STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

JWST Commissioning

JWST Users Committee

Scott Friedman (STScI)
Randy Kimble (GSFC)

December 9, 2020

Commissioning Overview

Definition of commissioning

- The collection of all flight activities required to assure that the Observatory is operational and ready to perform Cycle 1 science programs

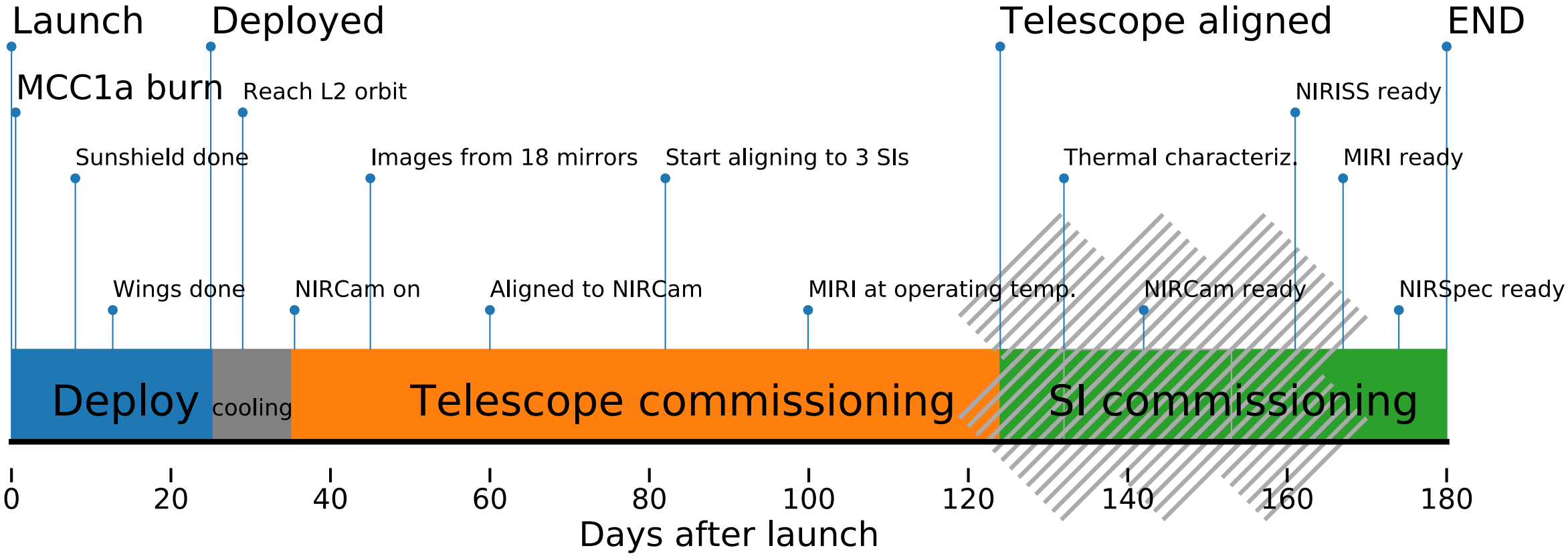
When does commissioning occur?

- Begins at launch
- *The planned commissioning phase shall end no later than six months after launch* (Level 2 Mission Requirement MR-45)

The timeline is success-oriented

- No contingency programs appear in the timeline

Three Phases Commissioning



Three Phases Commissioning – Phase 1

Spacecraft: days 0 – 26

- Launch & ascent, solar array deployment (31 minutes)
- Midcourse corrections 1a (12.5 hours) and 1b (2.5 days)
- Deployable Tower
- 5 layer sunshield deployment & tensioning
- Secondary mirror support structure deployed
- Primary mirror wings deploy
- Primary and secondary mirrors moved from launch snubbers to approximate optical positions
  - (12 mm of travel; takes ~10 days)
- MCC2 (29 days) – insertion into L2 halo orbit
- Cooling…cooling…cooling

Three Phases Commissioning – Phase 2

Optical Telescope Element (OTE): days 36 – 118

- Segment image location and identification
- Science instrument turn-on, initialization, mechanism characterization, darks, flat fields
- Image stacking
- Single field point (in NIRCam) fine phasing
- Multi-instrument multi-field fine phasing (two cycles + a third measurement)
- MIRI cryocooler operations and jitter measurements
- Wavefront sensing (every 2 days) and control (every 14 days)
- Cooling…cooling (steady state reached on about day 96)

