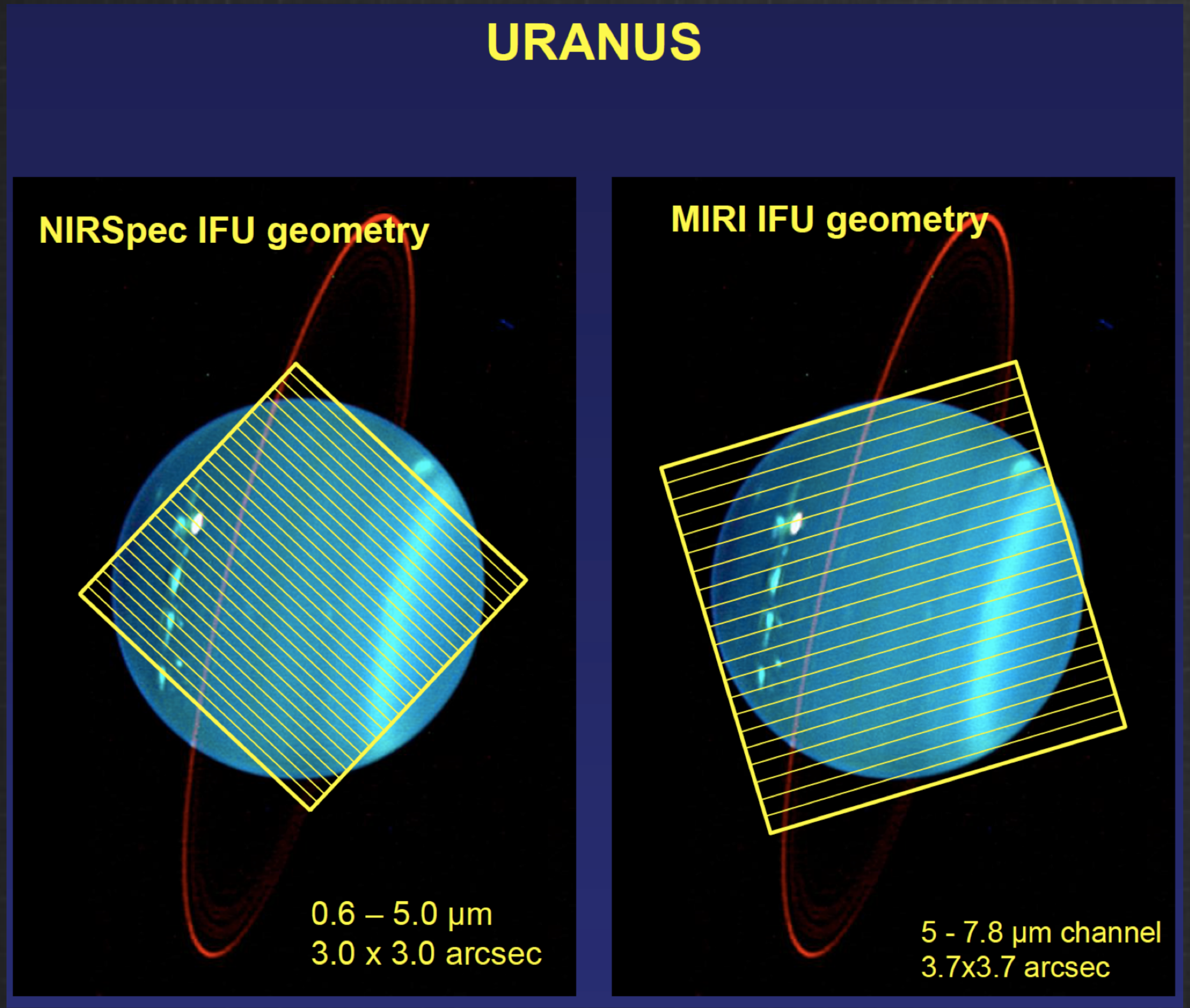
A. Ferguson - Resolving Populations in the Local Volume w/ JWST

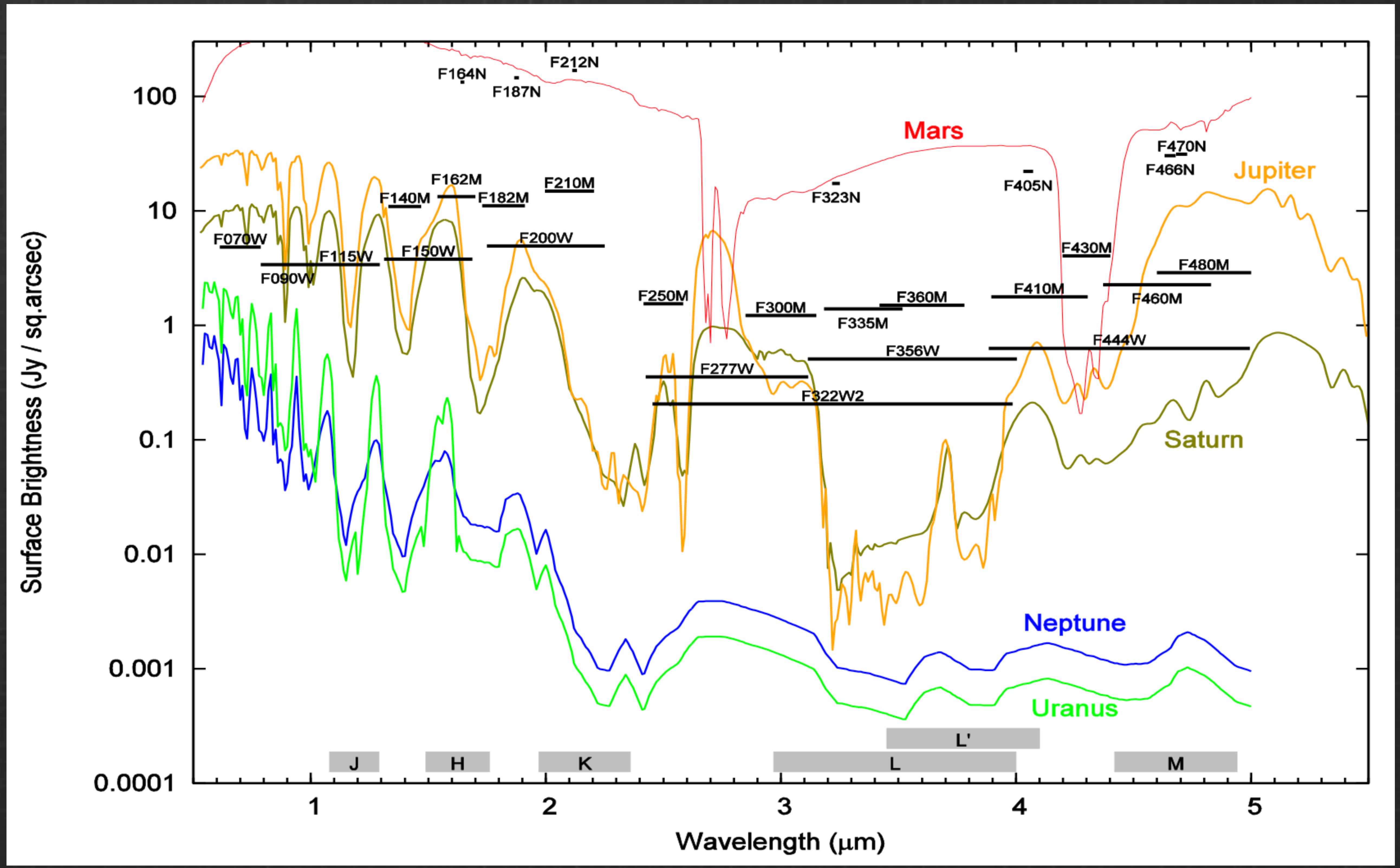
HST has been limited to direct measurements of the oldest stellar generations in the Local Group

JWST will measure the fossil record of different galaxy types in detail

- wonderful opportunity to connect near-field and far-field approaches that study galaxy assembly
- infrared baseline provides high precision ages of dark matter dominated UFDs (suppression by reionization)
- diverse history of dwarfs and their cosmological significance
- spatially resolved star formation histories for different galaxy types in the Local Volume

A More Complete Snapshot of Cycle 1 Science





H. Hammel - Giant Planet Systems w/ JWST

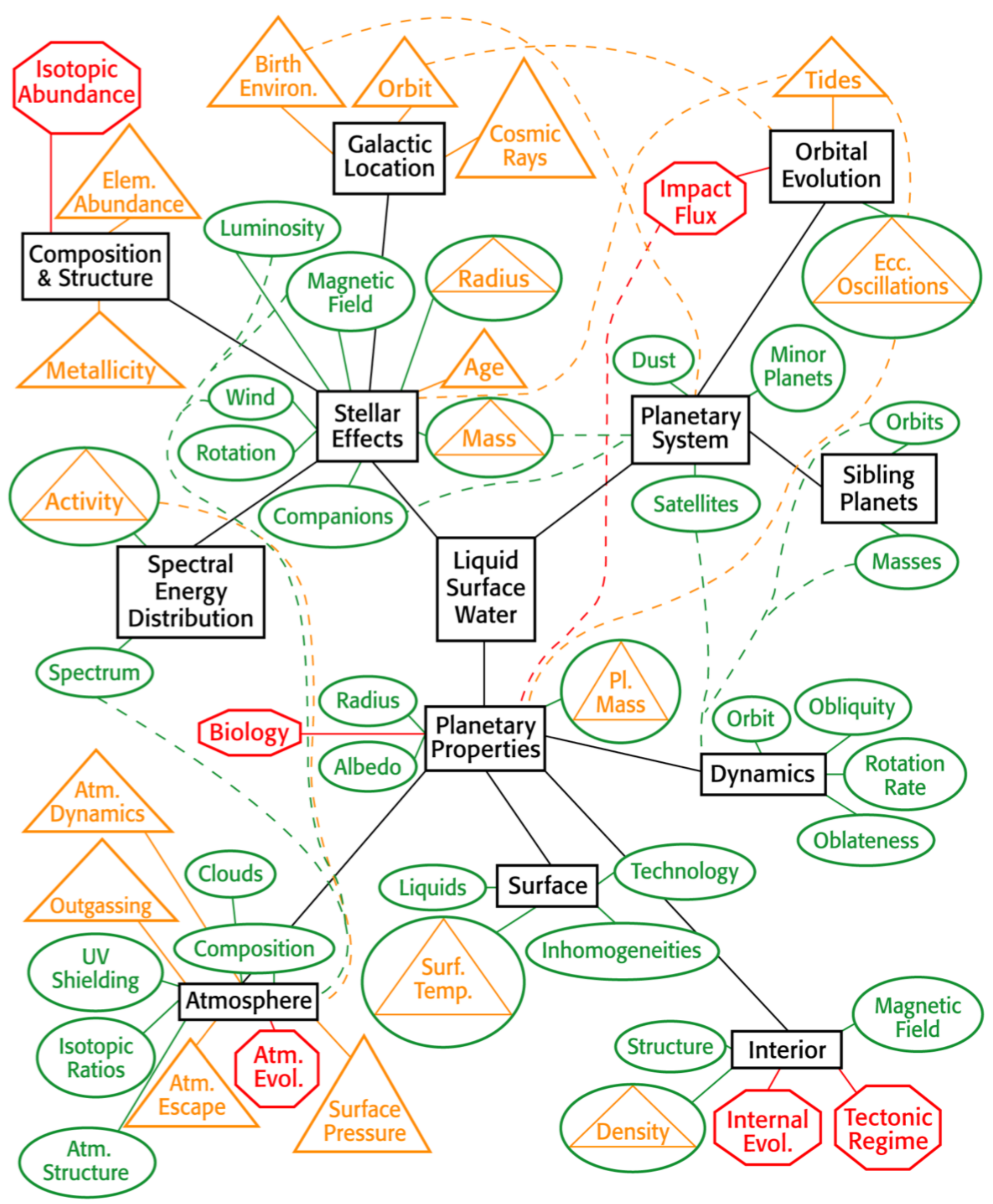
Great Observatories have played a tremendous role in studying the Solar System

JWST can track every object outside the orbit of Mars

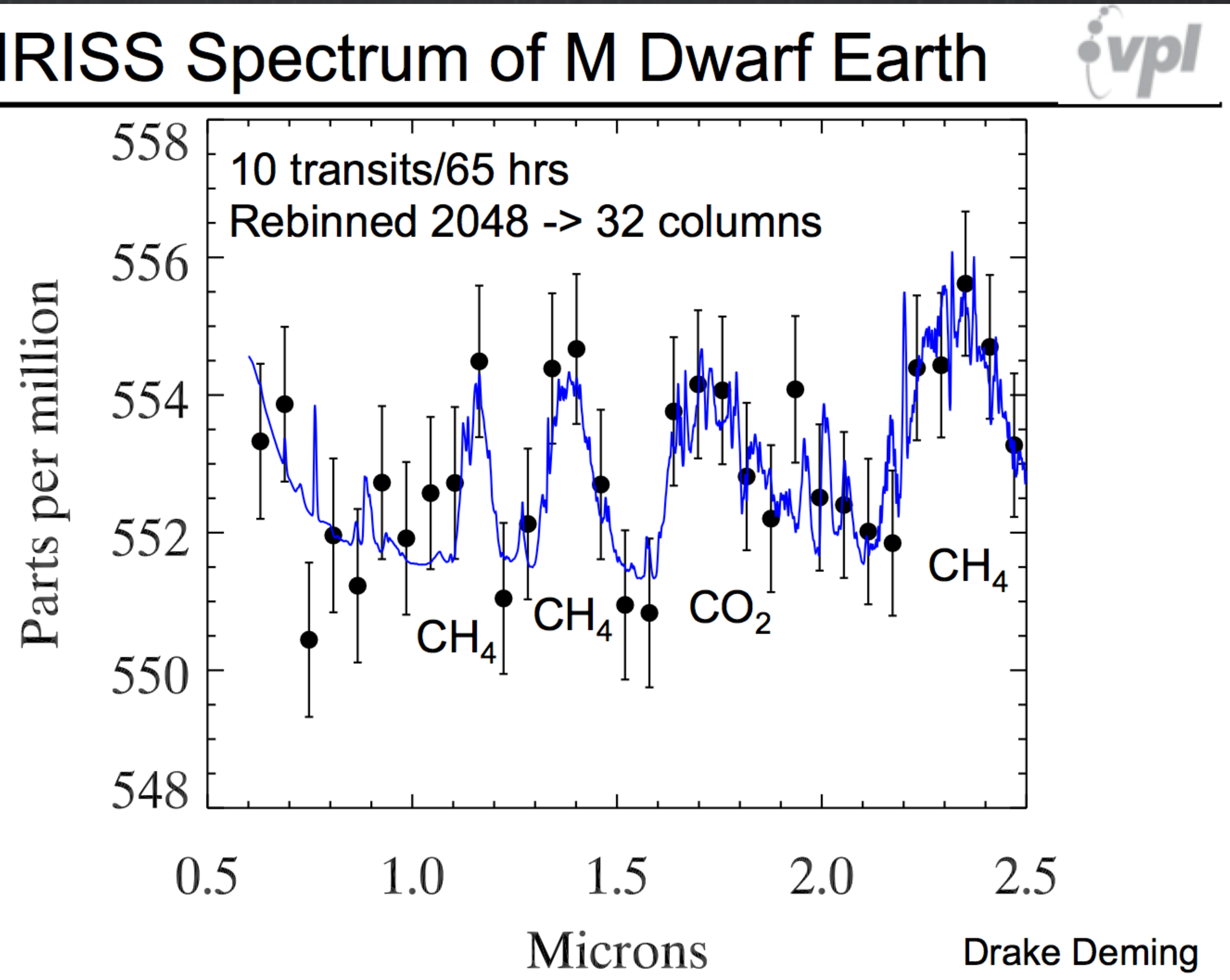
- atmospheric dynamics and chemistry of outer planets
- spectroscopy of moons and rings to assess temporal variation (seasonal and time variable effects)
- set the stage for future planetary missions to the outer Solar System
- dedicated talks on KBOs, comets, Titan, occultations, asteroids

A More Complete Snapshot of Cycle 1 Science

Assessing Potential Habitability



NIRISS Spectrum of M Dwarf Earth



V. Meadows - Characterizing Potentially Habitable Planets w/ JWST

K2 and TESS are (will) yield prime targets for JWST follow up

JWST provides our first opportunity to characterize habitable zone terrestrial planets

- JWST may be able to detect O4 dimer at 1.06 and 1.27 microns (Earth like planet at 5 pc)
    - will require ppm sensitivity, long integrations, and favorable conditions (e.g., no haze).
- warm mini Neptunes will be straightforward for JWST (cloud and atmospheric composition)
- lots of exciting mid infrared exoplanet science also

