Commissioning JWST

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The following text does not apply here…

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22 CFR 125.4(b)2 applicable

JWST Lite
it’s iTar Free!
Wavefront Sensing & Control
parties & people

• NASA, GSFC
  – Project leadership (Bill Hayden OTA syseng)
• Northrup Grumman Space Technology (NGST or NG)
  – Non-optical hardware, Prime Contractor
  – Commissioning Timeline (Wallace Jackson - Russ Makidon our rep))
• Ball Aerospace
  – Optical hardware, ‘algorithms’ (Paul Atcheson, Scott Acton)
  – Adaptive Optics Associates (Allan Wirth)
• STScI
  – Operations (self, Russ Makidon, Colin Cox, Ron Henry, Vicki Balzano…)
  – All the support stuff as for HST: data, cal, docs, cmds, proposals, pipeline
  – Optical testing (Babak Saif)
  – NIRCam (McCullough, Casertano)
  – FGS (Nelan)
• JPL
  – Wavefront Sensing and Control “Executive” (Antczak - Russ Makidon our rep)
• NIRCam team
  – Marcia Rieke (UA), Scott Horner (LMATC)
• FGS team
  – John Hutchings (HIA)
\[-\left( (1 - \mu) (1 - \mu + x)^2 \right) - \mu (\mu + x)^2 + x (1 - \mu + x)^2 (\mu + x)^2 = 0\]
RECENT ESTIMATES
Try to commission early

Launch at **day 0**

**30d/100K**
First Light
SM focus sweep
Segment Identification
Segment Search

**40d/80K**
Global Alignment
Image Stacking

**65d/60K**
Coarse Phasing
Prelim Fine Phasing

**180d/37K**
Final Fine Phasing

ON THE WEB
The telescope

- Primary ~ f/1.5 (by eye from the figure)
- ‘Cass’ f/16.7 (from the web)

- The Wavefront Sensor
  - NIRCam short wave arm ~1-5micron
  - 18.5 micron pixel H2RG
  - 30mas/pixel
  - Some special optics & software
Unfolding the telescope
Deployment accuracy

3 mm SM despace, decenter
1.5 mm PM segment piston
0.6 mm PM segment decenter
0.5 mrad tilt, clocking
Controlling the mirrors

18 primary mirror (PM) segments, 7 actuators/PMSA
Hexapod for 6 solid body degrees of freedom
Central ‘push-pull’ Radius of Curvature actuator

Actuators have a ‘coarse’ and ‘fine’ range
Engaging ‘coarse’ drive resets the ‘fine’ state
Prototypes are highly repeatable in-lab
Details are ITAR-restricted

The secondary mirror (SM) has a hexapod
It can be moved +/- ~6mm in despace

Despace and PM segment piston translate to
waves of defocus in image space with a
magnification-dependent factor: for JWST it’s ~200:1
Wow!! We were lucky!
OK, so PM segments are not all in the right surface…
We have some piston errors (a few waves)
Segment piston, and some astigmatism too
(‘clocking errors’ on each segment?)
Segment piston, astigmatism, and a common coma as well…
Maybe our secondary is skewed over a bit in its plane (‘decenter’).
Focus Sweep

- The secondary mirror is expected to be within ~3mm of ‘correct’ despace
- Move the secondary through ~5 positions, taking images at each step
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Segment Identification

- While pointing somewhere under star tracker alignment control
  - Take an image
  - Move a segment a bit (few arcseconds)
  - Take another image
  - Subtract the two

  The moved segment will show as a ‘positive-negative’ pair

  Simulations of this to date are ITAR-restricted
  Even though it is not rocket science!

  CONTINGENCY: missing segments
Segment Search (if needed)

- Move a missing segment in a ‘rectangular spiral’
  - Consider NIRCam FOV size
  - Consider inter-chip spaces
- Take an image at each step
- See if you find the segment

CONTINGENCY: segment PSF is very extended, therefore very faint
CONTINGENCY: we lose a segment
CONTINGENCY: we lose a wing
Global Alignment

• Place segment PSFs in a hexagonal pattern in NIRCam
  – Matching physical location in pupil
• Do a focus sweep
  – Solve for wavefront aberrations over each segment
  – Figure out how to move SM in 6 degrees of freedom
• Place Secondary Mirror in ‘best position’ for all segments.

• Minor contingency - focus sweep might overlap segments PSFs:
  – Return to SEGMENT ID stage and repeat till we get here again
Image Stacking

Co-aligned segment PSFs

~3 incremental steps towards co-alignment

Final step within ‘fine actuator range’ motion
Coarse Phasing - Dispersed Hartmann Sensing

Δ phase = h/2πλ

Opaque disk in NIRCam pupil wheel slot
Cut out a subaperture over 2 segments
Segment piston error ‘h’ (physical - microns)
Phase piston error h/2πλ radians at wavelength λ

Pass through a grism - to create a spectrum
Place on chip using a prism or wedge under the grating

Repeat over 9 more segment pairs
Make a second DHS element at 60 degrees
Coarse Phasing - fringe sensing

Cut a circular aperture across a diameter
Offset one half by some piston error ‘h’
Think: sub-aperture across a segment boundary

Look at PSF at various λ’s for the same ‘step’ or piston?

Slices of PSFs with wavelength increasing to the right

Do this ‘wavelength spreading’ with a grism (in pupil)
Put a wedge or tilt under grating to separate out the spectrum from each subaperture to a unique location on chip
Coarse Phasing - fringe sensing

Capture range of fringe sensing
(required: 150 microns)

Fewer dark fringes mean less piston error across segment gaps

Final state
(required: 1 micron in rms piston)

Actual procedure puts ~10 spectra across 2048 x 2048 detector
This simple simulation puts 19 spectra across a chip

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Co-phased PSF

Co-phased segment PSFs = single telescope PSF
Initial Fine Phasing
Multi-point Fine Phasing
Routine Maintenance Fine Phasing

Next lecture
Rules of thumb, definitions

• Resolution element (Res Elt) $\lambda/D$ radians
  – $0.2 \lambda$(in microns) / D (in meters) in arcseconds
• Nyquist sampling
  – Astronomer’s version - 2 pixels across 1.22 Res Elts
  – Nyquist’s version: 2 samples per Res Elt
• Effective focal length
  – $F = f D$ (where $f =$ focal ratio)
• Pixel size $p$
  – Angular size on sky = $p / F$ radians
  – $0.2 \ p$ (in microns) / $(f \ D \ (in \ meters))$
• Strehl ratio
  – Peak intensity (actual aberration) / Peak intensity (perfect wavefront)
Rough photometric zero points


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