OTE commissioning is the longest “single” activity in the commissioning flow

- Conservatively scheduled in the timeline
- Addition (or removal) of a MIMF cycle has large timeline implications
  - Up to 9 days per cycle, depending on number of steps required
  - This is a Key Decision Point

Three Phases Commissioning – Phase 3

Science Instrument (SI): days 119 – 179

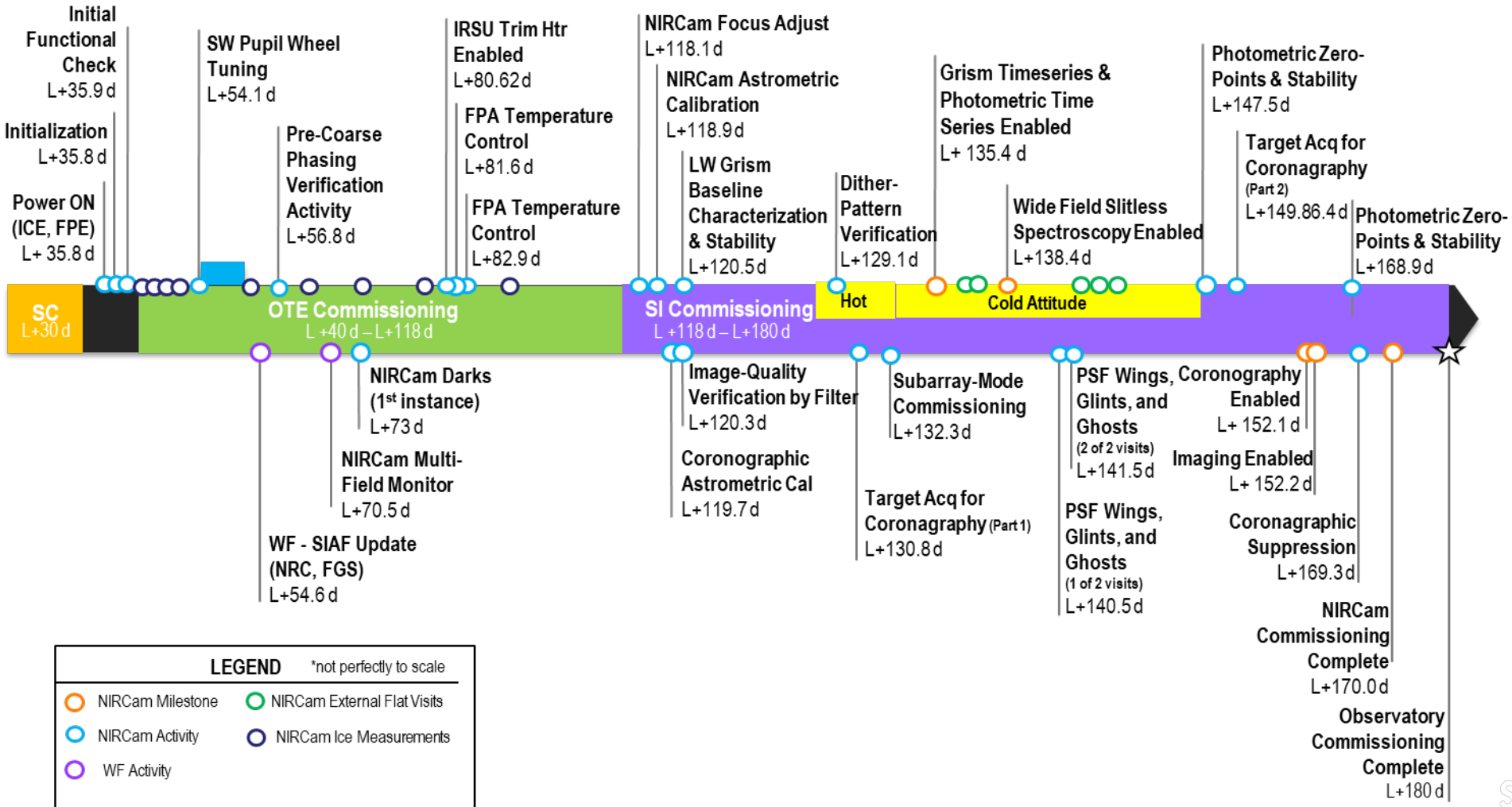
- SI focus (except MIRI)
- Astrometric calibration
- Photometric zero points
- PSF characterization
- Subarray characterization and location
- Spectroscopic characterization and wavelength calibration
- Scattered light and ghosts
- Photometric stability
- Target acquisition
- Thermal slew – characterization of observatory stability

