Observatory Update

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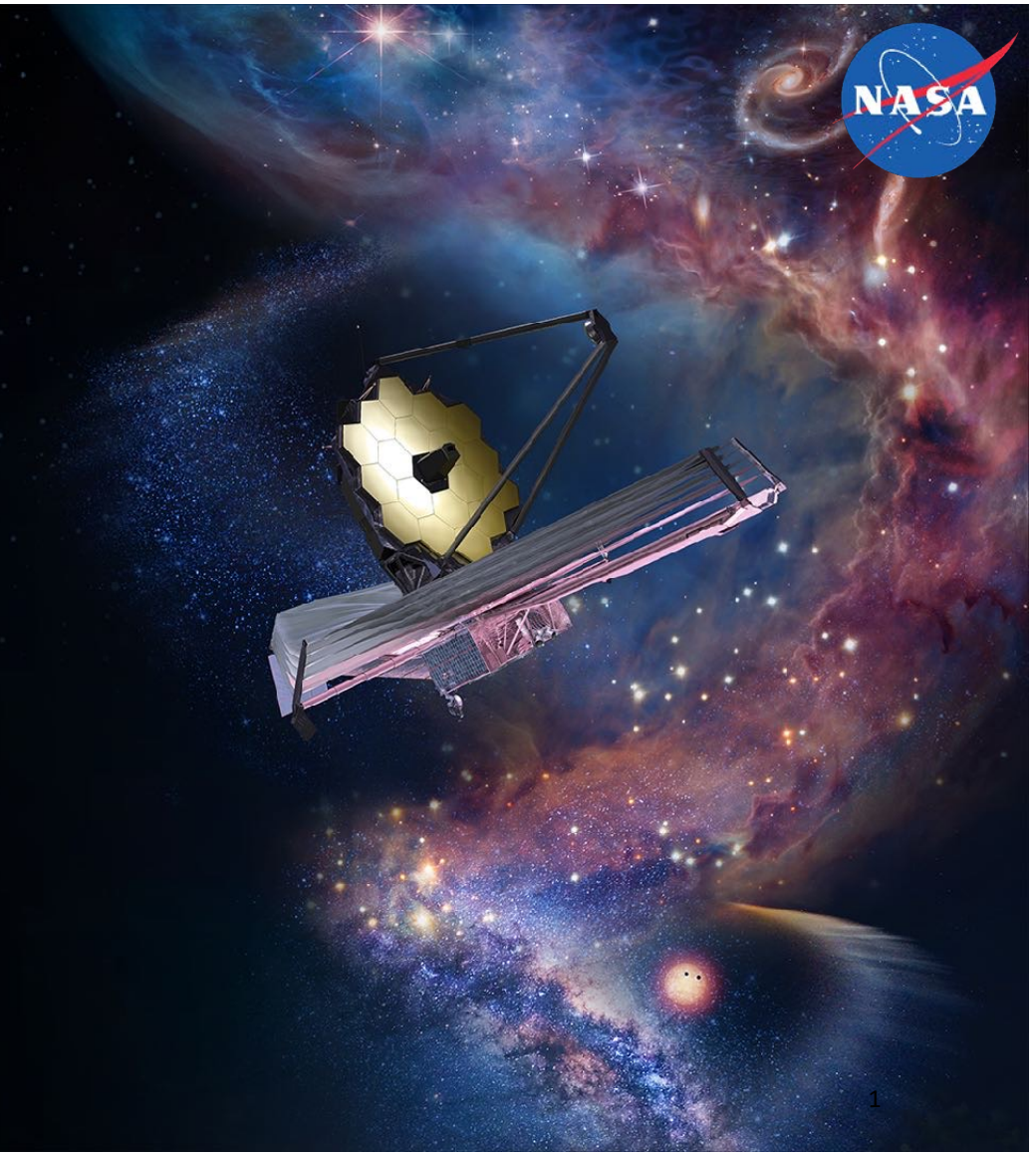
JSTUC Meeting #11
08 February 2022; L+45 days

