25^* Years of Contamination Control on the James Webb Space Telescope

Contamination, Coatings, Materials & Planetary Protection (CCMPP) Workshop
12 September 2023

Eve Wooldridge

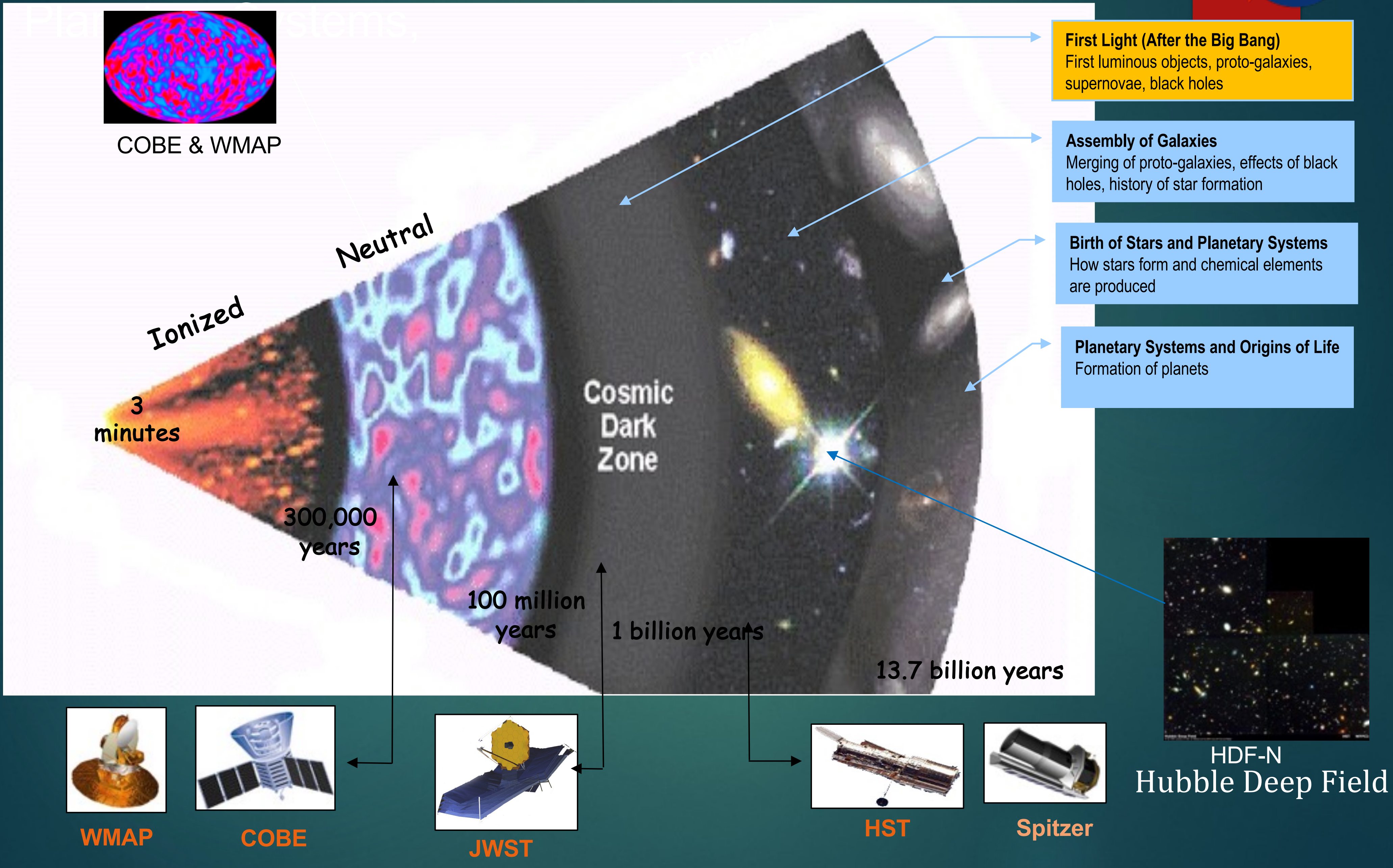
NASA/Goddard Space Flight Center

*25 Years: Spring 1996 – 25 December 2021

Origin of the Mission

- **1995: HST Deep Field first imaged**
  - **Billions of galaxies where previously nothing seen**
- **Next Generation Space Telescope (NGST) initiated**
  - **Cosmic Background Explorer (COBE) looked at the "Big Bang" – our universe's creation**
  - **Hubble Space Telescope (HST), showed galaxies, quasars, nebulae etc. that has formed since the Big Bang**
- **NGST: would allow astronomers to look at the universe just after its beginning with the "Big Bang" by looking at red shifted light**

Designed to observe Origins: First Galaxies, Birth of Stars & Planetary Systems, Origins of Life



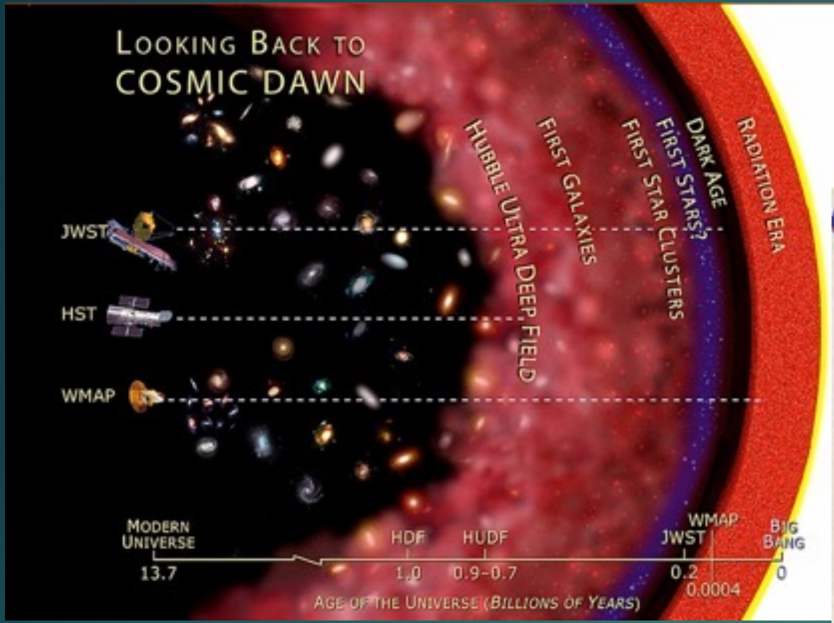
First Light (After the Big Bang)
First luminous objects, proto-galaxies, supernovae, black holes

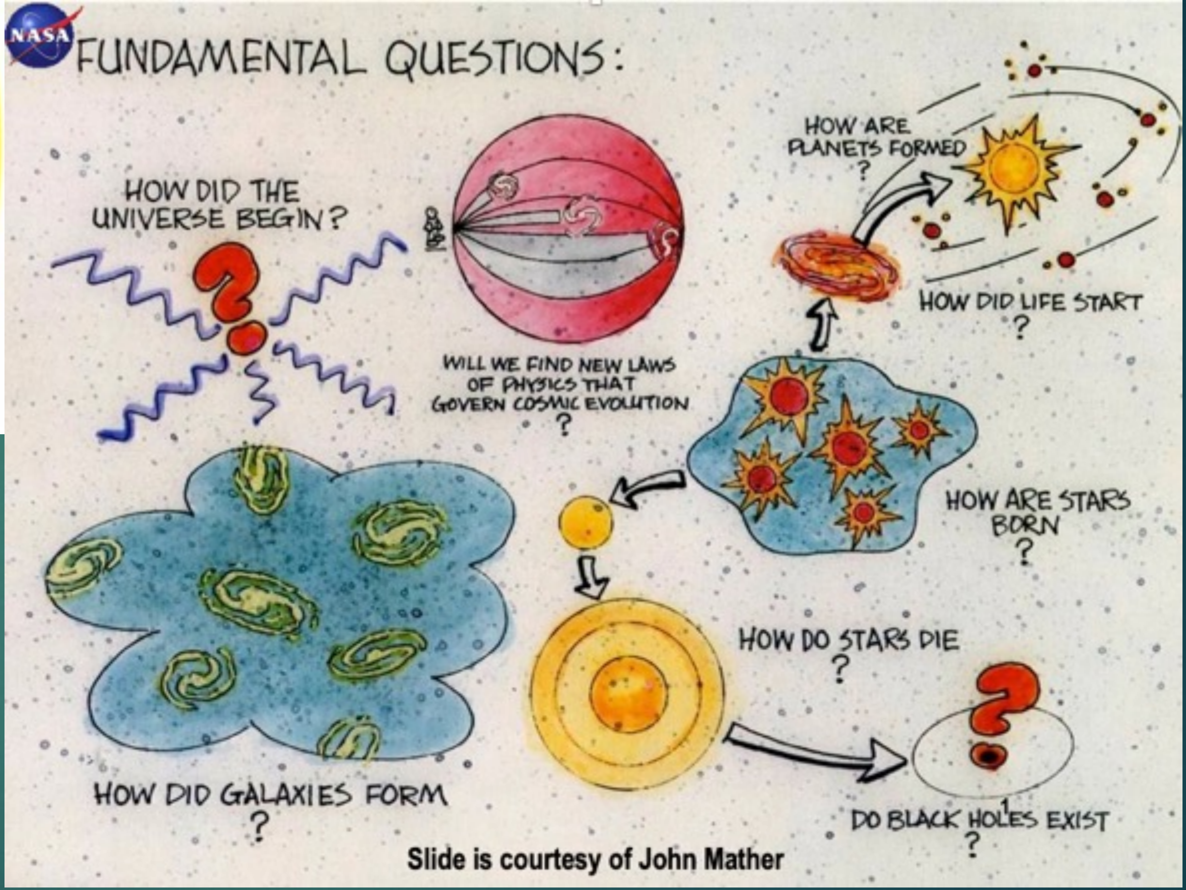
Assembly of Galaxies
Merging of proto-galaxies, effects of black holes, history of star formation

Birth of Stars and Planetary Systems
How stars form and chemical elements are produced

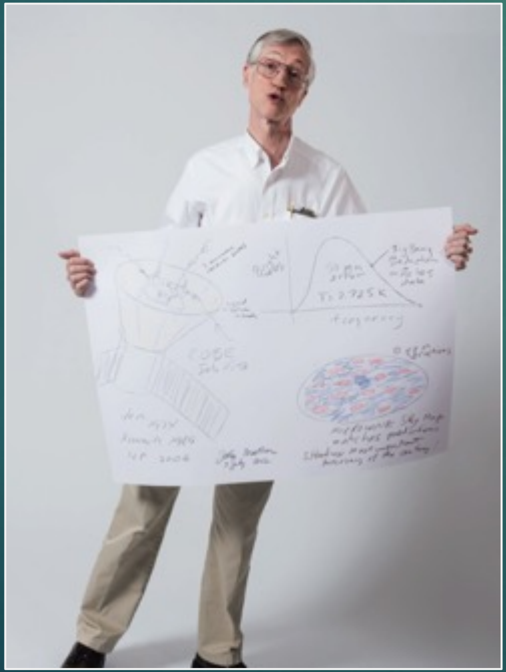
Planetary Systems and Origins of Life
Formation of planets

Dr. John Mather's Vision & Questions





Slide is courtesy of John Mather



Evolution of Galaxies Over Cosmic History

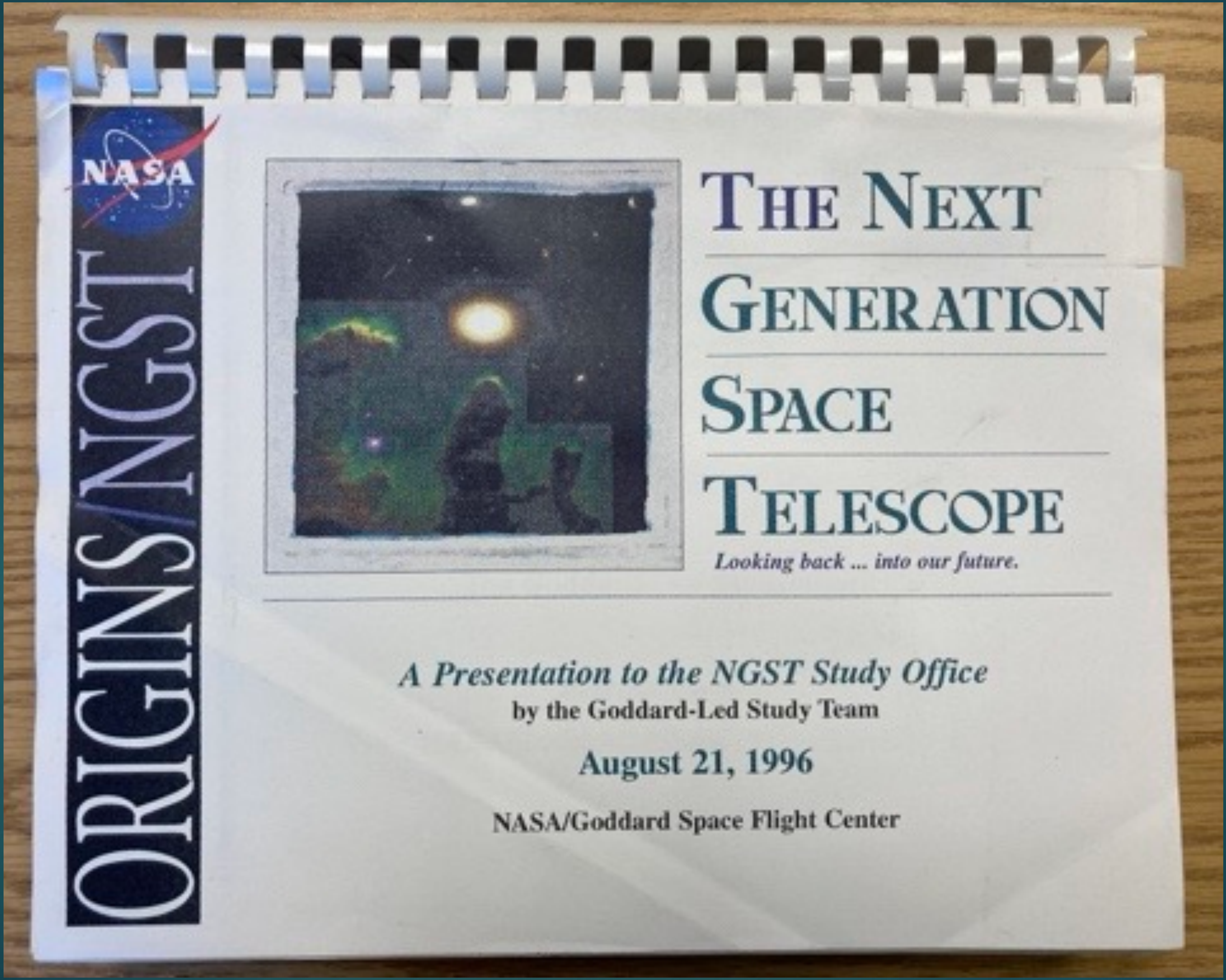
Galaxies in the Distant – Early Universe
Seem to Lack Structure

Galaxies in the Nearby – Contemporary Universe
Have Structure, Ellipticals and Spirals

How do Galaxies Like These

Evolve into Galaxies Like These

First study was completed 27 years ago



ORIGINS/NGST

THE NEXT GENERATION SPACE TELESCOPE

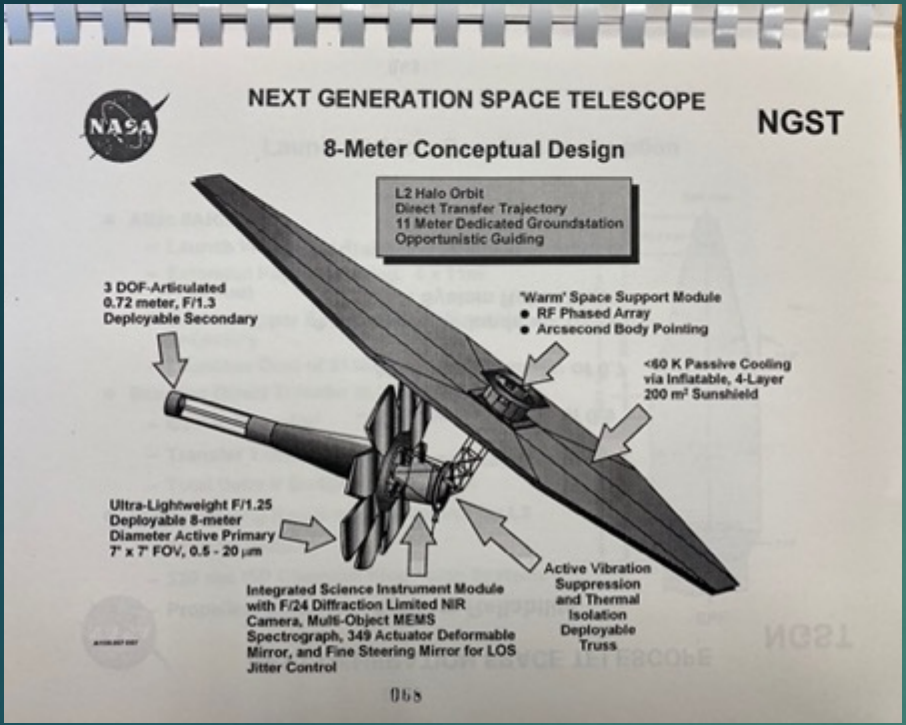
Looking back ... into our future.

