Electric Field Conjugation In The Presence of Model Uncertainty

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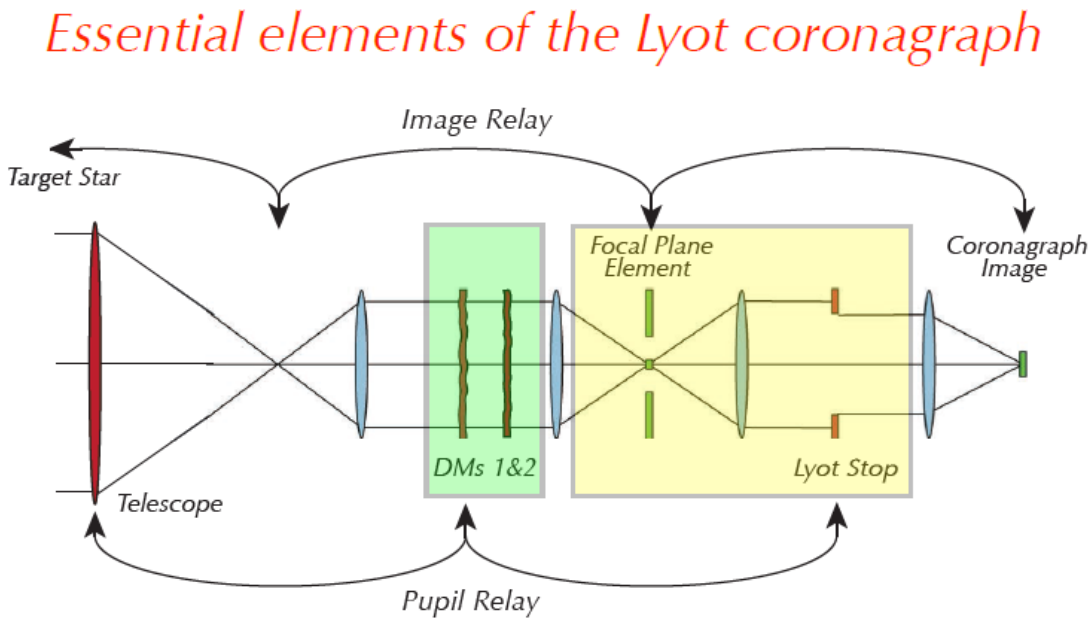
Outline

- Review of Electric Field Conjugation (EFC)
- Numerical Simulation of the Testbed with Calibration Error
- Simulation Results