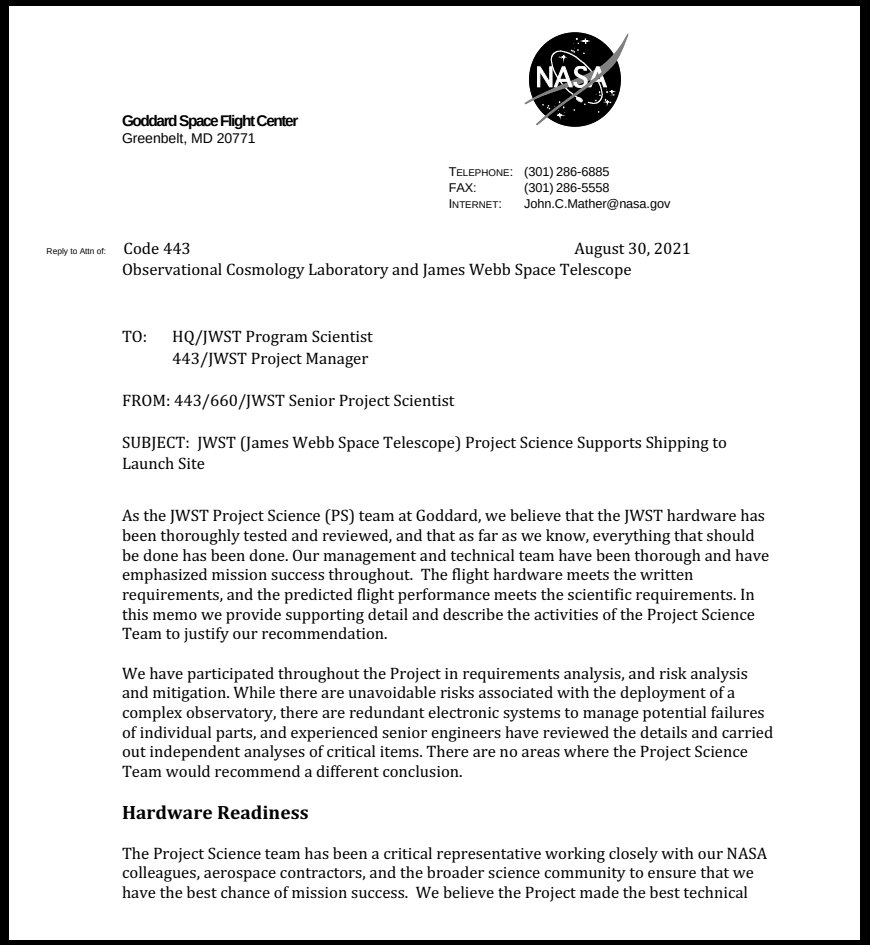


Observatory Status

- Observatory State of Health is ***GREEN***.
- Pre-launch performance requirements were met.
- Commissioning has gone spectacularly well to date.
  - Ariane launch perfect.
  - Mid course corrections made on time.
  - All deployments successfully executed.
  - Hardware modes all functional.

Project Science Support of Pre-Ship

- The Level 1 requirements from the Program Plan, the Science Requirements, and the Systems Engineering Technical Performance Metrics are all being met.
- Our management and technical team have been thorough and have emphasized mission success throughout.
- Project Science was involved throughout the development process, including reviews at a number of levels, from top level to technical discussions.



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Reply to Attn of: Code 443 August 30, 2021
Observational Cosmology Laboratory and James Webb Space Telescope

TO: HQ/JWST Program Scientist
443/JWST Project Manager

FROM: 443/660/JWST Senior Project Scientist

SUBJECT: JWST (James Webb Space Telescope) Project Science Supports Shipping to Launch Site

As the JWST Project Science (PS) team at Goddard, we believe that the JWST hardware has been thoroughly tested and reviewed, and that as far as we know, everything that should be done has been done. Our management and technical team have been thorough and have emphasized mission success throughout. The flight hardware meets the written requirements, and the predicted flight performance meets the scientific requirements. In this memo we provide supporting detail and describe the activities of the Project Science Team to justify our recommendation.

We have participated throughout the Project in requirements analysis, and risk analysis and mitigation. While there are unavoidable risks associated with the deployment of a complex observatory, there are redundant electronic systems to manage potential failures of individual parts, and experienced senior engineers have reviewed the details and carried out independent analyses of critical items. There are no areas where the Project Science Team would recommend a different conclusion.

Hardware Readiness

The Project Science team has been a critical representative working closely with our NASA colleagues, aerospace contractors, and the broader science community to ensure that we have the best chance of mission success. We believe the Project made the best technical

Observatory Performance Verified

- JWST performance follows a requirements-based framework, that flow from the JWST Program Plan (Level 1), down to the Systems/Segments (Level 2), and the Elements (Level 3).
  - 6,854 requirements in total.
- Verification is "a formal process using the method of test, analysis, inspection or demonstration, to confirm that a system and its associated hardware and software components satisfy all specified requirements."
- A Requirement Verification Report (RVR) was written and signed for each requirement before launch.