Science readiness established by observing mode

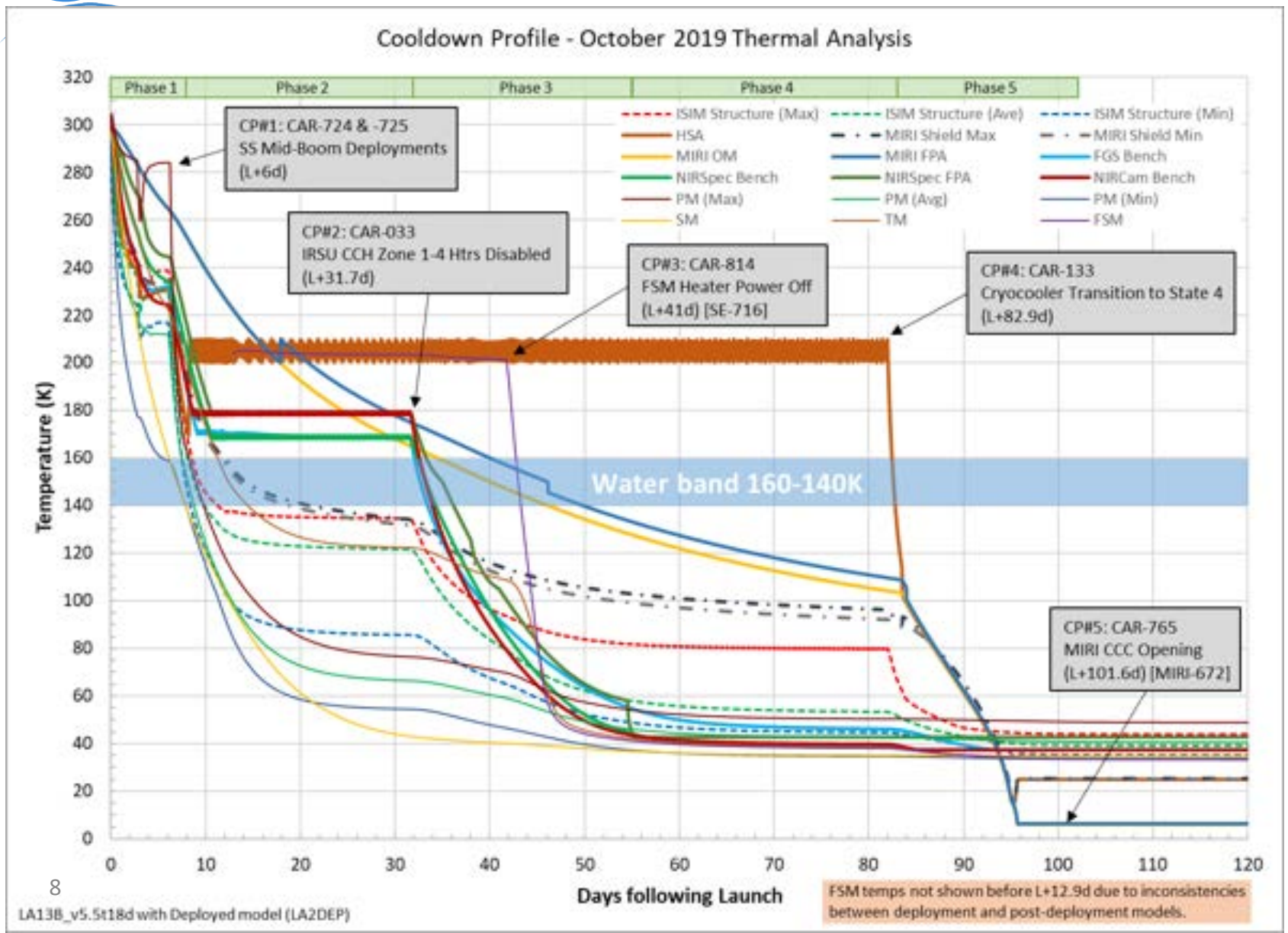
- NIRCam grism & photometric time series – day 136
- NIRSpec modes – day 179

