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Optical Analysis

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Minimum Mission Review
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Where does optical modeling fit in?

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- Develop optical sensitivity matrices for integrated modeling – ties together thermal and structure analysis with contrast measurements and requirements
- Verify contrast calculations in error budget

Assumptions

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- Most of the optical modeling is performed using raytrace analysis to measure the wavefront at the pupil image of the occulting mask, since this is where the wavefront error is most critical.
- The error budget specifies maximum allowable wavefront error based on simplified contrast model
- The analysis measures the change in the wavefront from a perfectly controlled system
- Only the primary mirror has surface figure errors, all other optics are ideal
- In this round of analyses, rigid body motions of the other optics were ignored
- Contrast results are for a radial $sinc^2$ mask, Lyot stop is hard-edged elliptical aperture

Optical Modeling Tool

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- MACOS
  - "Modeling and Analysis of Controlled Optical Systems"
  - JPL's optical analysis tool
  - Part of IMOS ("Integrated Modeling of Optical Systems")
  - MACOS is used for the raytracing as well as full near-field plane-to-plane diffraction modeling of the coronagraph

Process

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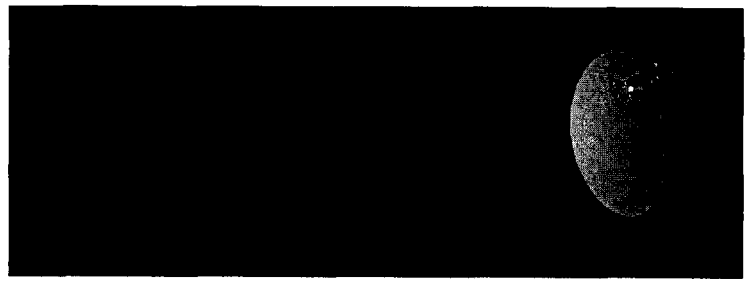
- Optical prescription converted from ZEMAX to MACOS (only one out of the four possible paths)



Process

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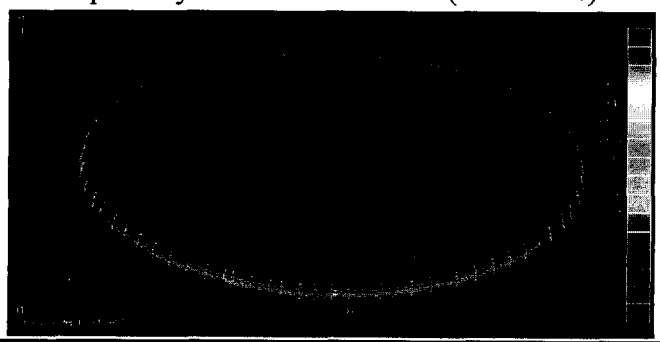
Linear optical sensitivity matrices are computed using the MACOS model

- Rigid body sensitivities
- Flexible primary mirror sensitivities (423 nodes)



Rigid body sensitivities

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- Rigid body sensitivities are generated by perturbing each optical element, one degree of freedom at a time
- The wavefront at the occulting mask is computed using raytracing
- Each resulting wavefront is reshaped into a vector and becomes a column in a sensitivity matrix
- There are 16 optical elements, resulting in 16 x 6 = 96 degrees of freedom

[DOF #1 wavefront | DOF #2 wavefront | . . . . . | DOF #96 wavefront] X [96 perturbations] = aberrated wavefront

List of Optics

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ele.	DOF	description
1	1-6	Primary
2	7-12	Secondary
3	13-18	Fold 1
4	19-24	Fold 2
5	25-30	DM Collimator
6	31-36	Polarizing Beam Splitter 1 (3 surfaces)
7	37-42	Polarizing Beam Splitter 2 (3 surfaces)
8	43-48	Steering Mirror
9	49-54	Michelson BS (3 surfaces, double pass)
10	55-60	Wedge 1 (2 surfaces, double pass)
11	61-66	DM 1
12	67-72	Fold 3
13	73-78	Relay OAP 1
14	79-84	Relay OAP 2
		Pupil Mask
15	85-90	Occulting OAP 1
16	91-96	Fold 4
17	97-102	Occulting Mask