Observatory Kept Clean

- Contamination control is of utmost importance to preserve Webb's high transmission, exquisite image quality, and low backgrounds.
- Launch site facilities were not designed for scientific spacecraft like Webb, necessitating that the budgets held significant allocations for launch processing.
- The Webb contamination team has worked alongside ESA to develop a HEPA filtration system and implement new contamination mitigation protocols.
- Contamination team preliminary report is that all contamination requirements have been met.

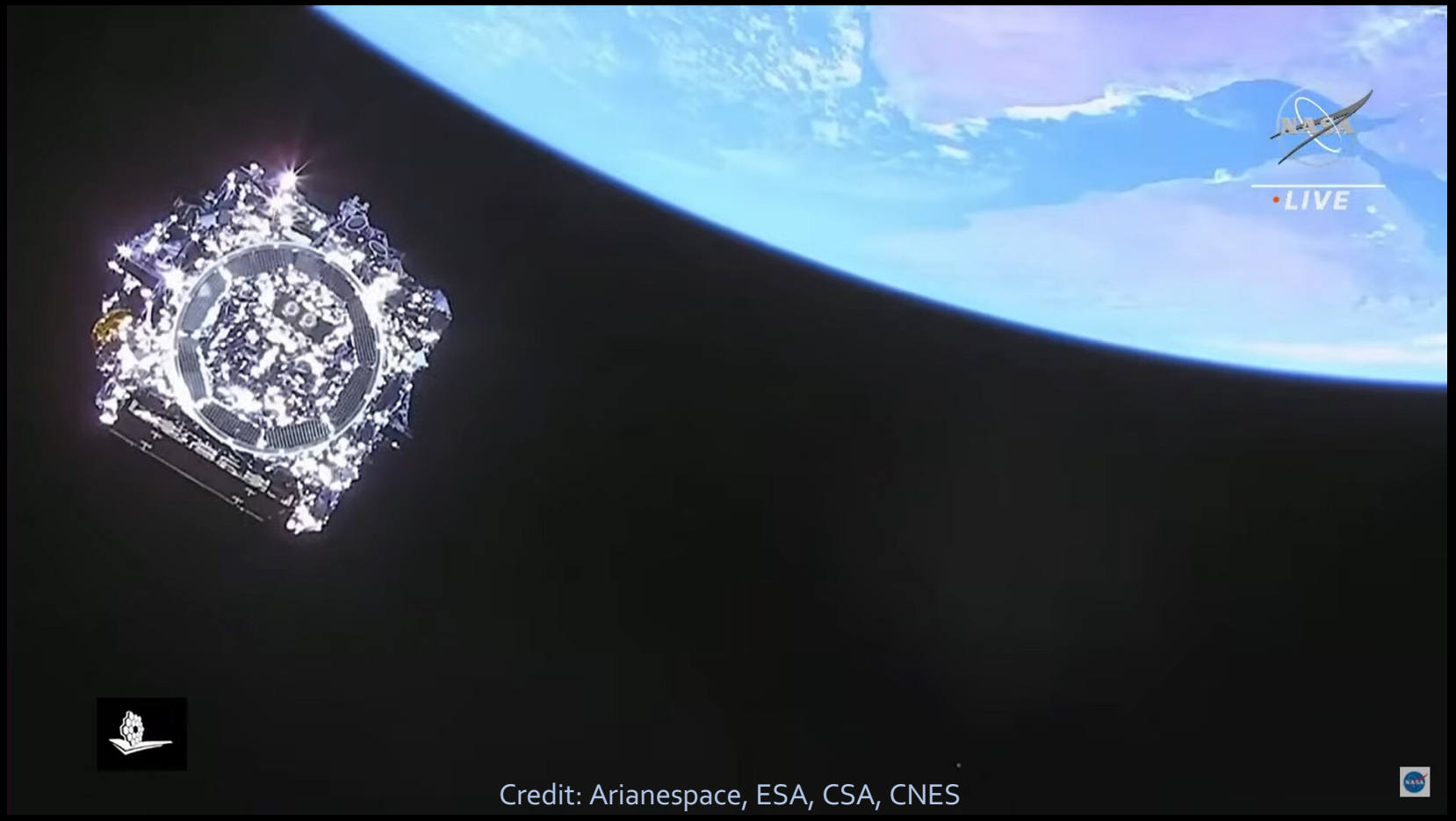
The primary mirror was cleaned following cryotesting at the Johnson Space Center (above). The secondary mirror was cleaned using similar brushing technique prior to shipping to the launch site.
Credit NASA/C. Gunn

Perfect Launch by Ariane

- Launched on Christmas morning EST (12/25) where the commentator made the call "lift off from a tropical rainforest to the edge of time itself."
- Ariane 5 launch nominal for both our separation velocity and launch and ascent thermal exposure.

