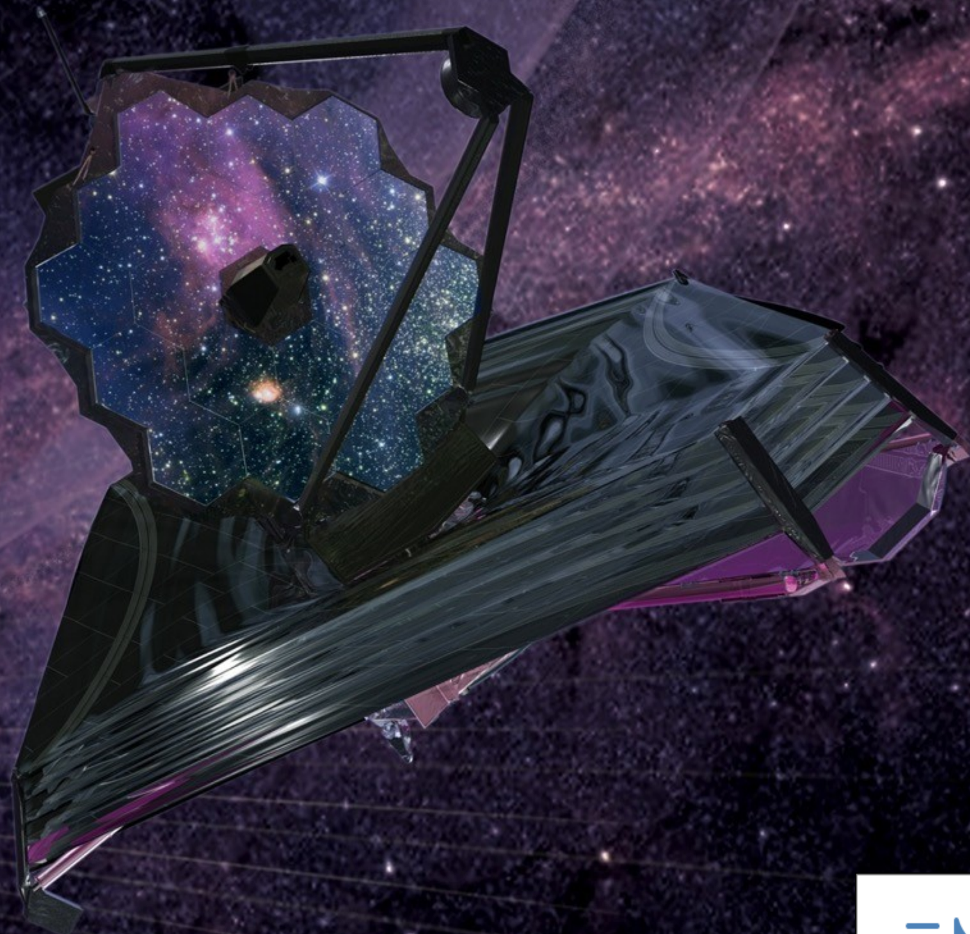
Preparing JWST for Science Operations



SPIE Meeting

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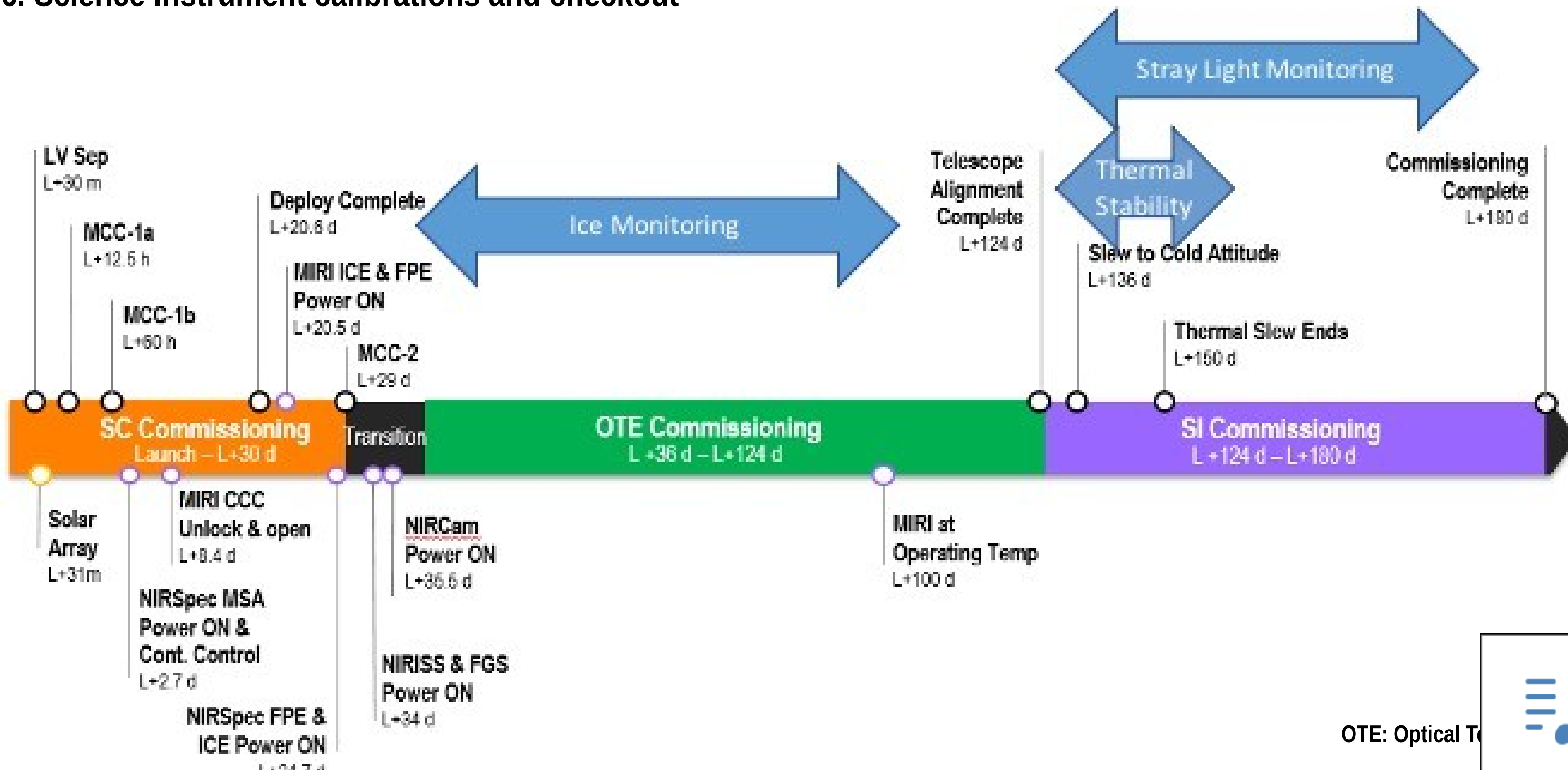
Commissioning At A Glance

Commissioning begins at launch and is ~ 180 days long marked by the following key events:

1. Launch and Ascent – power positive, safe attitude, and communications established
2. Mid Course Correction – MCC1 (a and b) corrects launcher dispersions for proper L2 trajectory
3. Deployments
4. Cool-Down/Cryo-Cooler Activation
5. Mirror segment deploy and wave-front control
6. Science Instrument calibrations and checkout