Example of a Real Timeline

NIRCam Commissioning



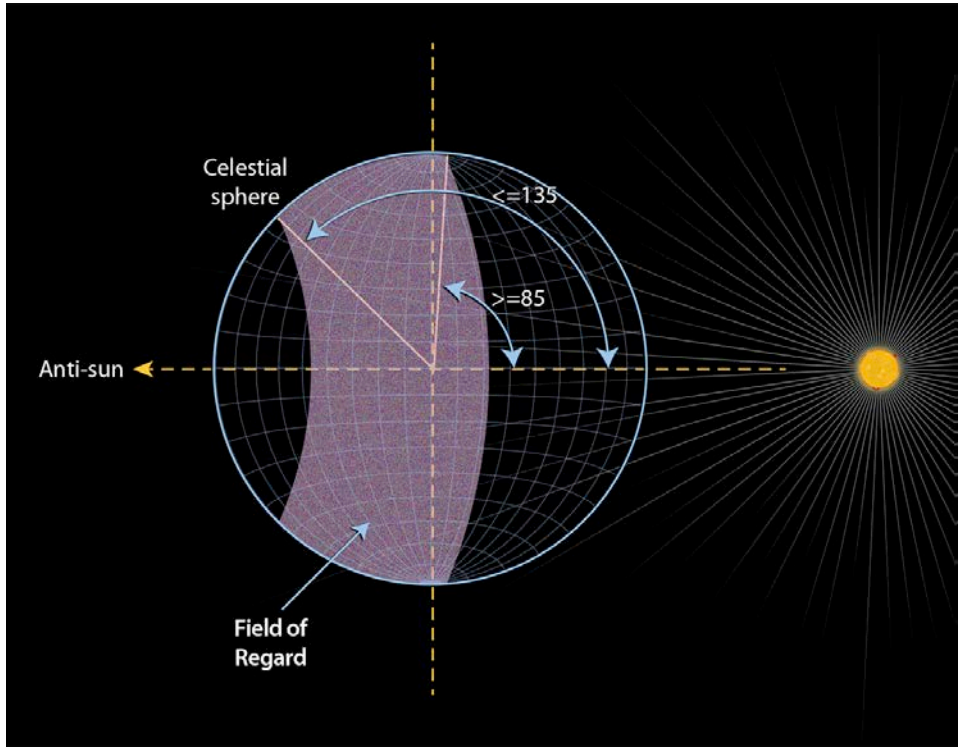
The Cooldown Profile

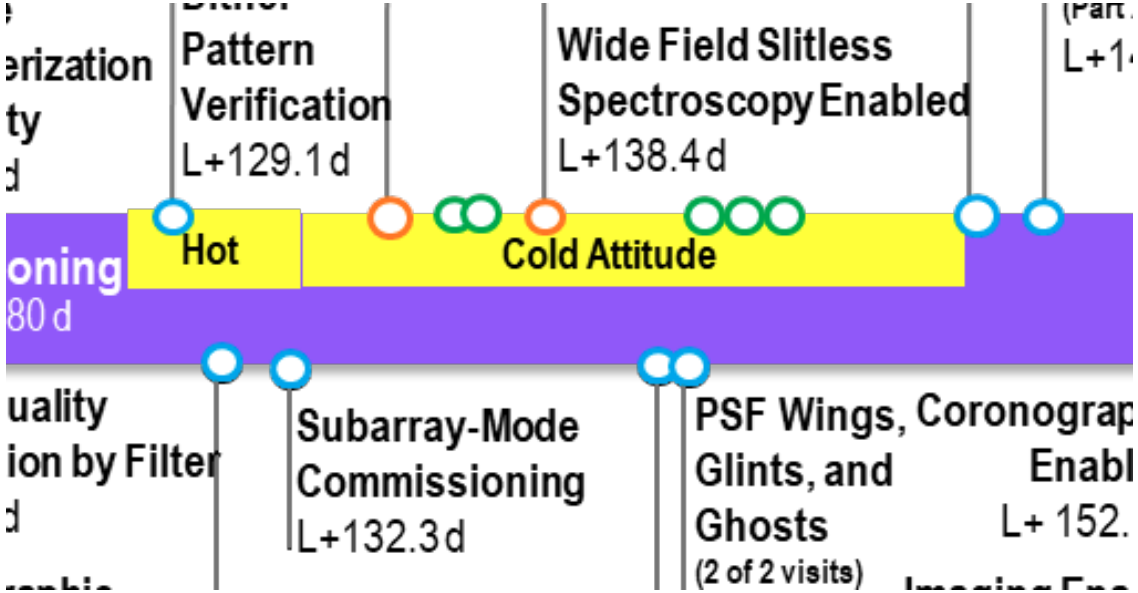


- Careful attention to contamination control, especially water ice
- MIRI cryocooler state transitions can disturb OTE primary mirror backplane temperature
- Many constraints must be satisfied as the observatory cools