Credit NASA/C. Gunn

Go forth, Webb



Credit: Arianespace, ESA, CSA, CNES

Propellant System

- Propellant is the only consumable aboard Webb.
- Launched with filled propellant tanks.
- Two types of propellant:
  - Fuel
  - Oxidizer
- Fuel + Oxidizer (bi-propellant SCAT thrusters) used for mid-course corrections and station keeping around L2.
- Fuel (mono-propellant smaller thrusters) used for momentum management.

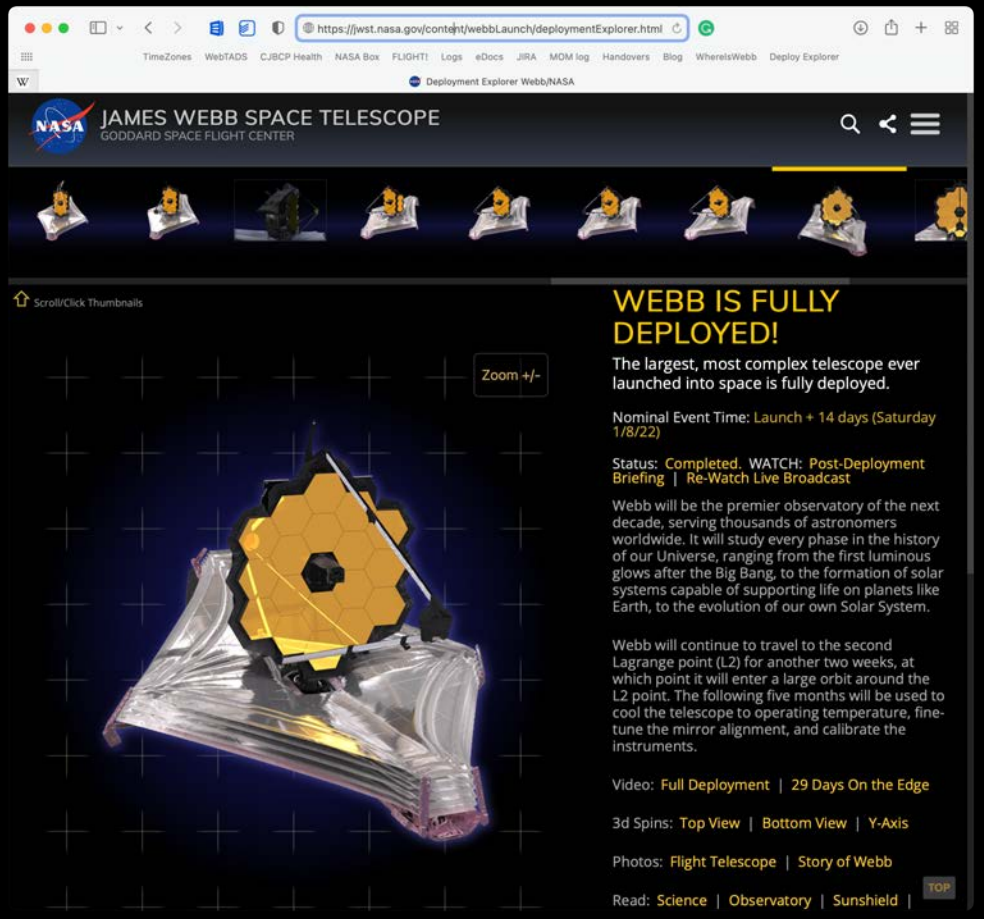
Webb fueling at the launch site.
Credit: ESA-CNES-Arianespace/Optique video du CSG – P Piron

Propellant Lifetime

- L1 Requirement: Level 1 performance shall be achieved for a minimum of 5 years.
- L2 Requirement: Propellant shall be sized for 10.5 years of operation after completion of the launch phase.
- Propellant posture is currently ***excellent:***
  - Launch date fortuitously required smaller mid-course corrections
  - Ariane executed a nominal launch
  - Mid-course corrections executed accurately and on time
  - Solar torque calibration that drives momentum accumulation and fuel consumption has been carried out (analysis expected later today).
- ***Preliminary estimate is > 20 years of propellant for operations!***