A Presentation to the NGST Study Office
by the Goddard-Led Study Team

August 21, 1996

NASA/Goddard Space Flight Center

First Study Design Concept



NEXT GENERATION SPACE TELESCOPE

NGST

8-Meter Conceptual Design

L2 Halo Orbit
Direct Transfer Trajectory
11 Meter Dedicated Groundstation
Opportunistic Guiding

3 DOF-Articulated
0.72 meter, F/1.3
Deployable Secondary

'Warm' Space Support Module
- RF Phased Array
- Arcsecond Body Pointing

<60 K Passive Cooling
via Inflatable, 4-Layer
200 m² Sunshield

Ultra-Lightweight F/1.25
Deployable 8-meter
Diameter Active Primary
7' x 7' FOV, 0.5 - 20 μm

Integrated Science Instrument Module
with F/24 Diffraction Limited NIR
Camera, Multi-Object MEMS
Spectrograph, 349 Actuator Deformable
Mirror, and Fine Steering Mirror for LOS
Jitter Control

Active Vibration
Suppression
and Thermal
Isolation
Deployable
Truss

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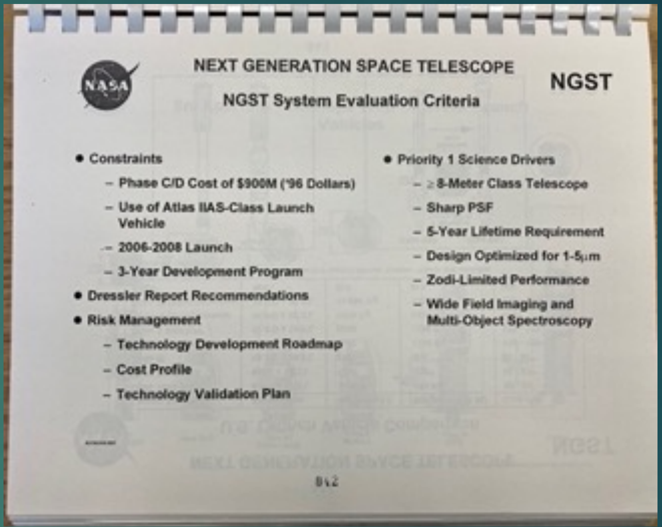

NEXT GENERATION SPACE TELESCOPE

NGST

NGST System Evaluation Criteria

- Constraints
  - Phase C/D Cost of $900M ('96 Dollars)
  - Use of Atlas IIAS-Class Launch Vehicle
  - 2006-2008 Launch
  - 3-Year Development Program
- Dressler Report Recommendations
- Risk Management
  - Technology Development Roadmap
  - Cost Profile
  - Technology Validation Plan

- Priority 1 Science Drivers
  - ≥ 8-Meter Class Telescope
  - Sharp PSF
  - 5-Year Lifetime Requirement
  - Design Optimized for 1-5μm
  - Zodi-Limited Performance
  - Wide Field Imaging and Multi-Object Spectroscopy

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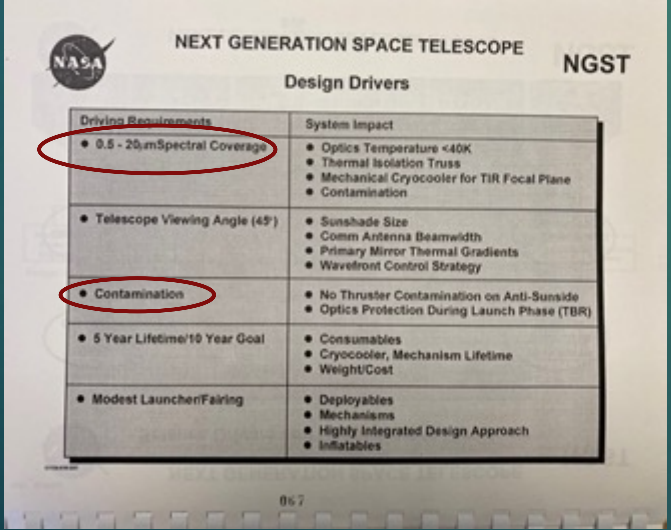

NEXT GENERATION SPACE TELESCOPE

NGST

Design Drivers

Driving Requirements	System Impact
• 0.5 - 20μmSpectral Coverage	• Optics Temperature <40K • Thermal Isolation Truss • Mechanical Cryocooler for TIR Focal Plane • Contamination
• Telescope Viewing Angle (45°)	• Sunshade Size • Comm Antenna Beamwidth • Primary Mirror Thermal Gradients • Wavefront Control Strategy
• Contamination	• No Thruster Contamination on Anti-Sunside • Optics Protection During Launch Phase (TBR)
• 5 Year Lifetime/10 Year Goal	• Consumables • Cryocooler, Mechanism Lifetime • Weight/Cost
• Modest Launcher/Fairing	• Deployables • Mechanisms • Highly Integrated Design Approach • Inflatables

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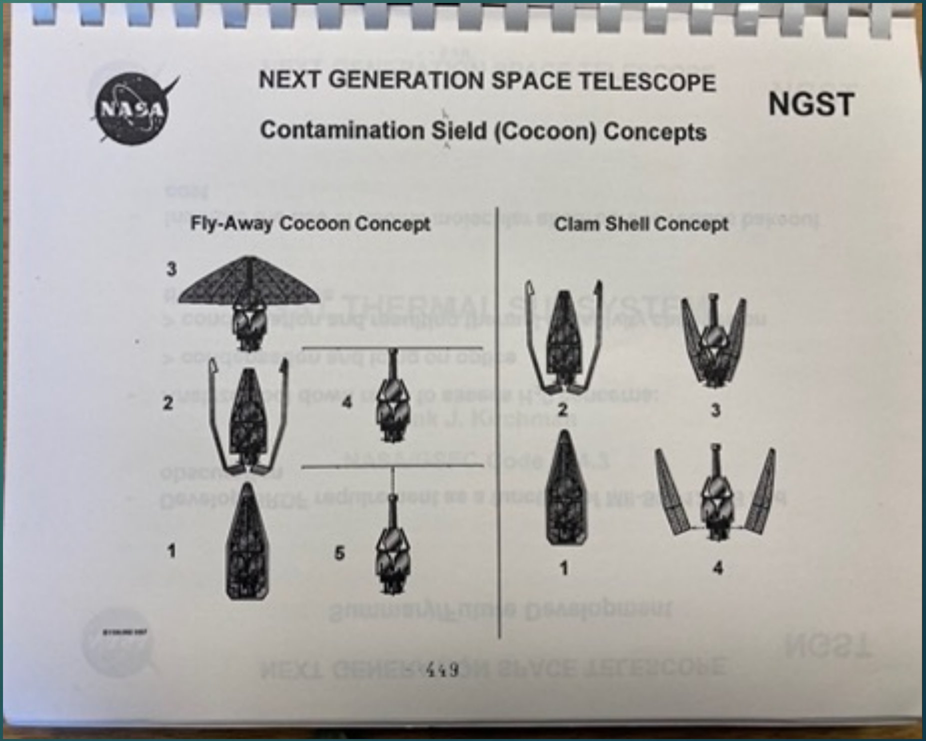

NEXT GENERATION SPACE TELESCOPE

NGST

Contamination Sield (Cocoon) Concepts

Fly-Away Cocoon Concept

Clam Shell Concept

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First Study CC Baseline

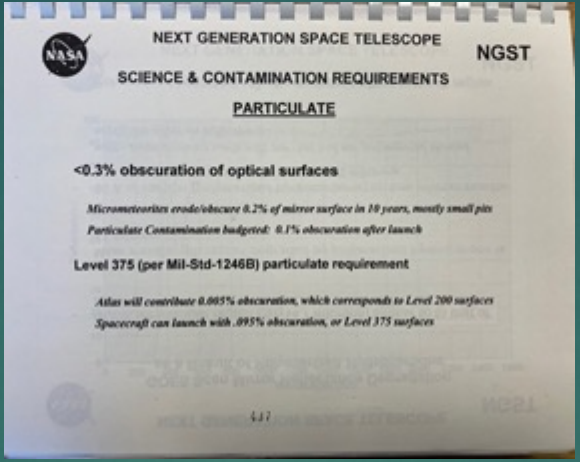
NEXT GENERATION SPACE TELESCOPE

NGST

Contamination Control

GSFC NGST Study Review
August 21, 1996

Randy J. Hedgeland
Eve M. Wooldridge
Code 724.4



NEXT GENERATION SPACE TELESCOPE

NGST

SCIENCE & CONTAMINATION REQUIREMENTS

PARTICULATE

<0.3% obscuration of optical surfaces

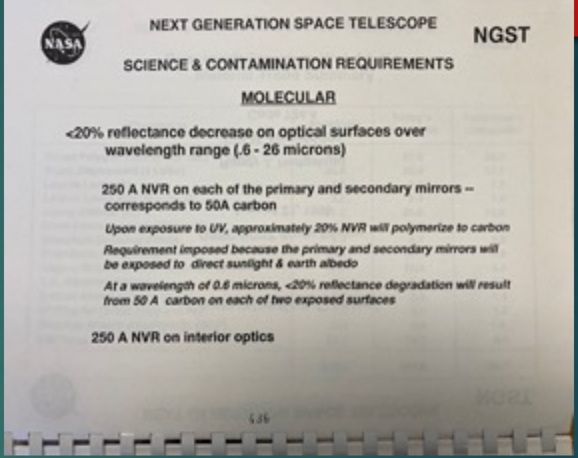
Micrometeorites erode/obscure 0.2% of mirror surface in 10 years, mostly small pits

Particulate Contamination budgeted: 0.1% obscuration after launch

Level 375 (per Mil-Std-1246B) particulate requirement

Atlas will contribute 0.005% obscuration, which corresponds to Level 200 surfaces

Spacecraft can launch with .095% obscuration, or Level 375 surfaces



NEXT GENERATION SPACE TELESCOPE

NGST

SCIENCE & CONTAMINATION REQUIREMENTS

MOLECULAR

<20% reflectance decrease on optical surfaces over wavelength range (.6 - 26 microns)

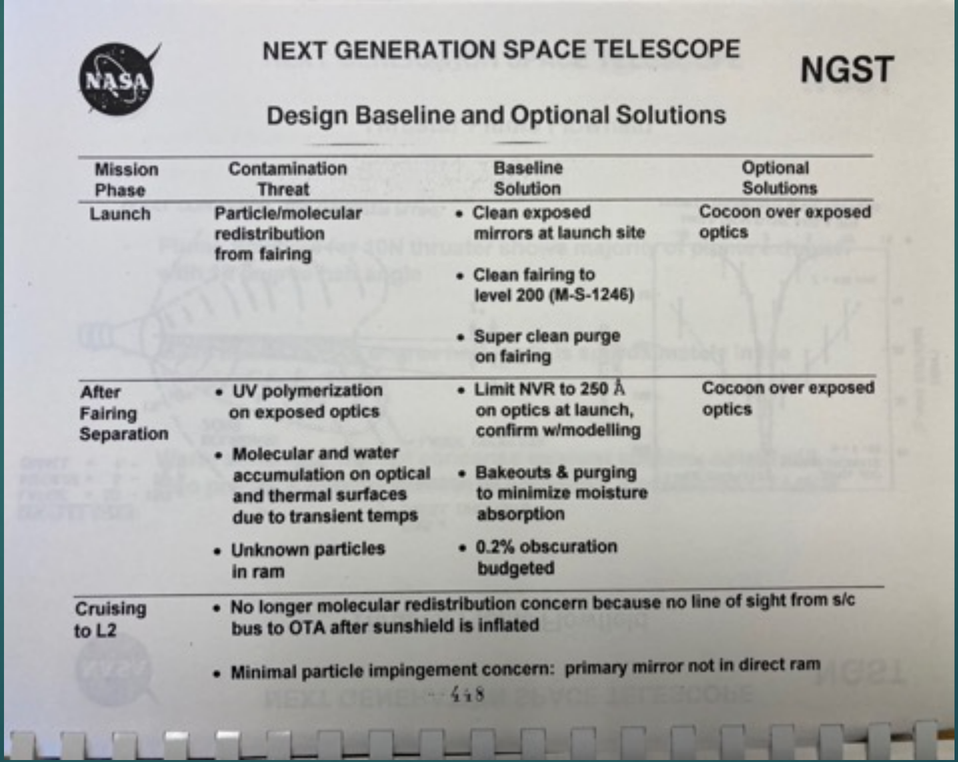
250 A NVR on each of the primary and secondary mirrors -- corresponds to 50A carbon

Upon exposure to UV, approximately 20% NVR will polymerize to carbon

Requirement imposed because the primary and secondary mirrors will be exposed to direct sunlight & earth albedo

At a wavelength of 0.6 microns, <20% reflectance degradation will result from 50 A carbon on each of two exposed surfaces

250 A NVR on interior optics



NEXT GENERATION SPACE TELESCOPE

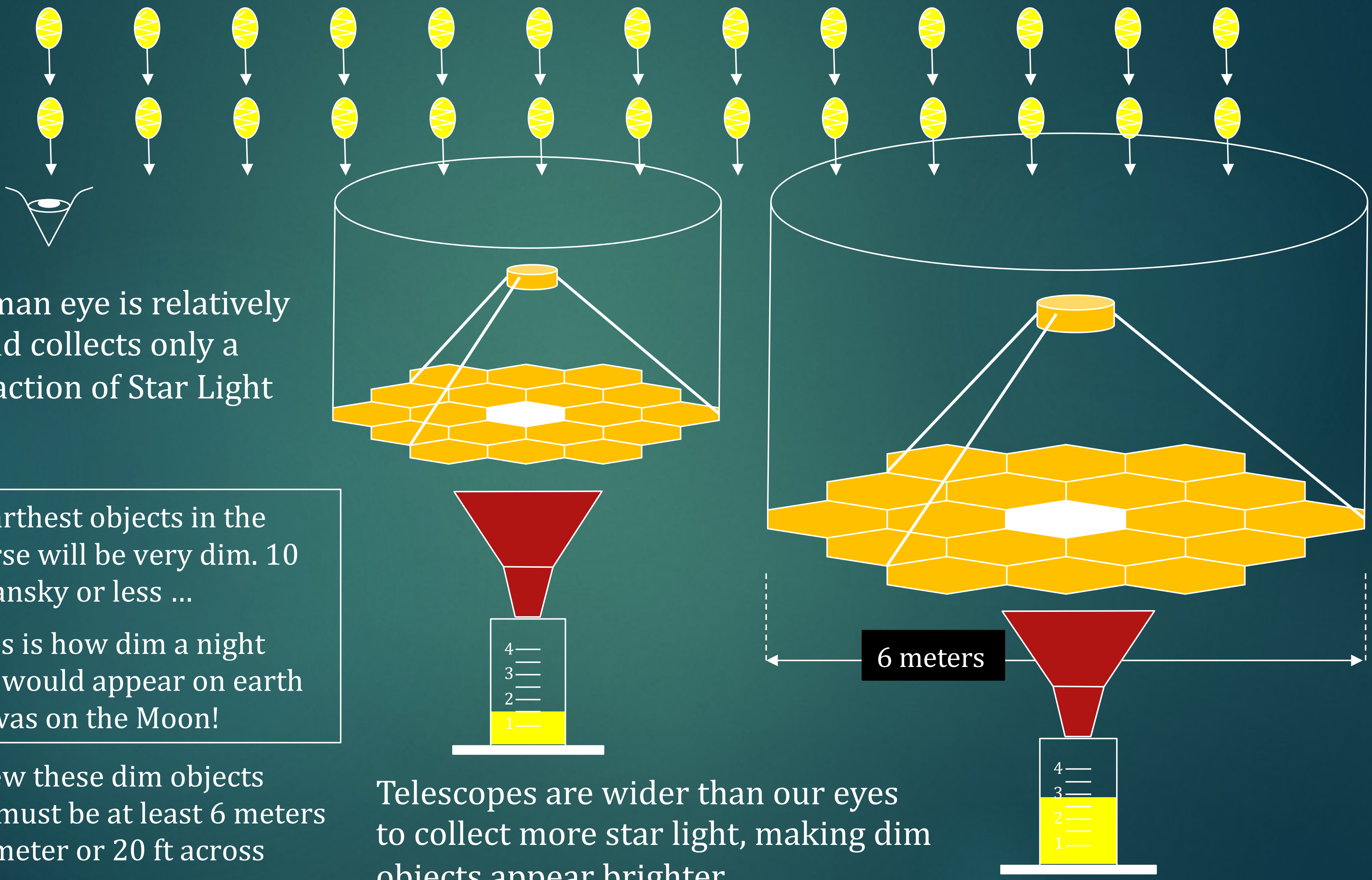
NGST

Design Baseline and Optional Solutions

Mission Phase	Contamination Threat	Baseline Solution	Optional Solutions
Launch	Particle/molecular redistribution from fairing	• Clean exposed mirrors at launch site • Clean fairing to level 200 (M-S-1246) • Super clean purge on fairing	Cocoon over exposed optics
After Fairing Separation	• UV polymerization on exposed optics • Molecular and water accumulation on optical and thermal surfaces due to transient temps • Unknown particles in ram	• Limit NVR to 250 Å on optics at launch, confirm w/modelling • Bakeouts & purging to minimize moisture absorption • 0.2% obscuration budgeted	Cocoon over exposed optics
Cruising to L2	• No longer molecular redistribution concern because no line of sight from s/c bus to OTA after sunshield is inflated • Minimal particle impingement concern: primary mirror not in direct ram		

To See First Light Objects, JWST must be Big

Star Light is a "Rain" of Light Particles called Photons



The Human eye is relatively small and collects only a small fraction of Star Light

- The farthest objects in the universe will be very dim. 10 nanoJansky or less …
  - …this is how dim a night light would appear on earth if it was on the Moon!

- To view these dim objects JWST must be at least 6 meters in diameter or 20 ft across

Telescopes are wider than our eyes to collect more star light, making dim objects appear brighter

Really big …

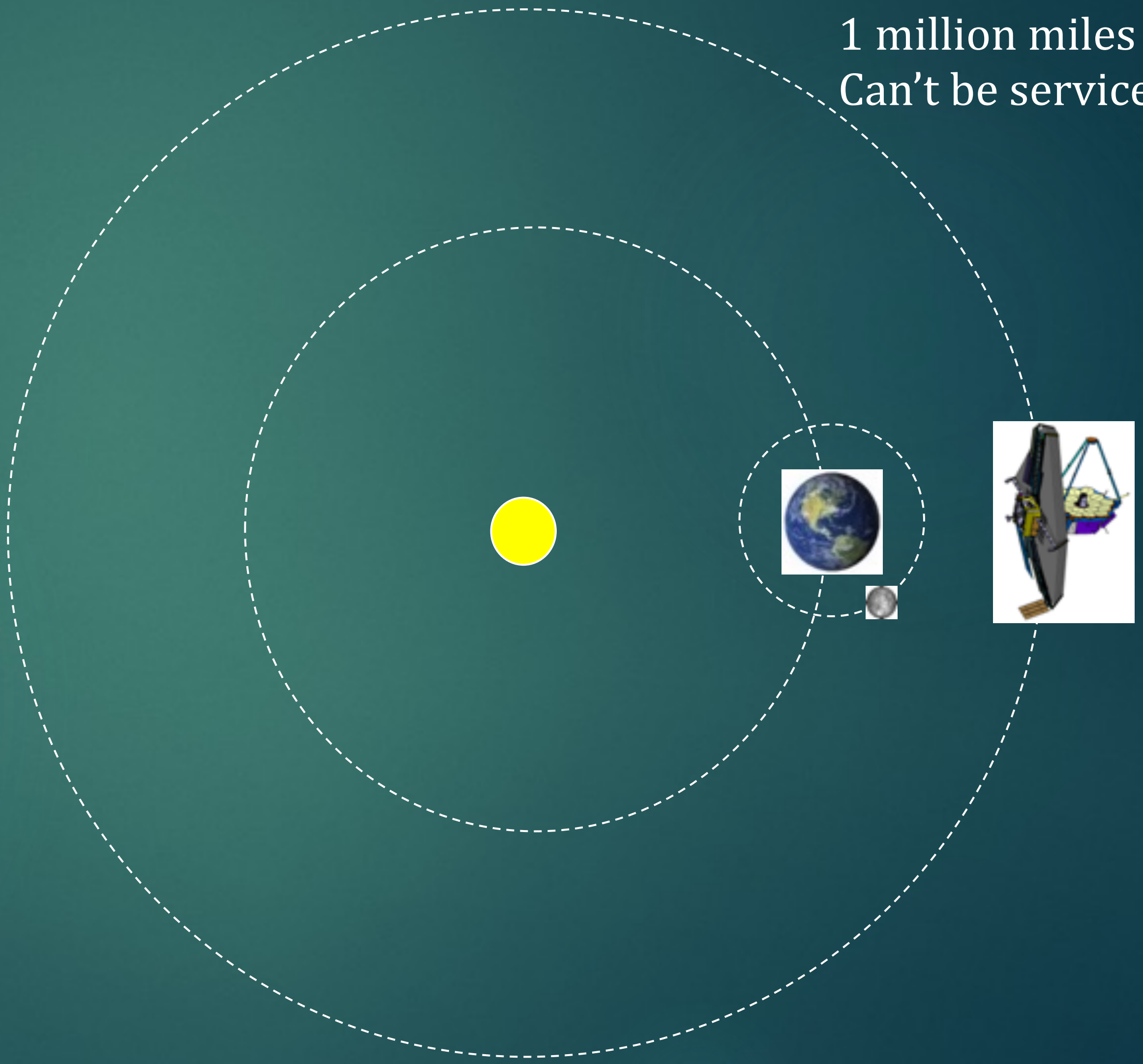
And it would take a *lot* of people – these are a fraction of them.