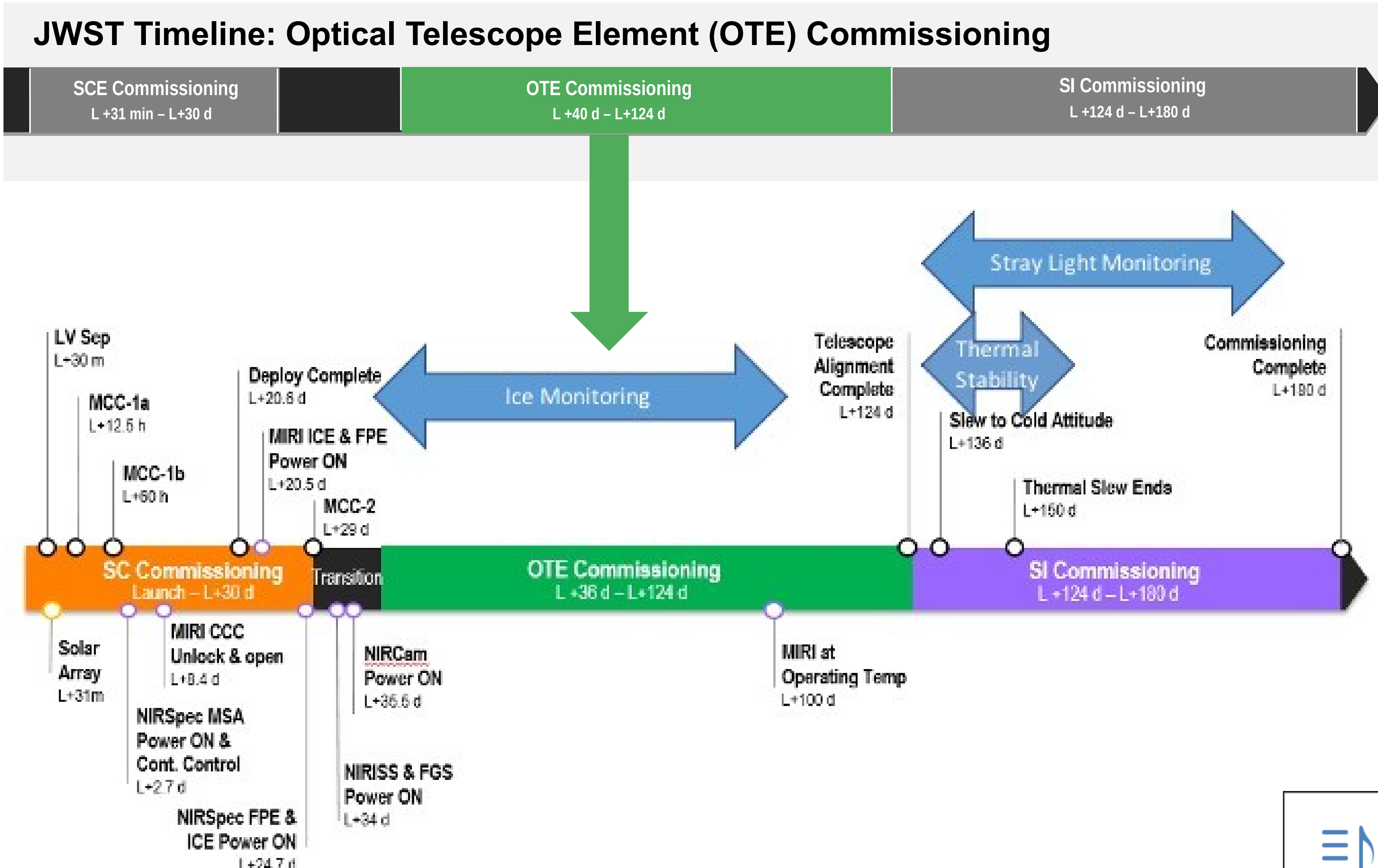
Launch and Deploy Phase (1–2)

Cool-Down/OTIS Phase (3–6)

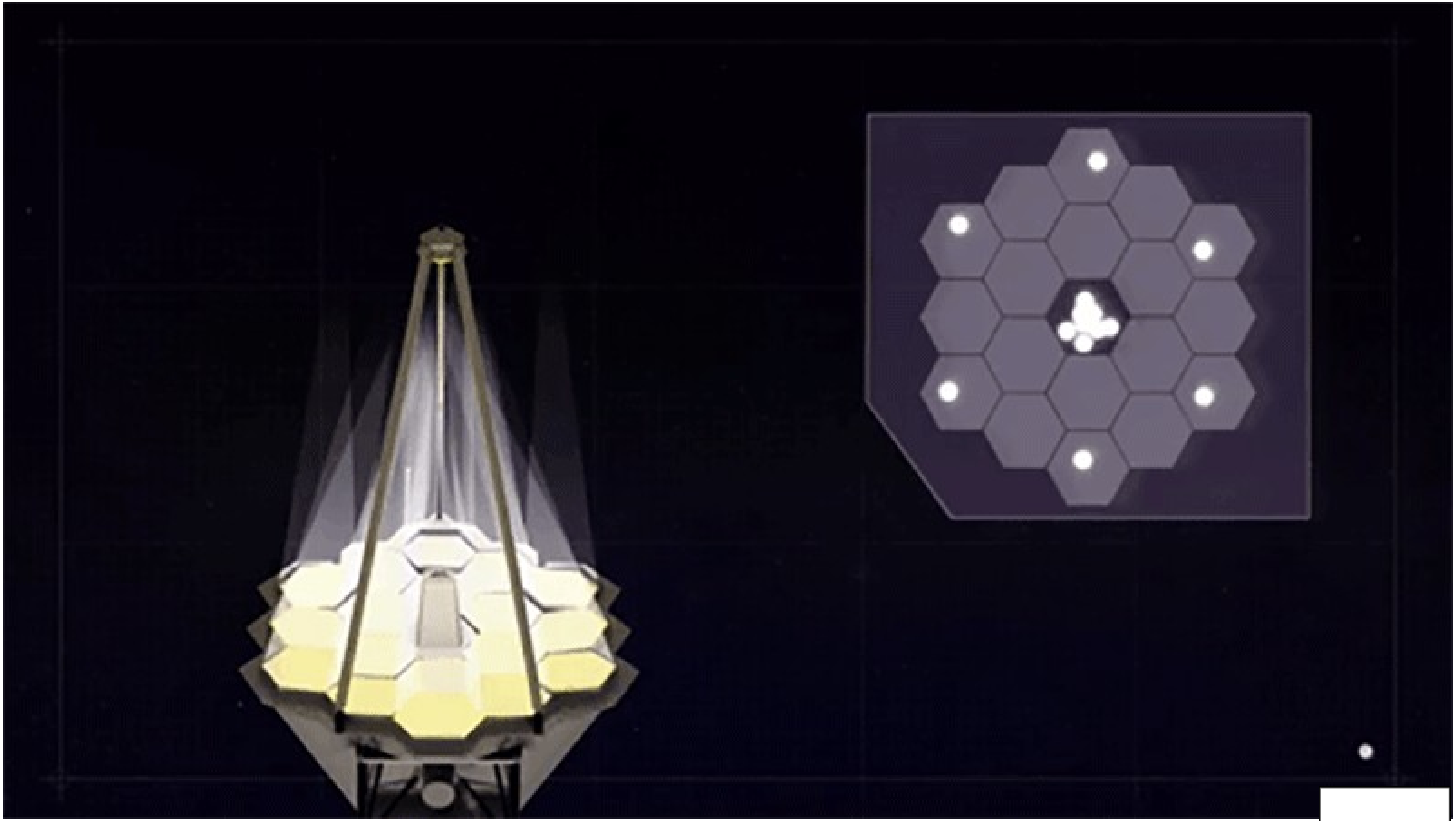


OTE: Optical T[illegible]nt

OTE in Overall Commissioning

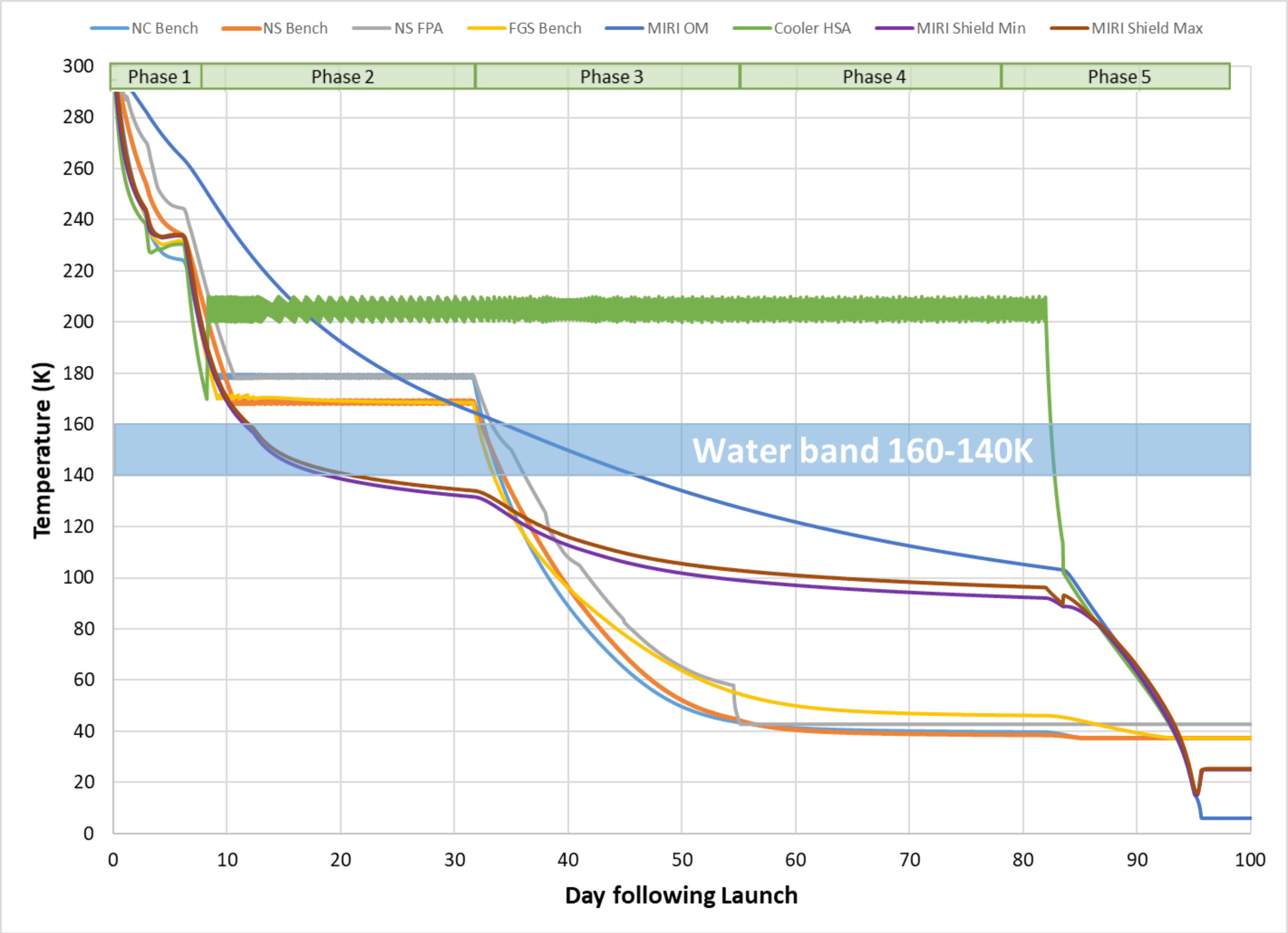


Mirror Segment alignment



https://www.nasa.gov/feature/goddard/2017/james-webb-space-telescope-s-laser-focused-sight

Cooldown Overview



Water Contamination Risk

Instrument performance and thermal management performance is reduced if too much moisture settles on OTE or ISIM critical surfaces.