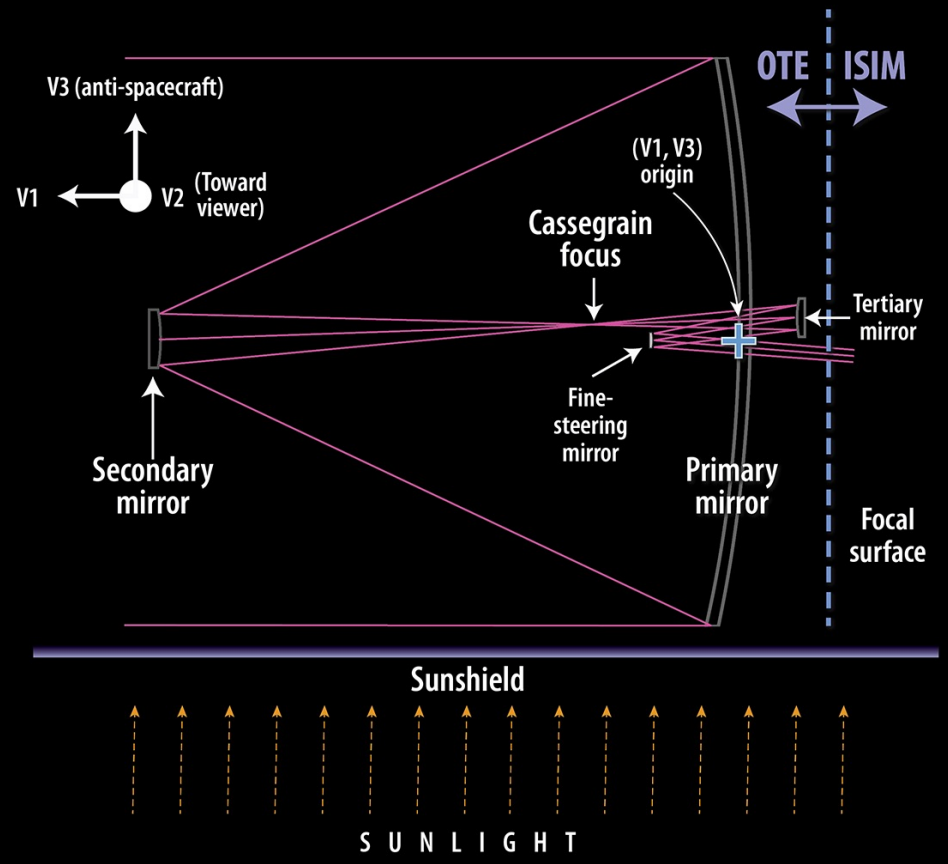
Major Deployments Complete

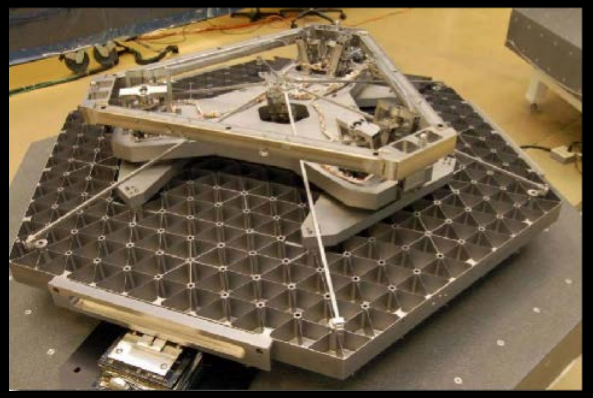
- All major deployments are complete, including all 178 of our release mechanisms.
- Fully tensioned sunshield should provide the right thermal isolation to meet our requirements.
- Completed on the planned schedule.



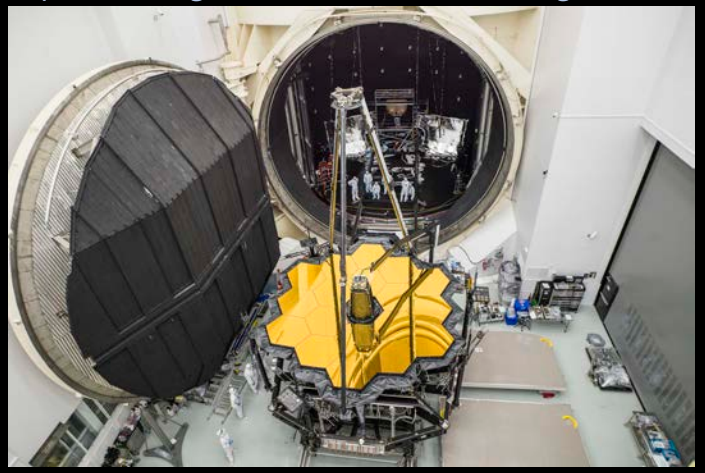
Webb Deployment Explorer webpage

Telescope Overview





Primary mirror segment actuators with 7 degrees of freedom



Telescope emerges after cryogenic testing at NASA/JSC

Telescope Commissioning Objectives

- Align the telescope (18 segments + secondary)
- Characterize Optical Performance
  - Line of sight
  - Wavefront static
  - Wavefront stability
  - Throughput
  - Backgrounds and stray light