To See in the Infrared, JWST needs to block light from Sun, Earth & Moon:

The HST Orbits the Earth

LEO, 340 miles

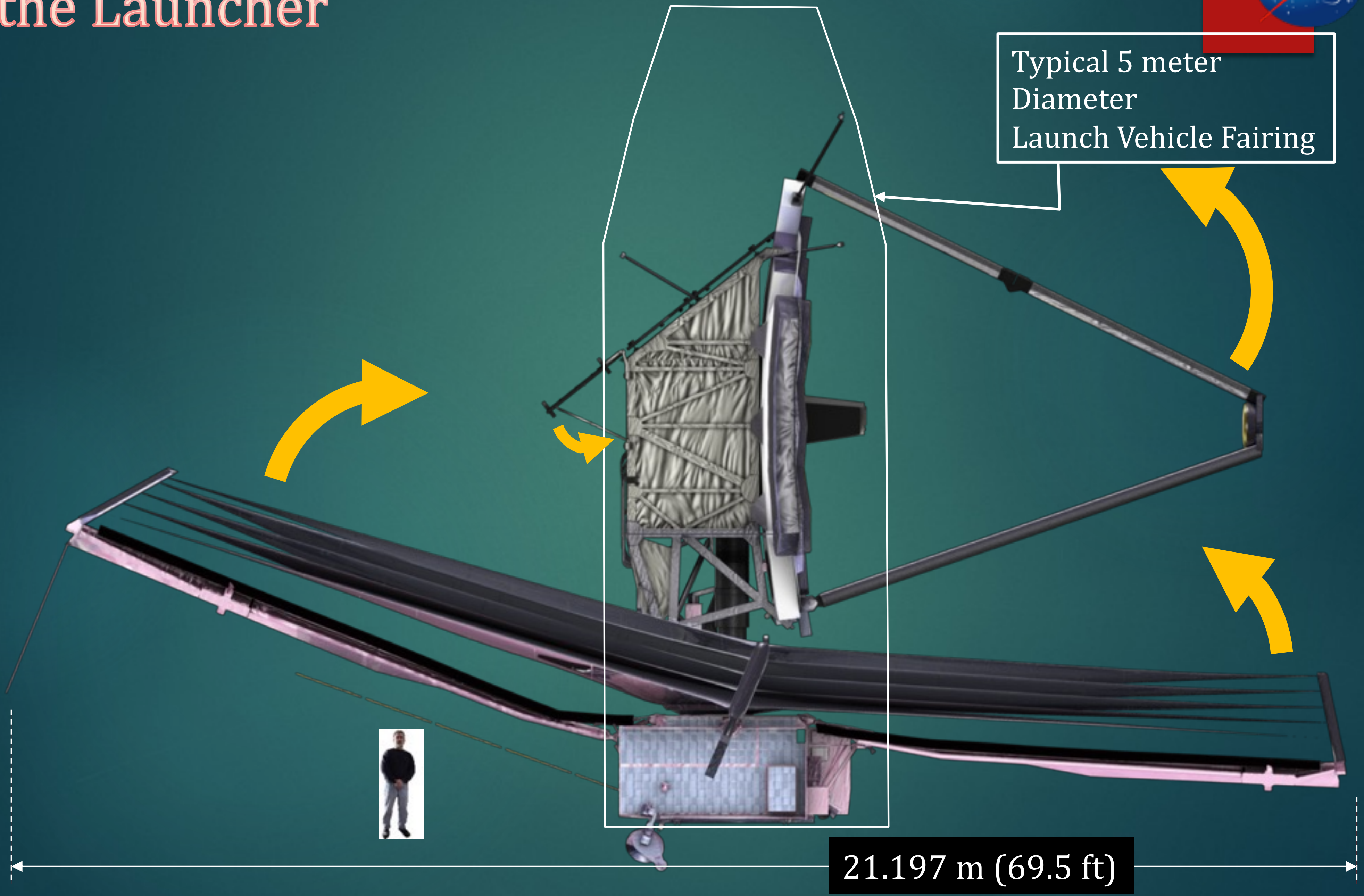
The JWST Orbits the Sun in Time with the Earth



1 million miles
Can't be serviced

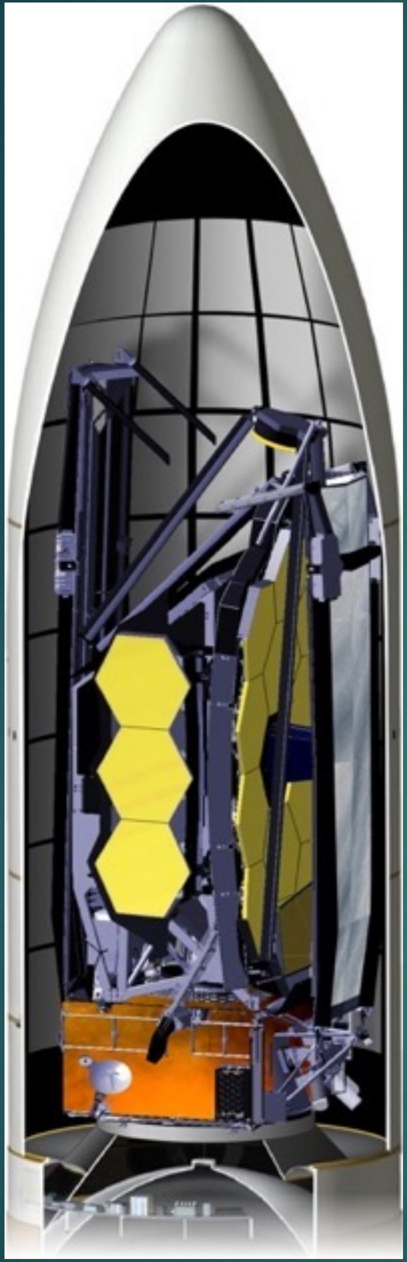
- By orbiting the Sun instead of the Earth, the Sun, Earth and moon are always on the same side of the observatory
- We can use an "umbrella" to shade the telescope from these bright and hot objects.
- The bad thing is that we cannot service JWST the way we did HST

JWST Observatory Must Fold-Up to Fit Into the Launcher



Typical 5 meter Diameter Launch Vehicle Fairing

21.197 m (69.5 ft)



Credit ESA - D. Ducros
NASA - J. Lawrence

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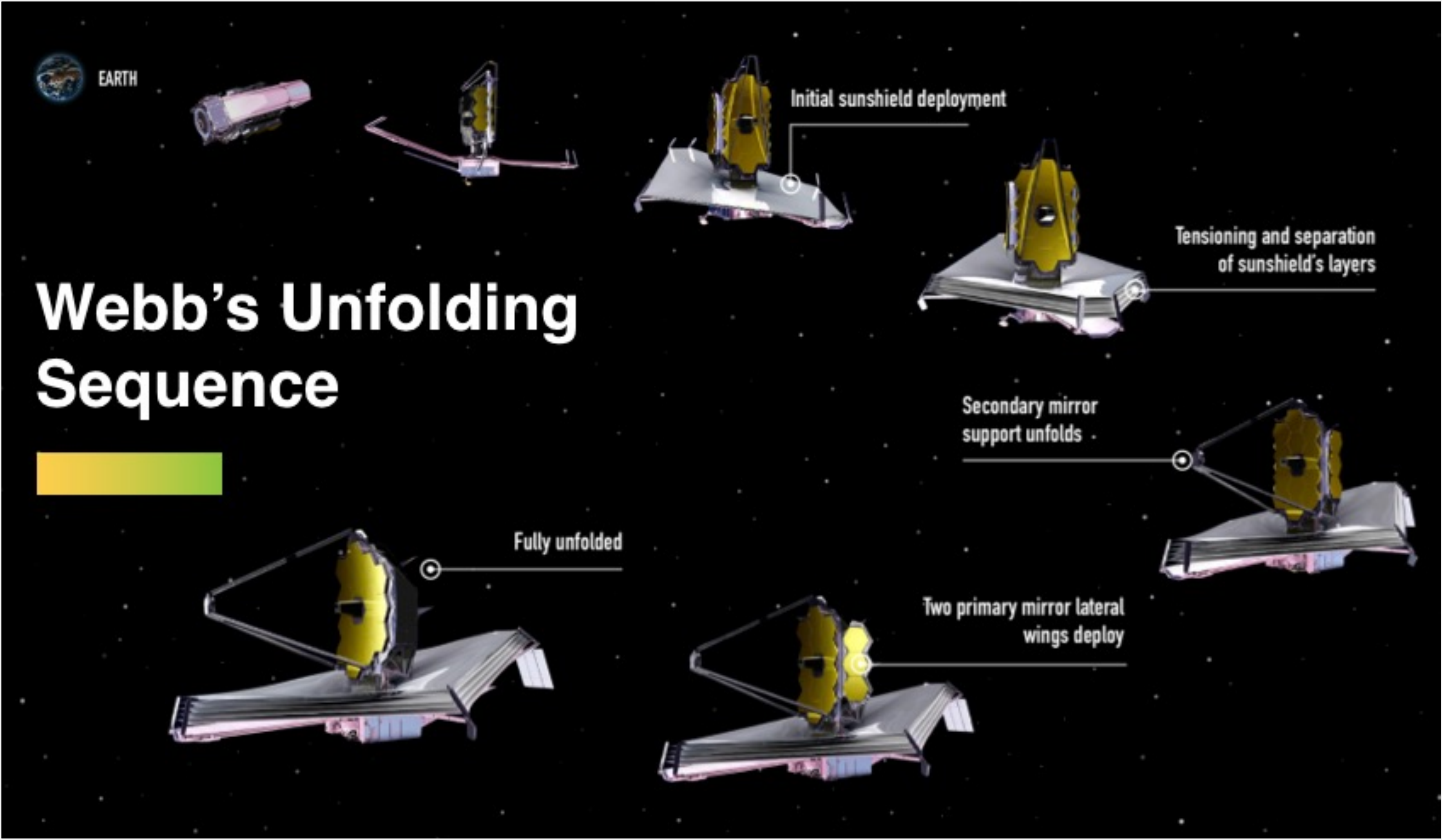
NASA - J. Lawrence

Deployments required, kept us in terror



Credit - NASA

Developments along the way

- 1998: First SPIE CC paper written
  - "Contamination Control Considerations for the Next Generation Space Telescope"
- 1999: NGST becomes Code 443
  - My daughter, Julia Wooldridge, is born in early September

- 2002: Renamed "James Webb Space Telescope"
  - Named for Apollo NASA Administrator, James Webb
- 2003: Heaters added to the ISIM instruments
  - Heaters??? When trying to passively cool a large structure & instruments?
    - First answer: absolutely not!
  - Then considered … *What If* ice accumulated on a surface and there were no way to remove it. Would it pass *The Washington Post test?* No, it would not.
  - Heaters added to keep instruments warm until structure and thermal enclosure were cold enough to no longer outgass water in cryo-testing and on-orbit commissioning.

Developments along the way

- 2002-2007: Launch Vehicle selection process
  - Competition between Delta 4 heavy, Atlas V, Ariane 5
  - Launch on a foreign carrier forbidden by policy
  - However – as an international mission, $100M contribution to come from ESA
    - 2003, ESA informs JWST Project they could move on Ariane 5 with Arianespace
    - 2004, Interagency coordination begins informally
    - 2005, NASA Administrator Griffin makes formal decision to pursue ESA contribution of Ariane 5 for JWST
    - 2006, First trip to CSG
    - 2007

      March - NASA HQ requests update on whitepaper explaining choice of Ariane 5 over US launchers to answer questions from Congress

      June – NASA Administrator Griffin and ESA Director General Jean-Jacques Dordain sign MOU defining the terms of the cooperation on the James Webb Space Telescope

Developments along the way

- 2010: Test Assessment Team (TAT) to examine ISIM & OTIS testing
  - Scheduled launch was then 2014
    - Could not be met, looking for ways to cut schedule
  - Could JSC testing be eliminated? Yes – this was seriously considered.
  - Of course, not – so TAT beautifully optimized ISIM and OTIS testing
    - Plan had been to have one major ISIM test followed by one OTIS test
    - The test plan changed to:
      - ISIM testing before and after instruments were delivered (2 were delayed)
        - Was 2 cryo-tests, CV1: ISIM structure, CV2: ISIM + instruments
        - Added a 3rd test when 2 instrument deliveries were delayed:
          - CV2 became: ISIM + 2 flight instruments,
          - CV3 added: ISIM + 4 flight instruments
      - JSC testing now had Optical and Thermal Pathfinder tests
        - Based on the Pathfinder tests, Thermal and CC decisions could be made in the flight OTIS test in real-time rather than waiting for weeks of analysis after the test

- *Instead of relying on one big ISIM test and then OTIS test, added tests to work out issues ahead of flight testing, made flight tests shorter*

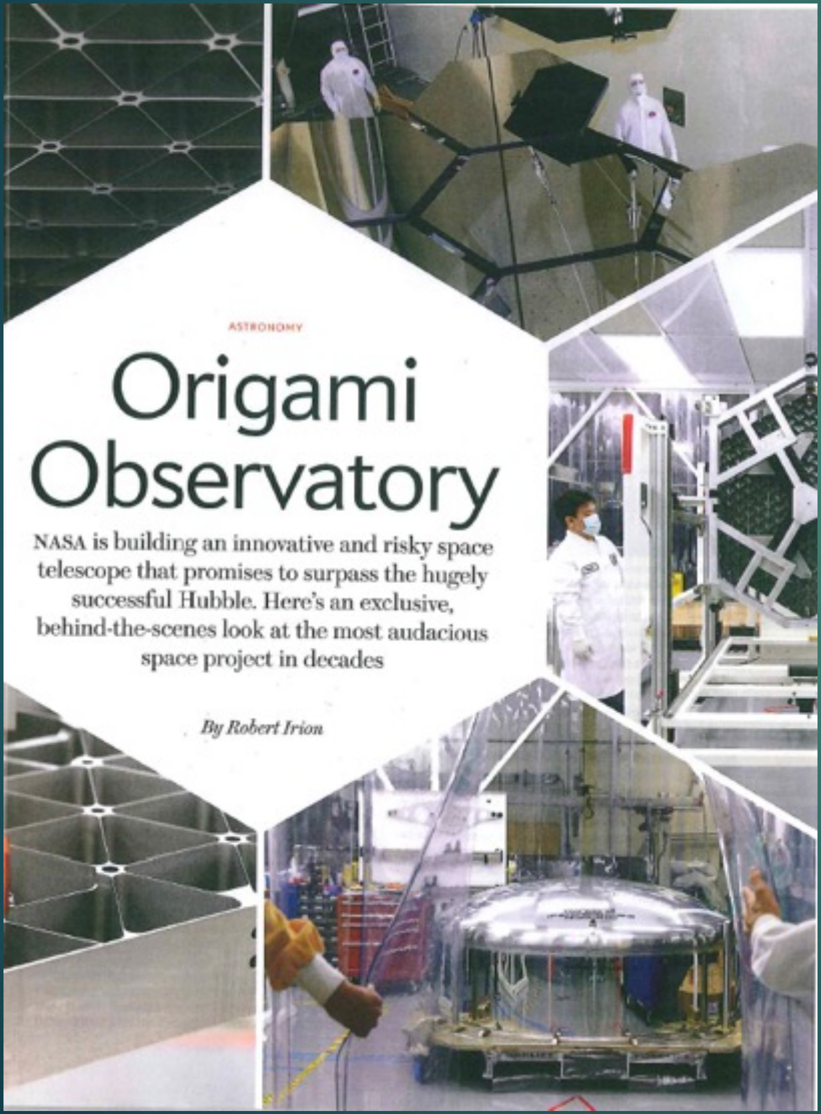
Assembly, Integration, Test & Launch

- 2015-2019: ISIM, OTE, Sunshield, Spacecraft and OTIS build, assembly, integration testing … much drama in the process with I&T delays, snowstorms, a derecho storm, record rainstorms, fires, Hurricane Harvey, and *at the end* – a Magnitude 5 Earthquake.
- 2019: OTIS and Spacecraft integration, we have an Observatory!
- 2020: Worldwide pandemic, JWST work continues at Northrop
- 2021: Completion of Observatory, delivery to CSG, and
  Christmas Day Launch

- Contamination Control had its own long process in these years

Scientific American, October 2010

"NASA had a strong desire to build the first of the new telescopes, rather than the last of the old." – Alan Dressler