Critical surfaces include:

- Fine Steering Mirror
- Telescope optics
- SI optics and detectors
- NIRSpec microshutters
- MIRI thermal shield
- MIRI cryocooler lines
- Sources of moisture could include:
- ISIM Structure
- Insulation
- Warm regions of the core (though unlikely)

Water ice deposition onto critical JWST components post-launch presents a risk to achieving full performance of ISIM science measurements .

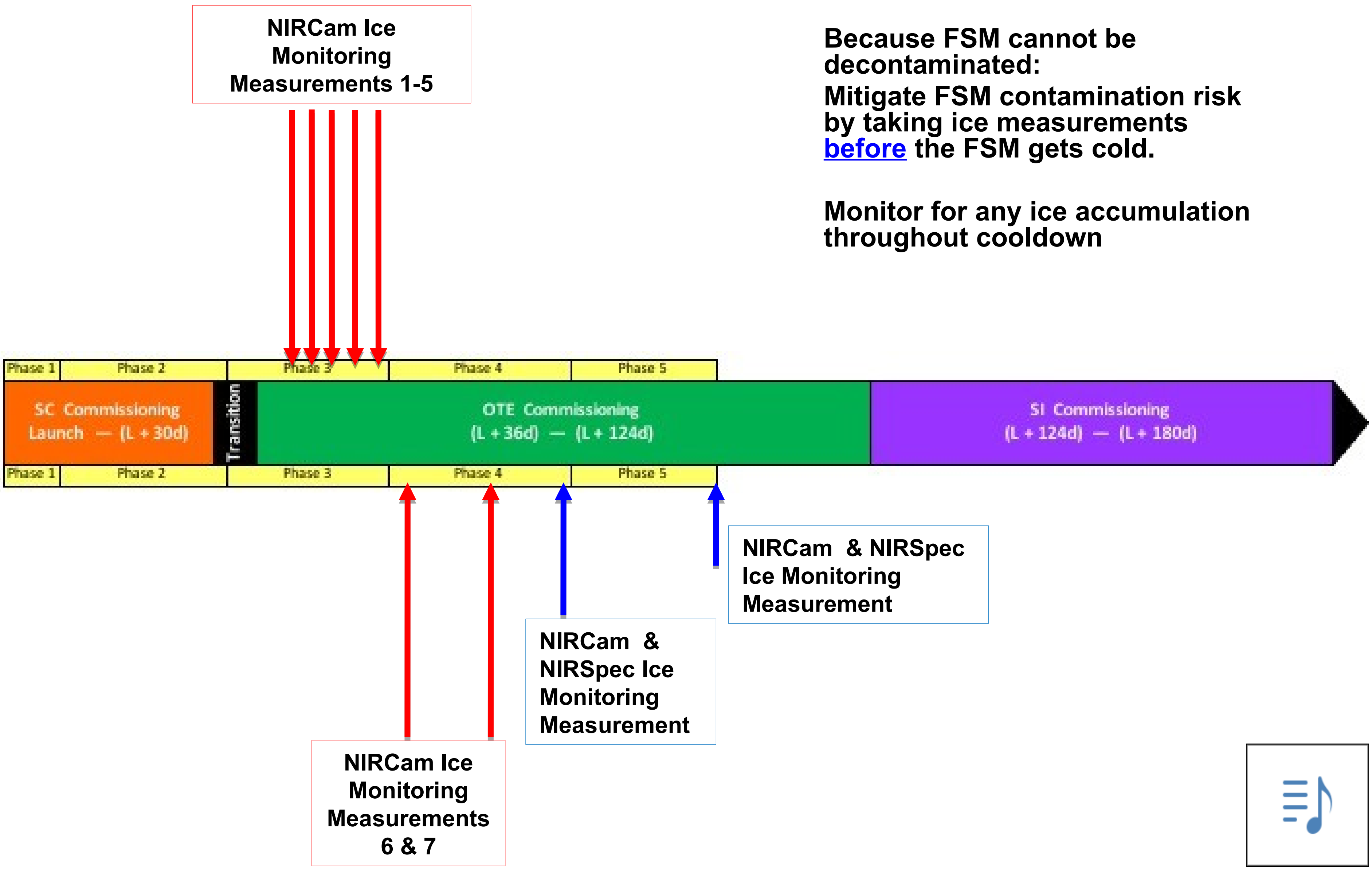
Ice Contamination Risk Mitigation

- **In general, the approach on-orbit to mitigate this risk is to**
  - Ensure that the cooldown is as controlled as possible and all sensitive surfaces remain warm until water-desorbing surfaces (composites and blankets) cool below water-freeze out temperatures (140K)
    - Keep FSM warm until ice contamination has been precluded
  - Ensure that the NIR SIs cool completely to operating temperature and take early measurements evaluating the amount of ice collected in the NIR SI optic train and in the telescope optics. If the ice found is within an acceptable range and not increasing, it will be safe to drop the MIRI to its operating temperature and open the MIRI Contamination Control Cover (CCC).
- **The best mitigation plan to minimize ice contamination is prevention, since SI decontamination warm-up would lead to only partial results, could make the contamination state worse, could carry unknown and untested risks, and would be a time-inte operation**

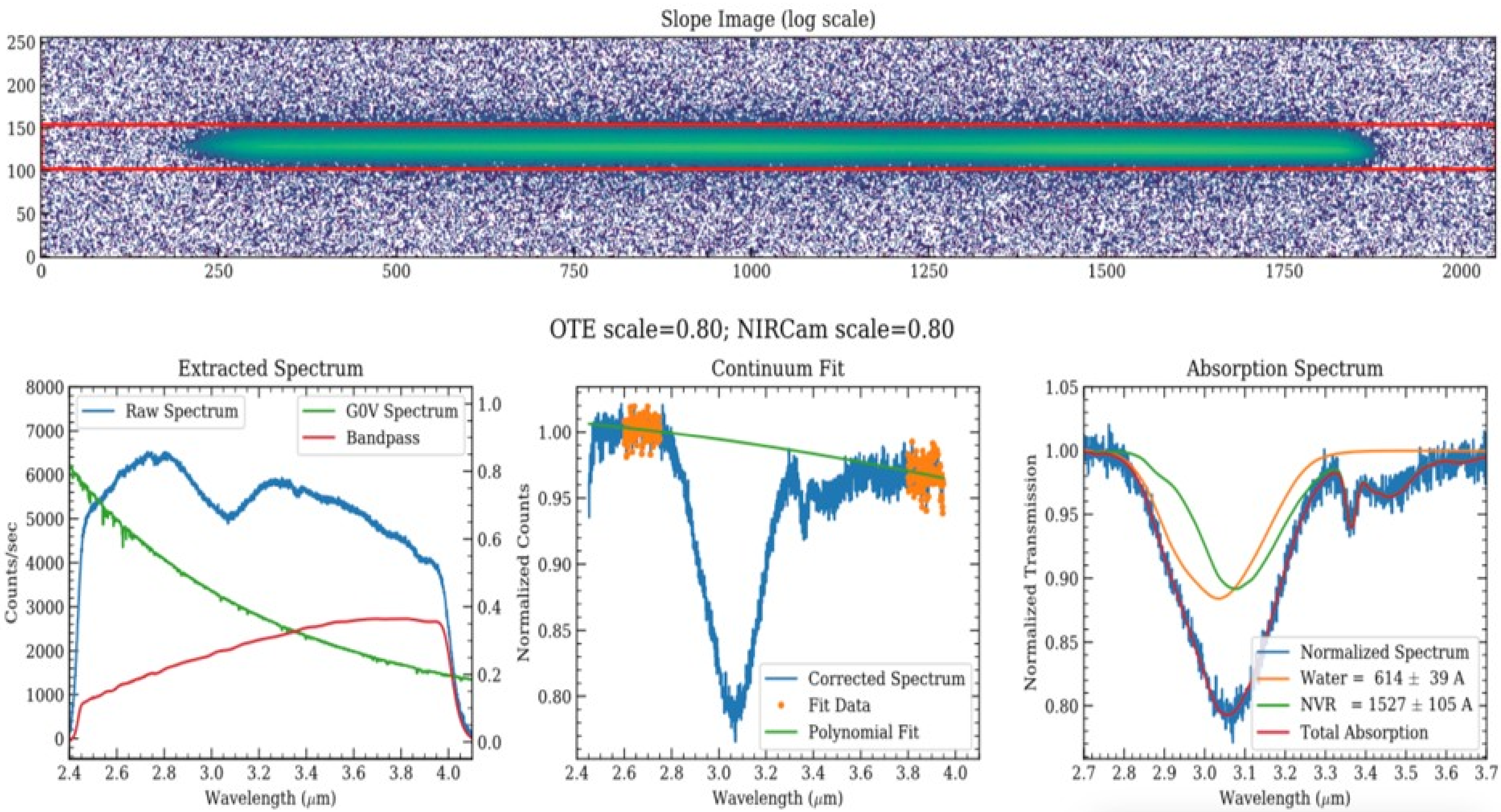
Ice Monitoring

Because FSM cannot be decontaminated:
Mitigate FSM contamination risk by taking ice measurements <u>before</u> the FSM gets cold.