A Better Snapshot of the Cycle 1 JWST Science Program

- Galaxy Assembly with Gravitational Lensing
- IFUs and the Distant Universe
- Embedded Phase of Star Formation
- Debris Disks
- First Light and Reionization (near & mid IR)
- Direct Imaging of Exoplanets
- Protoplanetary Disks
- Warm Molecular Hydrogen at High-z
- Galaxy Assembly and Physics of Galaxy Formation
- High Redshift Galaxy Clusters
- Stellar Pops Throughout the Local Volume
- Core Collapse Supernovae and Ejecta
- Organic Material in the Circumstellar
- Formation of Super Star Clusters
- Solid Icy Material in Star Forming Regions
- The Solar System
- Planet Formation
- Physics of Brown Dwarfs
- Mid-IR Spectroscopy of the Epoch of Galaxy Assembly
- Ultra Faint Dwarf Galaxies
- Star Formation in the Magellenic Clouds
- Characterizing Habitable Exoplanets
- Pre Main Sequence Stars and the IMF
- Interpreting near IR SEDs of Galaxies
- Star Forming Galaxies from z = 4 to 10

JWST Advisory Committee Activities

The JSTAC advises the STScI Director on STScI's readiness to support science operations, implementation of NASA policies, and other matters related to the GO science community

Represents the Scientific Community and Advises the STScI Director

Roberto Abraham (Toronto)
Neta Bahcall (Princeton)
Natalie Batalha (NASA Ames)
Stefi Baum (Manitoba)
Roger Brissenden (Chandra/SAO)
Hashima Hasan (NASA, ex-officio)
Tim Heckman (Johns Hopkins)
Garth Illingworth (Santa Cruz, Chair)
Malcolm Longair (Cavendish)
John Mather (NASA, ex-officio)
Mark McCaughrean (ESA, ex-officio)
Chris McKee (Berkeley)
Brad Peterson (Ohio State)
Alain Ouellet (CSA, ex-officio)
Joseph Rothenberg (JHR Consulting)
Eric Smith (NASA, ex-officio)
Lisa Storrie-Lombardi (Spitzer/Caltech)
Monica Tosi (Bologna)

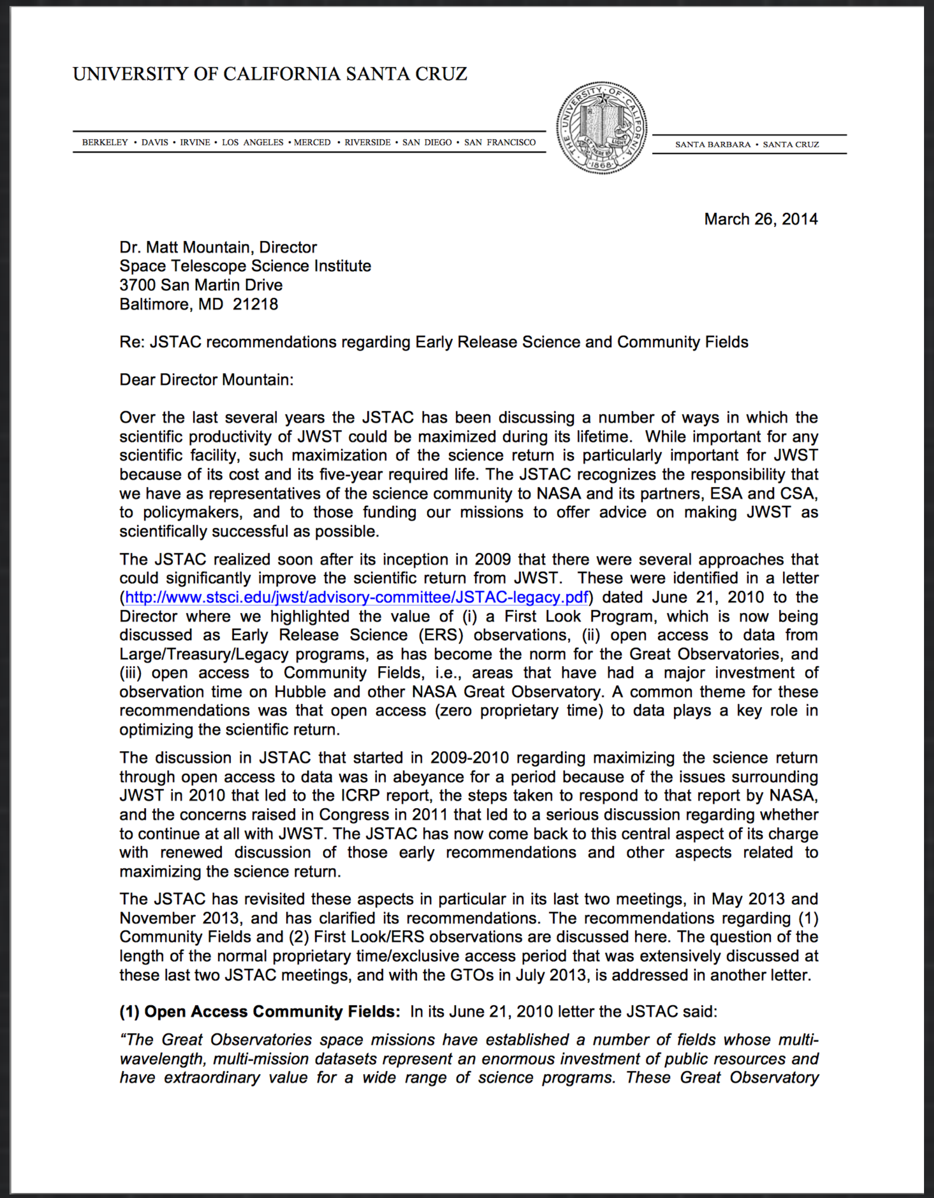
http://www.stsci.edu/jwst/advisory-committee

JWST Advisory Committee Activities

JSTAC is chaired by Garth Illingworth (UC Santa Cruz)
JSTAC meets at STScI twice every year (last meeting May 2015)
See http://www.stsci.edu/jwst/advisory-committee for more information

Recently, JSTAC has been focussed on ways to maximize early science from JWST

2014-2015 JSTAC recommendations to the STScI Director


UNIVERSITY OF CALIFORNIA SANTA CRUZ

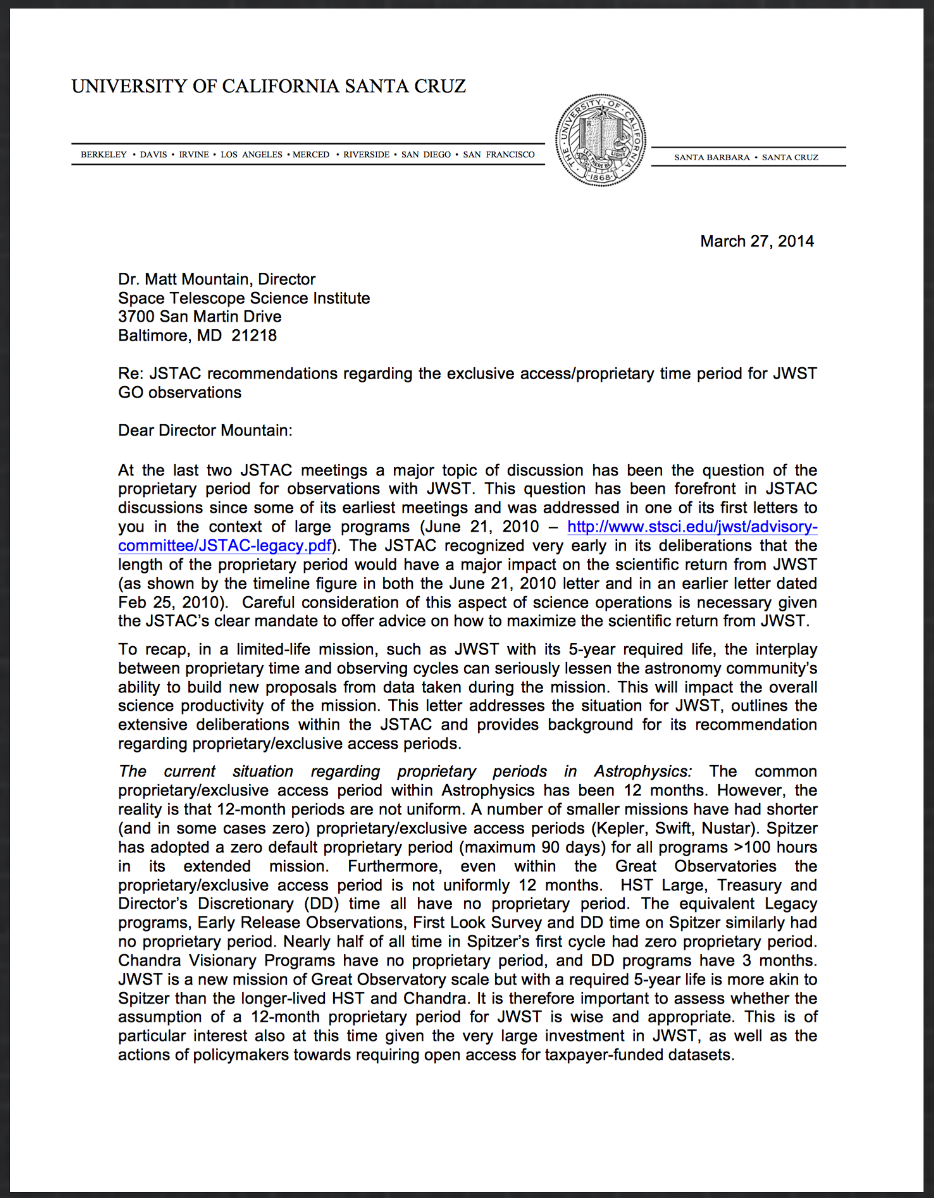
March 26, 2014

Dr. Matt Mountain, Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Re: JSTAC recommendations regarding Early Release Science and Community Fields

Dear Director Mountain:

Mar 2014
Early Release Science


UNIVERSITY OF CALIFORNIA SANTA CRUZ

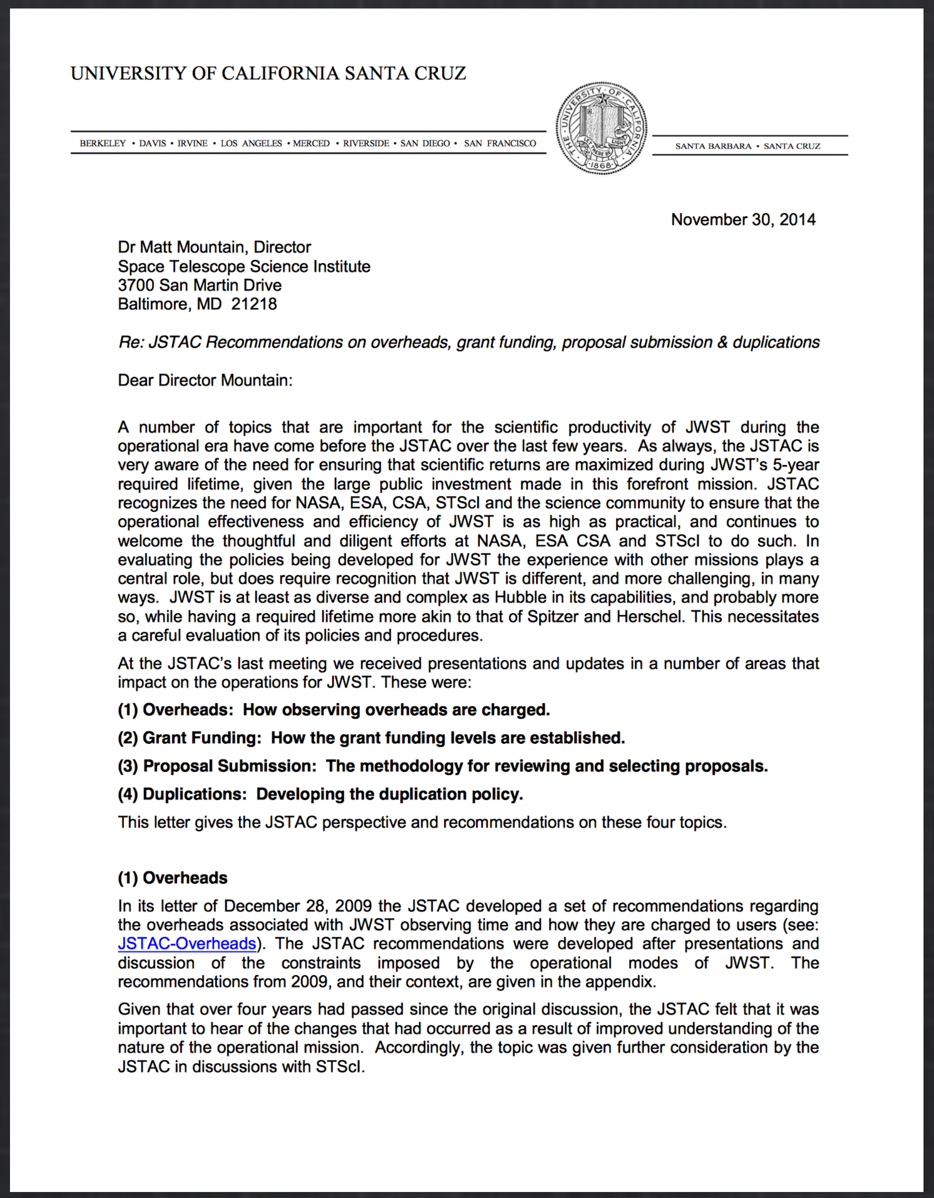
March 27, 2014

Dr. Matt Mountain, Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Re: JSTAC recommendations regarding the exclusive access/proprietary time period for JWST GO observations

Dear Director Mountain:

Mar 2014
Proprietary Time


UNIVERSITY OF CALIFORNIA SANTA CRUZ

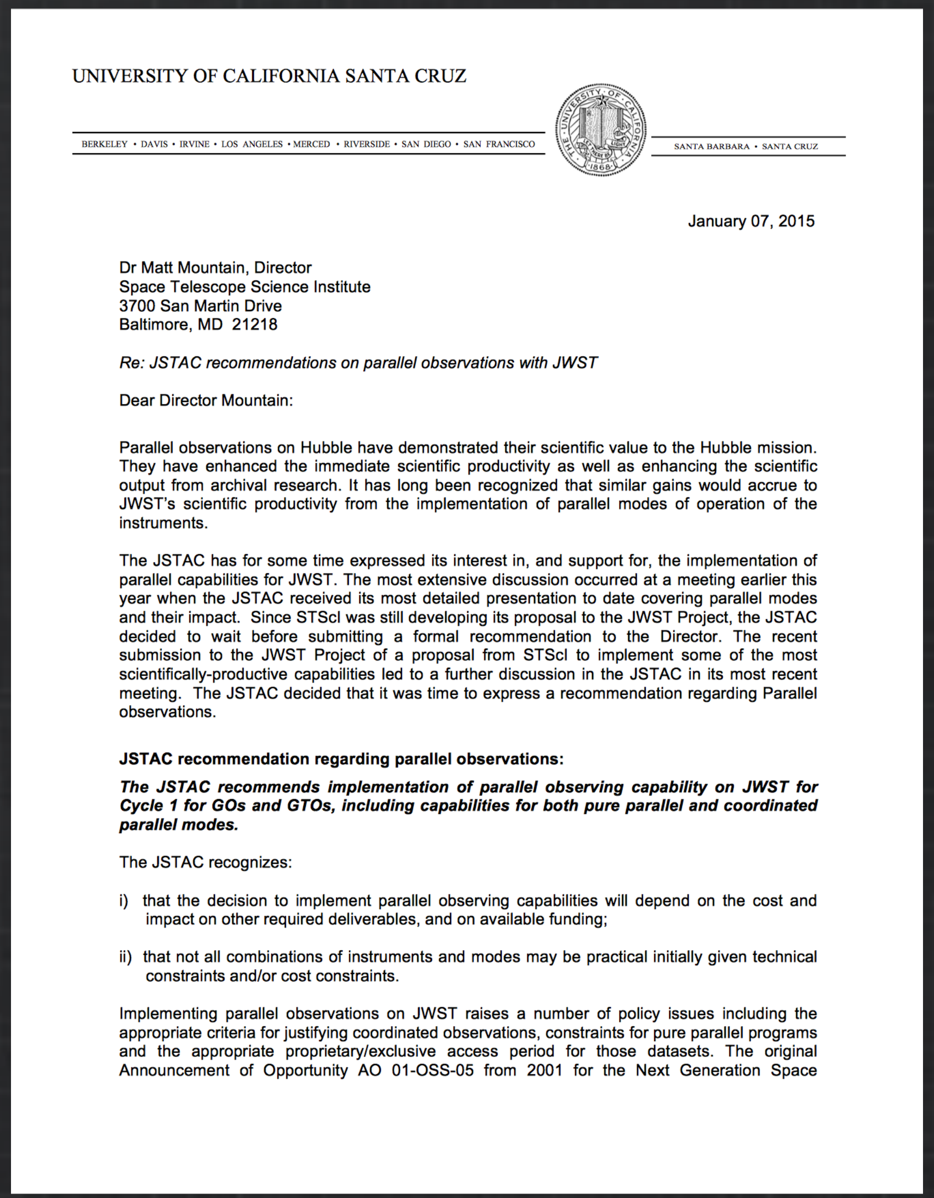
November 30, 2014

Dr Matt Mountain, Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Re: JSTAC Recommendations on overheads, grant funding, proposal submission & duplications