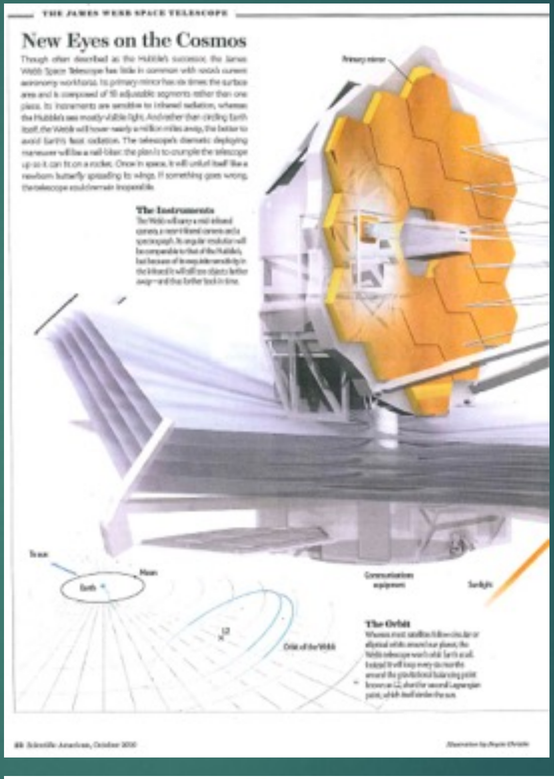


ASTRONOMY

Origami Observatory

NASA is building an innovative and risky space telescope that promises to surpass the hugely successful Hubble. Here's an exclusive, behind-the-scenes look at the most audacious space project in decades

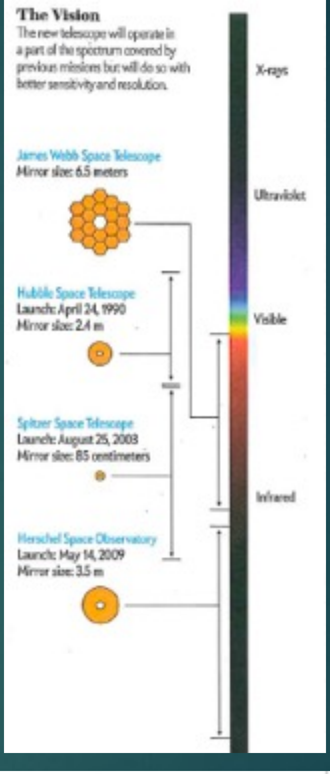
By Robert Irion



THE JAMES WEBB SPACE TELESCOPE

New Eyes on the Cosmos

The Instruments



The Vision

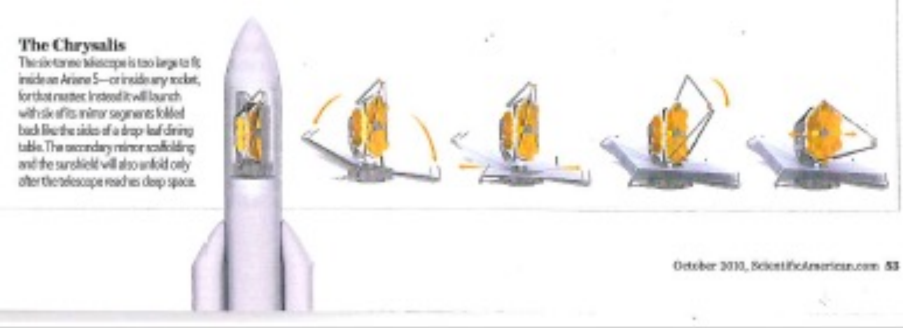
The new telescope will operate in a part of the spectrum covered by previous missions but will do so with better sensitivity and resolution.

James Webb Space Telescope
Mirror size: 6.5 meters

Hubble Space Telescope
Launch: April 24, 1990
Mirror size: 2.4 m

Spitzer Space Telescope
Launch: August 25, 2003
Mirror size: 85 centimeters

Herschel Space Observatory
Launch: May 14, 2009
Mirror size: 3.5 m



The Chrysalis

The six-tonne telescope is too large to fit inside an Ariane 5—or inside any rocket, for that matter. Instead it will launch with six of its mirror segments folded back like the sides of a drop-leaf dining table. The secondary mirror scaffolding and the sunshield will also unfold only after the telescope reaches deep space.

October 2010, ScientificAmerican.com 53

To see the faint signal, JWST needed to be very clean…

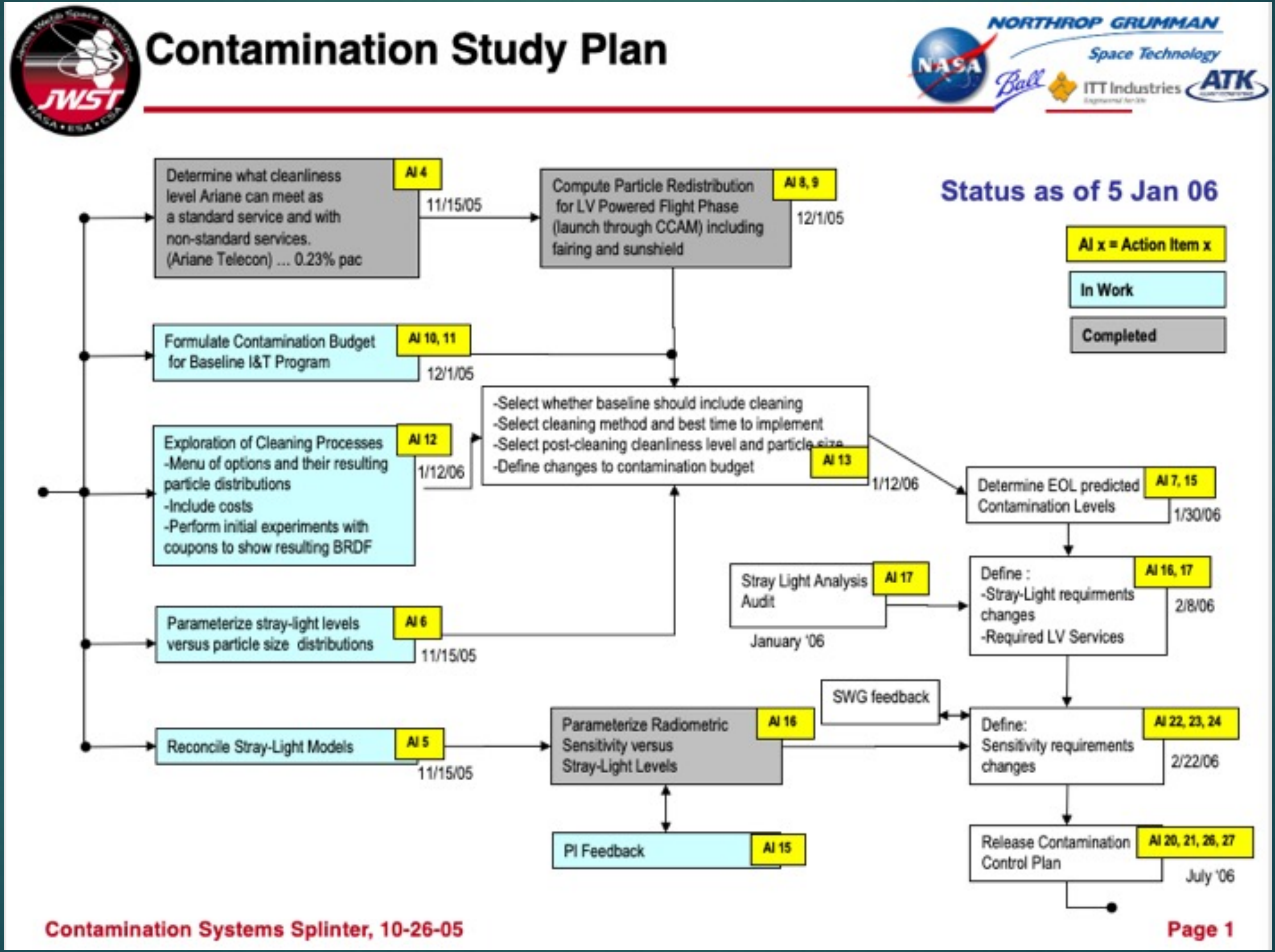
This presented a new set of interesting challenges for

Contamination Control

For the first of the new telescopes to be clean,
new contamination control approaches
would be required.

First – Establish CC Requirements

- 2005-2006: Examination of Contamination Levels vs. Stray Light & Sensitivity



Contamination Study Plan

Status as of 5 Jan 06

AI x = Action Item x

In Work

Completed

Determine what cleanliness level Ariane can meet as a standard service and with non-standard services. (Ariane Telecon) … 0.23% pac — AI 4 — 11/15/05

Compute Particle Redistribution for LV Powered Flight Phase (launch through CCAM) including fairing and sunshield — AI 8, 9 — 12/1/05

Formulate Contamination Budget for Baseline I&T Program — AI 10, 11 — 12/1/05

Exploration of Cleaning Processes
-Menu of options and their resulting particle distributions
-Include costs
-Perform initial experiments with coupons to show resulting BRDF
AI 12 — 1/12/06

-Select whether baseline should include cleaning
-Select cleaning method and best time to implement
-Select post-cleaning cleanliness level and particle size
-Define changes to contamination budget
AI 13 — 1/12/06

Determine EOL predicted Contamination Levels — AI 7, 15 — 1/30/06

Parameterize stray-light levels versus particle size distributions — AI 6 — 11/15/05

Stray Light Analysis Audit — AI 17 — January '06

Define :
-Stray-Light requirments changes
-Required LV Services
AI 16, 17 — 2/8/06

SWG feedback

Reconcile Stray-Light Models — AI 5 — 11/15/05

Parameterize Radiometric Sensitivity versus Stray-Light Levels — AI 16

Define:
Sensitivity requirements changes
AI 22, 23, 24 — 2/22/06

PI Feedback — AI 15

Release Contamination Control Plan — AI 20, 21, 26, 27 — July '06

Contamination Systems Splinter, 10-26-05

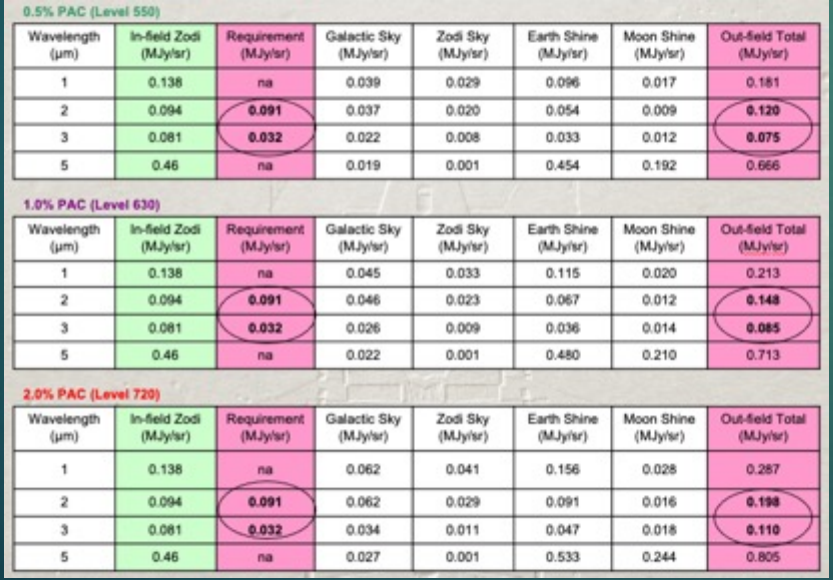
Page 1

CC Requirements - Particulate

Particulate Requirements

- April 2006 cleanliness requirements: 1% PAC for both Primary Mirror (PM) and Secondary Mirror (SM),
- Prediction of particulate level at time of launch indicated that to meet 1% PAC on PM, aggressive mirror covering techniques required – undesirable and often impossible for the PM in I&T
- The same analysis predicted that 1.4% EOL could be met without extreme protective measures
- Systems engineering evaluated relaxing PM reqt to <u>1.5% PAC</u>, and tightening SM reqt to <u>0.5% PAC</u>
  - PM integrated cup-up, very large and segmented, therefore much harder to maintain clean; SM easier to clean
- This change would minimize risk and cost

Stray Light fn(Cleanliness Level)



0.5% PAC (Level 550)

Wavelength (µm)	In-field Zodi (MJy/sr)	Requirement (MJy/sr)	Galactic Sky (MJy/sr)	Zodi Sky (MJy/sr)	Earth Shine (MJy/sr)	Moon Shine (MJy/sr)	Out-field Total (MJy/sr)
1	0.138	na	0.039	0.029	0.096	0.017	0.181
2	0.094	**0.091**	0.037	0.020	0.054	0.009	**0.120**
3	0.081	**0.032**	0.022	0.008	0.033	0.012	**0.075**
5	0.46	na	0.019	0.001	0.454	0.192	0.666

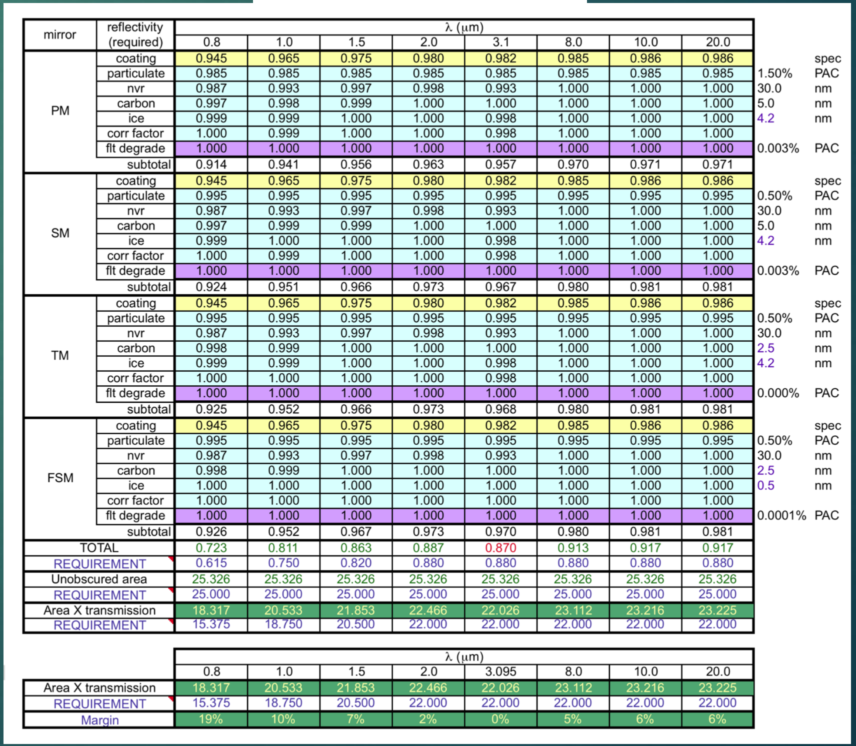
1.0% PAC (Level 630)

Wavelength (µm)	In-field Zodi (MJy/sr)	Requirement (MJy/sr)	Galactic Sky (MJy/sr)	Zodi Sky (MJy/sr)	Earth Shine (MJy/sr)	Moon Shine (MJy/sr)	Out-field Total (MJy/sr)
1	0.138	na	0.045	0.033	0.115	0.020	0.213
2	0.094	**0.091**	0.046	0.023	0.067	0.012	**0.148**
3	0.081	**0.032**	0.026	0.009	0.036	0.014	**0.085**
5	0.46	na	0.022	0.001	0.480	0.210	0.713

2.0% PAC (Level 720)

Wavelength (µm)	In-field Zodi (MJy/sr)	Requirement (MJy/sr)	Galactic Sky (MJy/sr)	Zodi Sky (MJy/sr)	Earth Shine (MJy/sr)	Moon Shine (MJy/sr)	Out-field Total (MJy/sr)
1	0.138	na	0.062	0.041	0.156	0.028	0.287
2	0.094	**0.091**	0.062	0.029	0.091	0.016	**0.198**
3	0.081	**0.032**	0.034	0.011	0.047	0.018	**0.110**
5	0.46	na	0.027	0.001	0.533	0.244	0.805

Transmission Budget



mirror	reflectivity (required)	λ (µm)									
		0.8	1.0	1.5	2.0	3.1	8.0	10.0	20.0		
PM	coating	0.945	0.965	0.975	0.980	0.982	0.985	0.986	0.986		spec
	particulate	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	1.50%	PAC
	nvr	0.987	0.993	0.997	0.998	0.993	1.000	1.000	1.000	30.0	nm
	carbon	0.997	0.998	0.999	1.000	1.000	1.000	1.000	1.000	5.0	nm
	ice	0.999	0.999	1.000	1.000	0.998	1.000	1.000	1.000	4.2	nm
	corr factor	1.000	0.999	1.000	1.000	0.998	1.000	1.000	1.000		
	flt degrade	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.003%	PAC
	subtotal	0.914	0.941	0.956	0.963	0.957	0.970	0.971	0.971		
SM	coating	0.945	0.965	0.975	0.980	0.982	0.985	0.986	0.986		spec
	particulate	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.50%	PAC
	nvr	0.987	0.993	0.997	0.998	0.993	1.000	1.000	1.000	30.0	nm
	carbon	0.997	0.999	0.999	1.000	1.000	1.000	1.000	1.000	5.0	nm
	ice	0.999	1.000	1.000	1.000	0.998	1.000	1.000	1.000	4.2	nm
	corr factor	1.000	0.999	1.000	1.000	0.998	1.000	1.000	1.000		
	flt degrade	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.003%	PAC
	subtotal	0.924	0.951	0.966	0.973	0.967	0.980	0.981	0.981		
TM	coating	0.945	0.965	0.975	0.980	0.982	0.985	0.986	0.986		spec
	particulate	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.50%	PAC
	nvr	0.987	0.993	0.997	0.998	0.993	1.000	1.000	1.000	30.0	nm
	carbon	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	2.5	nm
	ice	0.999	0.999	1.000	1.000	0.998	1.000	1.000	1.000	4.2	nm
	corr factor	1.000	1.000	1.000	1.000	0.998	1.000	1.000	1.000		
	flt degrade	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000%	PAC
	subtotal	0.925	0.952	0.966	0.973	0.968	0.980	0.981	0.981		
FSM	coating	0.945	0.965	0.975	0.980	0.982	0.985	0.986	0.986		spec
	particulate	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.50%	PAC
	nvr	0.987	0.993	0.997	0.998	0.993	1.000	1.000	1.000	30.0	nm
	carbon	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	2.5	nm
	ice	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.5	nm
	corr factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
	flt degrade	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.0001%	PAC
	subtotal	0.926	0.952	0.967	0.973	0.970	0.980	0.981	0.981		
TOTAL		0.723	0.811	0.863	0.887	0.870	0.913	0.917	0.917		
REQUIREMENT		0.615	0.750	0.820	0.880	0.880	0.880	0.880	0.880		
Unobscured area		25.326	25.326	25.326	25.326	25.326	25.326	25.326	25.326		
REQUIREMENT		25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000		
Area X transmission		18.317	20.533	21.853	22.466	22.026	23.112	23.216	23.225		
REQUIREMENT		15.375	18.750	20.500	22.000	22.000	22.000	22.000	22.000		