Monitor for any ice accumulation throughout cooldown

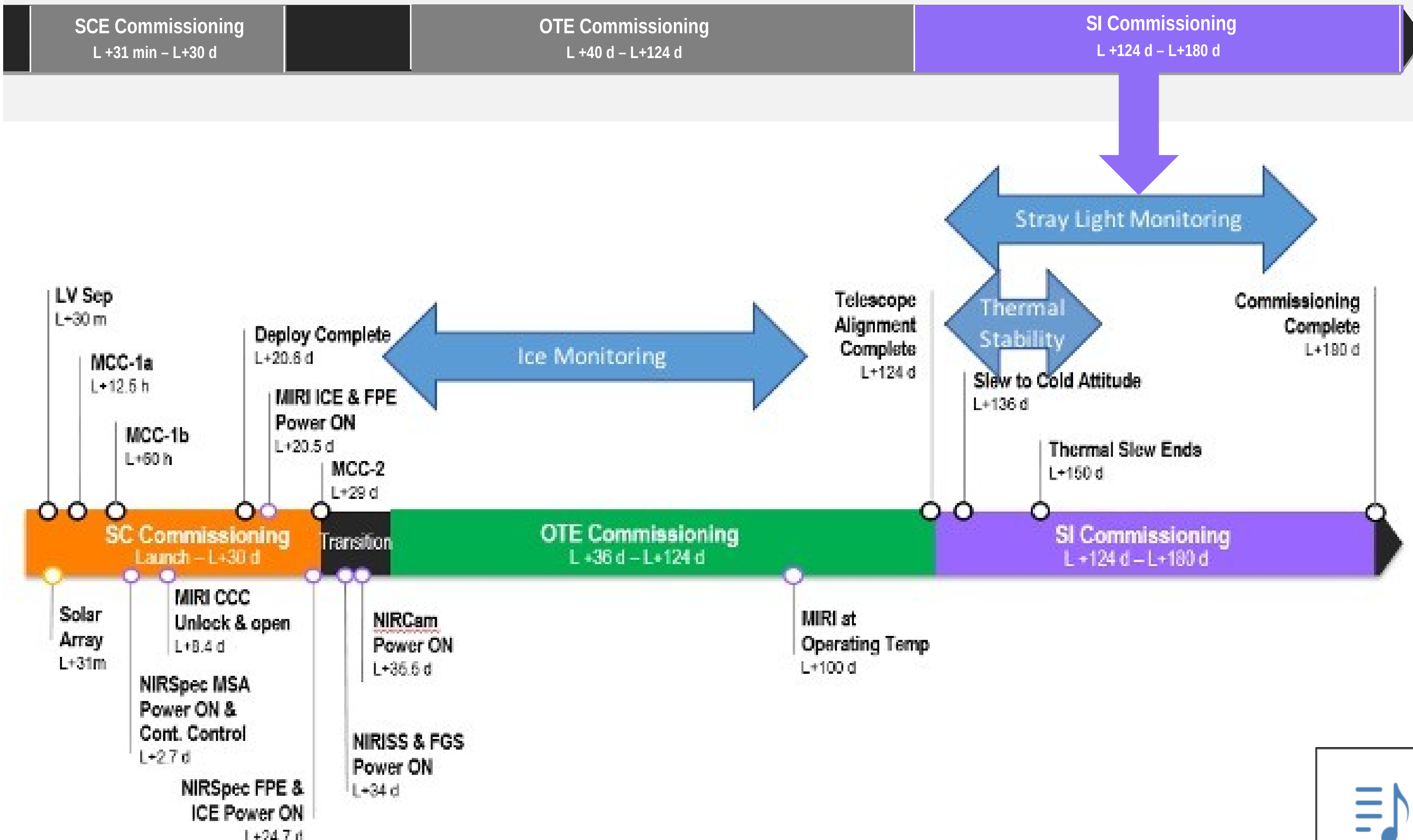


Ice Monitoring: Data analysis



Science Instruments in Overall Commissioning

JWST Timeline: Science Instrument (SI) Commissioning



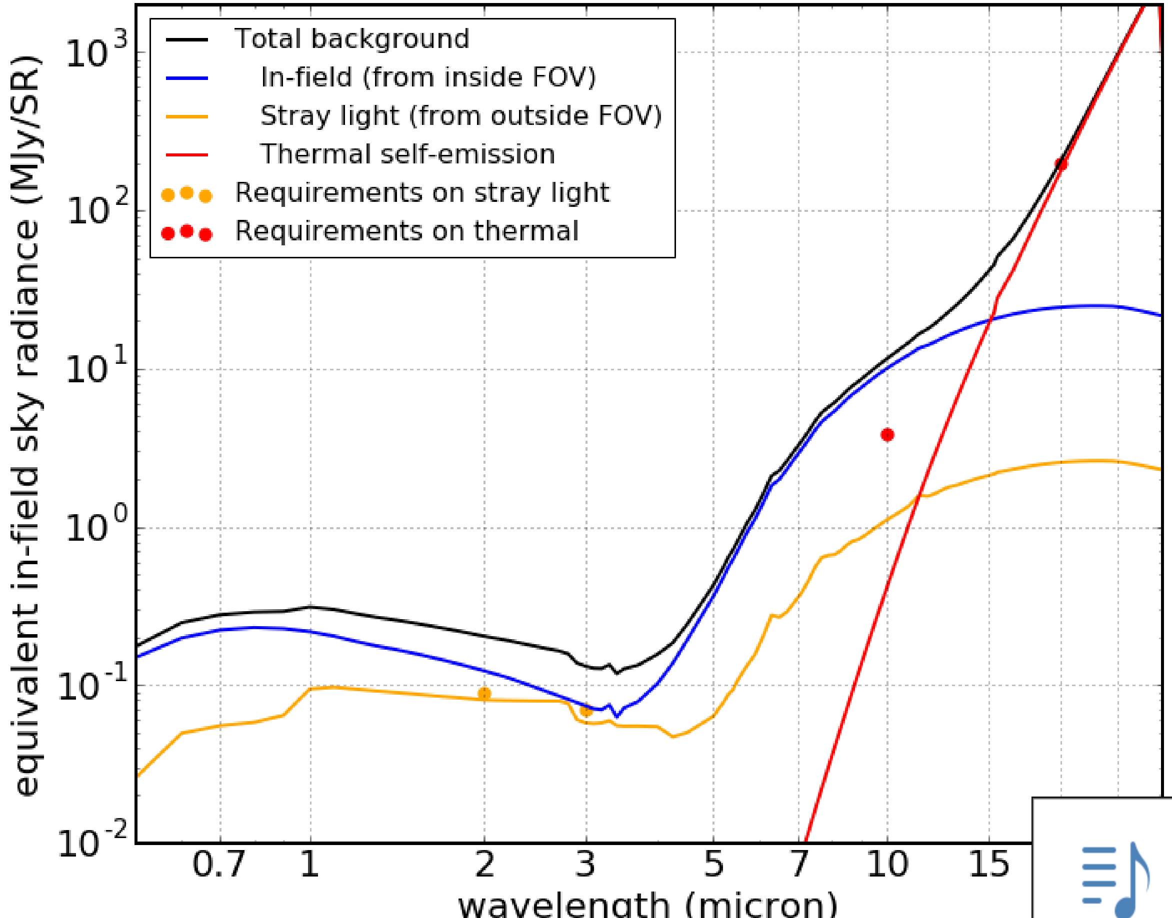
Background Characterization

- In many modes (NIR broadband imaging, long wavelength MIRI), the background contributors are dominant over the detector noise terms -- hence, an important part of commissioning is assessing the various contributors to the background

- Figure at right from STScI's JDox pages shows the nominal contributions to the background from the various terms (J. Rigby fit to P. Lightsey models)

From

https://jwst-docs.stsci.edu/jwst-observatory-functionality/jwst-background-model



Background Characterization

Use on-sky observations to characterize the stray light behavior, which will be used to 1) evaluate the JWST Backgrounds Tool for systematic offsets or anomalies and 2) trend any evolution to the stray light behavior.

