



STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

JWST Commissioning Progress

JWST Users Committee

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Overview of Commissioning

Level 2 Mission Requirement MR-45:

- *The planned commissioning phase shall end no later than six months after launch*

The timeline is success-oriented

- No contingency programs appear in the timeline

No commissioning data will be released during commissioning

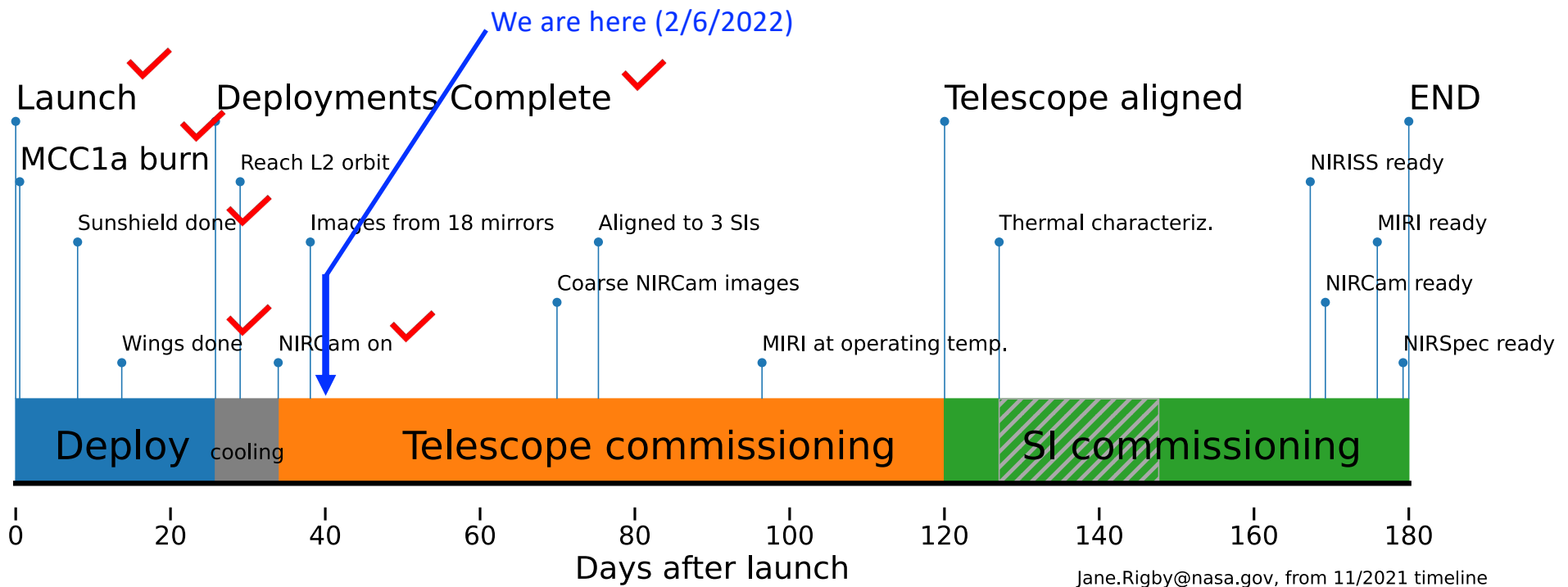
- When commissioning is complete all data will be released
- All observing programs are designed for commissioning needs but some may be scientifically interesting

Early Release Observations will be executed near or at the end of commissioning

- No commissioning data will be released before the EROs are released
- When commissioning is complete all data will be released



Three Phases of Commissioning





Launch & Midcourse Corrections

Ariane launch put us on excellent trajectory

- Less than 1 sigma deviation from design trajectory

Executed three highly accurate midcourse corrections

- Time critical MCC1a occurred exactly on time at L+12.5 hours
- MCC1b on time on day 2.5
- MCC2 executed on day 30, intentionally one day later than nominal but velocity change was so small that it did not matter
- All three burns within 1% of planned velocity change

Station-keeping maneuvers every 21 days to maintain halo orbit about L2

- Next one may be skipped – early projection is burn would be less than 10 sec.

Momentum unloads periodically, approximately every 1-2 weeks

- Momentum accumulates due to solar pressure

Fuel reserves are excellent

- Expect ~20 years of fuel life



Deployment Sequence

178 Non-explosive actuators... and they all worked!

- 12/25/2021: DOL – SC Solar Array (SA)
- 12/26/2021: L+1 – SC Gimbal Assembly (GAA)
- 12/28/2021: L+3 – Fwd & Aft Unitized Pallet Structure (UPS)
- 12/29/2021: L+4 – OTE Deployable Tower Assembly (DTA), Cryocooler Jitter Attenuator Assembly (CJAA) and +V3 ISIM Electronics Compartment Releases
- 12/30/2021: L+5 – SC Cryocooler, SS Aft Flap, SS Motor Aliveness & Membrane Cover Assembly Releases
- 12/31/2021: L+6 – SS Membrane Cover Assembly (MCA) Releases & SS +J2/-J2 Mid-Boom Assemblies
- 01/03/2022: L+9 – SS Membrane Layer 1, 2 & 3 Tensioning
- 01/04/2022 : L+10 – SS Membrane Layer 4 & 5 Tensioning, SC DRSA-V & STSA Releases
- 01/05/2022 : L+11 – OTE Secondary Mirror Support Structure (SMSS)
- 01/06/2022 : L+12 – OTE Aft Deployable ISIM Radiator (ADIR)
- 01/07/2022 : L+13 – OTE +V2 Primary Mirror Backplane Assembly (PMBA) Wing
- 01/08/2022 : L+14 – OTE –V2 Primary Mirror Backplane Assembly (PMBA) Wing