	λ (µm)							
	0.8	1.0	1.5	2.0	3.095	8.0	10.0	20.0
Area X transmission	18.317	20.533	21.853	22.466	22.026	23.112	23.216	23.225
REQUIREMENT	15.375	18.750	20.500	22.000	22.000	22.000	22.000	22.000
Margin	19%	10%	7%	2%	0%	5%	6%	6%

CC Requirements - Molecular

Molecular Requirements

- NVR, carbon (polymerized post launch), water block & absorb light

PM & SM	392 angstroms: 300 (NVR) + 50 (carbon) + 42 (water/ice)
TM	367 angstroms: 300 (NVR) + 50 (carbon) + 25 (water/ice)
SM	330 angstroms: 300 (NVR) + 50 (carbon) + 5 (water/ice)

Ground Processing & cool-down redistribution

- Throughout I&T, including cryo-vac testing, and for on-orbit commissioning, water/ice proved to be the greatest challenge
- In OTIS cryo-vac testing, discovered that molecular accumulation during return to ambient was not the problem we thought it would be
- For many areas, single layer insulation (SLI) dog-houses and shields were built to protect the most vulnerable optics
  - Relying on thermal control too precarious -any unexpected shift could blind an optic with ice
- Cool-down and warm-up constraints during OTIS cryo-vac testing were established and monitored closely. These led to on-orbit commissioning requirements that were monitored by CCEs as a decision-making part of the commissioning team
- Molecular redistribution analysis performed in the year before launch became a critical tool for planning timing of commissioning deployments & heater activation/deactivation

Papers

- 4 of the 16 papers on JWST will expound on work done to meet JWST molecular/ice requirements

Then – meet the CC requirements

- This meant …
  - Keeping Exposed Instruments and Optical surfaces clean over years that turned into decades of
    - building
    - testing
    - transporting
    - launching
- This was done in dozens of different facilities, each with varying contamination control capabilities

To meet the challenge

- Apply the fundamentals of Contamination Control, and then some
  - Work in cleanrooms, wear cleanroom garments
  - Start with mirrors as clean as possible, and at a measured cleanliness level
  - Keep close track of the contamination increase
  - Cover whenever possible
  - Create clean areas when the work can only be done in uncontrolled areas
  - When testing, transporting, or at the launch site – find whatever way possible to keep clean
  - Watch all activity, clean the facilities and equipment every day: constant presence
  - Be prepared to clean the primary and secondary mirrors

- Launch campaign in remote location and during a world-wide pandemic
  - Make Class 8 facilities operate as Class 7 facilities
  - Clean the fairing
  - Bring far more than needed for the time planned – plan for potential delays
  - Use local resources to extend what we brought
  - Manage the jungle environment that made facilities vulnerable to bugs, birds & bats

Inspecting each mirror on delivery

- with each organization represented

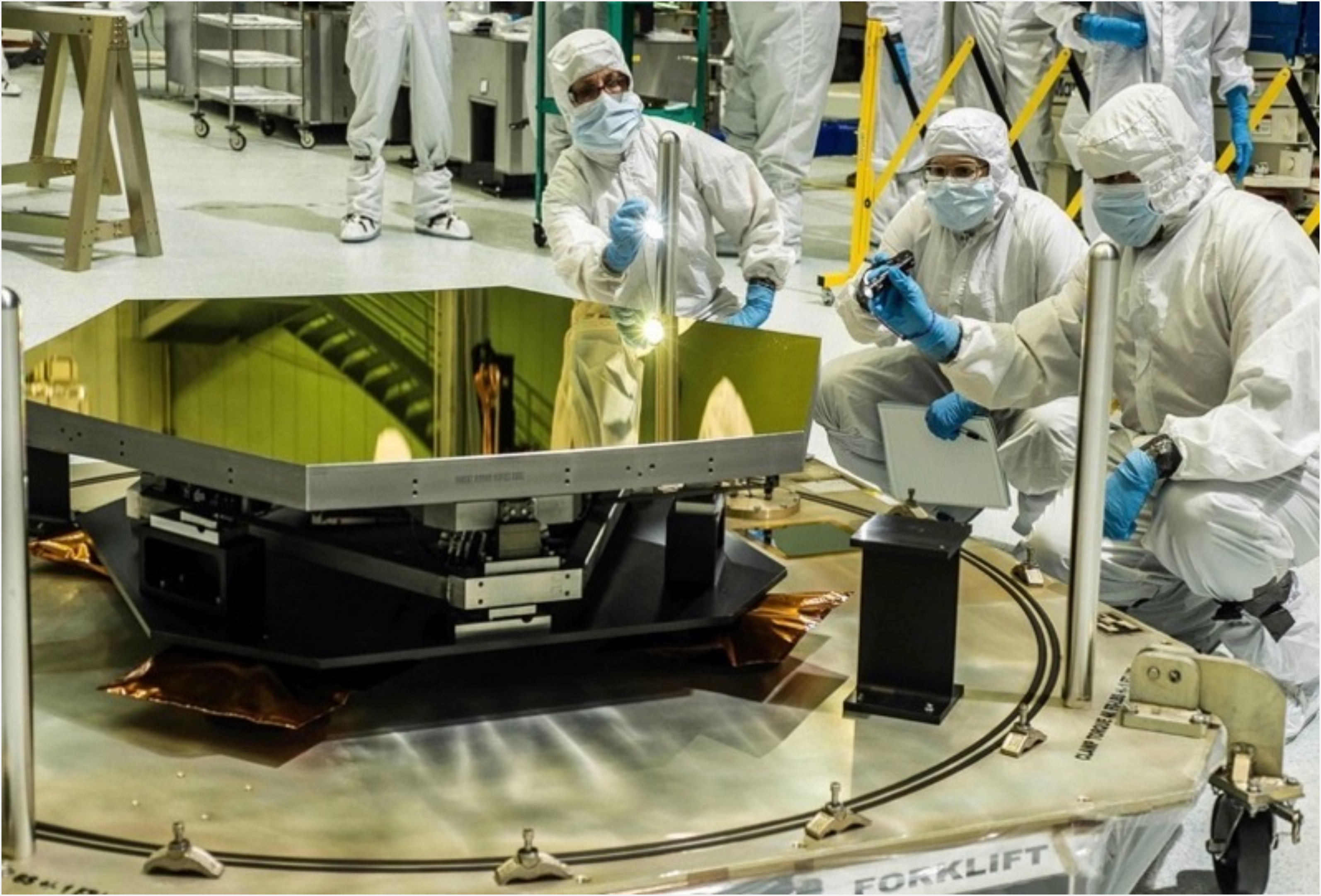


Photo Credit Chris Gunn

Secondary Mirror Inspection

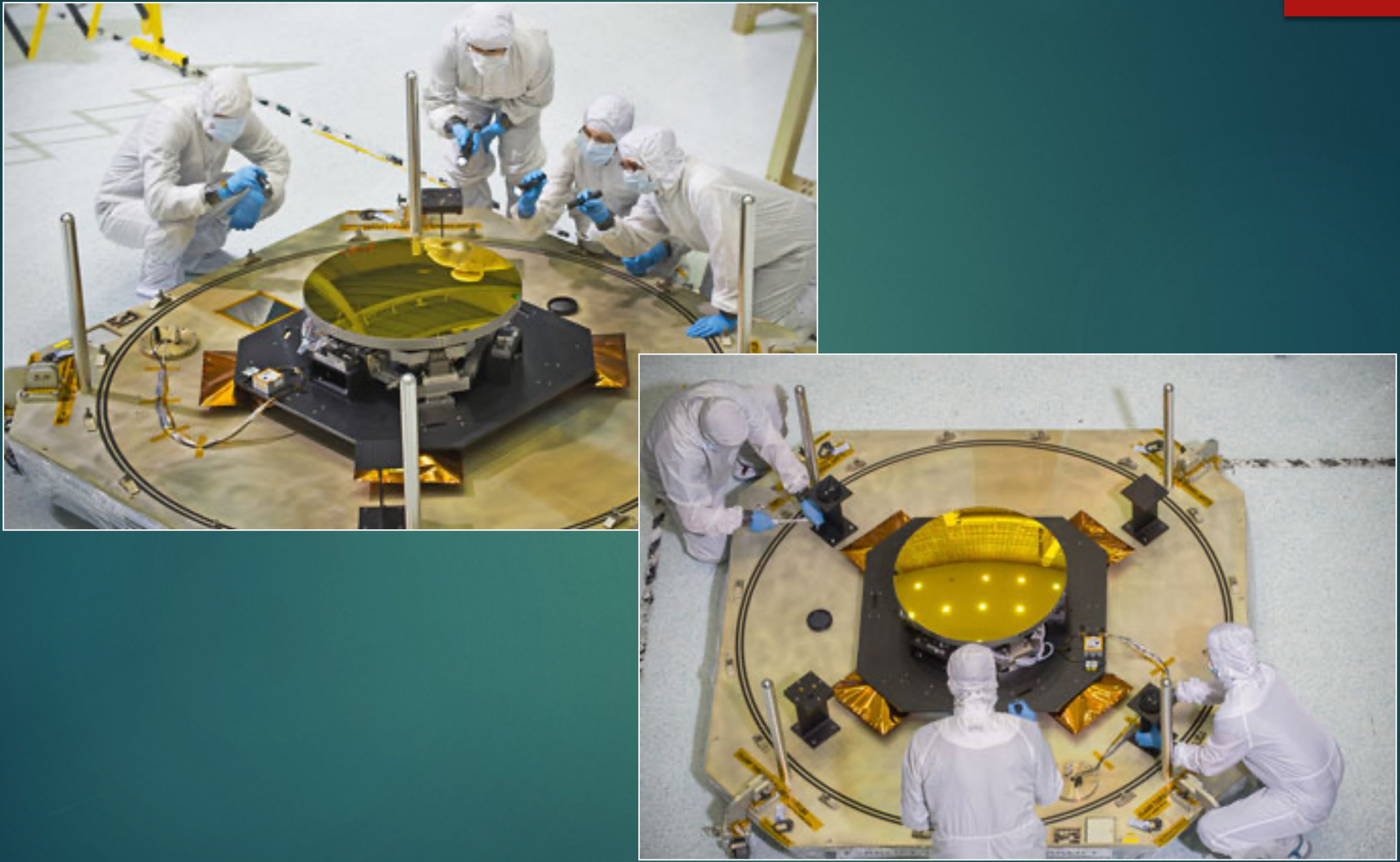


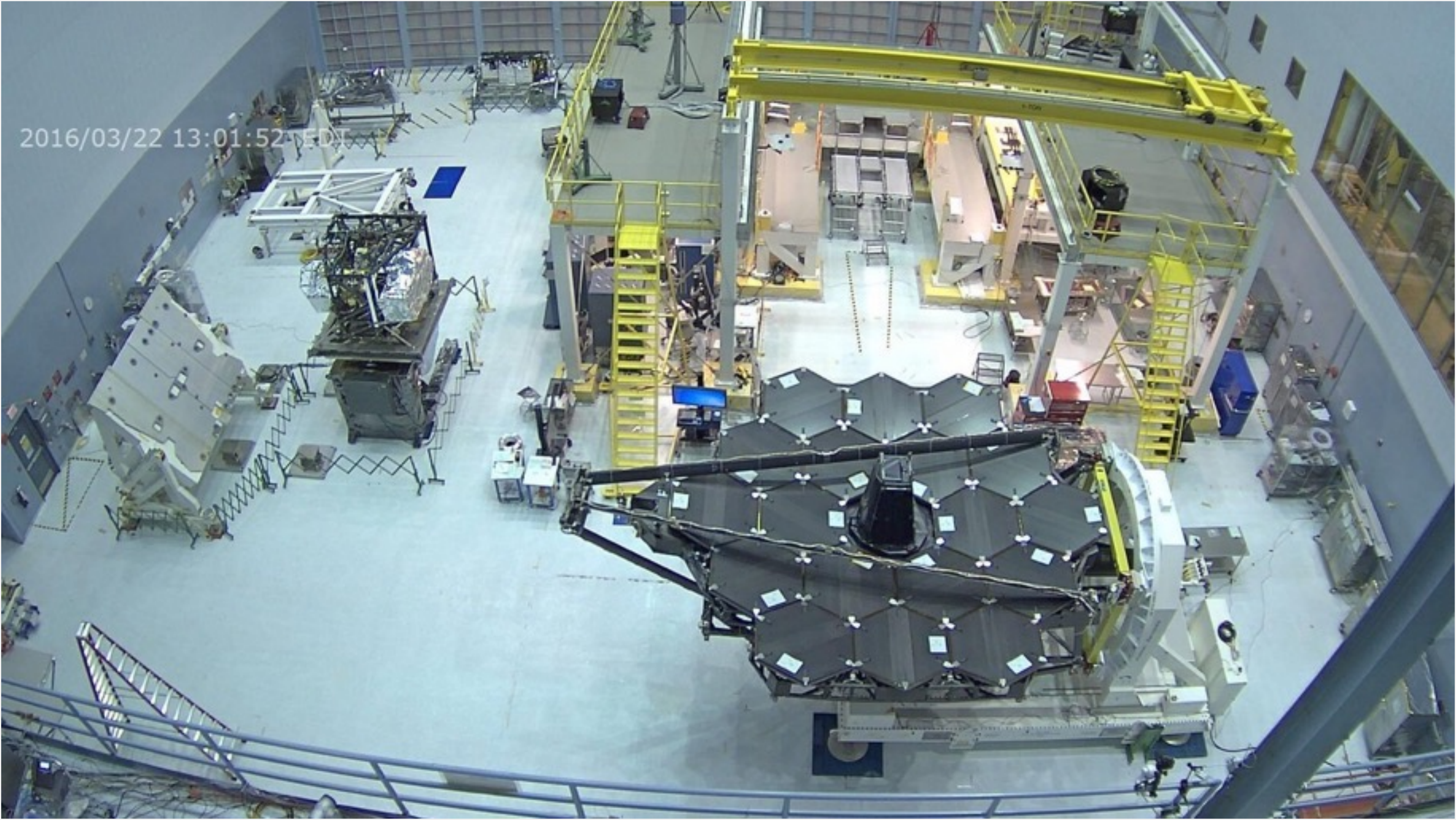
Photo Credit Chris Gunn

Monitoring by Proxy

Photo Credit Chris Gunn

2 wafers placed with each mirror when delivered and followed the mirrors until final closeouts.