Dear Director Mountain:

Nov 2014
Proposal Selection,
Observing Overheads,
Duplication Policy


UNIVERSITY OF CALIFORNIA SANTA CRUZ

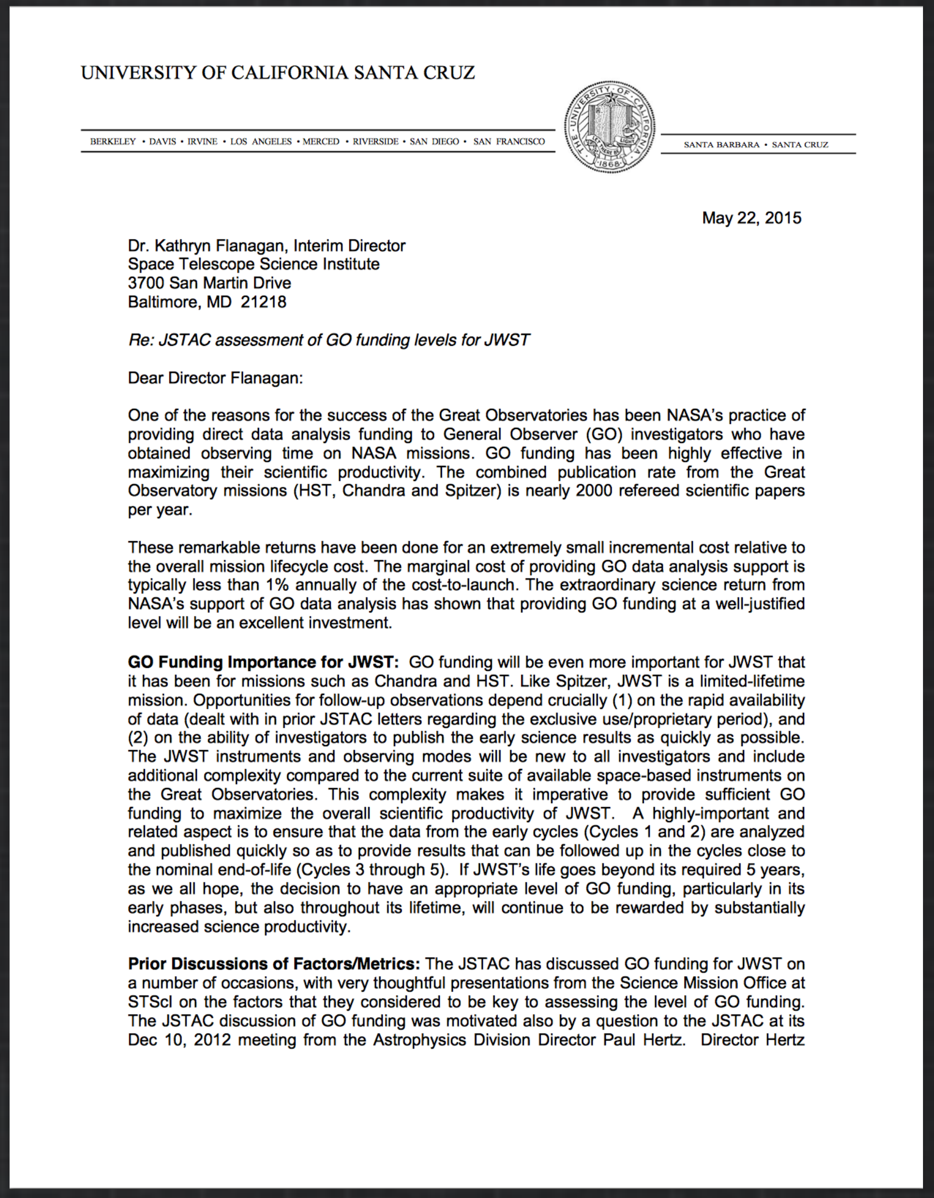
January 07, 2015

Dr Matt Mountain, Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Re: JSTAC recommendations on parallel observations with JWST

Dear Director Mountain:

Jan 2015
Parallel Observations


UNIVERSITY OF CALIFORNIA SANTA CRUZ

May 22, 2015

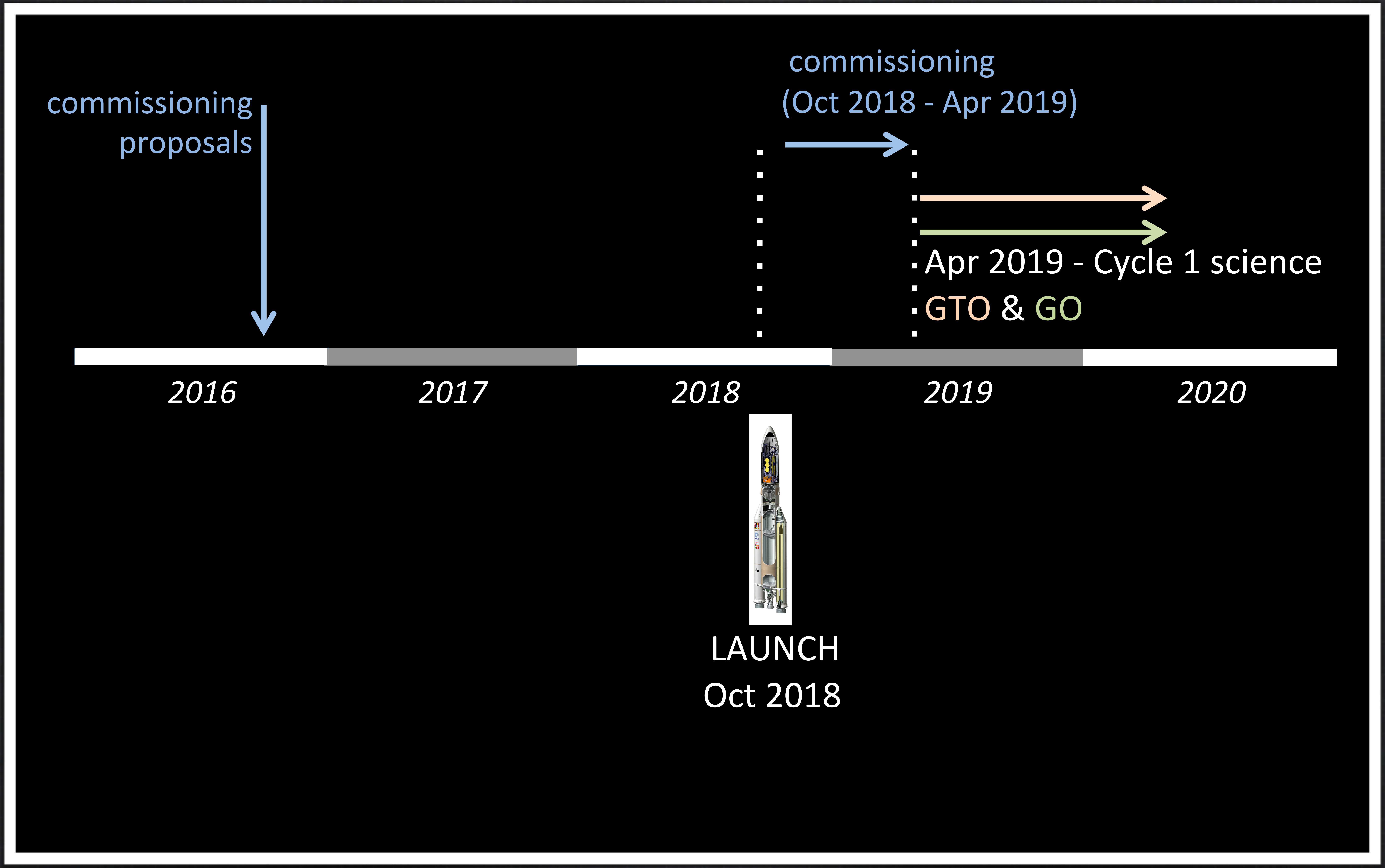
Dr. Kathryn Flanagan, Interim Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Re: JSTAC assessment of GO funding levels for JWST

Dear Director Flanagan:

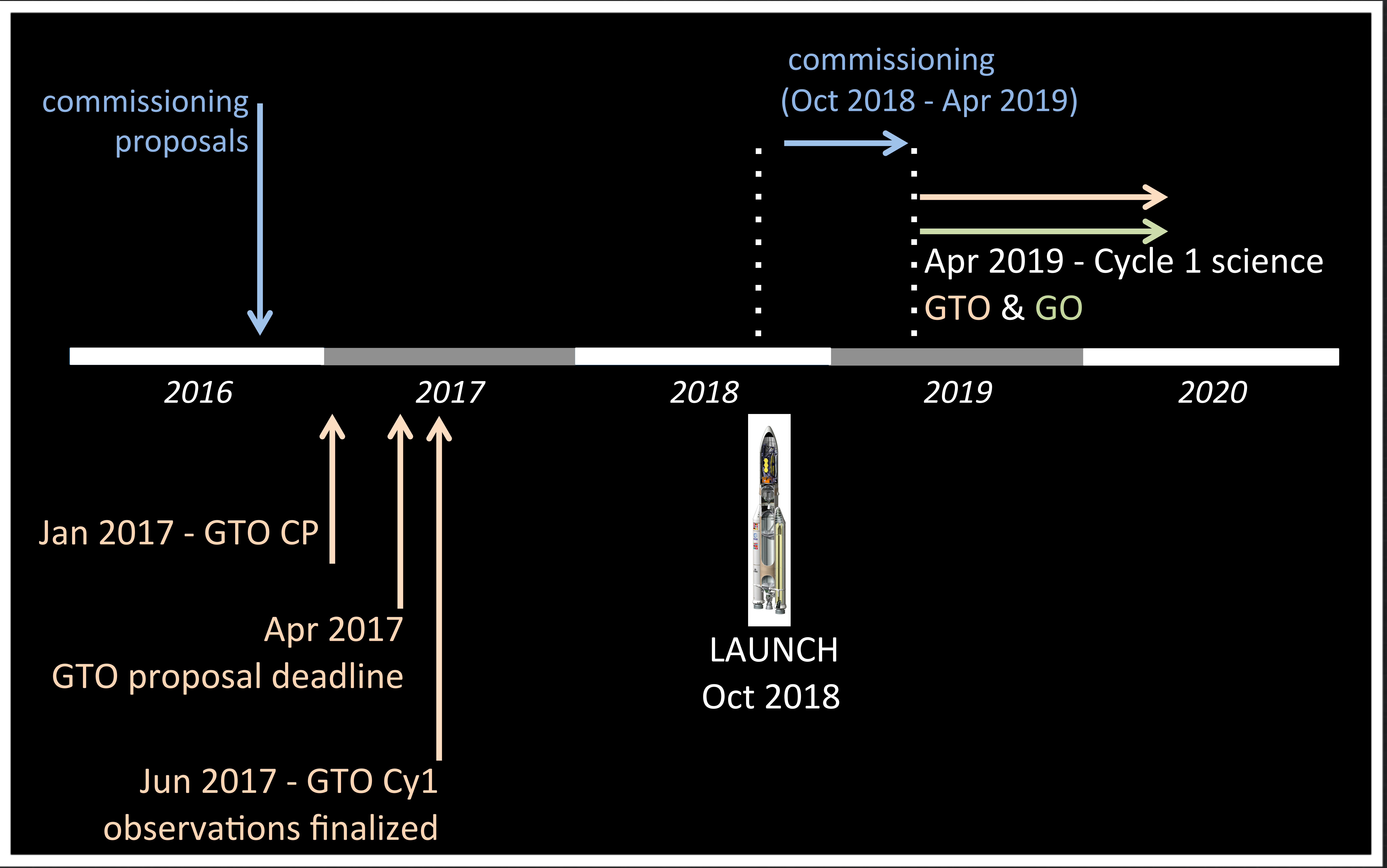
May 2015
GO Funding Level

JWST Science Planning Timeline



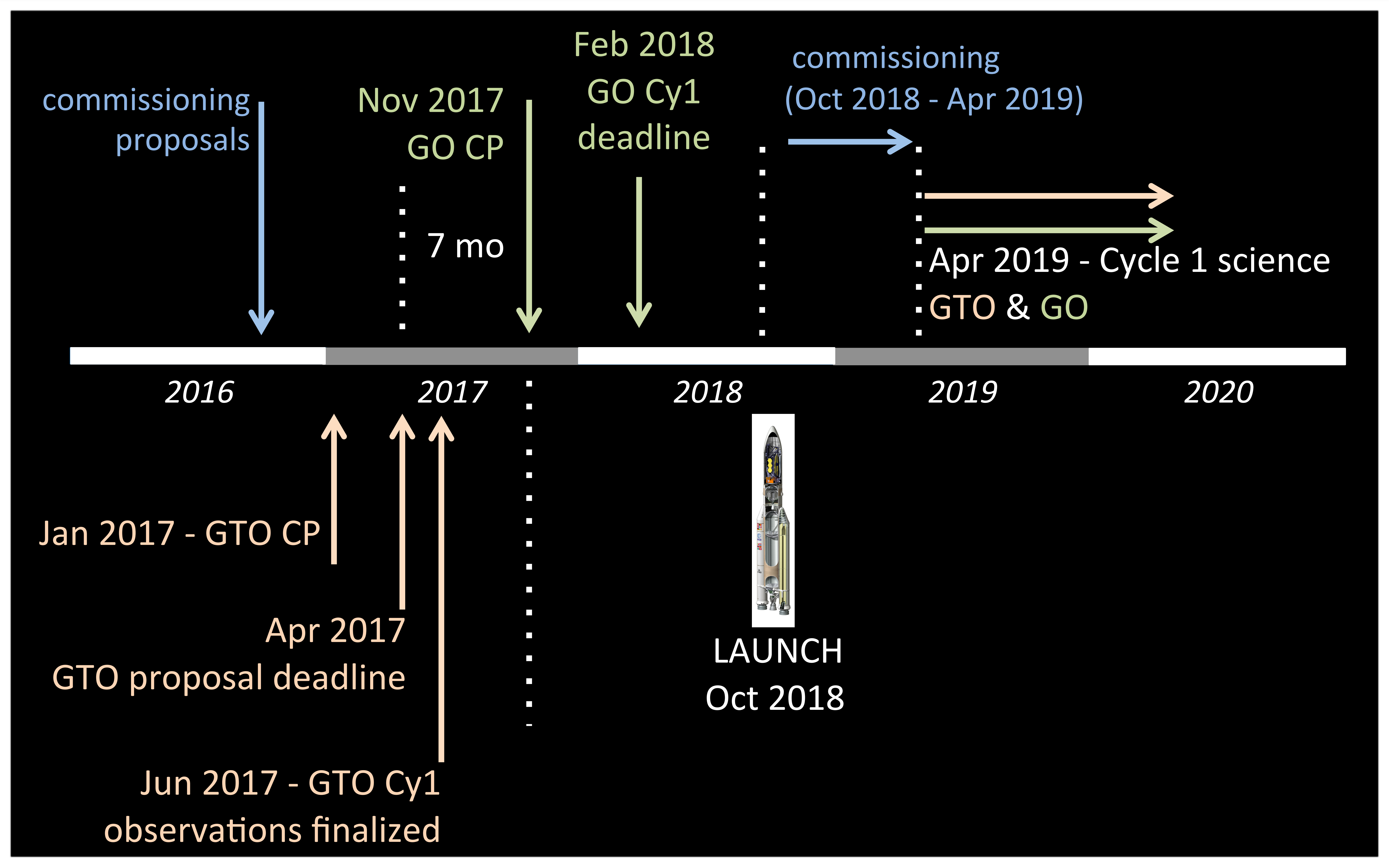
Draft (Jan 2016)