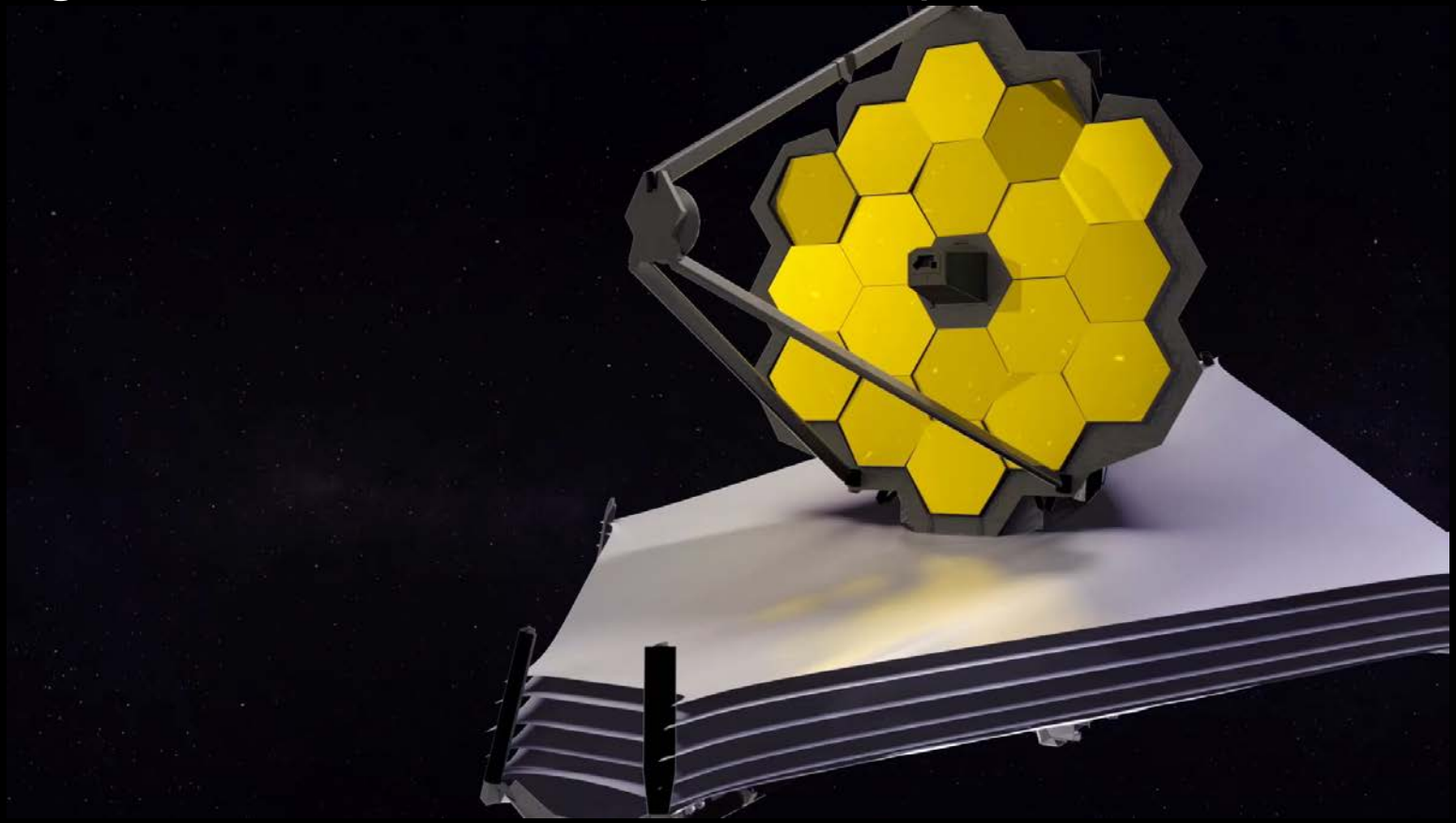
Telescope Commissioning

Here →

Telescope Commissioning Stage	Goal
Segment Deployments	release segments from launch positions and nominal deploy
Segment Image Identification	determine segment positions and telescope boresight
Segment alignment	minimize wavefront error within each segment
Image Stacking	overlaps the 18 individual segment PSFs
Coarse Phasing	aligns segments within a wavelength
Fine Phasing	aligns segments to fraction of a wavelength
Telescope alignment over field of view	achieves good alignment seen from all SIs
Iterate alignment for final correction	repeat process as needed to iterate to convergence
Thermal Stability Assessment	characterization of on-orbit stability
Monitoring and Maintenance	ensures alignment over time