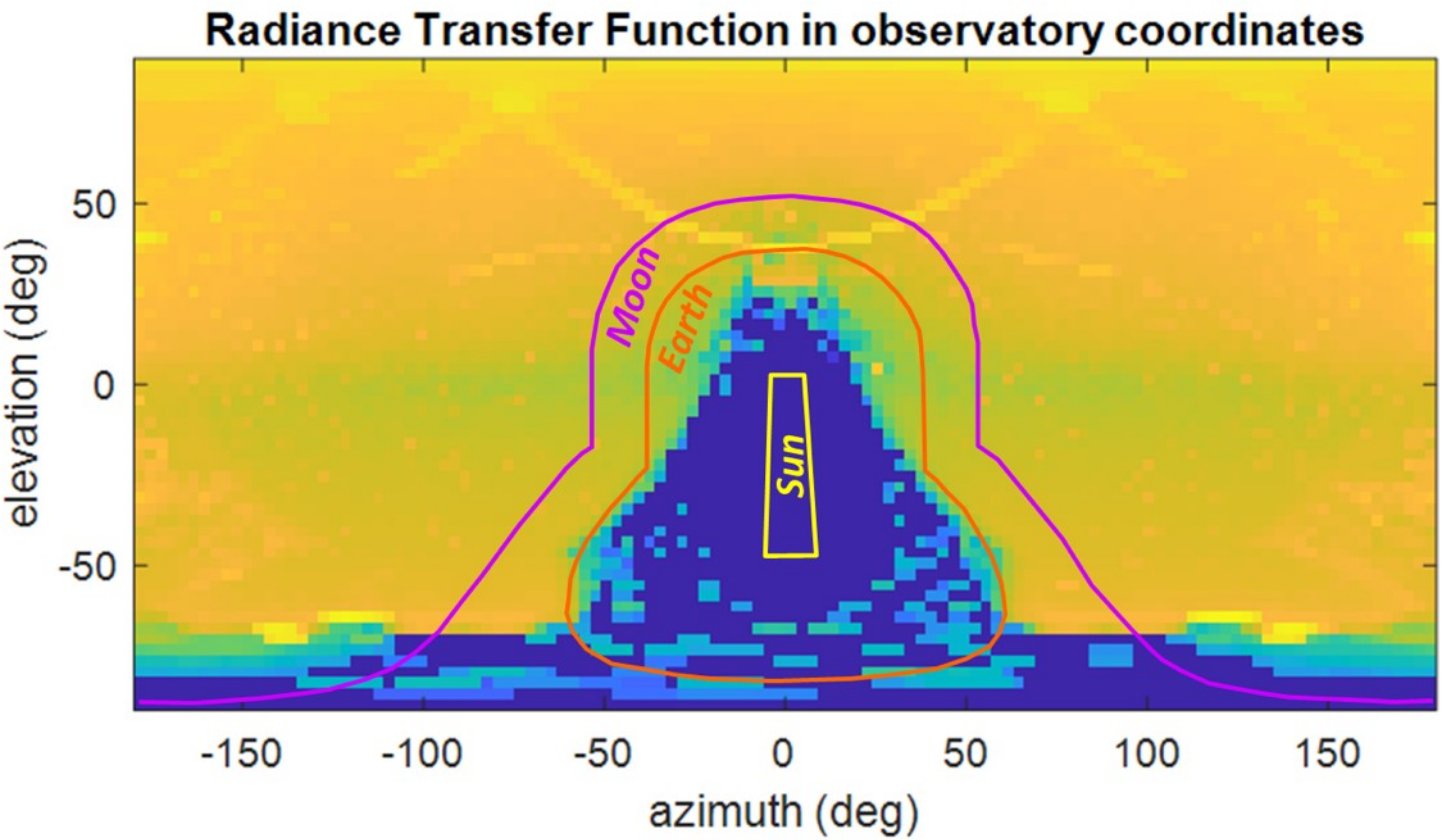
During commissioning, we will use pointed observations at important fields and attitudes, using a compliment of filters with broad wavelength coverage.

- NIRCam + MIRI measurements at 8 selected fields, including stressing cases chosen to evaluate the extremes of the background model and key scientific fields.
- MIRI measurements at extremes of the field of regard (“hot attitude” and “cold attitude”) to characterize the thermal background performance of the Observatory

Contingency commissioning observations could include additional pointed observations or a request for expanded filter imaging following planned science instrument commissioni activities.

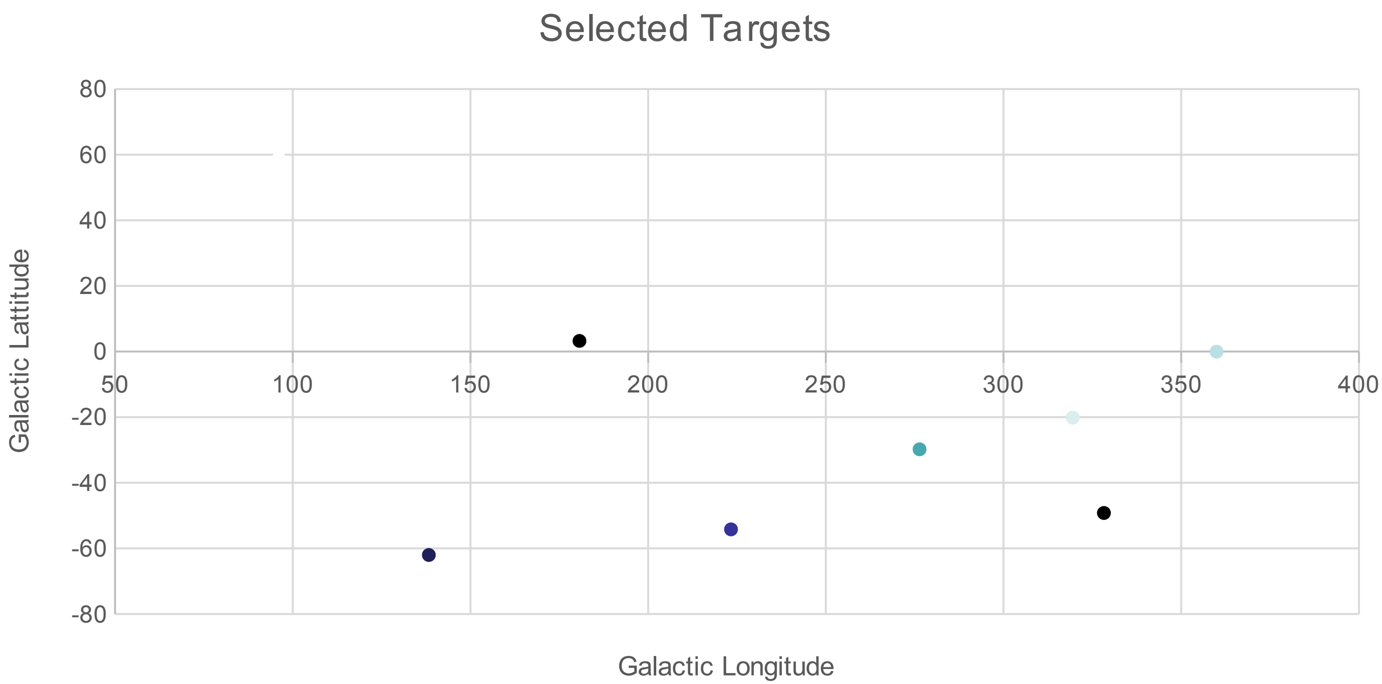
Background Characterization

- The out-of-field sky background scattered into the JWST beam is characterized by the Radiance Transfer Function (see Lightsey and Bowers, Proc. SPIE 10398, 103980L, 2017)
- The predicted scatter contribution to the background is the convolution of the sky background (zodi + Milky Way) with this susceptibility map; the telescope line of sight is at (azimuth, elevation) = (0,90) on this plot