JWST Science Planning Timeline



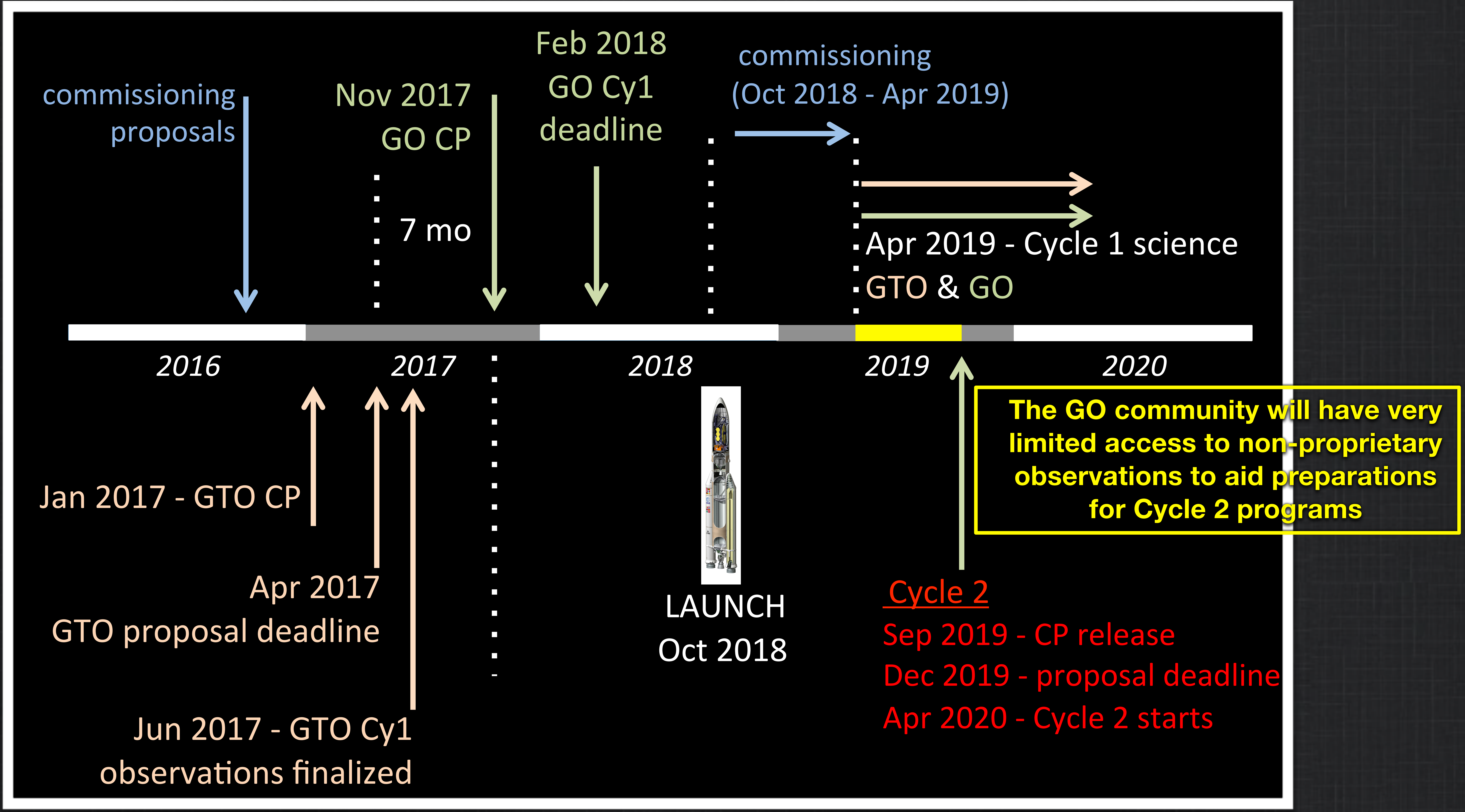
Draft (Jan 2016)

JWST Science Planning Timeline



Draft (Jan 2016)

JWST Science Planning Timeline



Draft (Jan 2016)

The Early Release Science Program (ERS)

The JSTAC has recommended an Early Release Science Program for JWST

June 2010

"..to obtain images and spectra that would be used to demonstrate key modes of the JWST instruments. The goal of this program is to enable the community to understand the performance of JWST prior to the submission of the first post-launch Cycle 2 proposals that will be submitted just months after the end of commissioning."

"The JSTAC recommends that the First-Look data be released both in raw form and with any initial calibrations as soon as possible; the key aspect is speed."

The JSTAC has reiterated its support for the ERS in recent meetings (e.g., see March 2014 letter)

Program Implementation

- ★ STScI had an open dialogue about ERS concepts at recent meetings (e.g., Jan 2016 AAS meeting)
- ★ Program will be supported by Director's Discretionary time (assume ~15 modes x 20-25 hrs)
- ★ Program will be shaped with significant involvement of the astronomical community
- ★ Program will be selected to span key JWST observing modes, data analysis challenges, science areas
- ★ Program will execute early in Cycle 1 and have no proprietary time
- ★ ERS teams will be responsible for rapid delivery of science enabling products to MAST

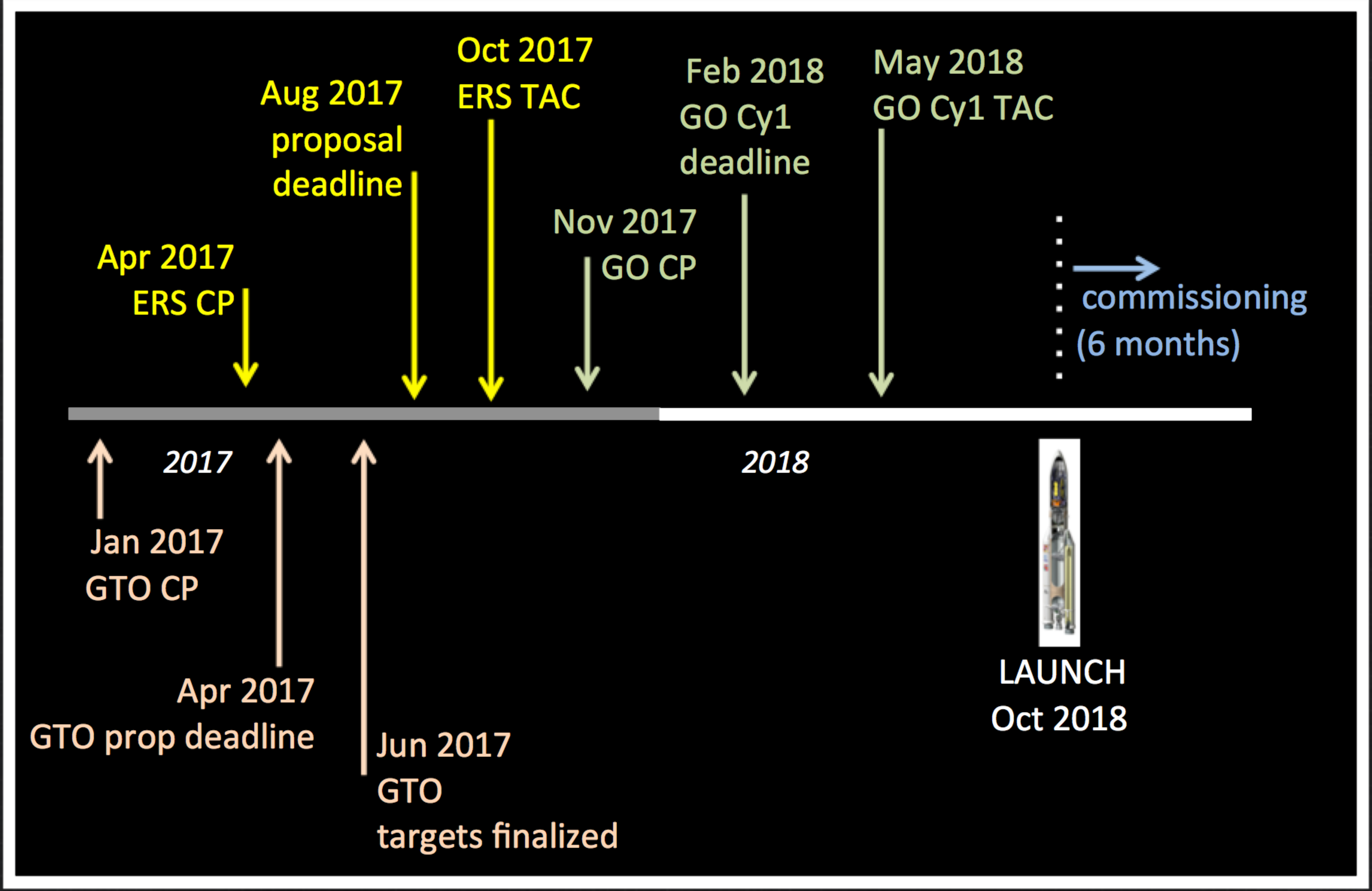
The ERS program is a fantastic opportunity to become an expert on JWST

http://www.stsci.edu/jwst/science/ers

N. Reid's ERS Presentation from the Jan 2016 AAS Meeting:

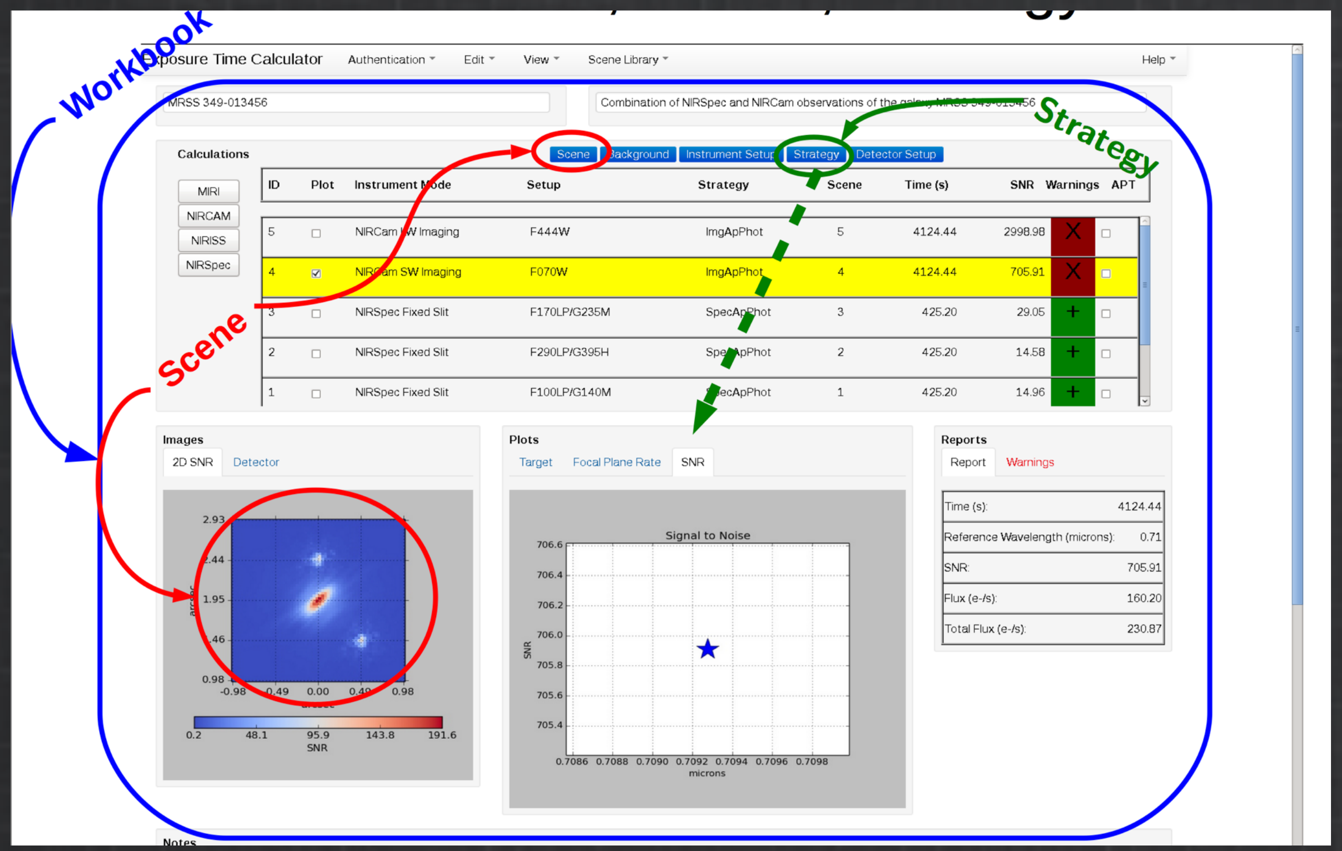
http://www.stsci.edu/jwst/doc-archive/presentations

JWST Cycle 1 Early Release Science (ERS) Timeline



Draft (Jan 2016)

Upcoming JWST Milestones for User Tools



ETC Engine Release (development)