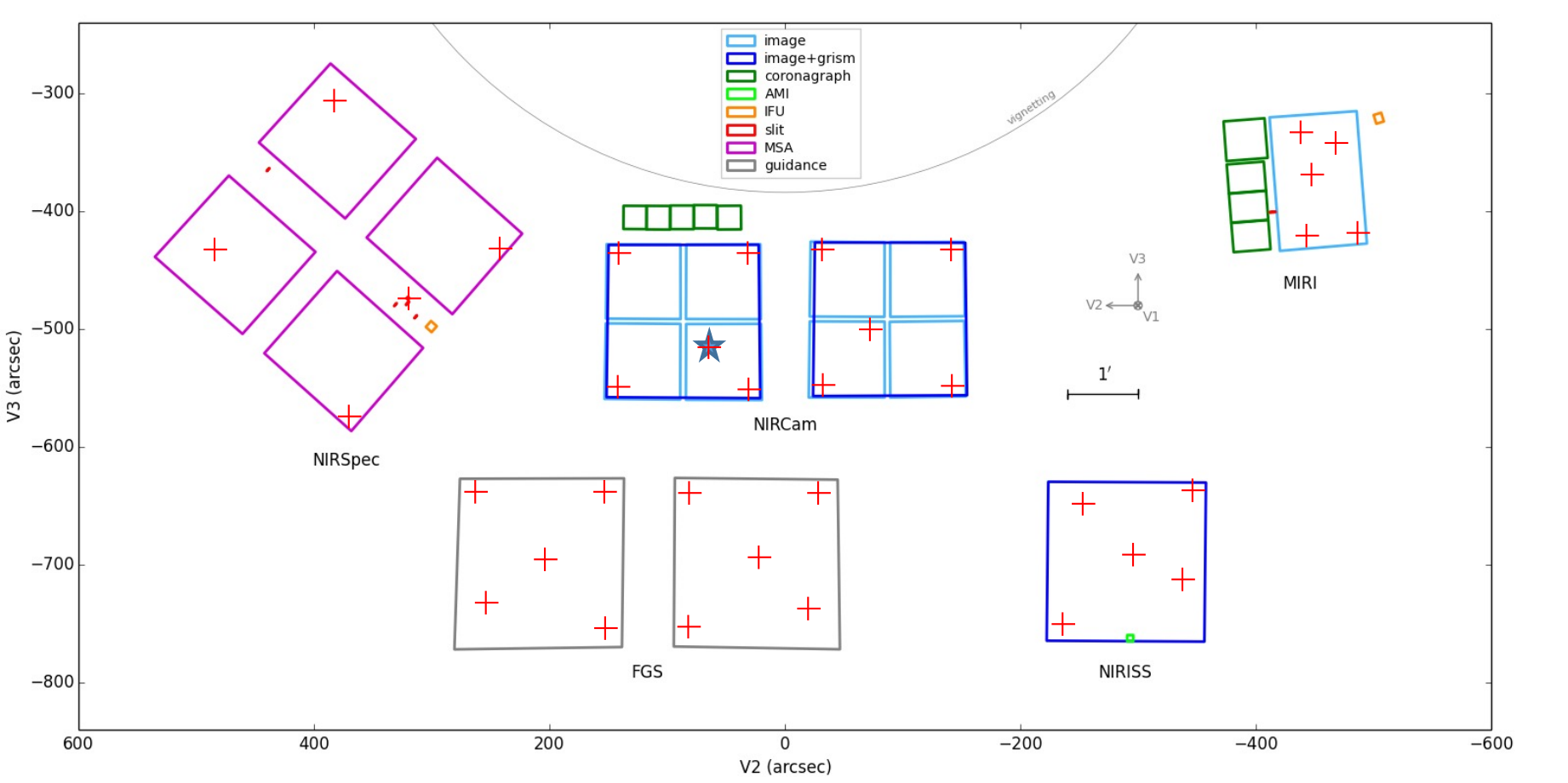
Telescope Alignment

Telescope Alignment
(using Science Instruments, primarily NIRISS and NIRCam)