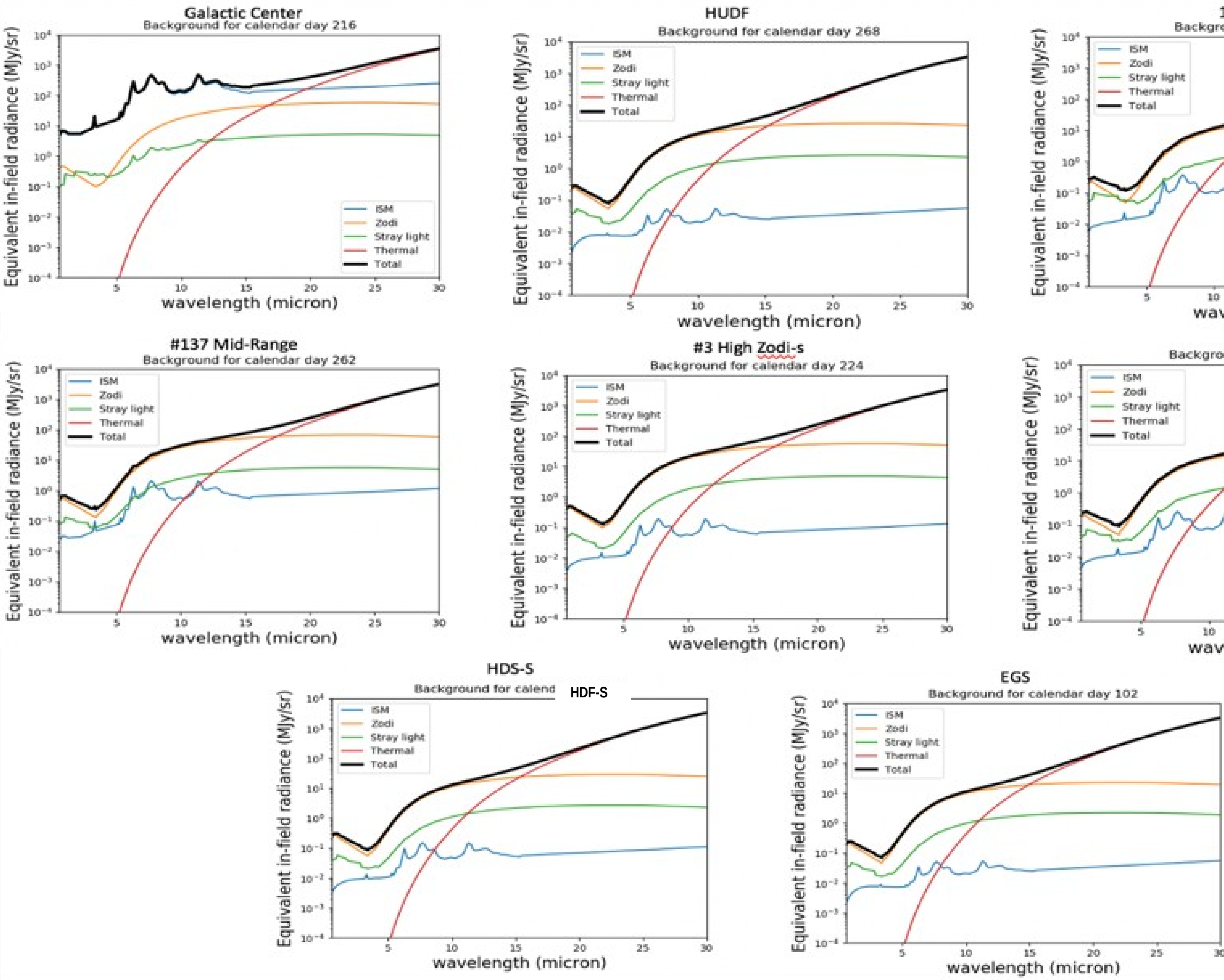


Pointings

ID	FIELD NAME	Background	Rationale
1	HUDF (offset)	Low NIR background	Key field
2	Ext Groth Strip (offset)	Low NIR background	Key field
3	HDF-S	Low NIR background	Key field
4	1.2 min zody	High NIR background	Requirement Benchmark
5	Galactic Center	High NIR & MIR background	Stressing NIR/MIR case
6	Mid-Range Background	Moderate NIR & MIR background	Moderate background field
7	CVZ-S	High MIR background	Monitoring
8	High Zodi, Low non-Zodi	High MIR background	Stressing MIR case



Background Characterization



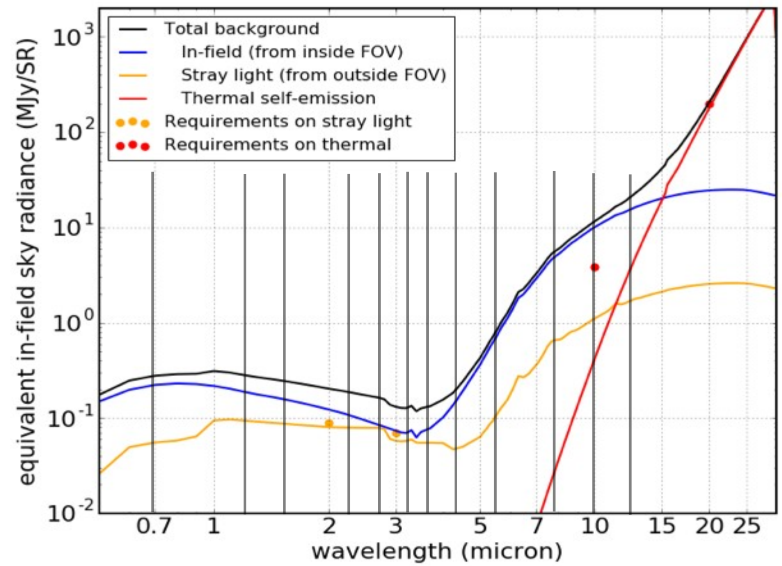
Proposed Filter Usage

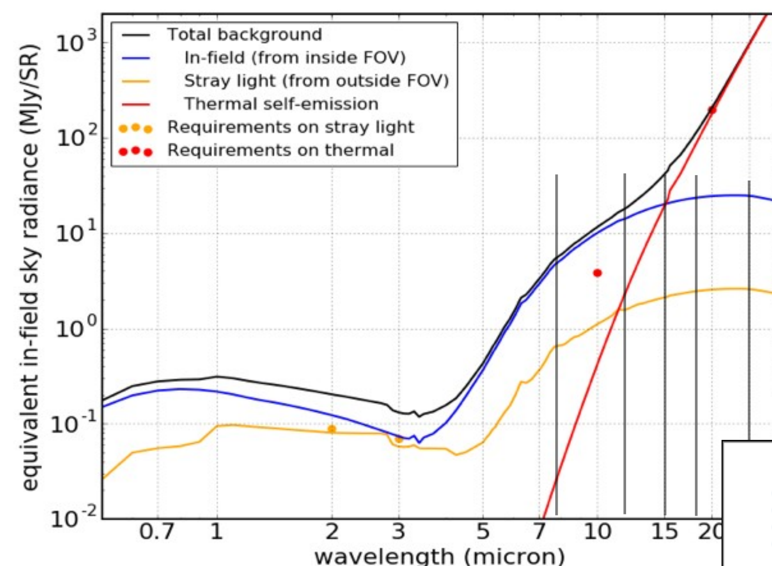
Pointed Stray Light filter usage

	Science Instrument	Filter
1	NIRCam	F070W
2	NIRCam	F115W
3	NIRCam	F150W
4	NIRCam	F220W
5	NIRCam	F277W
6	NIRCam	F322W2
7	NIRCam	F356W
8	NIRCam	F444W
9	MIRI	F560W
10	MIRI	F770W
11	MIRI	F1000W
12	MIRI	F1280W

Thermally-dependent MIR background measurement filter usage

	Science Instrument	Filter
1	MIRI	F770W
2	MIRI	F1280W
3	MIRI	F1500W
4	MIRI	F1800W
5	MIRI	F2100W
6	MIRI	F2500W