ETC WebApp + Simulator Flight Release

Early Release Science Program Deadline

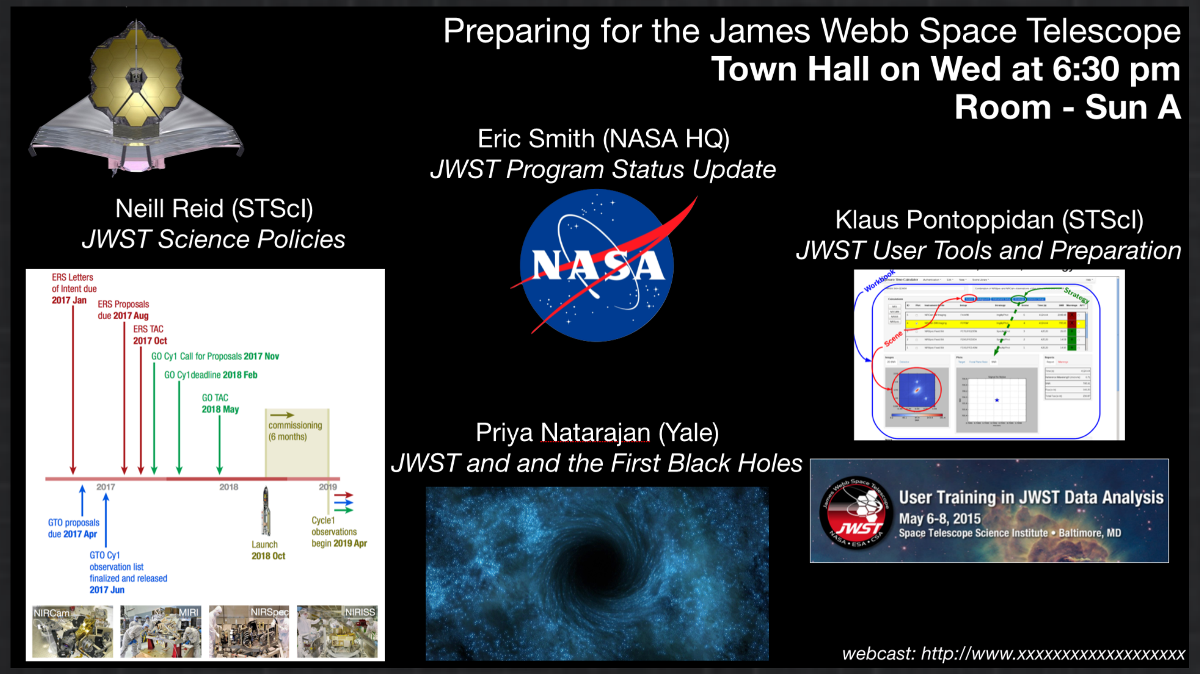
Cycle 1 Deadline

2016

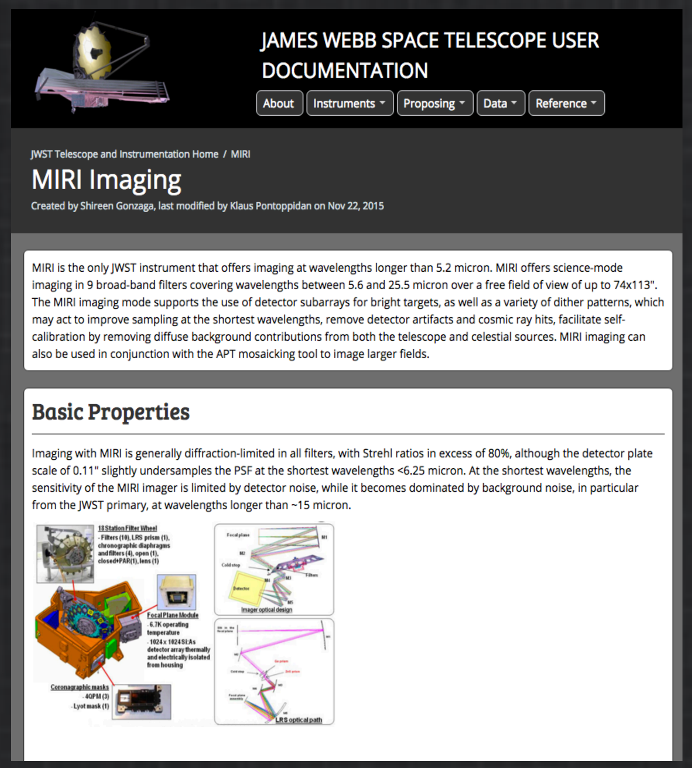
2017

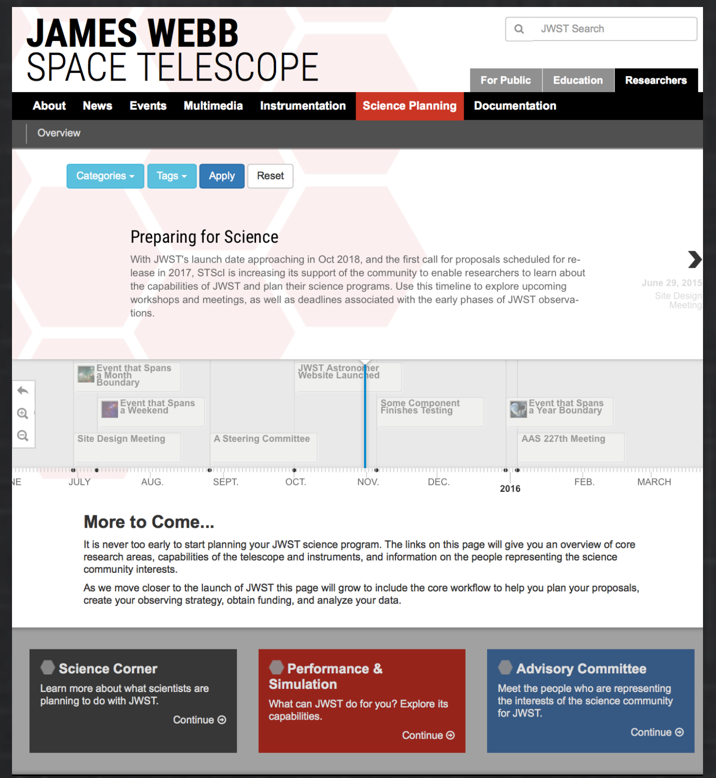
2018

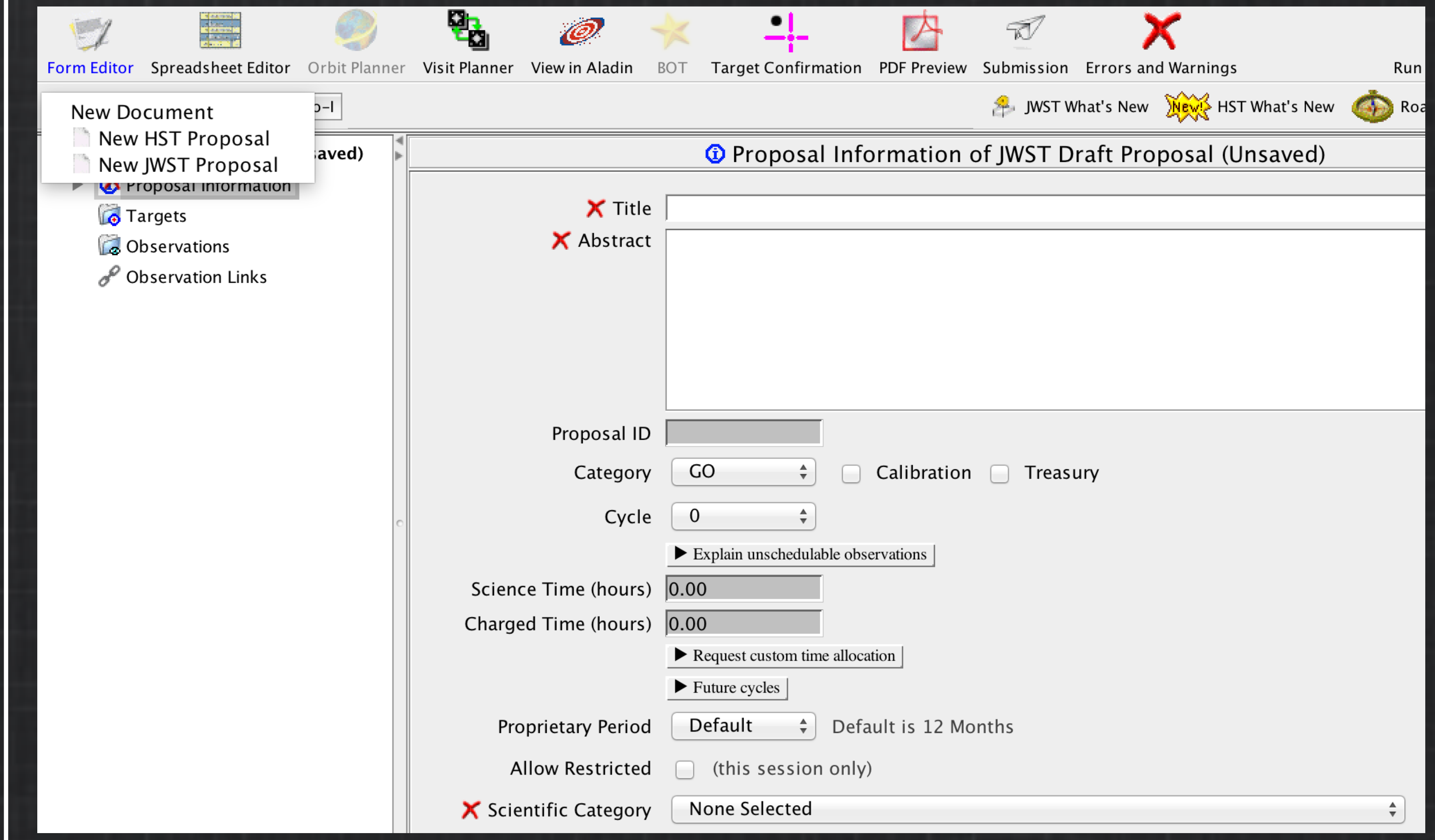
227th AAS Conference



First User Documentation Release (incremental)



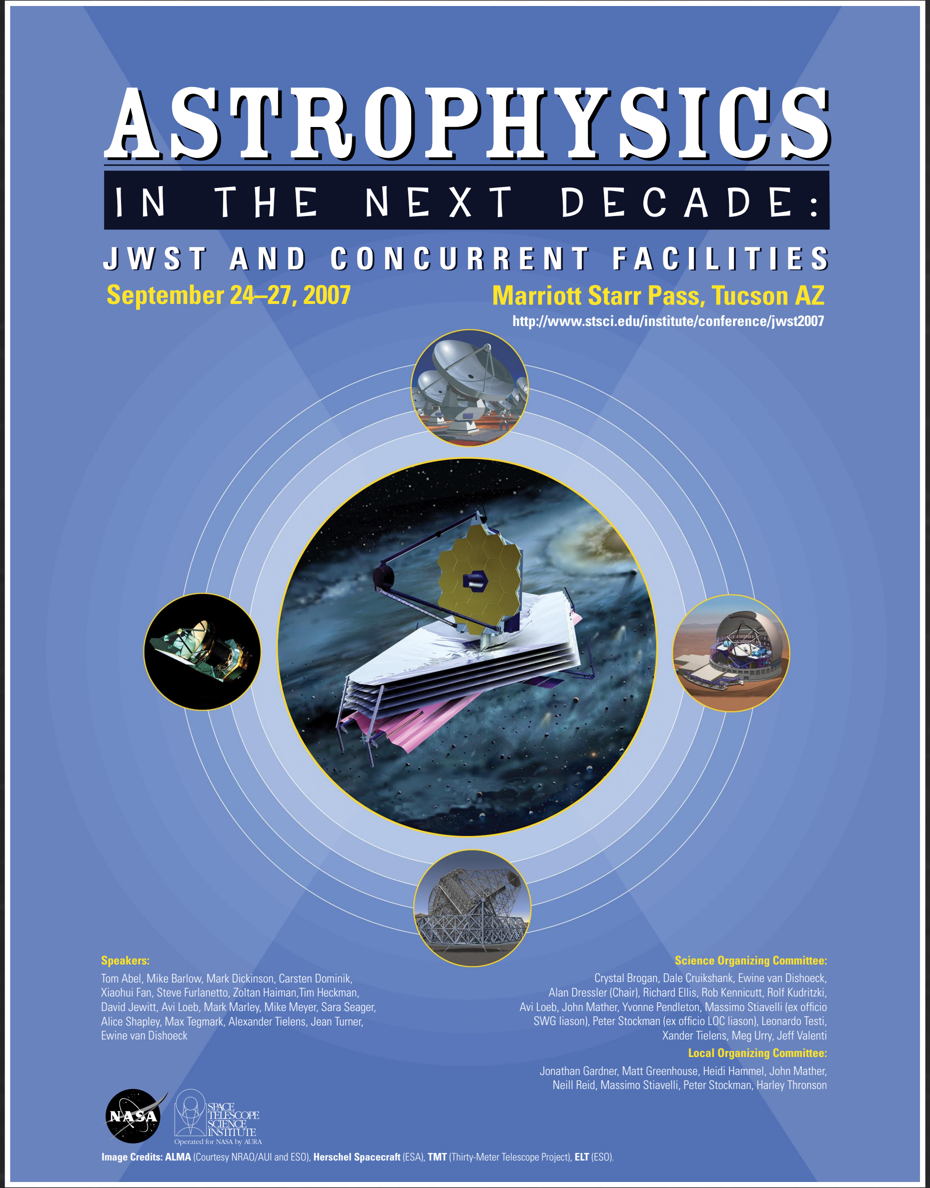




APT Flight Release

Lots of science workshops and training sessions planned throughout

Coming Soon: Exploring the Universe with JWST II



Sept 2007 (Tucson)

Jun 2011 (STScI)

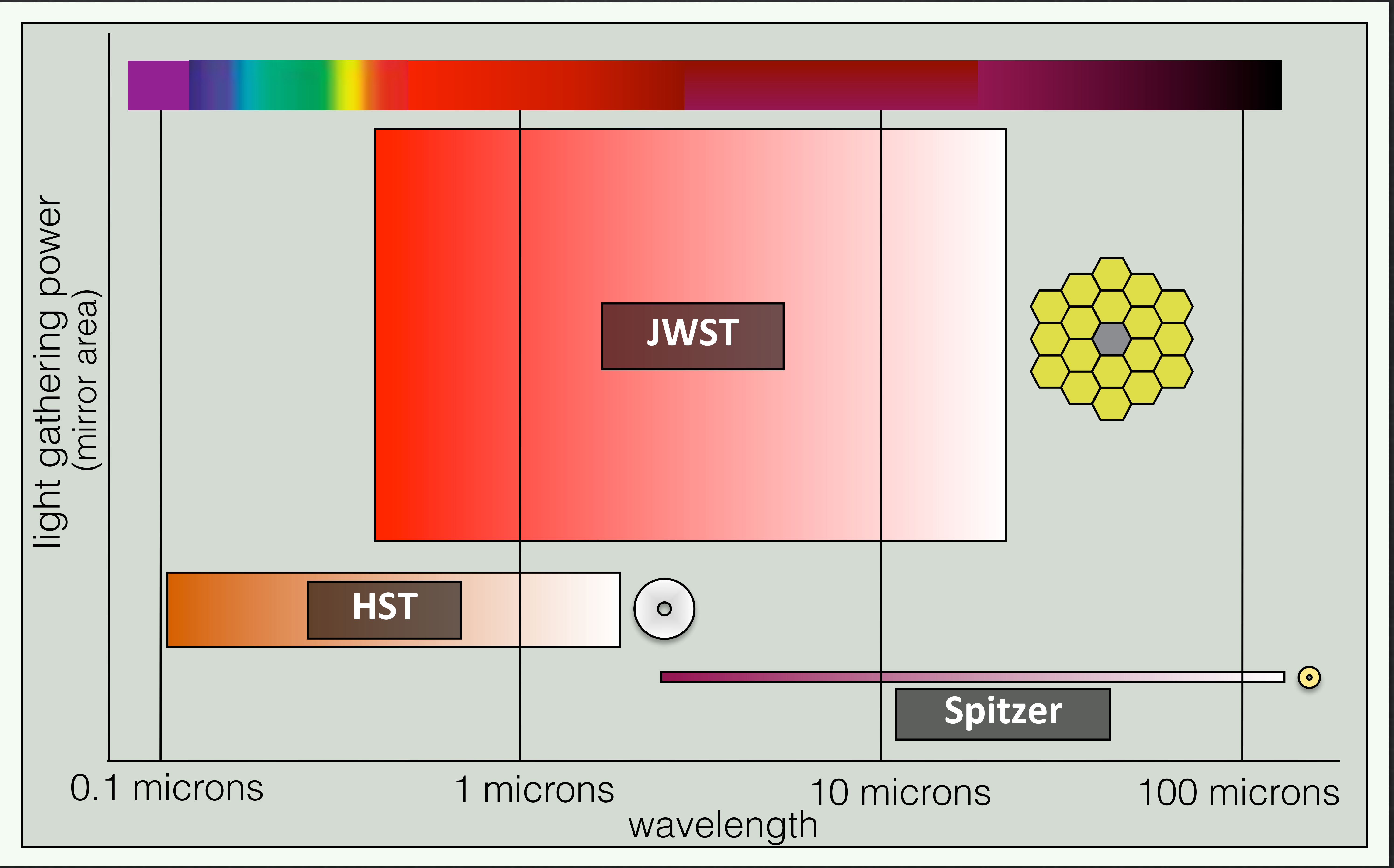
Oct 2015 (ESTEC)

October 24-28th, 2016
Montreal, Canada

#JWST

A Breakthrough in Photon *and* Diffraction Limited Science

Photon Limited Science



Diffraction Limited Science

Hubble pixels are 0.04-0.05” at <1 micron and 0.13” at > 1 micron

Spitzer pixels are 1.2” at < 8 micron and 2.55” at 24 micron

⟶ Hubble does not achieve Nyquist sampling of the diffraction limit

⟶ Spitzer only achieves Nyquist sampling at > 24 microns

JWST achieves Nyquist sampling of the diffraction limit at at 2, 4, and 7+ microns

JWST Commissioning Phase (6 months)

Phase I - Commission the Spacecraft (30 days)

Launch and mid-course corrections
Deployment of solar arrays, sunshield, mirrors
Subsystem check outs
NIR instrument cooldown modifications

Phase III - Commissioning the Science (60 days)