Investigating Thermal Stability

- Allowable solar pitch angle (85° – 135°) of boresight defines the Field of Regard (FOR)
- Normal science will be many short visits (~hrs) with some long visits (~days).
- Solar illumination of observatory will change frequently
- Thermal equilibrium will typically *not* be reached during or between observations





The Thermal Slew

Goal is to measure the response of observatory to thermal changes

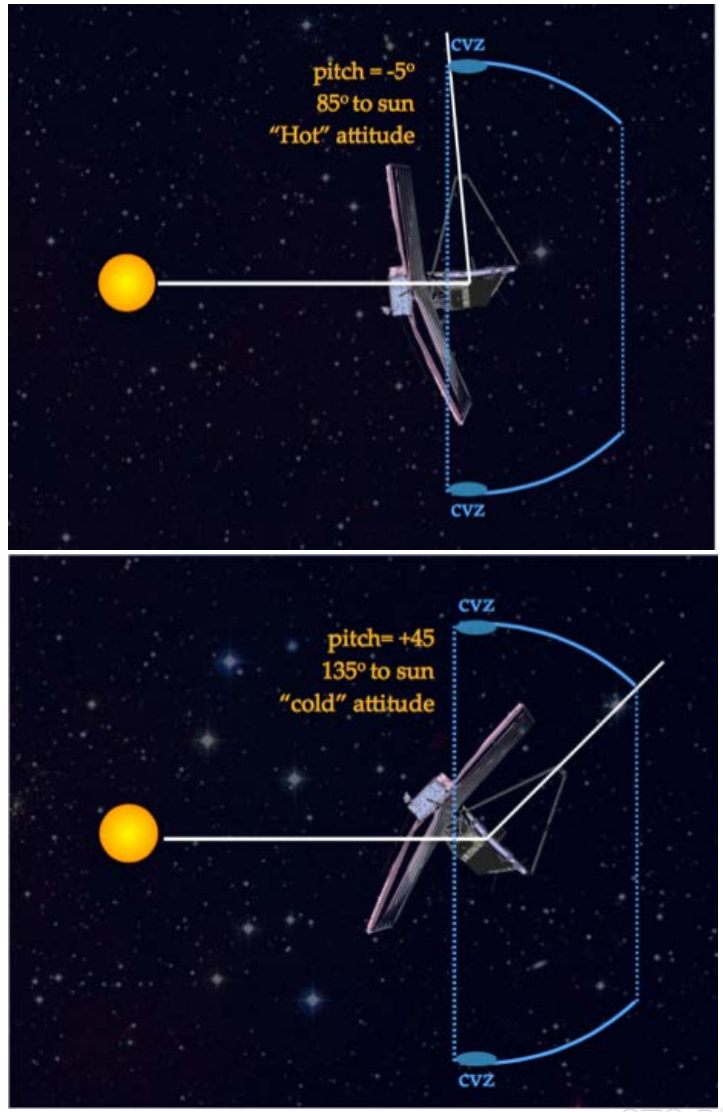
- Back plane instability
- Soft structure effects on primary mirror backplane
- Star tracker/boresight creep

Thermal time scale 6– 9 days

Observing plan

- 90° ± 5° (hot) for 5 days
- 130° ± 5° (cold) for 14 days
- 90° ± 5° (hot) for ½ day
- Other commissioning activities will fill about 15 days of this time

This is the only chance we will have to do this test



Commissioning Analysis Plans

With the CARs mature, attention turns to Commissioning Analysis Plans (CAPs)

- Detailed plans for analysis of data, pass/fail criteria, required products, etc.
- Often have been (or will be) validated with simulated data
- Teams have identified working groups associated with each CAP
  - Includes primary and secondary subject matter experts
- Internal reviews of CAPS have been ongoing

A Few Other Commissioning Items of Interest (1/3)

Stray light and background programs will validate background model used in the ETC

- Pointed NIR observations will look at directions of interest including Galactic center, min zodi, near HUDF, southern CVZ
  - Led by Goddard Project Science team
- MIRI program will characterize thermal background at hot and cold attitudes during thermal slew

Contamination monitoring program will look for water ice on optics

- 9 observations from days 40 – 97
- NIRCam grism and NIRSpec prism (for observations 8 & 9)
- Observing strong 3.1 micron absorption feature
- Models predict no significant contamination but options to drive off ice close out if we wait too long