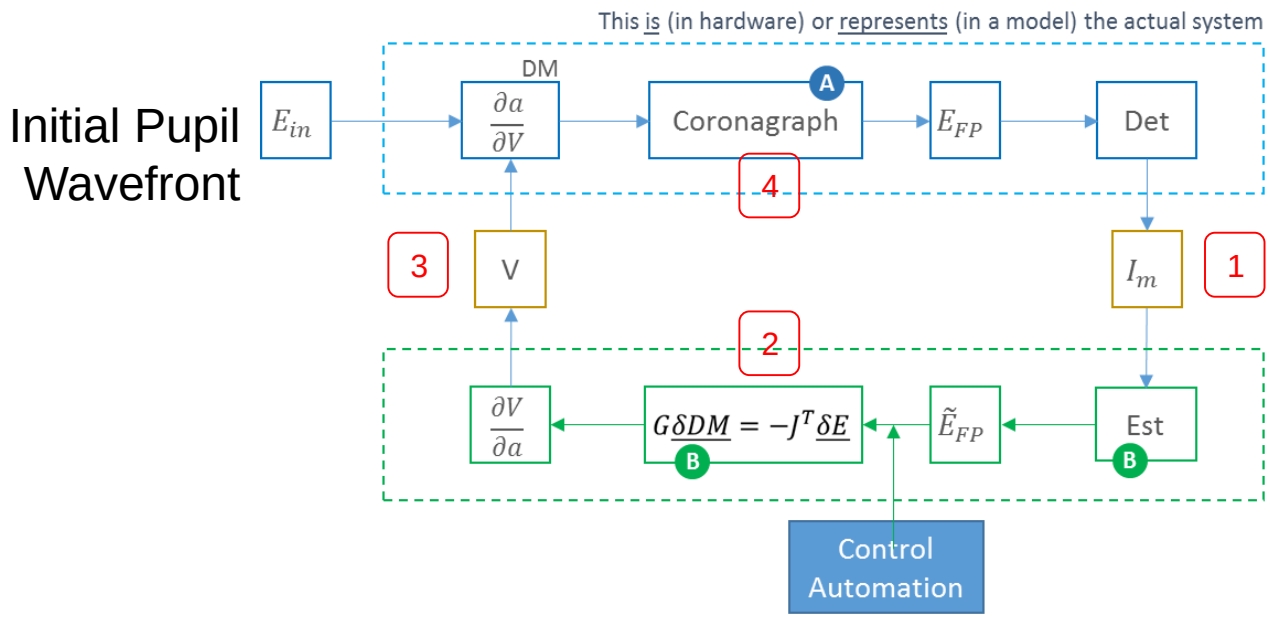
Hybrid Lyot Coronagraph Overview



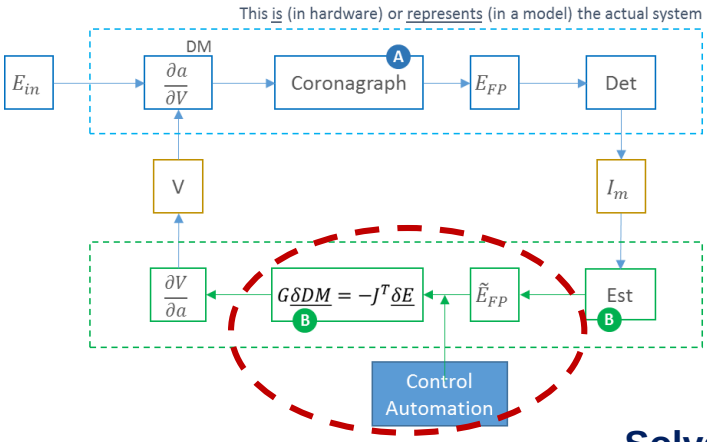
- **HLC is one of two coronagraph technologies forming the baseline WFIRST Occulting Mask Coronagraph (OMC) architecture**
  - **Responsible for planet discovery in the current DRM**
- **WFIRST Hybrid Lyot coronagraph essential elements:**
  - 2 deformable mirrors
  - Focal plane occulting mask
  - Lyot stop

One EFC Iteration

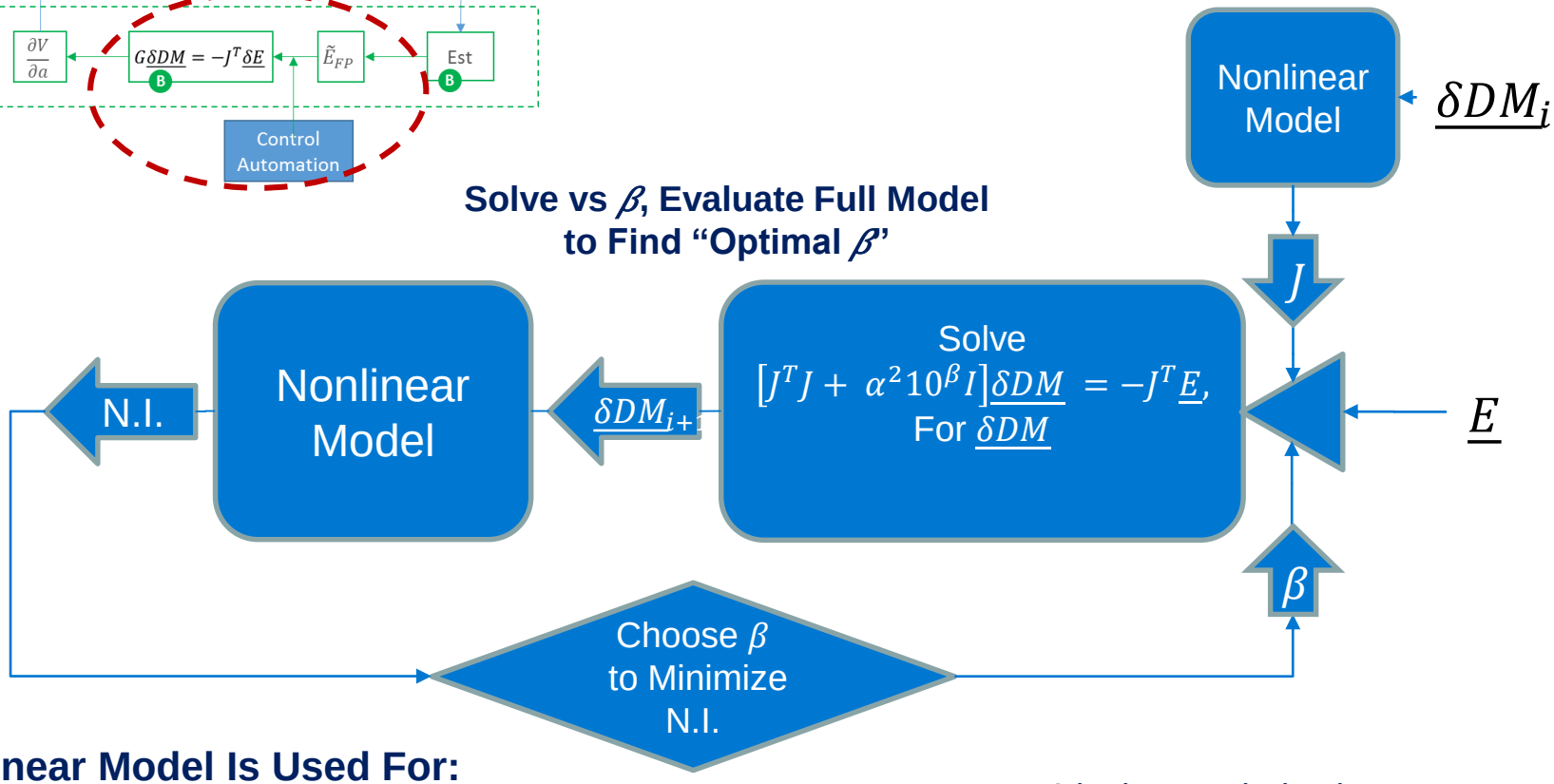
- **1. Probe the Coronagraph to Estimate Electric Field, *E* k**
- ***2.* Calculate Jacobian and Solve For New $\underline{\delta DM}$**
  - *Includes Choosing Regularization and Other Control Automation*
- **3. Apply Actuator Gain and Send New Actuator *V* Volts to Coronagraph**
- **4. Apply Actuator *V* to DM's And Record Images.**