Covering to Protect from Fallout



Removing the Covers

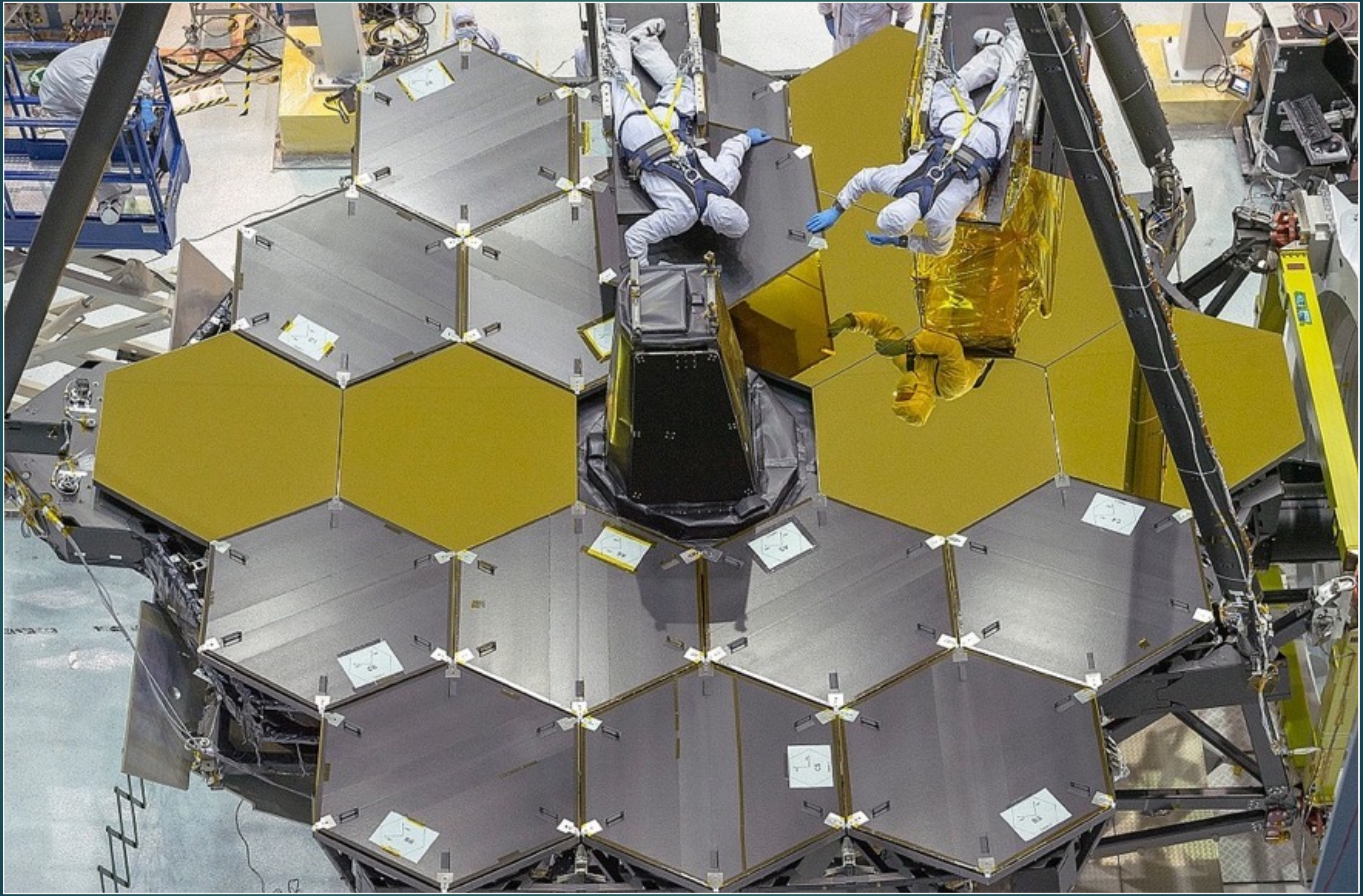


Photo Credit Chris Gunn

First view of Primary Mirror in 2016

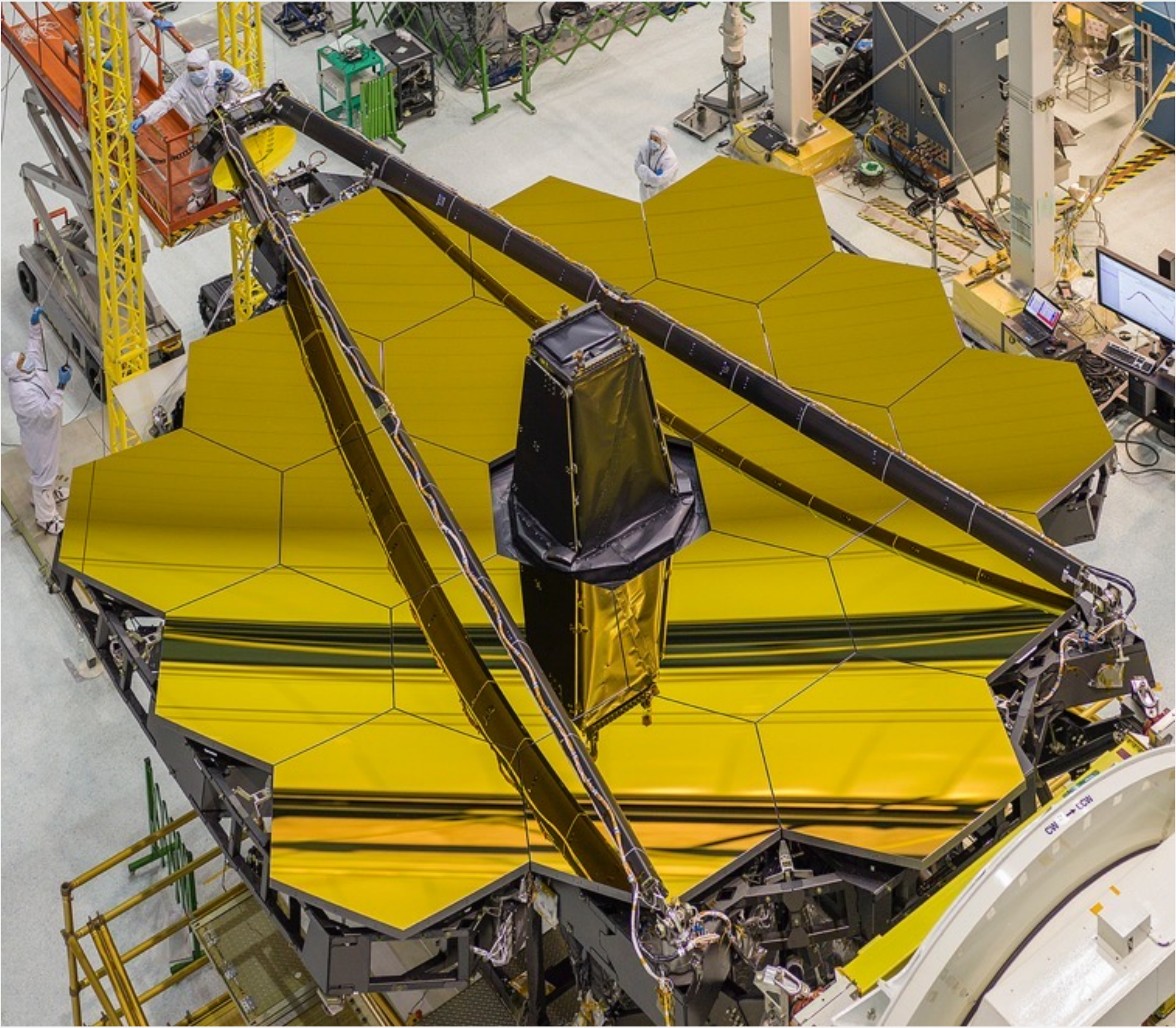
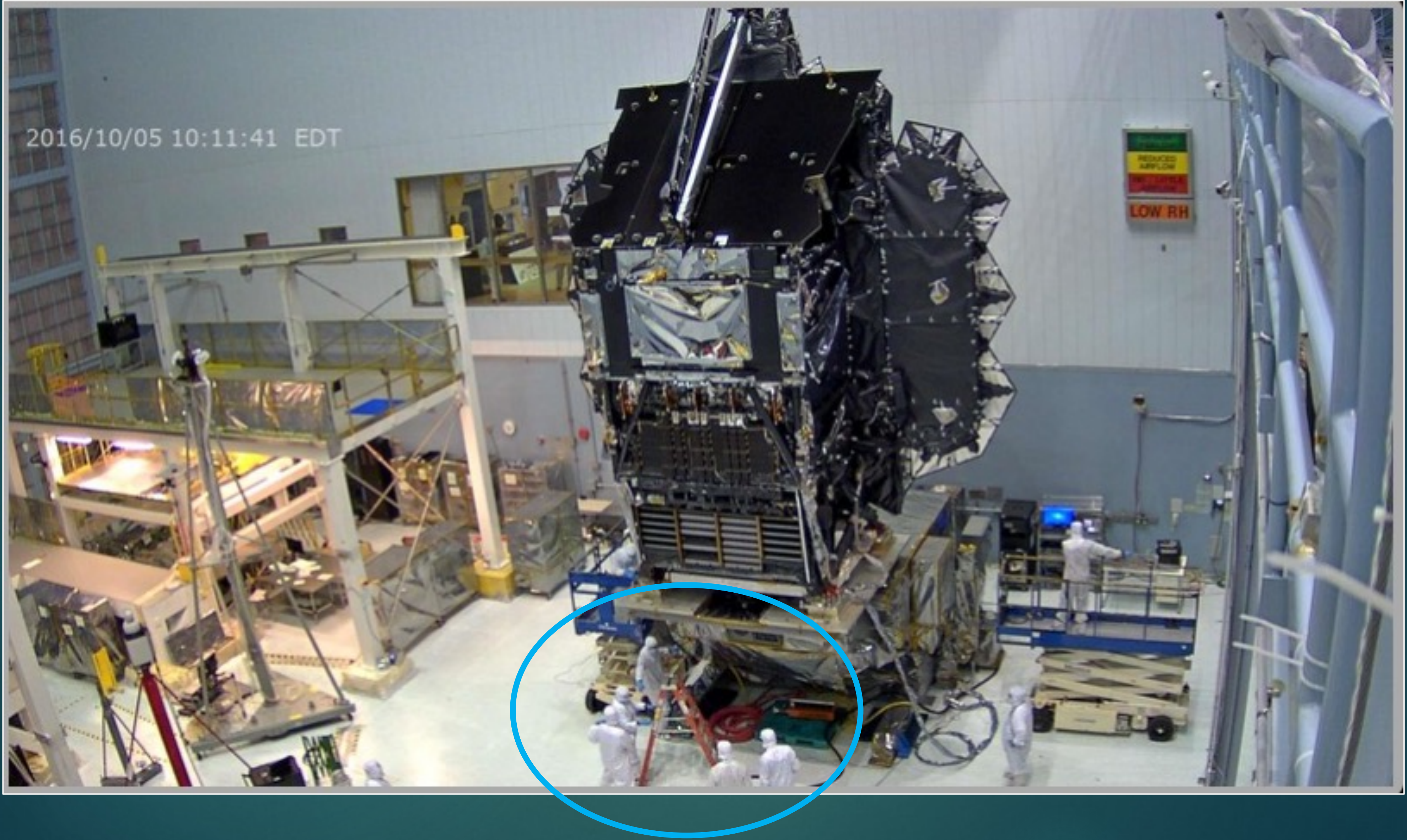


Photo Credit Chris Gunn

Inspecting & Cleaning



More Inspecting & Cleaning

Photo Credit: Russell Wooldridge

Portable Cleanroom for Environmental Testing

Photo Credit Chris Gunn

Lifting to the Vibration Table

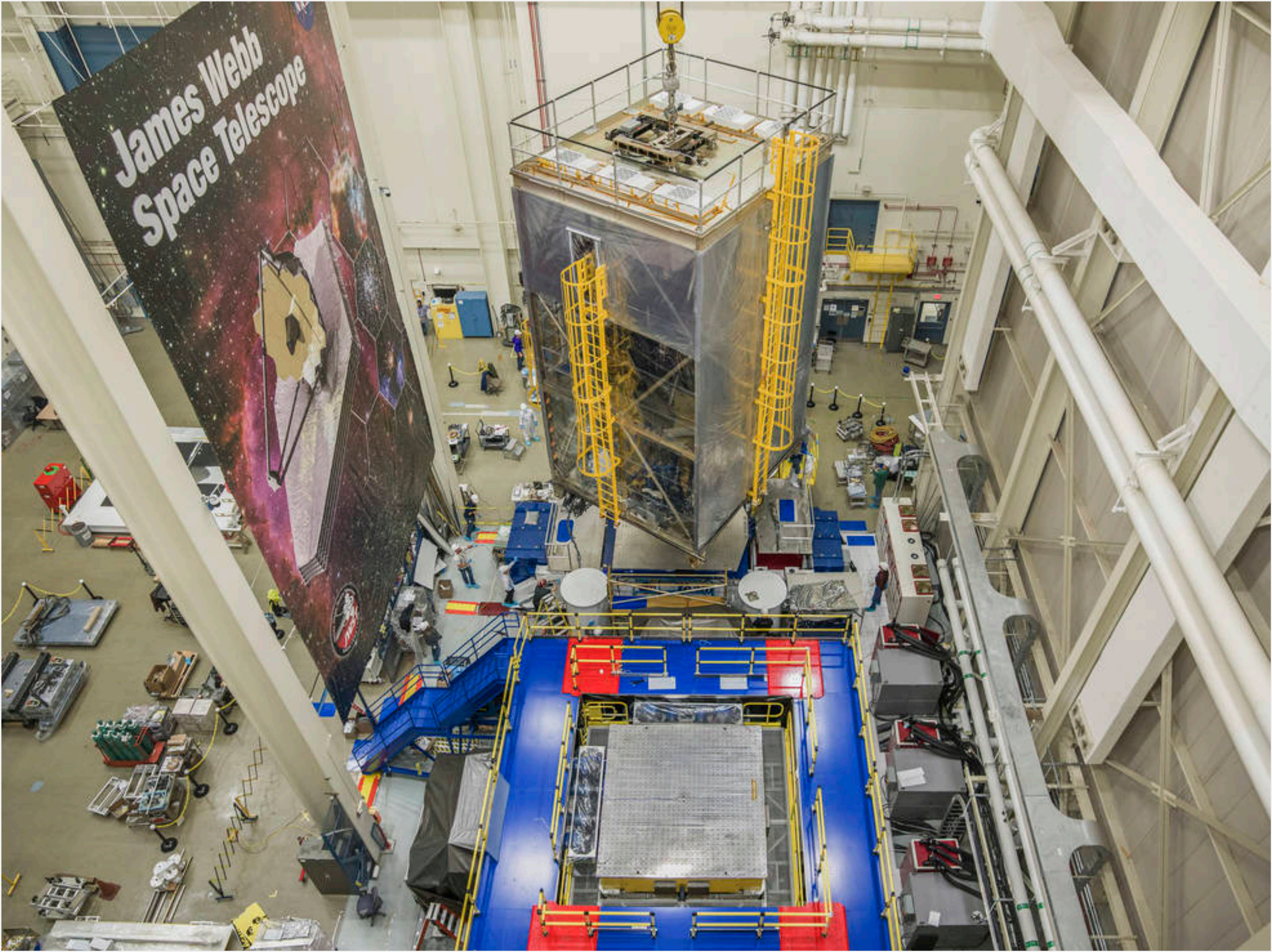


Photo Credit Chris Gunn

Inspecting often …

with lights out as often as possible

“A Ghostly Inspection”