A Few Other Commissioning Items of Interest (2/3)

A moving target test will be done for each SI

- Done in two parts: first at slow speed (3–8 mas/sec) then at fast speed (20–30 mas/sec)

A giant planet scattered light test will be done for each SI

- Goal is to show the FGS can perform guide star ID near bright planets, then guide on them
- Best targets by far are Jupiter and Saturn but visibility is a slight problem
  - Jupiter: 2022-06-23 to 2022-08-15
  - Saturn: 2022-05-10 to 2022-07-01 and 2022-09-27 to 2022-10-01+
  - For 2021-10-31 launch commissioning ends on 2022-04-28
  - These observations currently scheduled for 2022-04-19

Stationkeeping will be done every 3 weeks

- Required to maintain halo orbit at L2
- Fuel is the only expendable we have. Used for stationkeeping and momentum unloads.

A Few Other Commissioning Items of Interest (3/3)

Many rehearsals completed to practice commissioning

- Early Commissioning Exercises 1 – 4
- Mirror Deployment Rehearsals 1 – 2
- Deployment Rehearsal 1
- Wavefront Rehearsals 1 – 4
- Science Instrument Rehearsals 1 – 2
- Operational Readiness Exercises 1 – 4
- Contingency Planning Rehearsals 1 – 3
- More of these to come

6 formal launch rehearsal campaigns

- Launch Readiness Exercise 1 was in November 2020

Science Readiness – When Are We Done? (1/2)

Discussions held with SI PIs & Science Working Group for more than 1 year

- Want to start science as soon as possible but instruments and observatory must meet a minimum level of performance
  - Cycle 1 proposals were guided by performance shown in APT, JDox, etc.
- We were guided by good communication & cooperation between teams and management during cryo-vacuum campaigns
  - Additional test time granted for well-justified reasons
- We arrived at a limited number of modest criteria
  - Allows flexibility to respond to unanticipated problems
  - They do not indicate a willingness to accept performance below requirements without serious consideration of mitigations
  - Our intent is always to meet or exceed requirements. In some cases trades may be needed in terms of devoting observatory time to meet requirements
- It is our responsibility to investigate all deviations from expected performance and their effect on science mission success, even if the readiness criteria are met
- Criteria are documented in a technical memo that is almost complete

Science Readiness – When Are We Done? (2/2)

Examples of readiness criteria

- Imaging
  - Sensitivity within 30% of ETC predictions
  - FWHM or EE within 15% of prediction at a minimum of 1 field point in each filter
  - Optical ghosts are consistent with ground measurements or modelling
  - The relative flux calibration between full frame and subarray readouts has been characterized in at least one filter
- Spectroscopy
  - Sensitivity within 30% of ETC predictions, 40% for IFU spectroscopy
  - Dispersion solution errors less than 50% of a resolution element
  - Optical ghosts are consistent with ground measurements or modelling
- Coronagraphy
  - NIRCam: 5σ contrast of 10^4 at 1 arcsec with F335M and MASK335R with reference star subtraction
  - MIRI: contrast at radius of 6λ/D > 2400 for 4QPMs and > 1200 for the F2300C; rejection factor > 10. These criteria hold after reference star subtraction. [6λ/D is 2.0 and 4.4 arcsec at 10.65 and 23 microns, respectively.]

Science Readiness – When Are We Done? (3/3)

Key Decision Point meeting will be held for each observing mode. Will include review of

- All CARs and CAPs related to the observing mode
- Calibration reference files delivered to DMS
- Operations performance including slew accuracy, target acquisition, dithers, mosaics
- The disposition of all problem reports
- Performance of ground system especially the front end (APT, OPGS, P&S)
- Any deviations from expected performance
- Performance relative to the readiness criteria

Final decision made by Mather & Sembach with advice from

- SI PIs
- STScI mission head
- GSFC project science team
- STScI & GSFC commissioning scientists

Conclusions

Commissioning planning has matured greatly since my last briefing to the JSTUC (3 years ago)

- The Commissioning Activity Requests (CARs) are largely complete
- The Commissioning Analysis Plans (CAPs) continue to mature, will be ready when needed
- The programs required to demonstrate science readiness are in place
- We have a commissioning plan that fits within the 6-month requirement
- The large number of rehearsals have been valuable in identifying problems and training the teams
- We have agreed on a set of science readiness criteria for each observing mode
- We will be ready to support the launch of JWST next October 31