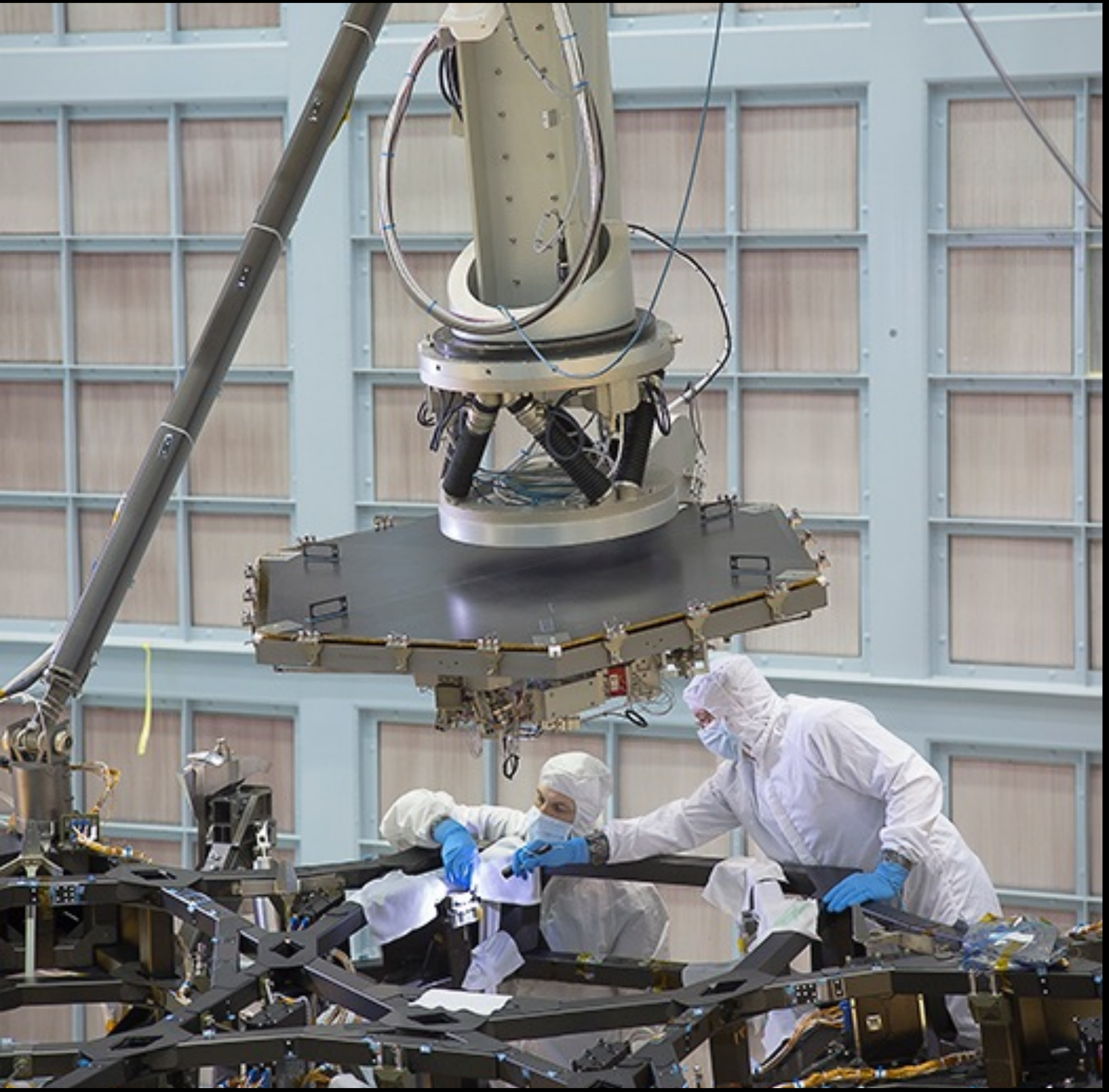
Each instrument is independently focused, calibrated, and characterized
Science instruments participate in observatory level tests (thermal slew, stray light, mechanism disturbance, moving target)
Begin ERO, ERS, Cycle 1 science and calibration programs asap

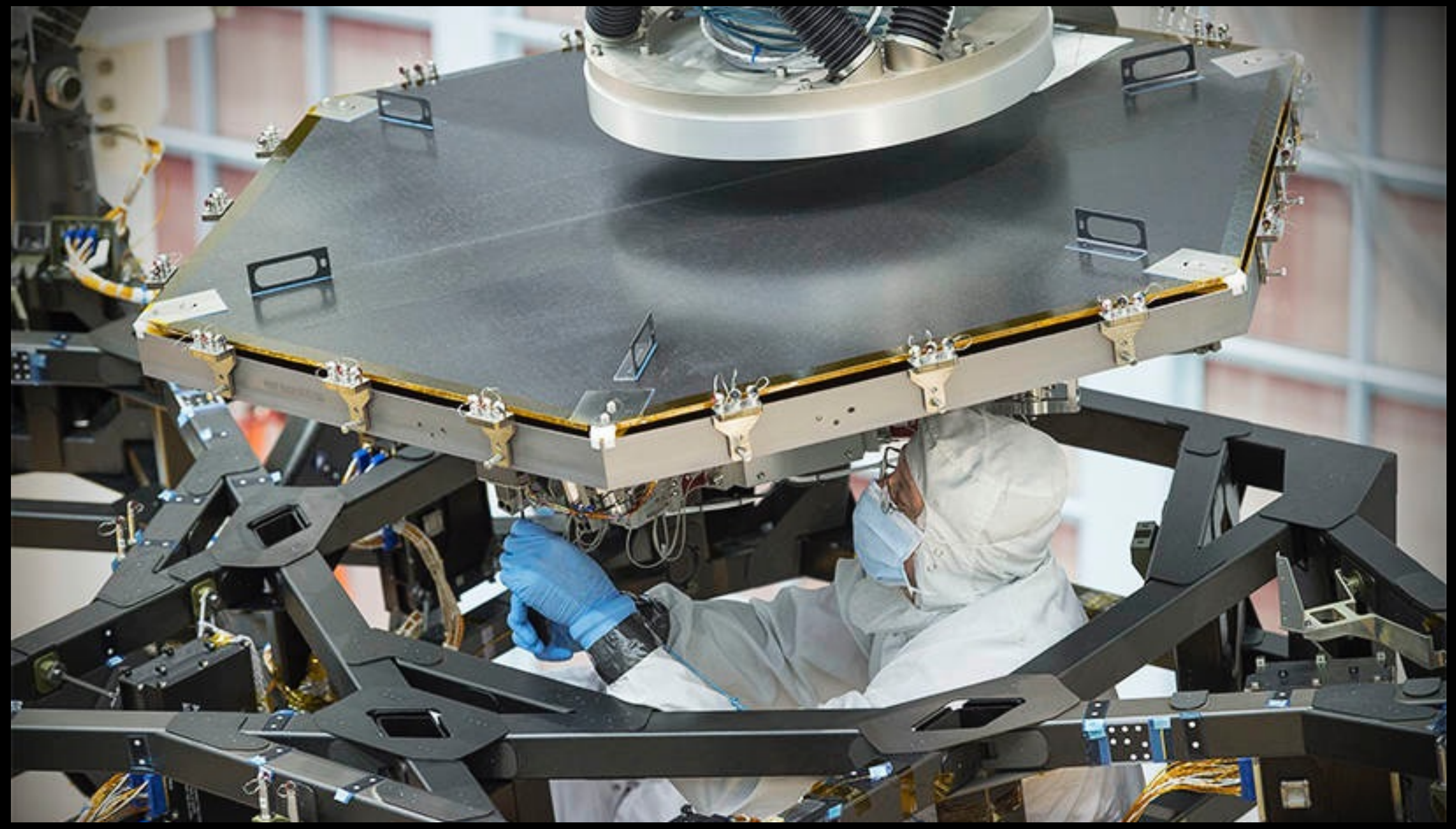
Oct 2018 — April 2019

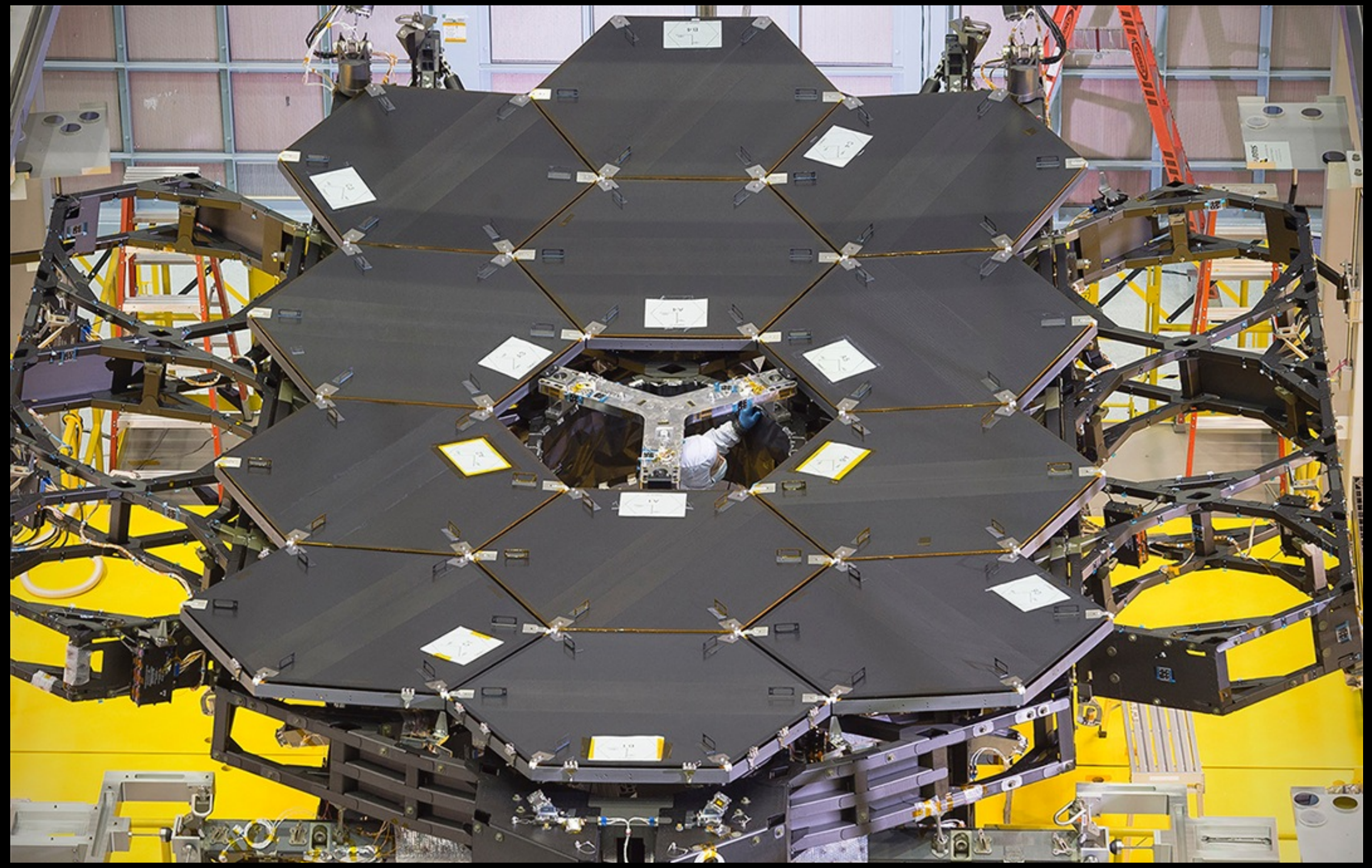
Phase II - Commissioning the Telescope (90 days)

Fine phasing of Optical Telescope Element (OTE) with NIRCam & FGS
NIR instruments are activated and checked out
MIRI cooldown via the cryocooler
All science instruments used to align and optimize OTE

#MirrorSeason







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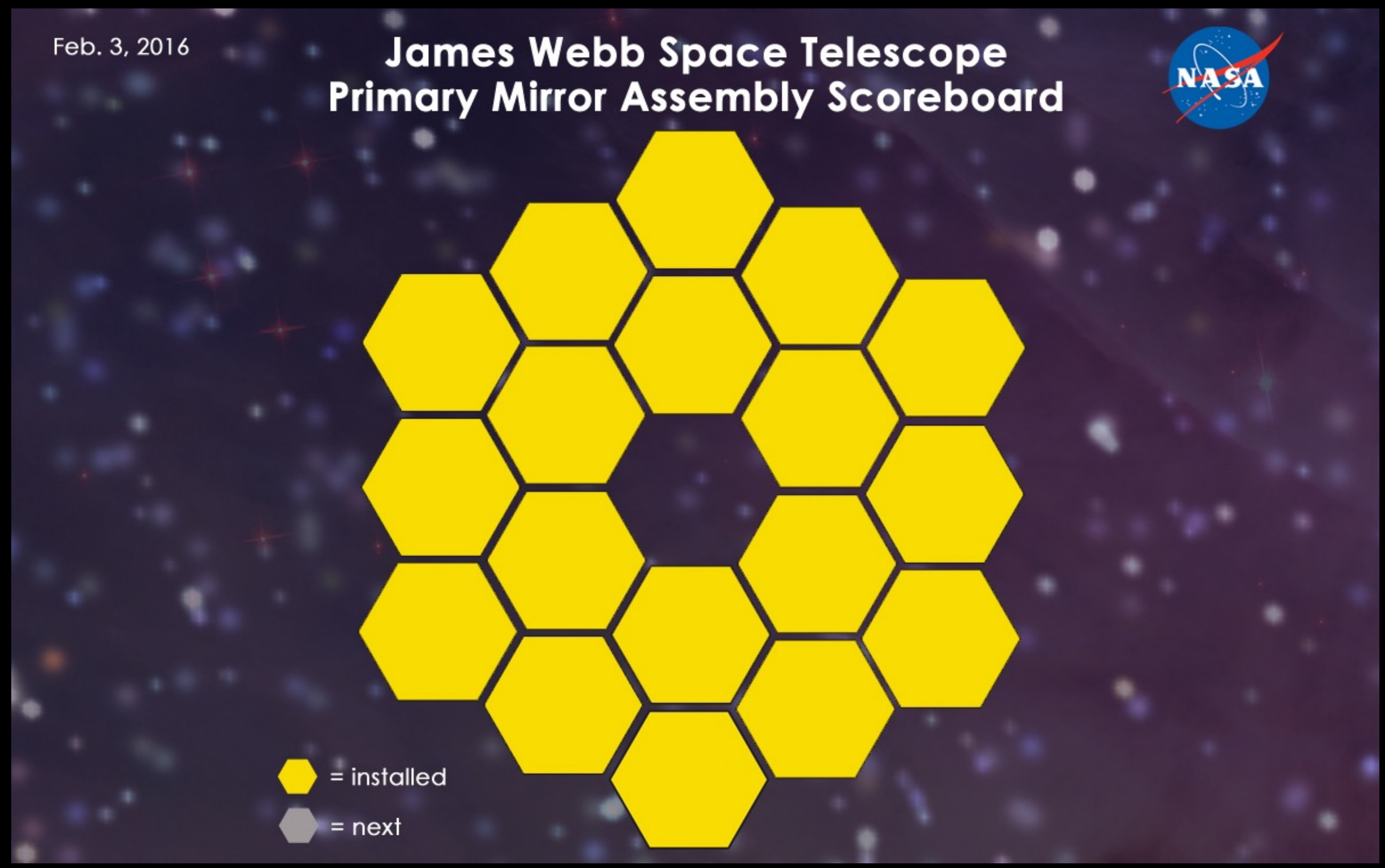

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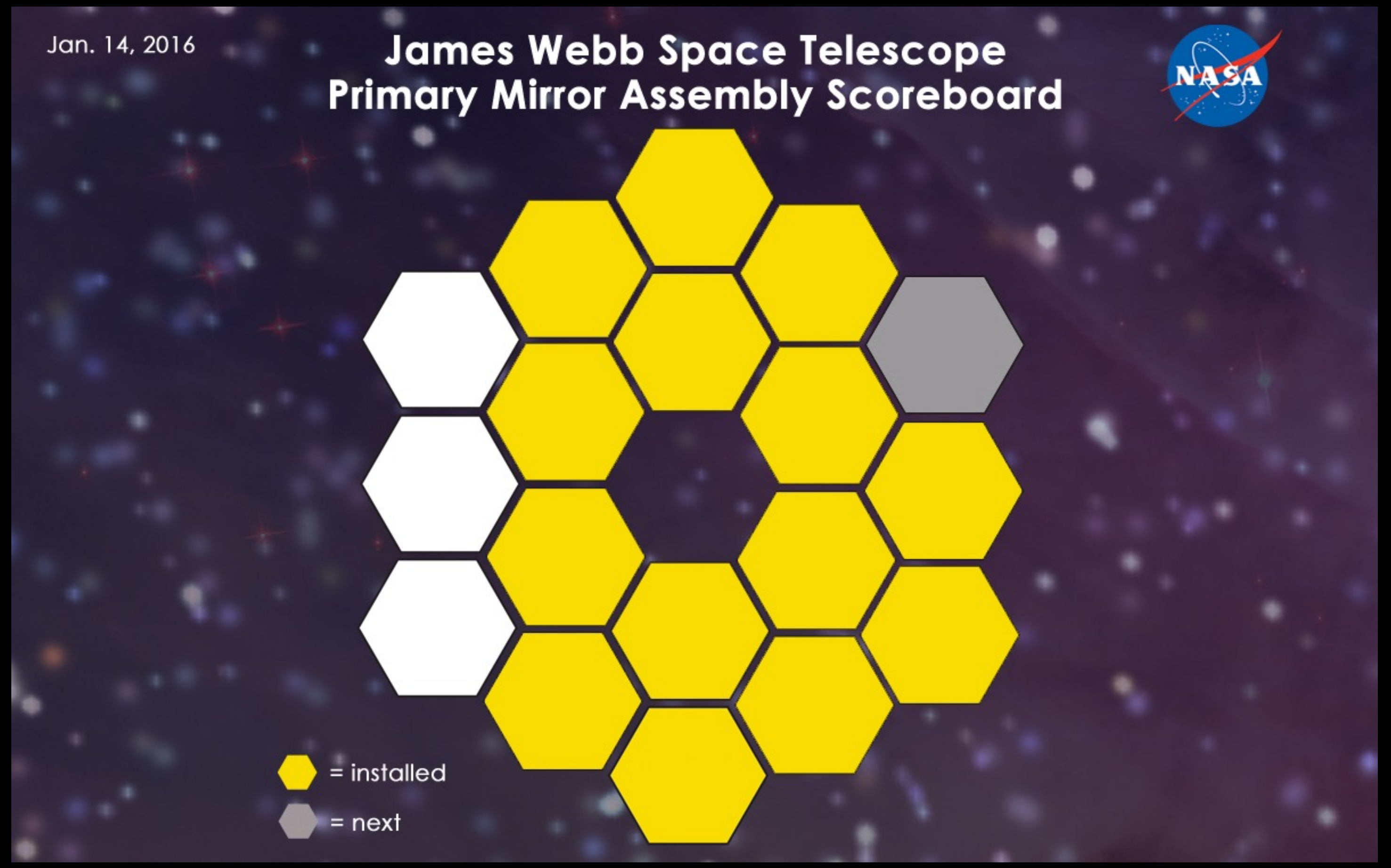