https://svs.gsfc.nasa.gov/12721; See Knight et al. 2012

Telescope Alignment Across Multiple Fields

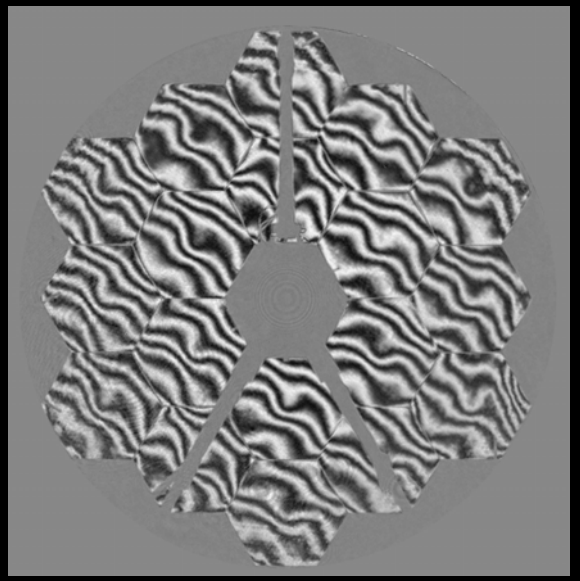


See JDox JWST Field of View

Prepared for Alignment Activities

Testbed Telescope at Ball Aerospace

Webb Cryotesting at NASA Johnson Space Center



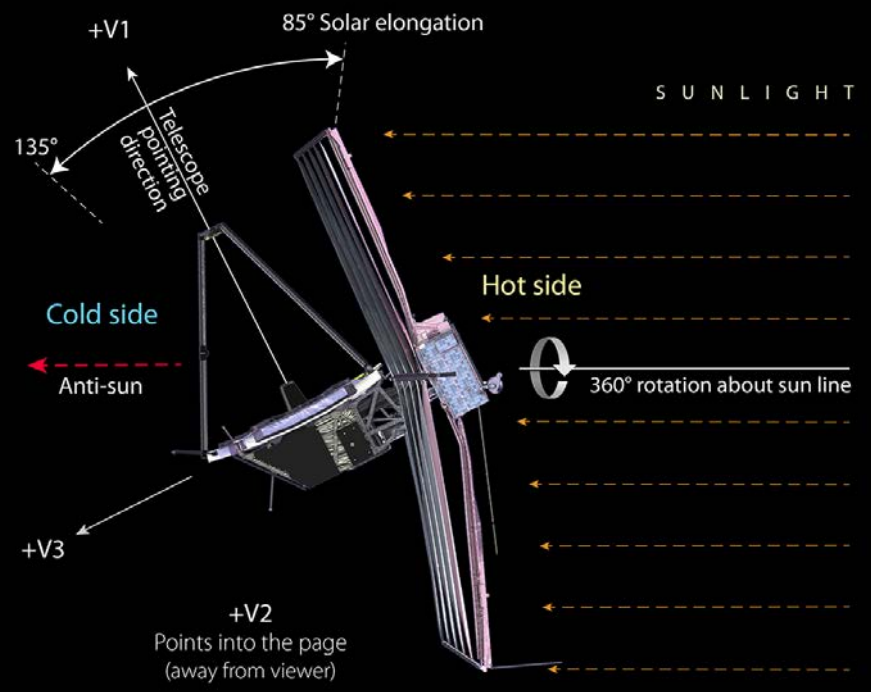
Interferogram from JSC Cryotesting

Line of Sight

- **Pointing** with orientations from the star trackers (coarse pointing), < 8" abs.) or the star trackers and the fine guidance sensor (fine pointing, < 1" abs.).
- **Fine guiding stability** (i.e., jitter) uses a low frequency control loop from the fine guidance sensor to the fine steering mirror.
  - Uncorrected LOS jitter disturbances are driven by reaction wheel and cryocooler exported vibrations. An activity is planned to change cryocooler pulse frequency while monitoring the line of sight jitter and select the optimal frequency.
- **Moving target tracking** for targets at rates of 30 mas/s with testing up to 60 mas/s.

Wavefront Stability

- Wavefront drifts anticipated as Webb is pointed within its field of regard, from solar heating variations that change temperatures (< 100 mK, < 50nm drift).
- Commissioning activities will measure the wavefront stability at minutes, hours, and days. The drift amplitudes and time constants will be measured.
- We will begin monitoring wavefront stability every 2 days for the duration of the mission, with an expectation to correct no more than every 2 weeks. The commissioning stability activity will characterize drifts over this 2 week period for a worst case slew in pitch.



The dominant solar heating variations come from changes in the solar elongation (pitch) angle.

Background Characterization

- In many modes (NIR broadband imaging, long wavelength MIRI), the background contributors are dominant over the detector noise terms.
- Figure at right from STScI's JDox shows the nominal contributions to the background from various terms (J. Rigby fit to P. Lightsey models).
  - In-field = Sky background
  - Stray light = Sky scattered