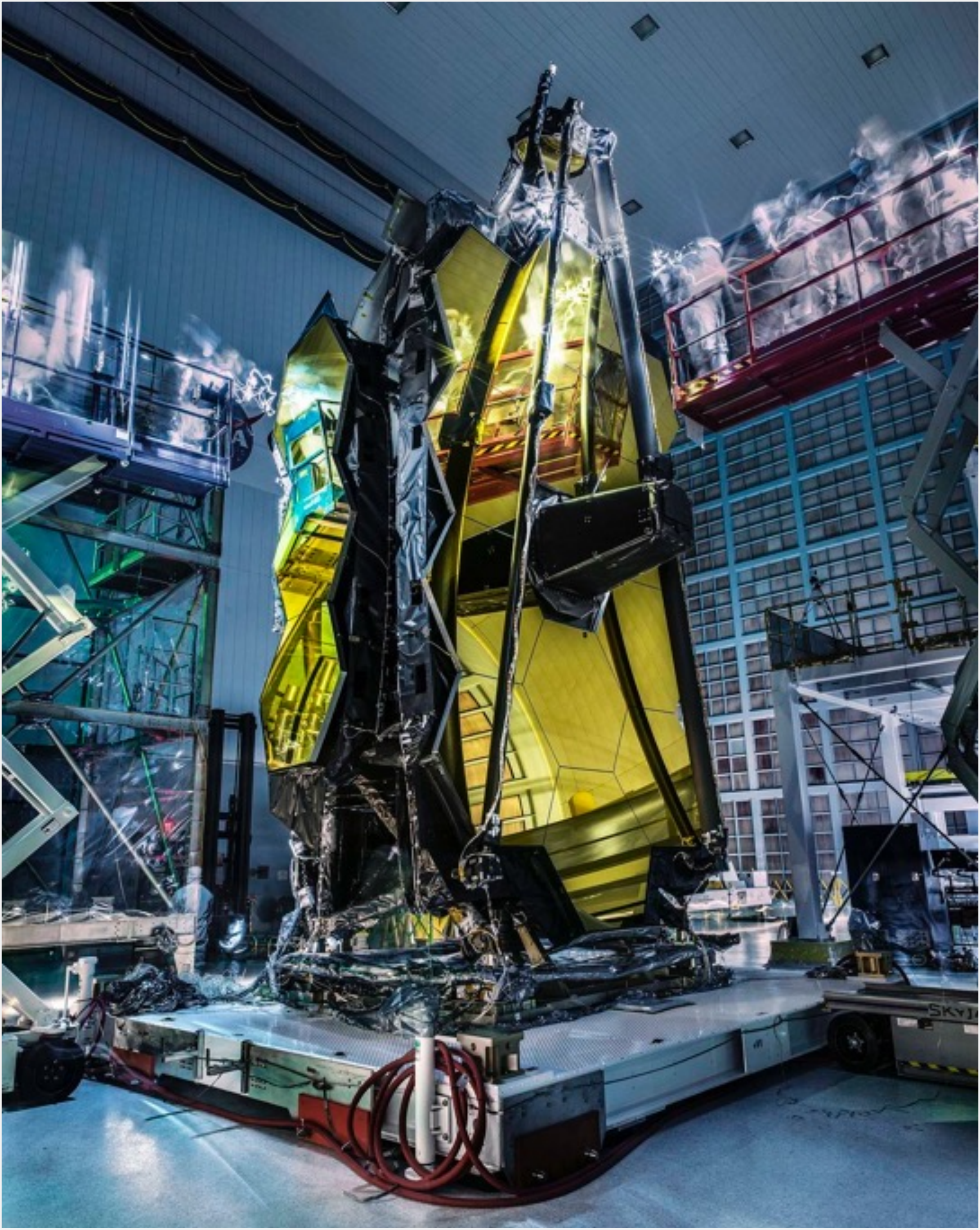


Photo Credit Chris Gunn

Cryo-Vac Testing
at Johnson Space Center in Houston

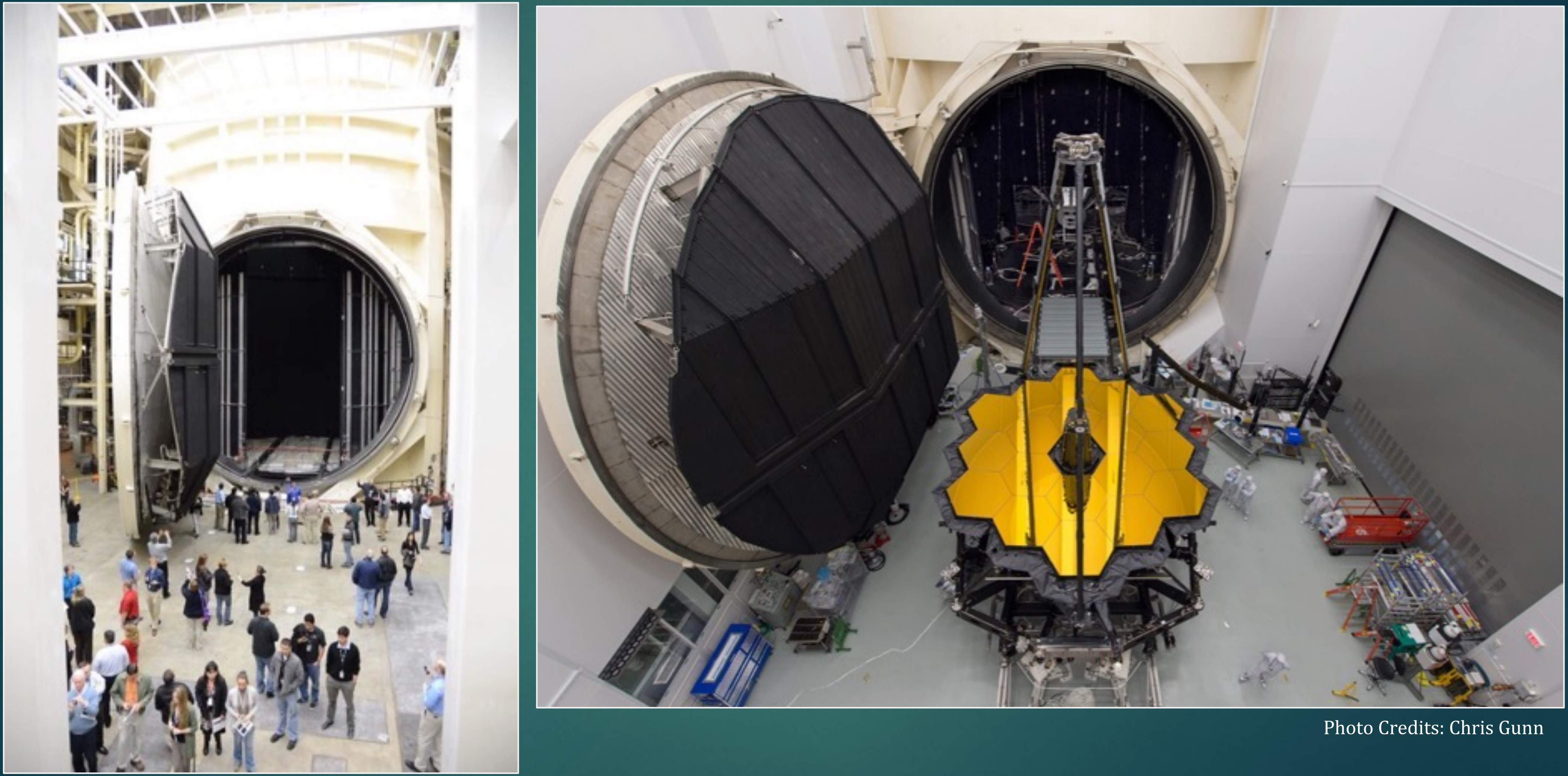


Photo Credits: Chris Gunn

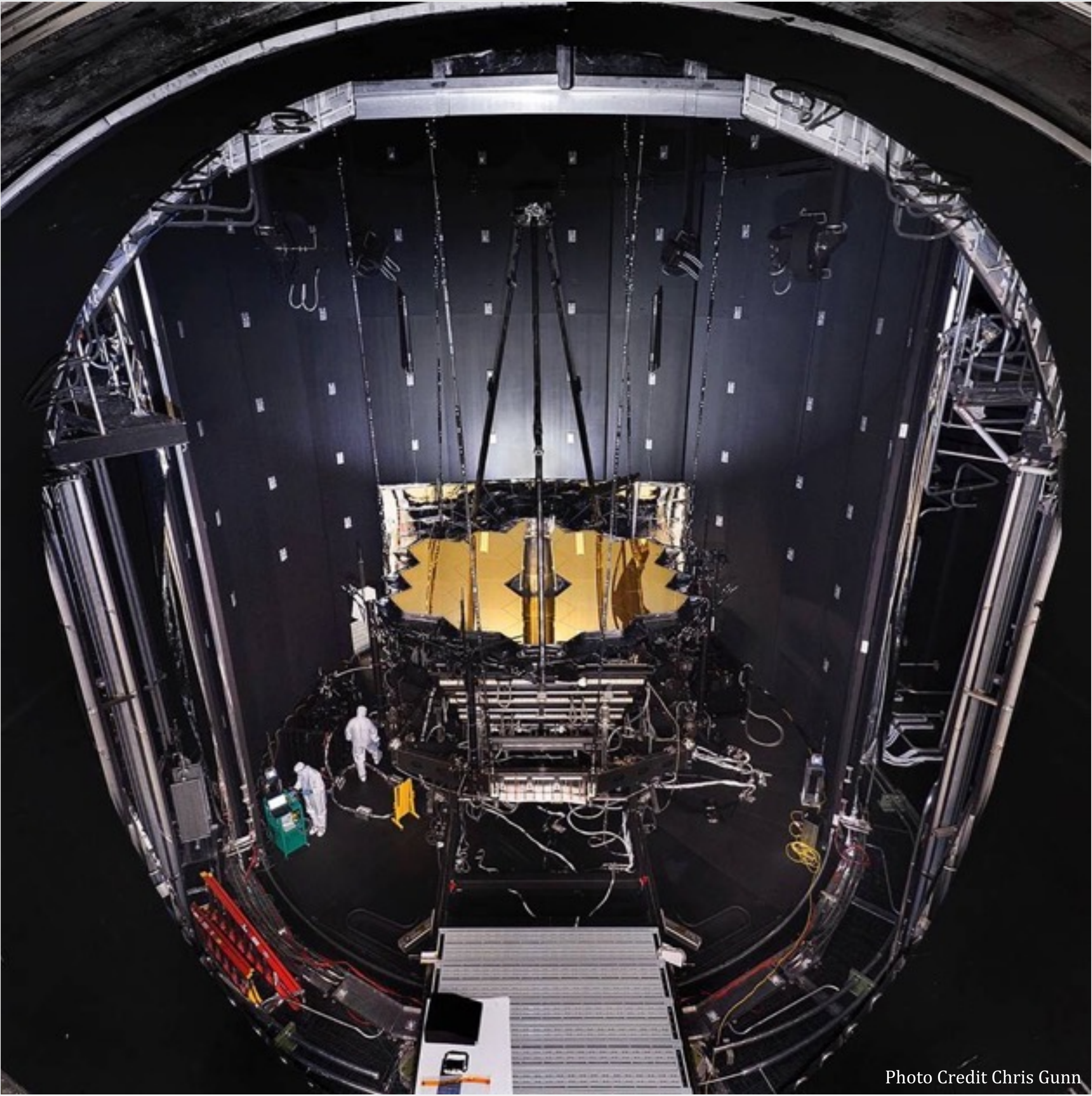


Photo Credit Chris Gunn

Cleaning Mirrors in 2017, after Cryo-Vac

Time in I&T kept increasing, so contingency procedure was needed … twice

Photo Credit Chris Gunn

Transporting JWST - in a mobile cleanroom

Photo Credits Chris Gunn

Integrating the Observatory

Photo credits: NASA flicker/Chris Gunn

“Lens cover” removed, Observatory ready to ship

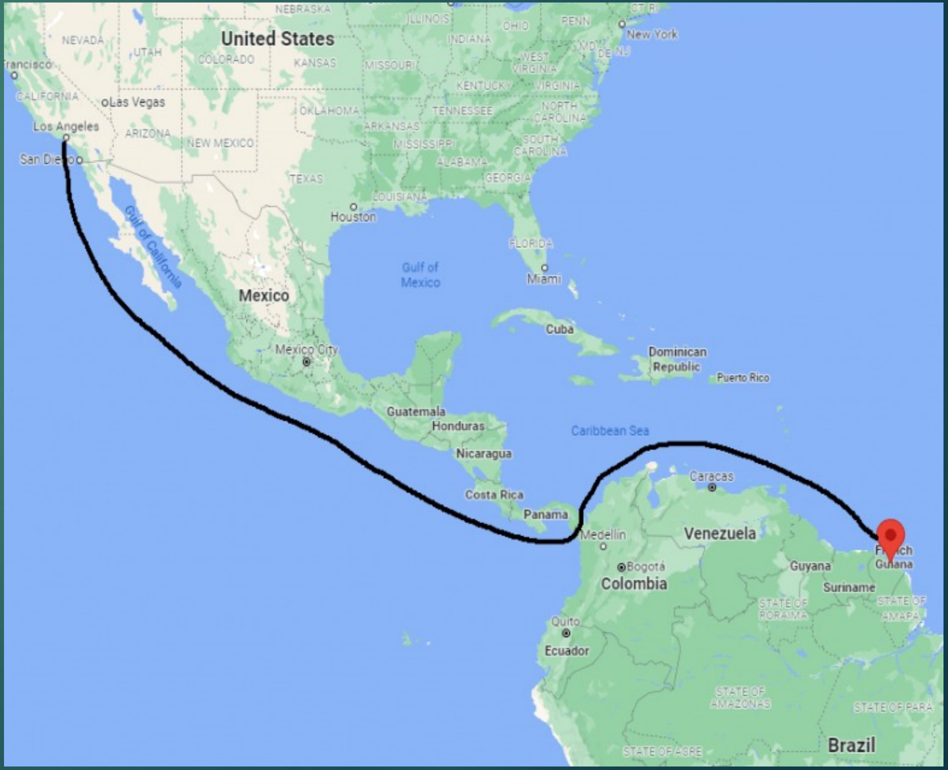
Photo credits: NASA flicker/Chris Gunn

After 15 Years of Ariane 5
rocket preparations
with ESA & Arianespace,
at last came …

The Launch Campaign at Centre Spatiale Guyanais (CSG)

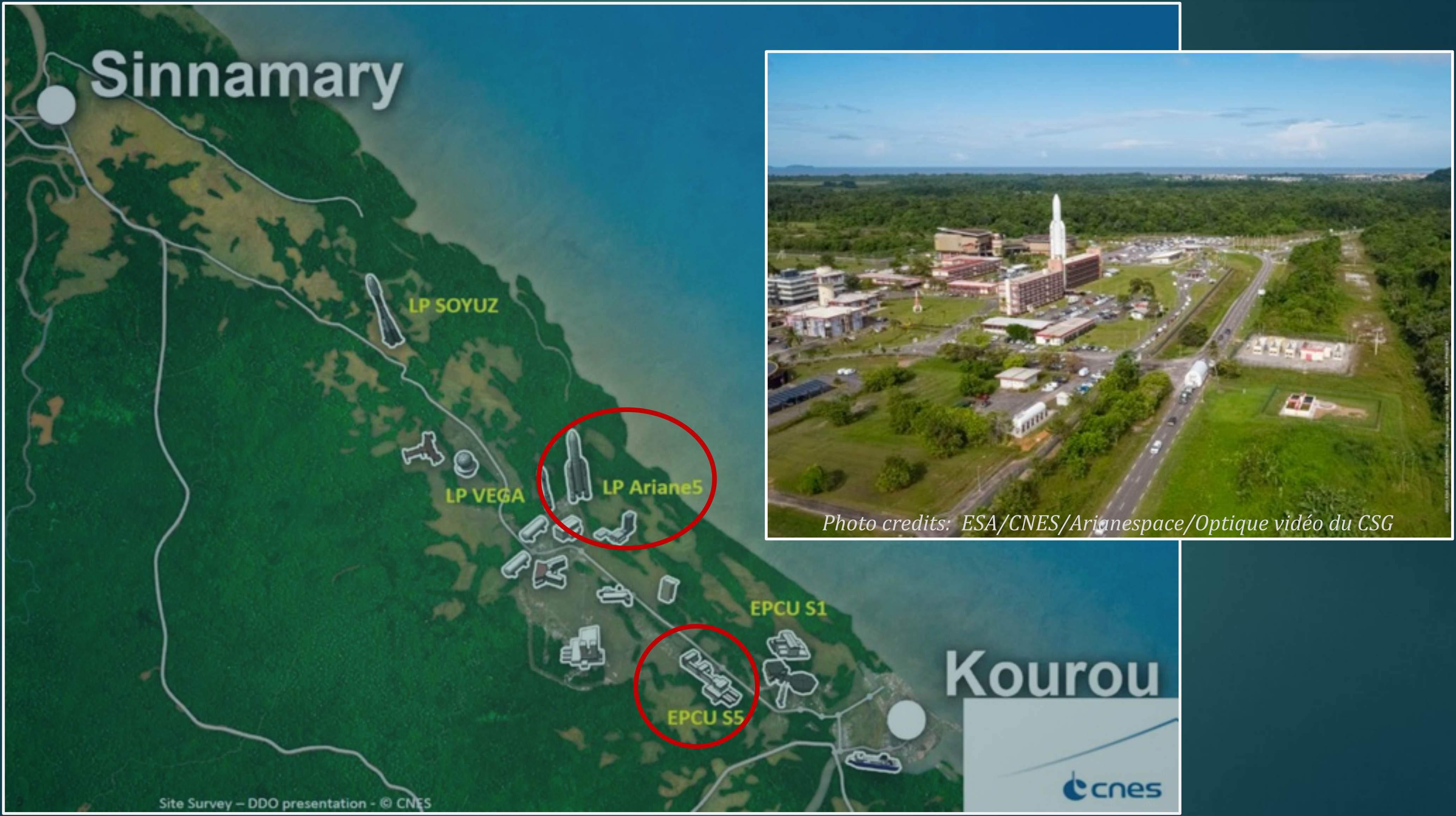
17 Septembre – 25 Decembre 2022

Kourou, French Guyana



Departure from LA and Arrival in Kourou

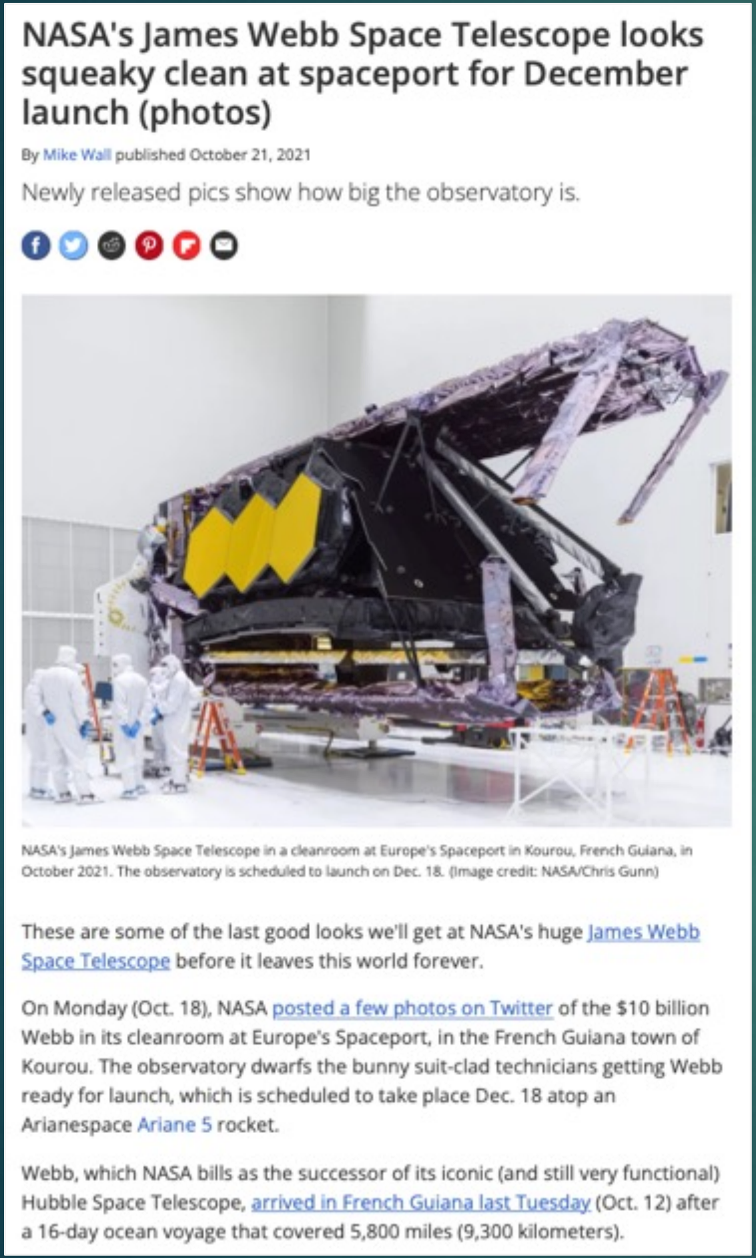
CSG in Kourou, French Guyana



Site Survey – DDO presentation - © CNES

Photo credits: ESA/CNES/Arianespace/Optique vidéo du CSG

The Telescope arrived squeaky clean …



NASA's James Webb Space Telescope looks squeaky clean at spaceport for December launch (photos)

By Mike Wall published October 21, 2021

Newly released pics show how big the observatory is.

NASA's James Webb Space Telescope in a cleanroom at Europe's Spaceport in Kourou, French Guiana, in October 2021. The observatory is scheduled to launch on Dec. 18. (Image credit: NASA/Chris Gunn)

These are some of the last good looks we'll get at NASA's huge James Webb Space Telescope before it leaves this world forever.

On Monday (Oct. 18), NASA posted a few photos on Twitter of the $10 billion Webb in its cleanroom at Europe's Spaceport, in the French Guiana town of Kourou. The observatory dwarfs the bunny suit-clad technicians getting Webb ready for launch, which is scheduled to take place Dec. 18 atop an Arianespace Ariane 5 rocket.

Webb, which NASA bills as the successor of its iconic (and still very functional) Hubble Space Telescope, arrived in French Guiana last Tuesday (Oct. 12) after a 16-day ocean voyage that covered 5,800 miles (9,300 kilometers).

… except for one little oily spot

Portable HEPA filter banks used in each room with JWST

Each area transformed -
by cleaning, bagging, sealing covering, removing

The outstanding LS CC Team included

- 10 Engineers
    - 7 NASA
    - 3 NG
- 8 Technicians

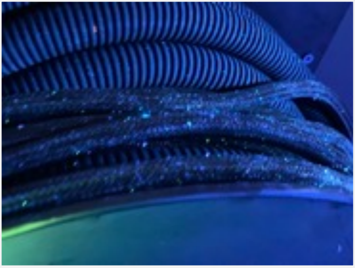


Photo Credits: NASA

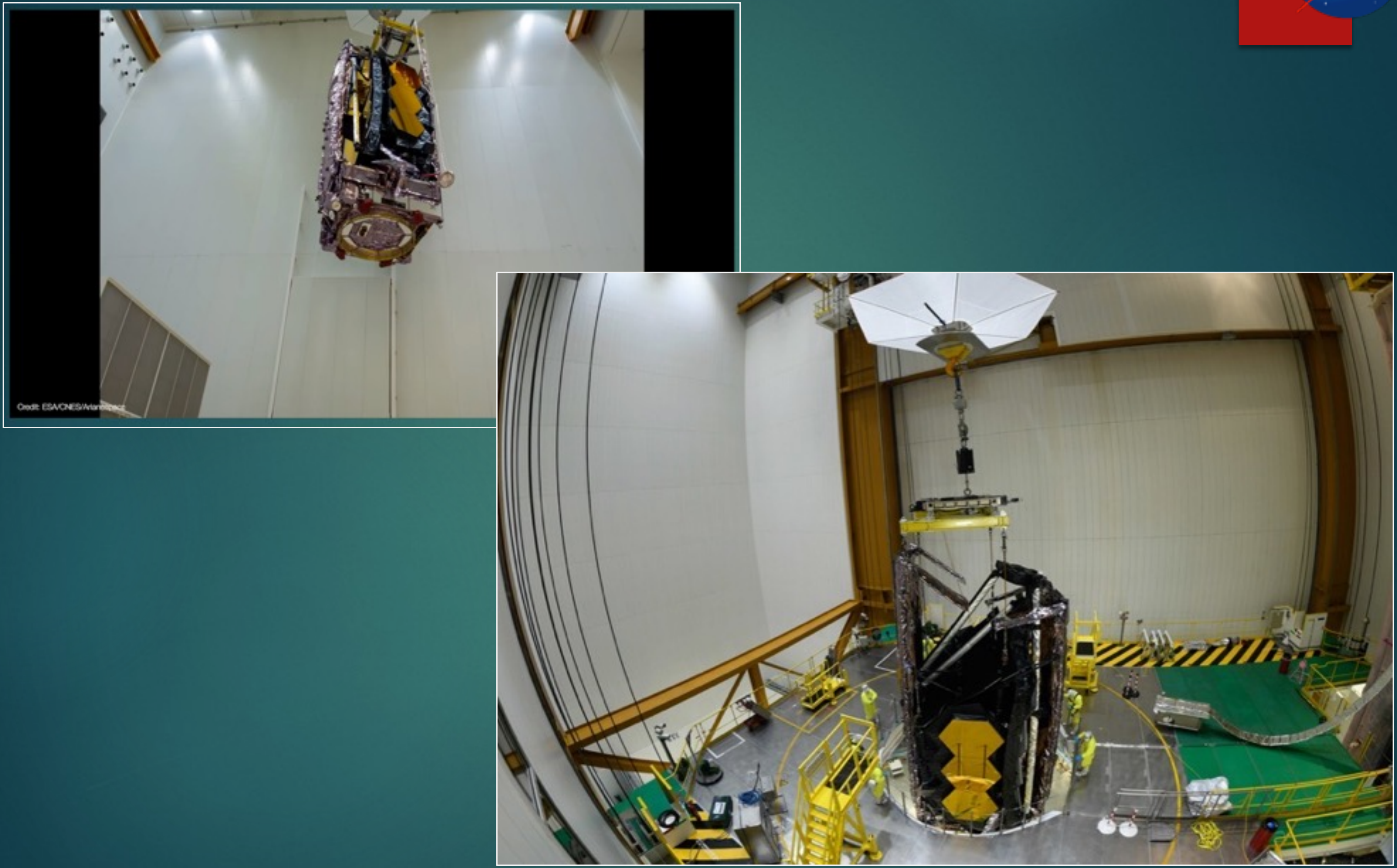
Used Local Resources, worked with CSG Counterparts