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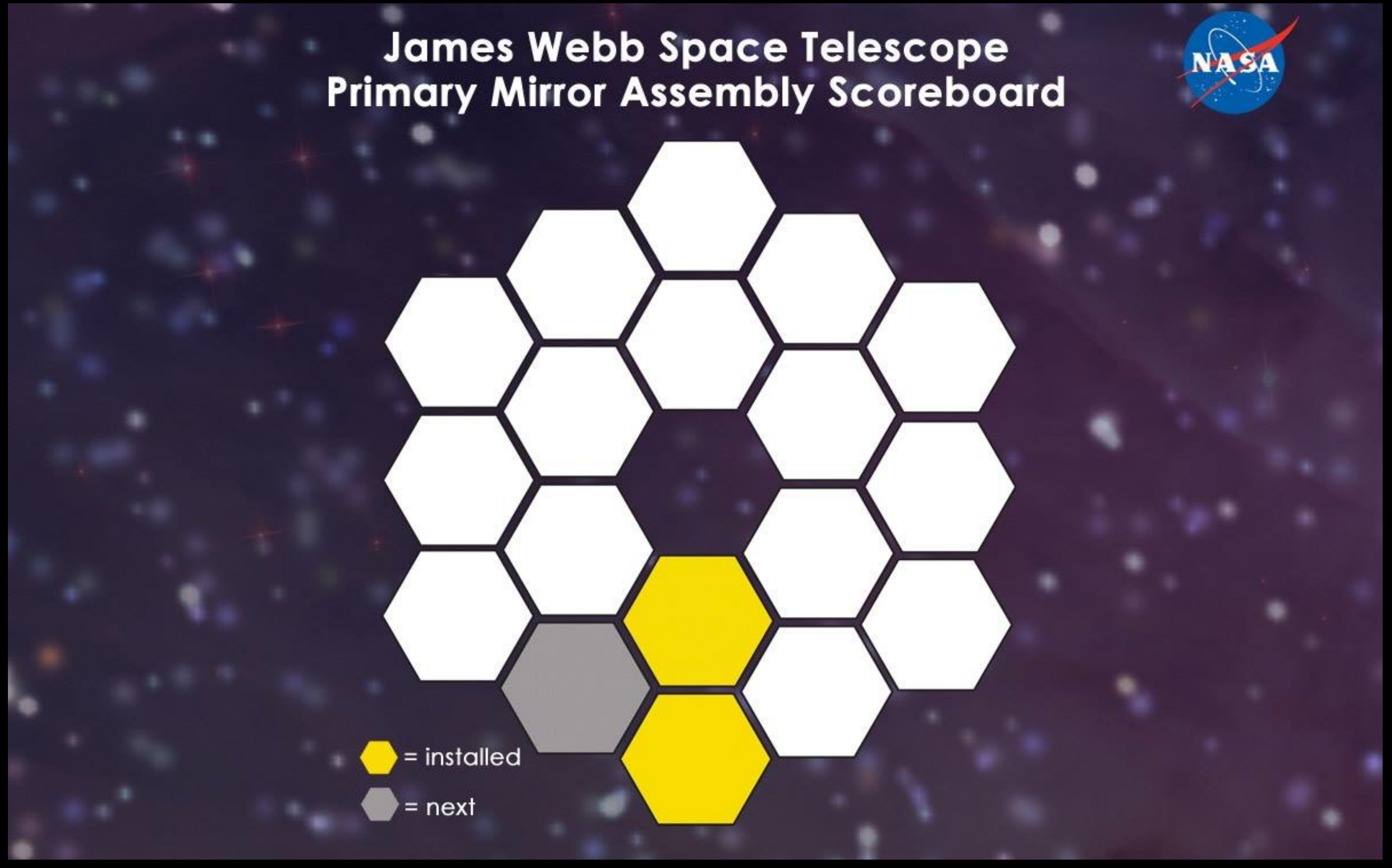

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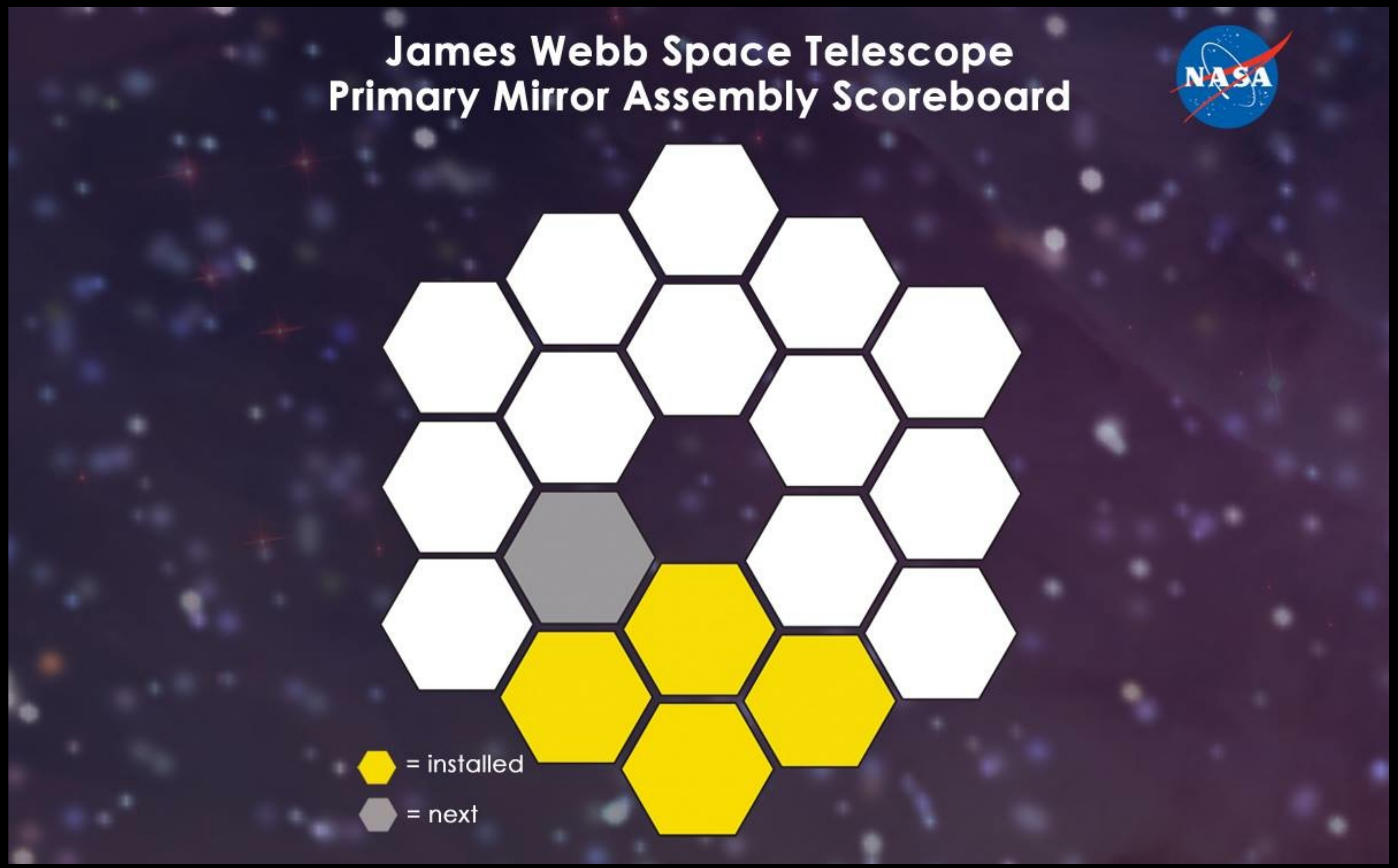

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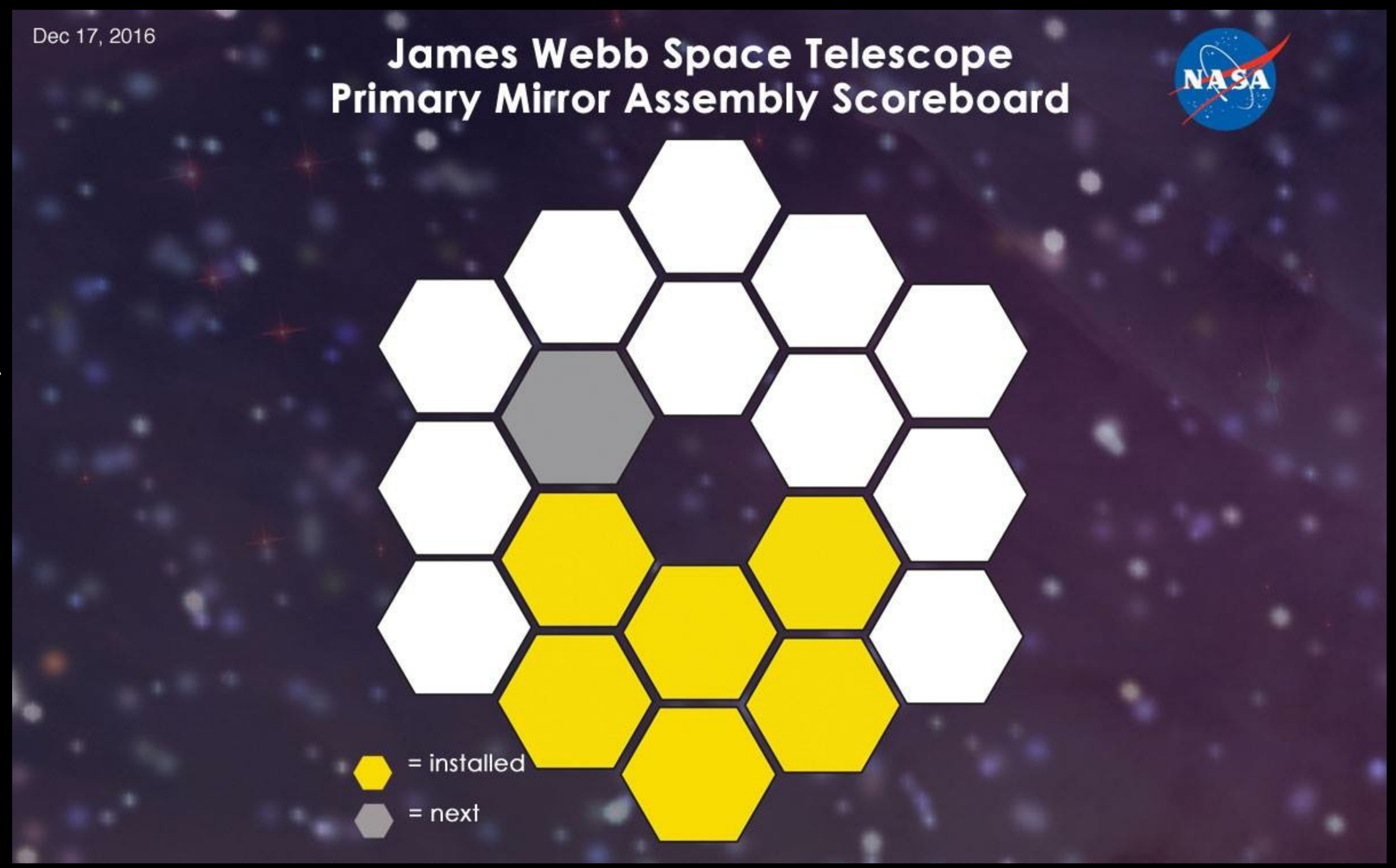
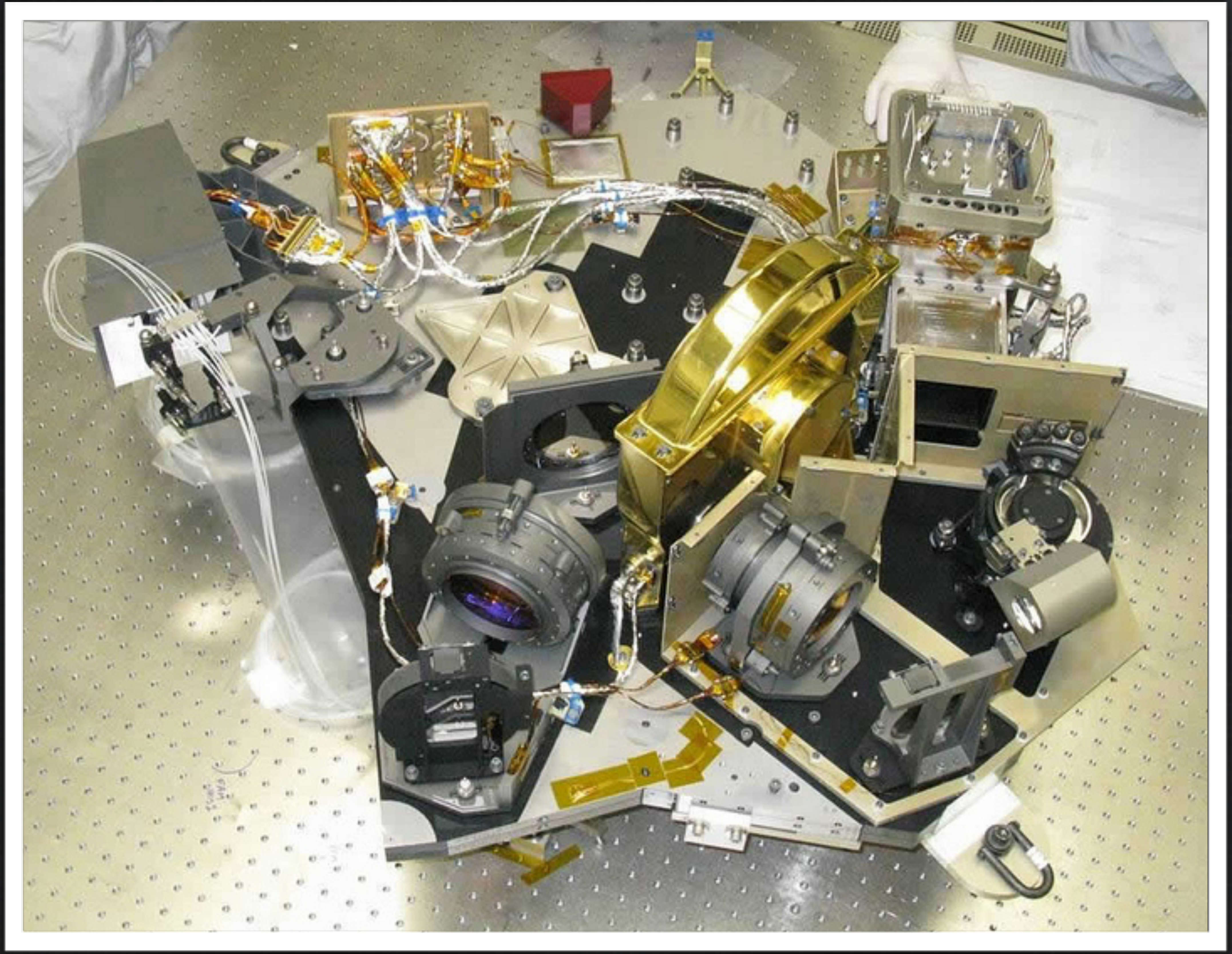
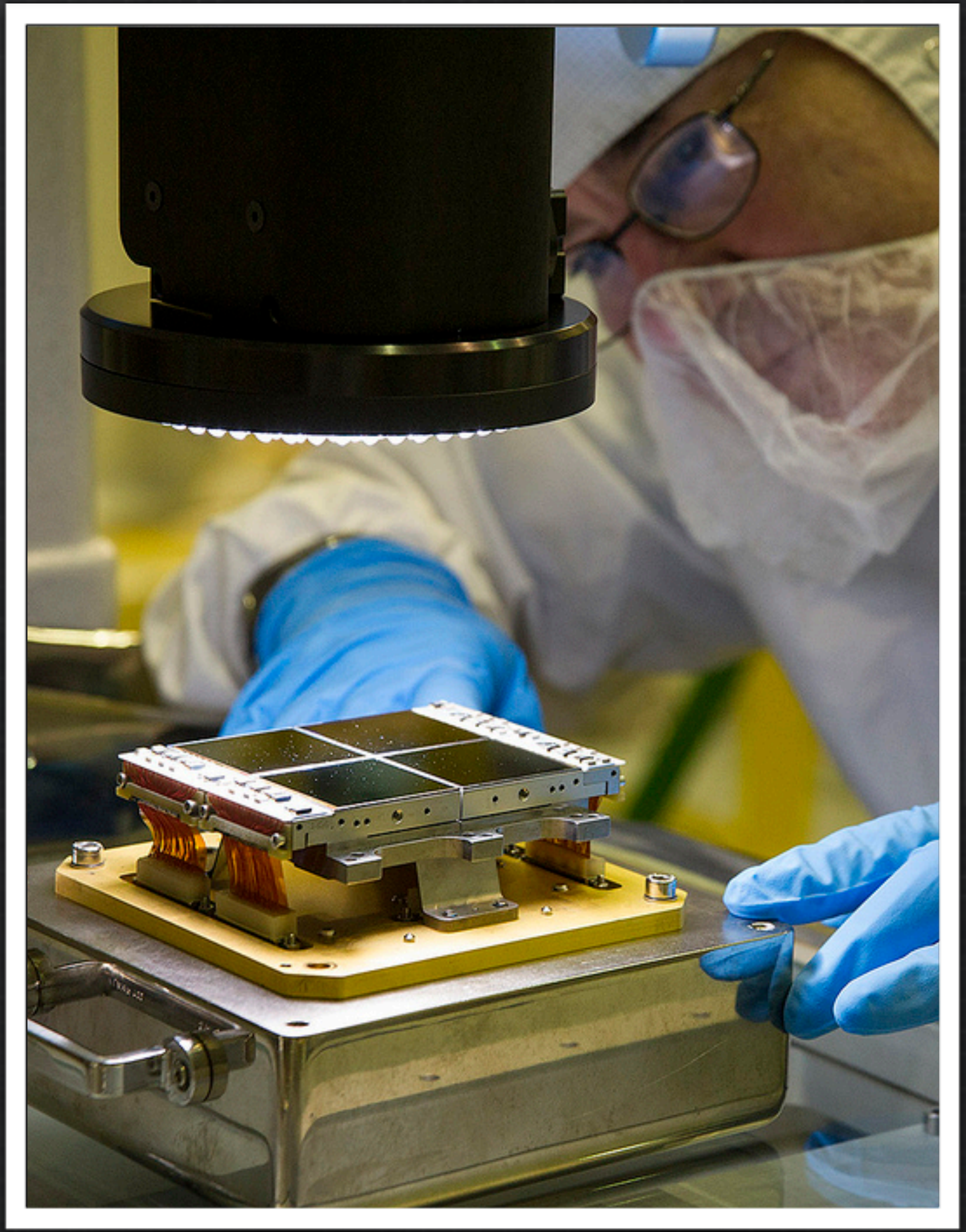