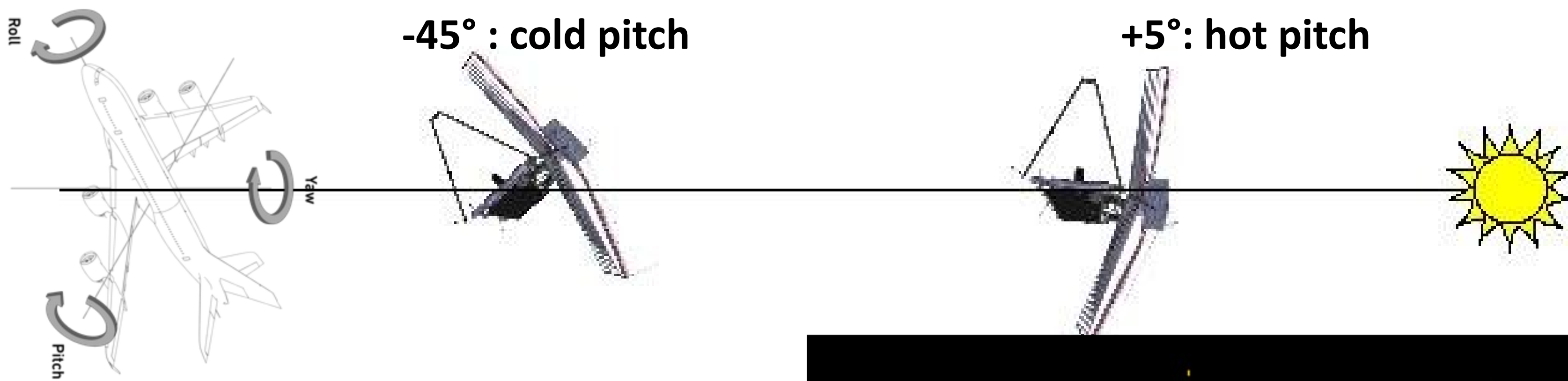




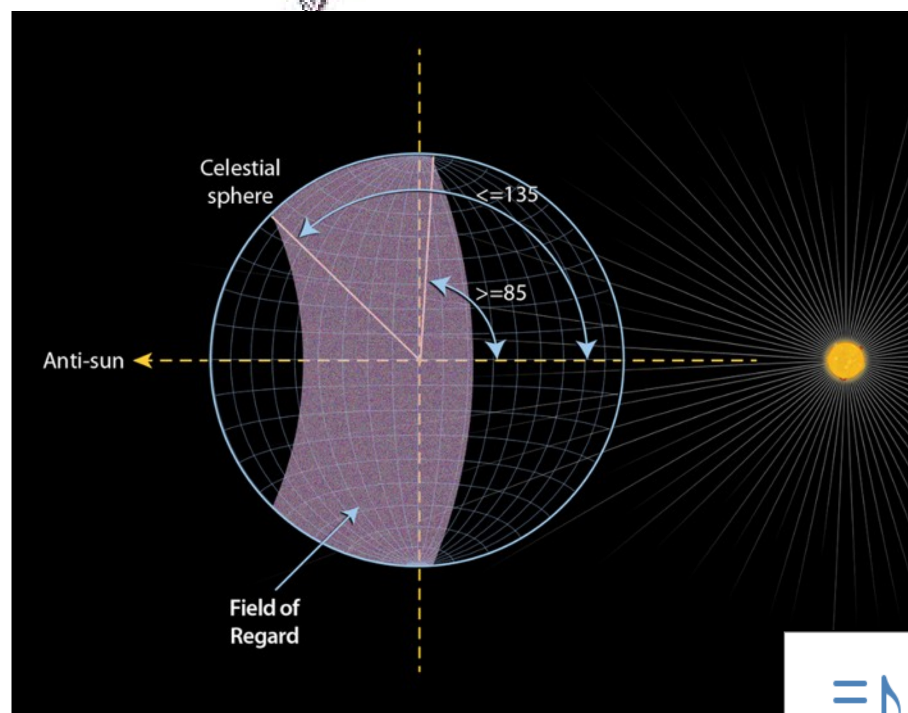
Sensitivity Expected Outcomes & Contingencies

- ***Throughput***
  - Expectation is that we will simply update our planning tools (e.g., Exposure Time Calculator [ETC]), as standard star fluxes are known more accurately than our current throughput uncertainty from ground measurements
  - There is an early throughput contingency regarding *unexpected* levels of ice accumulation. Unlikely to have remedial actions available at the time we're taking standard star measurements.
- ***Backgrounds***
  - Expectation again is that we may need to update our planning tools – JWST Background Model, ETC – for deviations from current predictions
  - Current predictions are thought to be *conservative*; e.g., predicted Beginning-of-Life temperatures are somewhat cooler than what is used in current tools
  - Monitoring of background over the commissioning program could potentially reveal an issue with higher background near the edge of the Field of Regard – again, NOT expected, but in principle could impose operational restrictions

Thermal State Dependance on Pointing

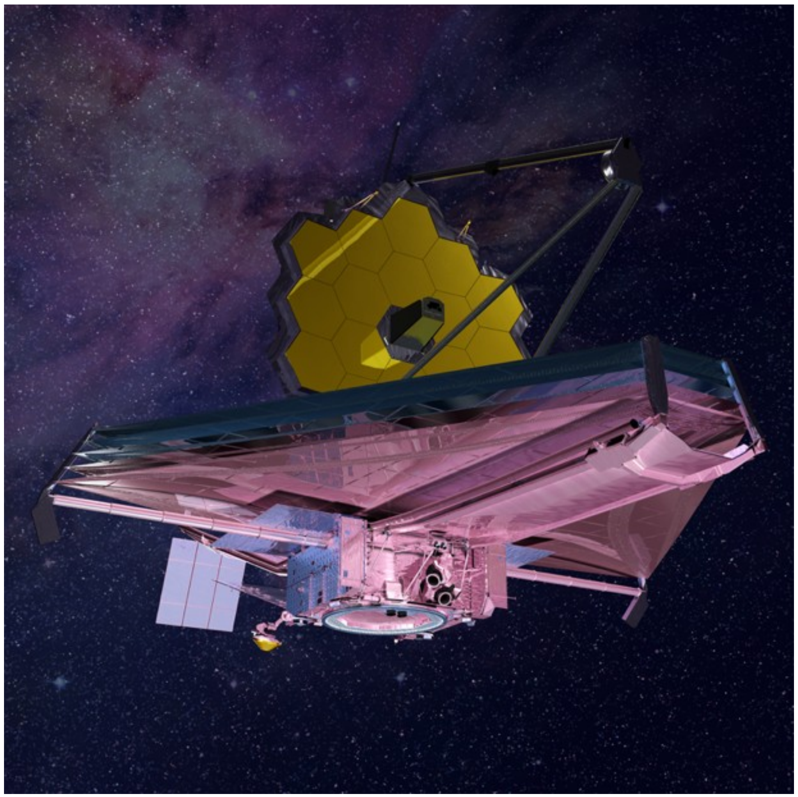


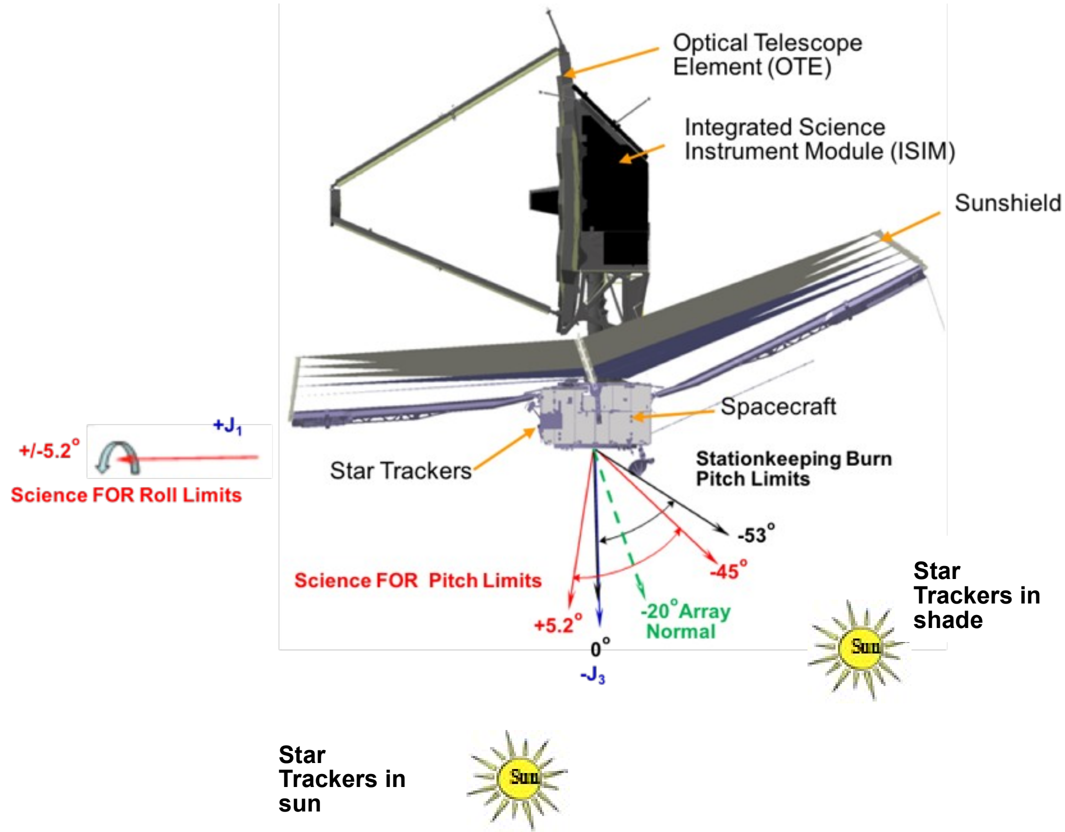
- The JWST science field of regard is +5 to -45 degrees in pitch and +/- 5 degrees in roll.
  - Normal science observations will be carried out at various pointings within the field of regard (FOR), smoothing over the thermal state extremes to some extent.
- Momentum unloads (MUs) are nominally executed at a pitch of 0 and -44 degrees and station keeping maneuvers (SK) are at pitches between 0 and -53 degrees.
  - MU and SK can be carried out at either the hot or cold attitudes.



https://jwst-docs.stsci

Thermal Slew: Star Tracker Thermal Response





Known Optical Drifts from Thermal Changes

- **Design drifts: When a large slew in pitch (i.e., toward or away from the sun) is made, thermal changes on the spacecraft and OTE contribute to optical stability changes.**
  - <u>*Pointing stability*</u>: from thermal changes to the star tracker assembly and OTE which affect the relative coordinates, resulting in a roll about the boresight (i.e., not sensed or corrected by the fine guidance sensor loop).
  - <u>*OTE thermal distortion*</u>: from structural displacements to the OTE backplane and secondary mirror motion, resulting in a change in the wavefront error.
- **As-built drifts: During cryovacuum testing, three additional instabilities were observed.**
  - <u>*IEC cyclic wavefront drifts*</u>: from the IEC radiator panel heater turn on/off which coupled into the backplane through the harness, much of which was attributed to the GSE IEC support. *This is not reliant on a thermal slew.*
  - <u>*Frill & PMSA close-out thermal distortion*</u>: from frill and PMSA installations that did not have the requisite slack to operate across the OTE temperature range without imparting forces on the backplane. Inspections and rework completed to add slack to much of the frill and PMSA close-outs, reducing the expected drifts in flight.
  - <u>*PMSA tilt events:*</u> unpredictable tilt events, likely due to backplane stress relief from the structural cooldown to operational temperatures. Several events were identified during OTIS cryo-stable but had plausible non-flight contributors. Data monitors have been developed to detect tilt events during observations (e.g., with FGS) or at the 2-day WF monitoring observations. *They are not expected to be induced by the small temperature changes from a thermal slew.*