Mirror deployments from launch capture location to nominal operating location

- 8 days to move 12.5 mm (slower than grass grows but more exciting to watch)



Cooldown and Contamination

Cooling accelerated when the sunshield was deployed and tensioned on days 6 – 10

Primary concerns are safety of hardware and avoidance of contamination, mostly ice

- Keeping temperatures and gradients within specified limits
- Keeping some vulnerable surfaces $\sim 10\text{K}$ warmer than surrounding structures
 - NIRSpec MSA heater was turned on immediately after MCC1b on day 2.7
- Maintain this through the “water band” from 140 – 165K below which ice will not migrate

Contamination control heaters used to manage the cooldown of the instruments

- Similar cooldown strategy used in OTIS test
- All instruments are below water band and most heaters have been turned off
- Steady state temperatures will be reached approximately 2 months from now

Water ice will be measured multiple times throughout cooldown using the NIRCам grism and (later) the NIRSpec grism

- Measure the equivalent width of 3.1 micron water ice absorption feature vs. time



Telescope Alignment

First steps on road to alignment have been done

- NIRCam first light was a prerequisite and successfully completed last week

Major steps remaining include

- Segment ID: which stellar image belongs to which mirror segment
- Global alignment: correct wavefront error on individual PM and SM segments with tip, tilt, decenters
- Closed loop guiding: 1st use of a guide star. Requires star trackers and FGS. Enables jitter characterization (induced by cryocooler and reaction wheels)
- Image stacking: single image produced by 18 small telescopes. Large piston errors between segments.
- Coarse phasing: reduce piston errors to a few microns. Done 3 times in commissioning.
- Fine phasing: refine segment tips and tilts using NIRCam weak lenses. Done 3 times. Results in a phased telescope at a single NIRCam field point.
- Multi-instrument multi-field (MIMF) WF sensing: correct WF error first in full NIRCam field, then in fields of NIR instruments, then over all instruments.
- MIMF2 and MIMF3: refinement of WF error

Telescope alignment complete on about day 120



Science Instrument Commissioning

Many SI activities during “Telescope Commissioning” (partial list)

- Power on & initialization, functional checks, wheel calibrations, MSA shutter checks, preliminary focus adjustments, darks, noise and gain estimates, subarray checks, MIRI cryocooler state transitions, MIRI detector anneals, internal flats and wavelength calibrations (especially NIRSpec)
- MIMF observations in support of OTE alignment

On-sky activities in months 5 & 6 (partial list)

- Final focus, astrometric cals, throughput, PSF characterizations, dither pattern verifications, wavelength cals, photometric zero points, grating flux and trace cals, slit transmission, photometric stability, NIRISS NRM performance, coronagraphic scattered light and contrast ratios, glints & ghosts



Observatory Level Activities

These activities cross SI borders or involve spacecraft performance

- Wavefront sensing & control. Sense every 2 days, control every 14 days
- Target acquisition
- Moving target tracking
- Guiding performance near giant planets
- Zodiacal emission and observatory thermal emission at mid-IR wavelengths
- Out-of-field scattered light
- Fuel slosh test – determines if small slews can be accelerated
- Medium angle maneuver test – can we skip guide star ID after $\lesssim 5$ arcmin slews?

Thermal stability test – the “thermal slew”

- Hot pitch for 5 days → cold pitch for 14 days → hot pitch for ½ day. These are the limits of FOR.
- Multiple instances of WF sensing – but *not* control – over this period
- Goal is to measure WF and roll stability under limiting conditions of solar illumination
 - Although full roll range not probed, validate stability over most taxing FOR pointings



When Are We Done? – Mode Readiness Criteria

SI teams, Project Scientists, and Commissioning Scientists developed quantitative criteria to establish readiness.

- Criteria usually less stringent than requirements. Striking a balance between performance and getting started on the science.
- We are not accepting performance less than requirements but a trade may be needed if a large amount of observatory time or work effort are needed to mitigate the problem
- Any unusual behavior will be investigated and mitigated to the extent possible
- Greatest utility of criteria expected to be for complex modes which we know will improve with time – coronagraphy, time series observations, and aperture masking interferometry
 - These will improve with experience, accumulation of reference library images, operational improvements, etc.
 - Can only get better by starting
- The 17 observing modes will be commissioned (declared science ready) separately
 - May start science with a small number of modes held back to complete commissioning activities and related investigations



When Are We Done? – Mode Readiness Criteria Examples

Imaging

- Sensitivity (minimum detectable flux to achieve a given S/N within a given time) should be no greater than 130% of exposure time calculator (ETC) predictions
- Full width at half maximum (FWHM) or encircled energy (EE) better than 85% of prediction at a minimum of 1 field point in each filter

Spectroscopy

- Sensitivity no greater than 130% of ETC predictions, 140% for IFU spectroscopy, averaged over the observed wavelength interval
- Dispersion solution errors less than 50% of a resolution element

Coronagraphy

- NIRCam: 5-sigma contrast of 10,000 at 1 arcsec with F335M and MASK335R with reference star subtraction

Time Series Observations

- Noise level of science target ≤ 100 parts per million (ppm) after removal of systematic effects, and within 30% of photon noise limit

Aperture Masking Interferometry

- Detect AB Dor C. Corresponds to a contrast of approximately 50 at ~ 0.3 arcsec.

Relative Photometric Stability

- The relative photometric response of imaging and spectroscopic modes shall be stable to better than 10%