Near Infrared Camera (NIRCam)

NIRCam Capabilities

2 channel imager from $\lambda = 0.6$ to 5.0 microns, get $\lambda < 2.5$ & $\lambda > 2.5$ micron simultaneously
Nyquist sampling of diffraction limit at 2 microns (0.032”/pixel) and 4 microns (0.065”/pixel)
2.2’ x 4.4’ field of view
Short and long wavelength coronagraphy
Slitless spectroscopy for $\lambda = 2.4 – 5.0$ micron



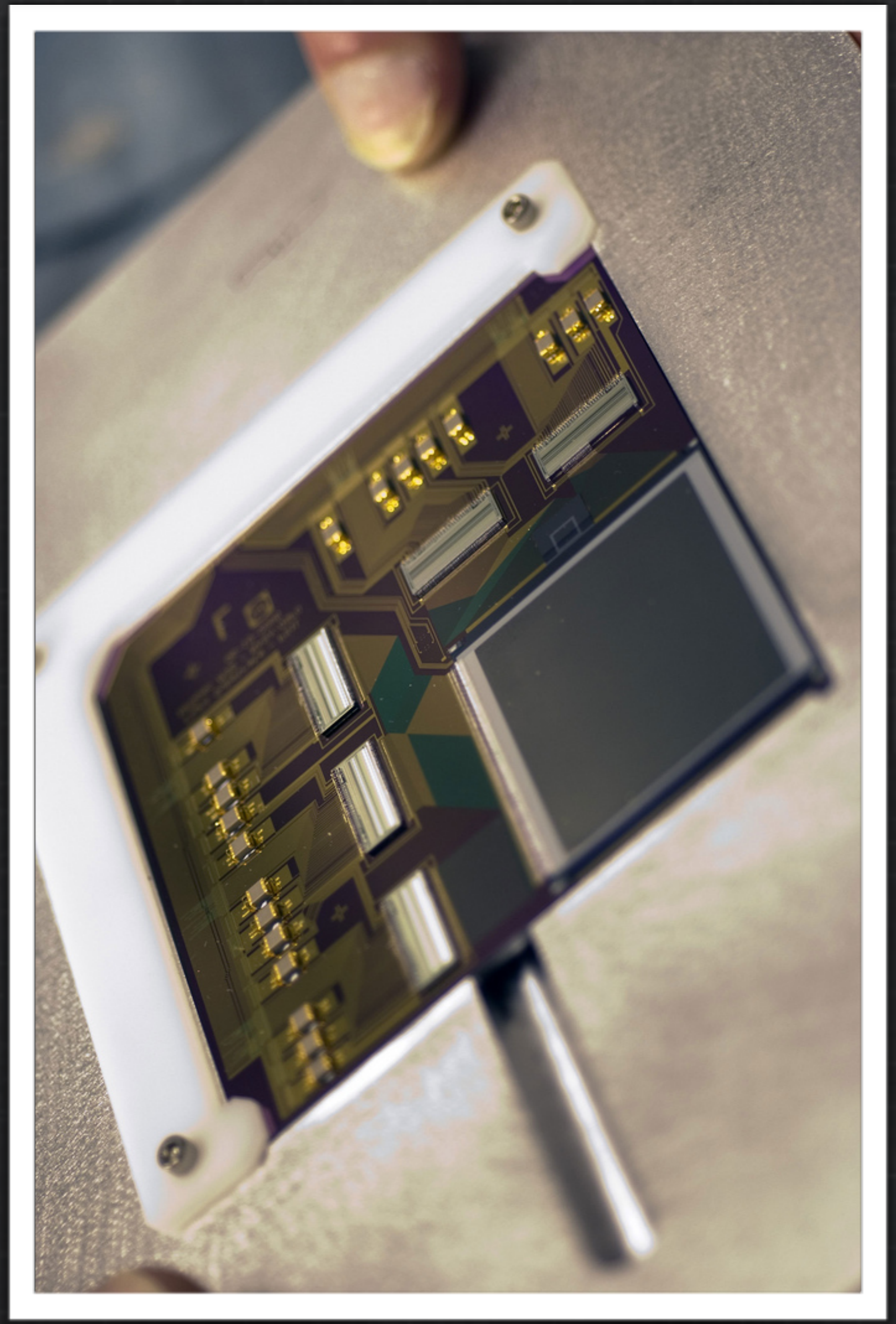


Built by Univ. of Arizona and Lockheed-Martin

Near Infrared Spectroscopy (NIRSpec)

NIRSpec Capabilities

Near Infrared wavelength coverage of λ = 0.6 to 5.0 microns
Three different spectral resolutions of R = 100, 1000, and 2700
Modes: Single Slit Spectroscopy (slits with 0.4” x 3.8”, 0.2” x 3.3”, 1.6” x 1.6”)
Integral Field Unit (3.0” x 3.0”)
Multi Object Spectroscopy (3.4’ x 3.4’ with 250,000 - 0.2” x 0.5” microshutters)



Built by ESA and Airbus

Mid Infrared Instrument (MIRI)

MIRI Capabilities

High resolution imager with sensitivity from λ = 5 to 28 microns, 10 broad-band filters

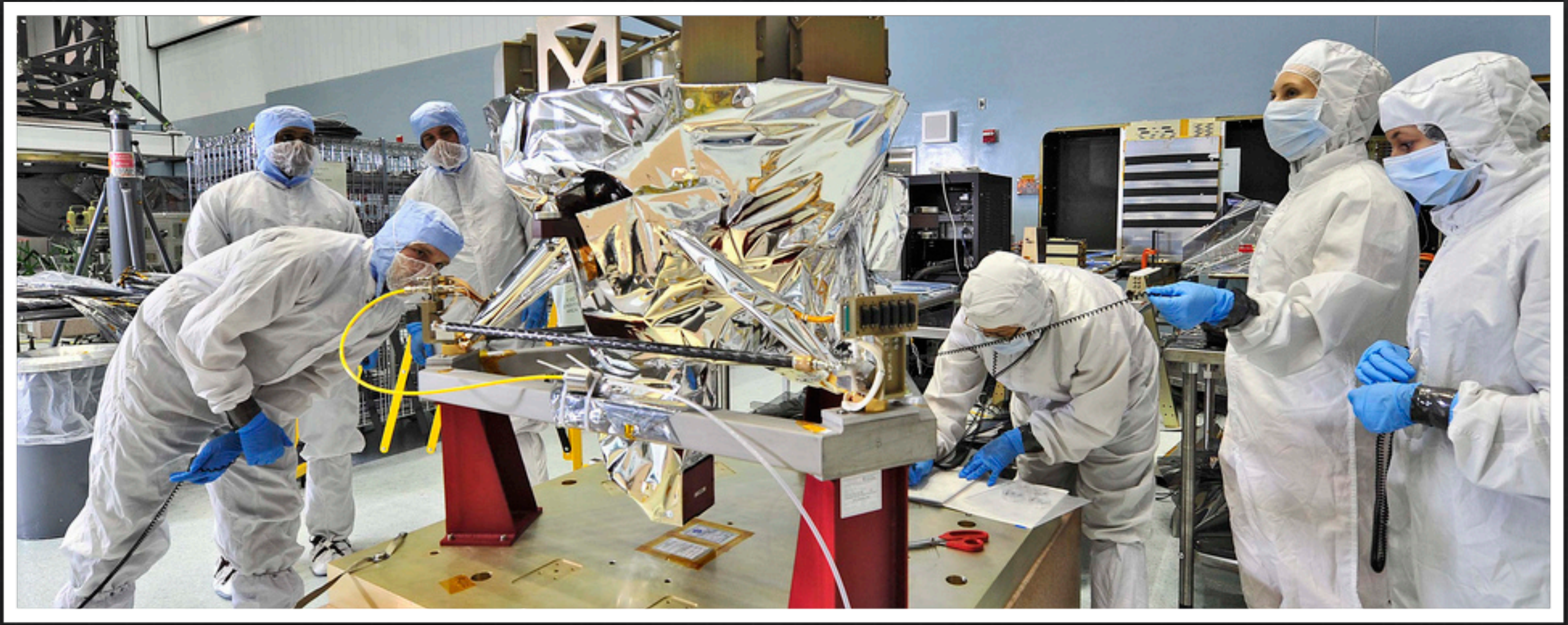
λ = 5.0 to 28.3 microns with 0.11” pixels

1.23’ x 1.88’ field of view

Coronagraphy at 10.65, 11.4, 15.5, and 23 microns (24” to 30” field of view)

Integral Field Unit with R = 2200 to 3500, at 4 wavelengths (image slices 0.18” to 0.64”)

Single Slit Spectroscopy from 5.0 to ~14 microns in 0.6 x 5.5” slit (R ~ 100 at 7.5 microns)

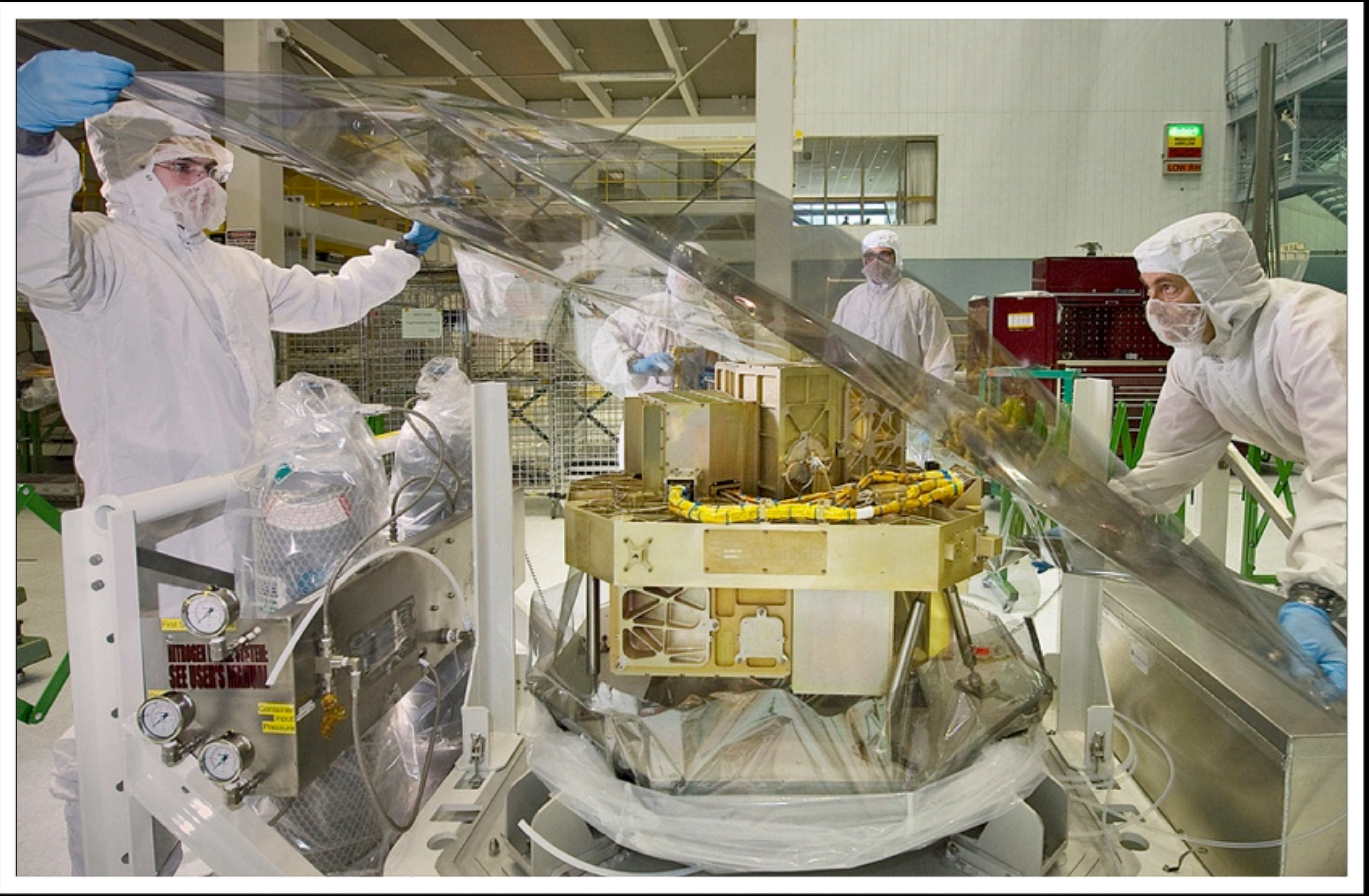


Built by ESA and JPL

Near Infrared Imager and Slitless Spectrograph

NIRISS Capabilities

Imaging - λ = 0.9 to 5.0 microns over a 2.2’ x 2.2’ field of view with 0.065” pixels
Wide Field Slitless Spectroscopy - λ = 1.0 to 2.5 microns at R ~ 150
Single Object Slitless Spectroscopy - λ = 0.6 to 2.5 microns at R ~ 700
Aperture Mask Interferometry - λ = 3.8 to 4.8 microns, enabled by non-redundant mask



Built by CSA and COMDEV

JWST Primer

Description

Deployable infrared telescope with a 6.5 meter segmented adjustable primary mirror
Cryogenic temperature telescope and instruments optimized for IR performance
Launch in Oct 2018 on an ESA Ariane 5 rocket to Sun-Earth L2 point (1 million miles)
10-year science mission goal

Organization

Mission lead: NASA's Goddard Space Flight Center
International collaborators: European and Canadian Space Agencies (ESA and CSA)
Prime Contractor: Northrop Grumman Aerospace Systems
Flight and Science Operations Center: Space Telescope Science Institute