Primary Mirror Sensitivities

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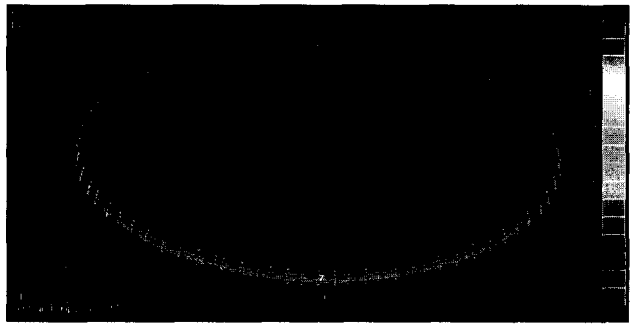
- Each node on the primary mirror is given a unit displacement in the Z-direction, one at a time, and the resulting wavefront is stored as a column vector
- Same process as for rigid body sensitivities



Contrast

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- The resulting wavefront is characterized by the first 15 Zernike terms, which can then be compared to requirements in the error budget
- We have verified that the errors can be well-represented by the first 15 Zernike terms
- Contrast results can be obtained by applying the perturbations directly to the MACOS model (plane-to-plane diffraction between each optical element).

Verification of error budget

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- The error budget used a simplified Fourier optics model of a coronagraph to compute the relationship between wavefront error at the occulting mask and the contrast
- MACOS uses a full near-field diffraction model of the optical system to compute the contrast

Future work

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- Monte Carlo verification of error budget contrast results
- Include additional masks and stops
- Model polarization effects

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BACKUP SLIDES

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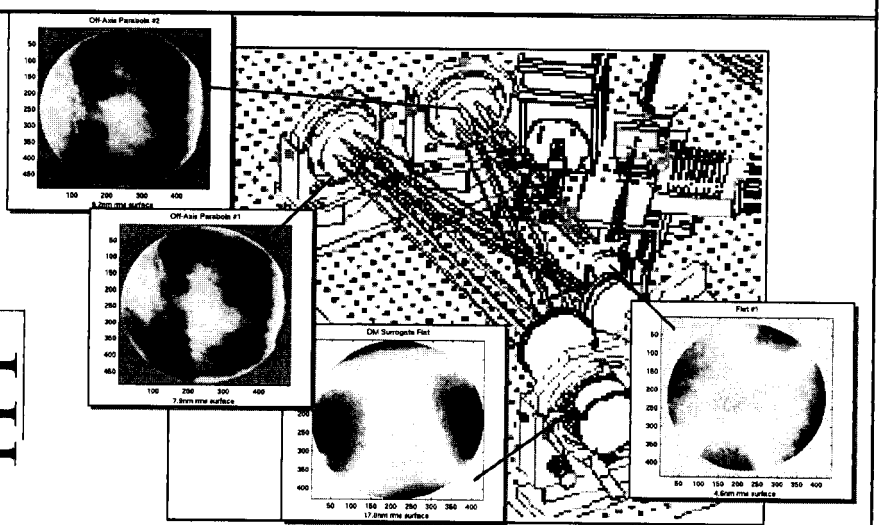
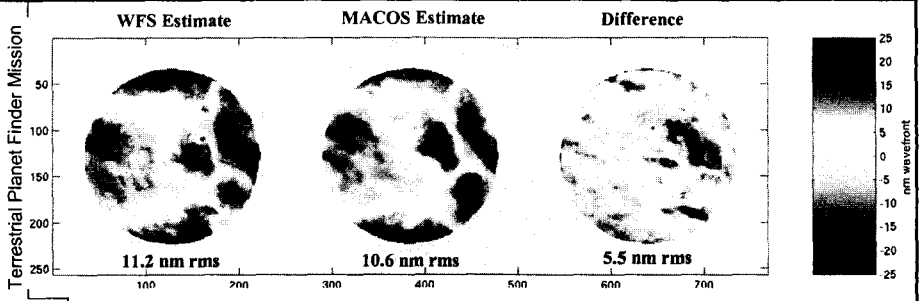
HCIT verification of diffraction model



Measured optical surfaces for the optics leading to the occulting spot

HCIT verification of diffraction model



Estimate of the wavefront at the exit pupil of the occulting mask and the estimate that MACOS computes

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