Photo Credits: NASA

Last steps in the Final Assembly Building (BAF)

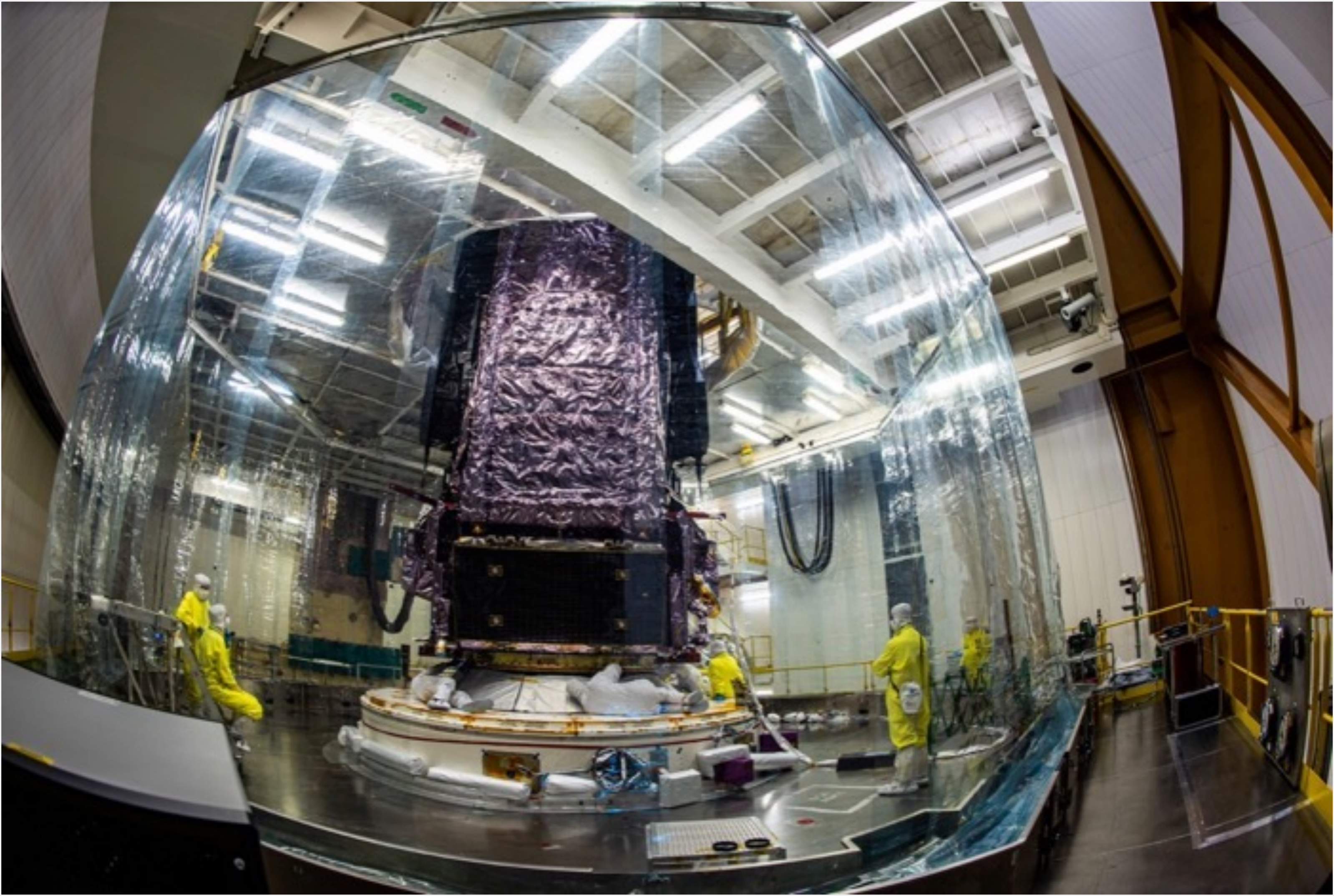
The Biggest Challenge of the campaign was in the BAF

In the BAF, JWST was lifted to the rocket

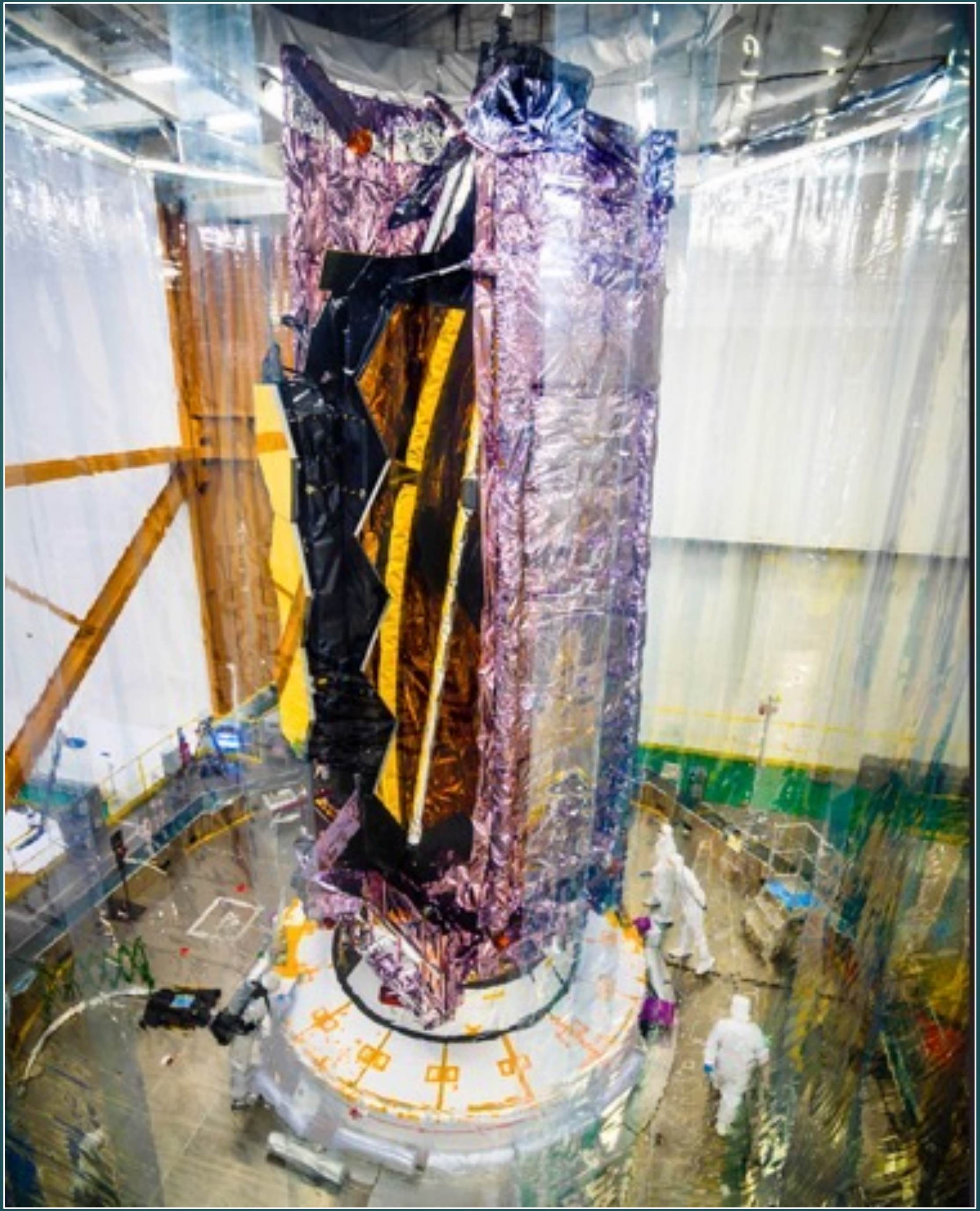


Credit: ESA/CNES/Arianespace

… and enclosed in a special-built enclosure



Platform was raised, and a cleanroom created



Enclosed in the Fairing and Ready to Launch

Launch Pad Astronomy Recap of the CC Effort

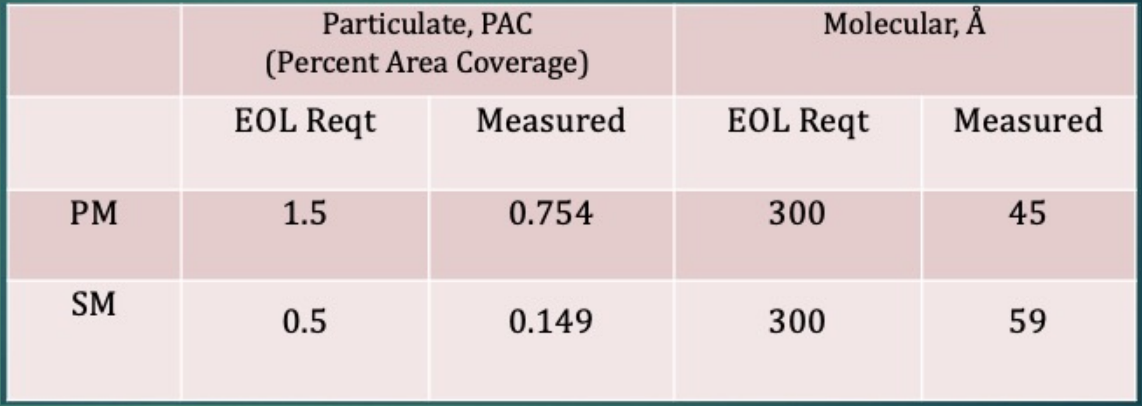

Credit: ESA/CNES/Arianespace

Launch Pad Astronomy podcasts, (https://www.youtube.com/watch?v=SnGhe19f5Ws) titled James Webb Telescope to Launch Christmas -Eve- Day!

At last,
after 25
years,
a
Christmas
Day
Launch!

Results Achieved

- Cleanliness levels
  - Better than required

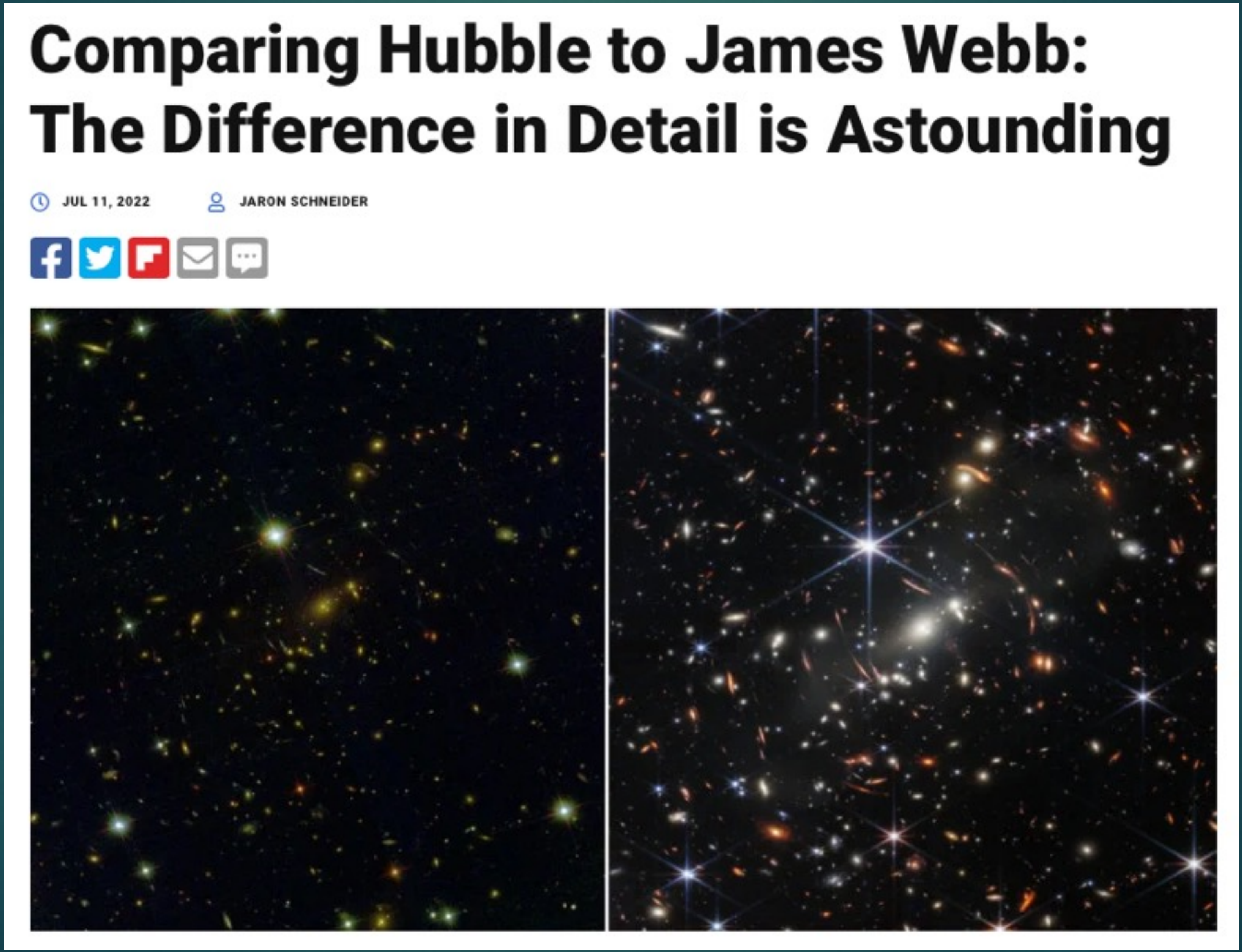


	Particulate, PAC (Percent Area Coverage)		Molecular, Å	
	EOL Reqt	Measured	EOL Reqt	Measured
PM	1.5	0.754	300	45
SM	0.5	0.149	300	59

- Water deposition
  - NONE on any sensitive surface
- Throughput and Sensitivity
  - Exceeded scientists' highest hopes and expectations

The Results that Matter Most

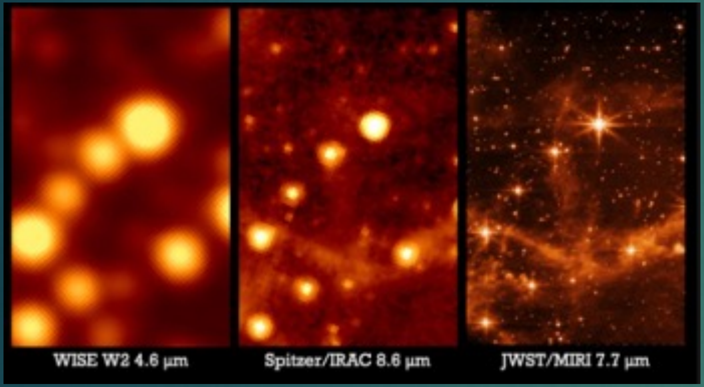
“The Webb Telescope Works. Perfectly.” - *NASA Watch*



Comparing Hubble to James Webb: The Difference in Detail is Astounding

JUL 11, 2022   JARON SCHNEIDER

The Results that Matter Most




Carina Nebula

Credit: NASA, ESA, and the Hubble Team

Credits: NASA, ESA, CSA, and STScI


Stephen's Quartet

The Results that Matter Most

Webb's First Images Displayed on Piccadilly Lights
by NASA's James Webb Space Telescope

Aug 2, 2022

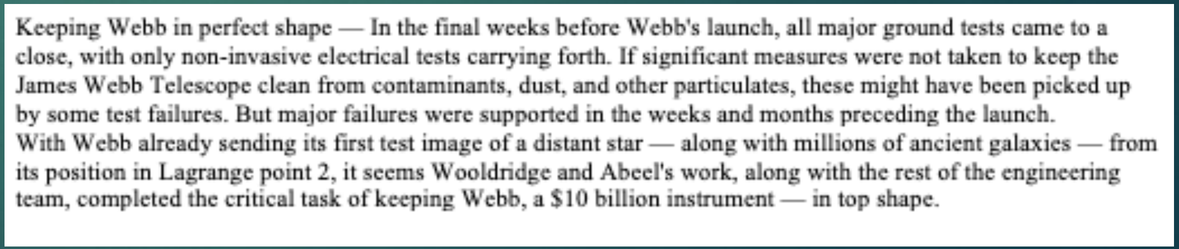
Webb Captures Stellar Gymnastics in The Cartwheel Galaxy

A large pink, speckled galaxy resembling a wheel with with a small, inner oval, with dusty blue in between on the right, with two smaller spiral galaxies about the same size to the left against a black background.
Credits: NASA, ESA, CSA, STScI

James Webb Telescope: How to keep a $10 billion instrument 100 percent clean

Any small particulates or molecular films could drastically reduce Webb's sensitivity.

Brad Bergan
Created: *Mar 18, 2022, 4:55 PM*



Keeping Webb in perfect shape — In the final weeks before Webb's launch, all major ground tests came to a close, with only non-invasive electrical tests carrying forth. If significant measures were not taken to keep the James Webb Telescope clean from contaminants, dust, and other particulates, these might have been picked up by some test failures. But major failures were supported in the weeks and months preceding the launch.
With Webb already sending its first test image of a distant star — along with millions of ancient galaxies — from its position in Lagrange point 2, it seems Wooldridge and Abeel's work, along with the rest of the engineering team, completed the critical task of keeping Webb, a $10 billion instrument — in top shape.

On a Personal Note,

My daughter Julia's life has spanned that of the James Webb Space Telescope.

In February 2022 there was good news:

Both my Daughter and my Telescope were working!