Thermal Stability Characterization

After the Observatory reaches operational temperatures, there are several activities where the hot and the cold pointings have been grouped together to provide:

- A stable hot period
- A single slew to coldest pointing
- A stable period in the cold pointing

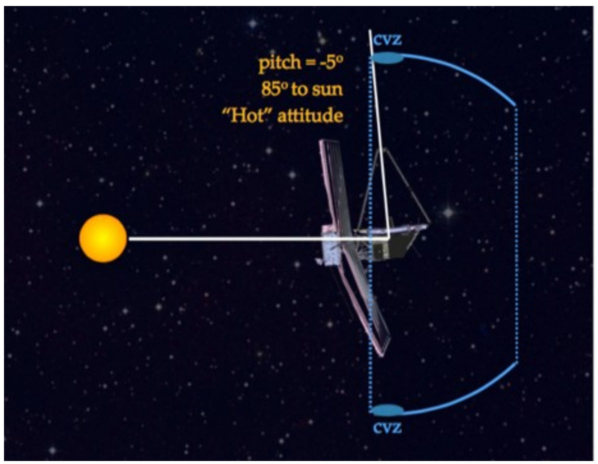
In these periods, we will characterize the flight optical stability performance by measuring:

- Pointing stability
- OTE Thermal Distortion
- cyclic wavefront drifts
- Frill and Primary Mirror Segment Assembly (PMSA) closeout thermal distortion
- Check for unknown drifts for the as-flown Observatory over critical science timescales prior to critical science instrument commissioning measurements

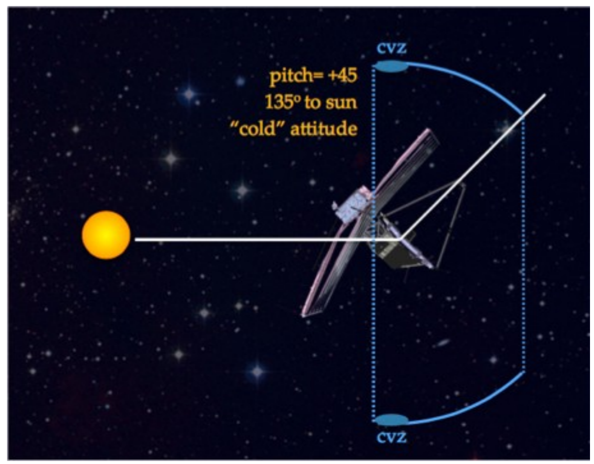
Thermal Stability: Pointing & Distortion Effects

Objectives: Measure and characterize the JWST thermal profile to 1) validate observatory thermal models and 2) determine WFSC update expectations.

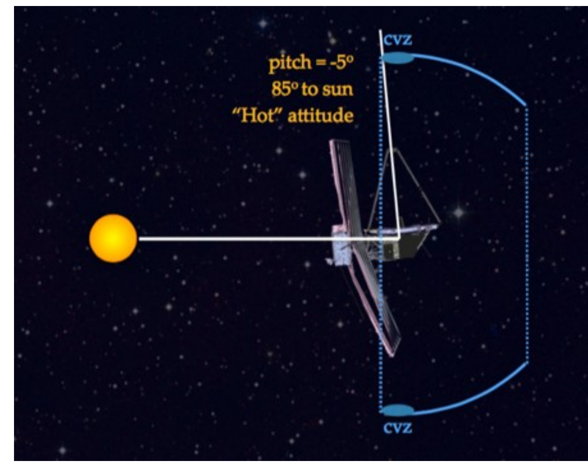
All thermal stability measurements take ~4.6 days over a 20 day time period (WF monitoring activities have been absorbed in the new measurement). The additional time is filled with other commissioning activities on a non-thermal interference basis.



Stabilize at Hot attitude
Assess IEC cyclic wavefront or other short timescale drifts and establish warm stable baseline performance for pointing and wavefront stability.



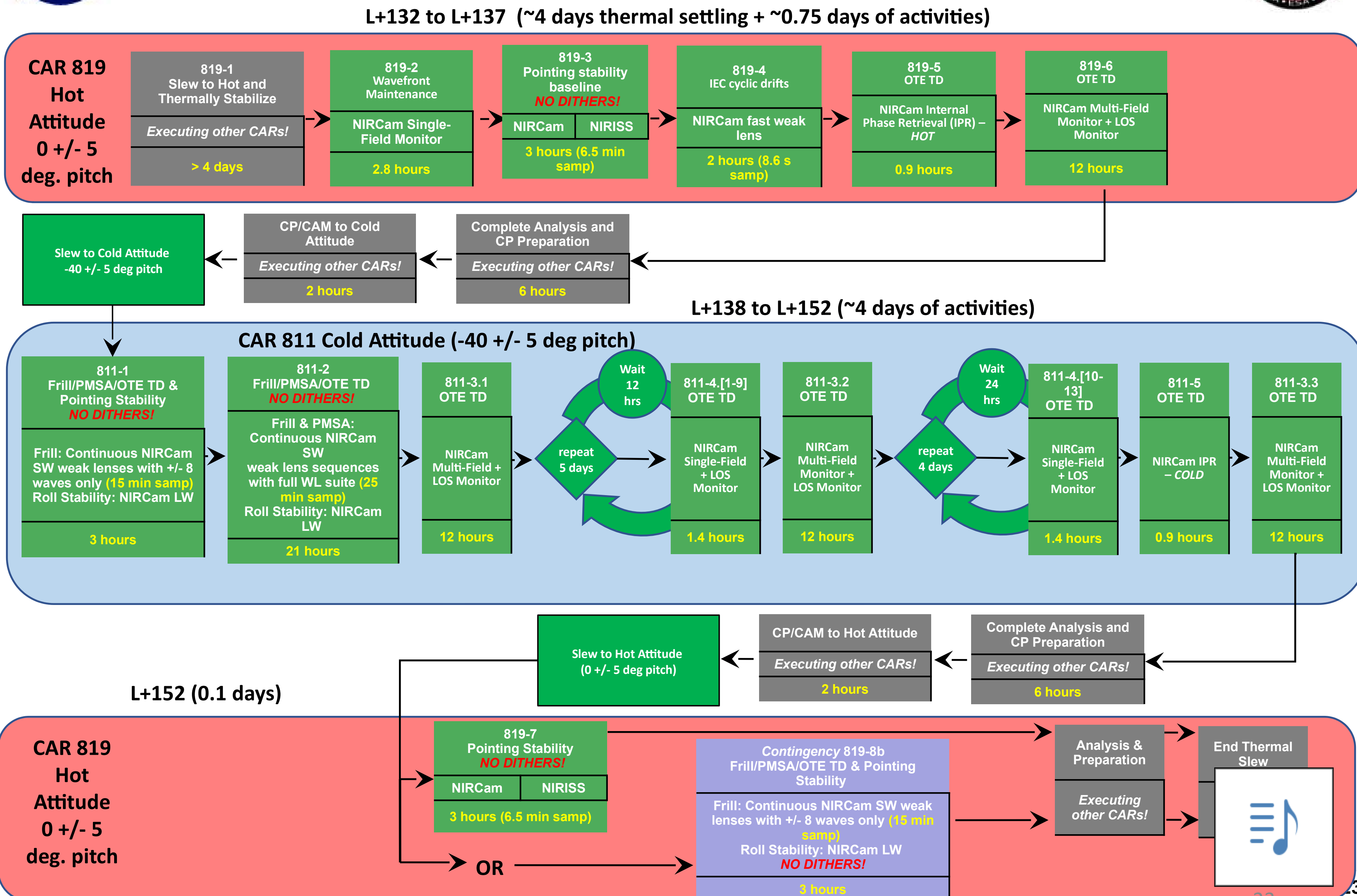
Slew to Cold attitude
Assess frill/PMSA/OTE wavefront drifts and pointing stability over 14 days.



Return to Hot attitude
Verify consistency with prior hot to cold pointing stability

Observables: telemetry data from the observatory, heater sensors, image quality evolution, transient behaviors

Thermal Stability Characterization Flow



Summary and Conclusions

JWST Commissioning is a careful process designed to optimize observatory performance and science operations

Spacecraft, OTE and SI commissioning build on one another for an iterative process

Observatory Commissioning captures activities involving coordination of multiple systems:

- Ice Monitoring
  - Ensures sensitive optical surfaces are free from water ice
    - Starts before FSM heater turns off, continues throughout OTE commissioning
    - Carefully coordinated with wavefront team
- Stray Light
  - Assesses Stray Light and Background models
  - Includes stressing pointings, regions of interest and benchmark locations
- Thermal Stability Characterization
  - Assesses the thermal and pointing stability of the telescope during and after a large change in thermal profile
  - 4 Days stabilization at Hot attitude, slew 45 degrees to cold attitude, remains 14 days at ‘cold’ attitude, returns to hot attitude