Solve For Next Iteration



Solve vs β, Evaluate Full Model to Find "Optimal β"



- **Nonlinear Model Is Used For:**
  - Calculating Jacobian
  - Choosing β ➔ Model Evaluates $\delta E(\delta DM; \beta)$
  - β is the regularization parameter
  - $J_{m,n} = \frac{\partial E_m}{\partial DM_n}$,

Testbed Calibrations

- **Calibration Error: Hardware $\neq$ Model**

- **Pupil Wavefront**
  - Phase Retrieval

- **FPM Alignment**
  - Symmetric DM Actuator Pokes + Phase Retrieval

- **Lyot Mask**
  - Direct Imaging

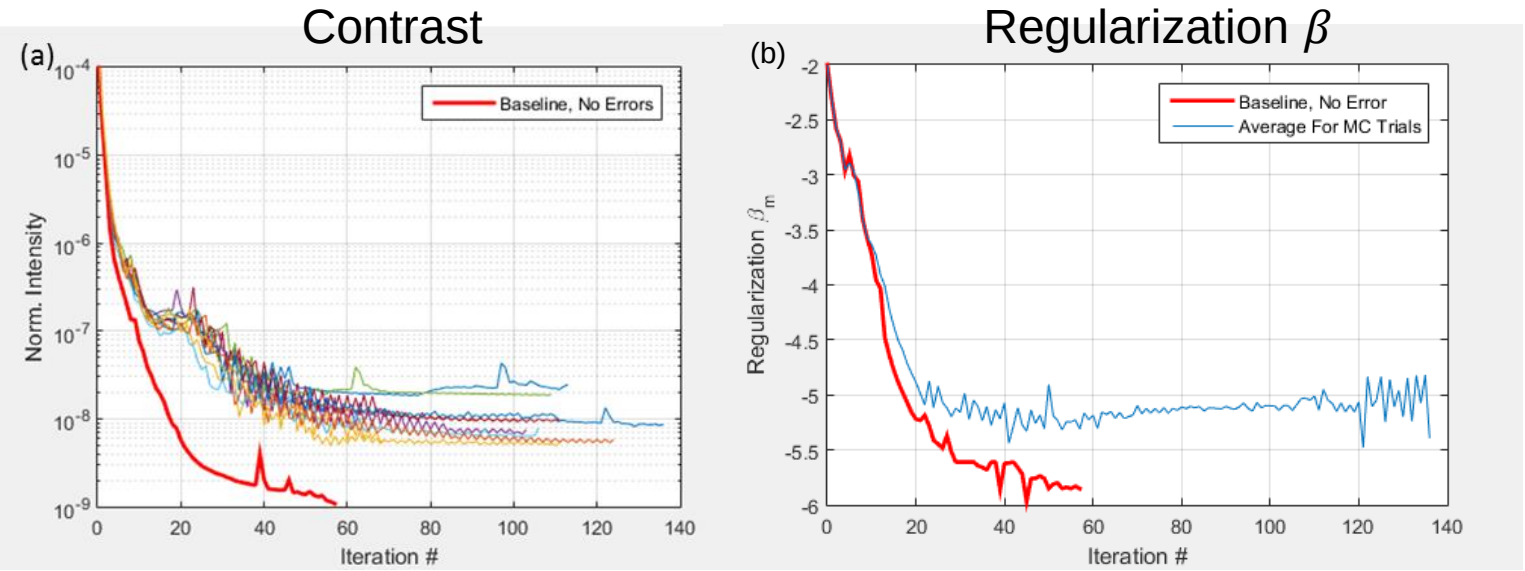
- **DM1 ⇔ DM2 ⇔ Pupil Registration**
  - DM Actuator Grid + Phase Retrieval

Numerical Simulation

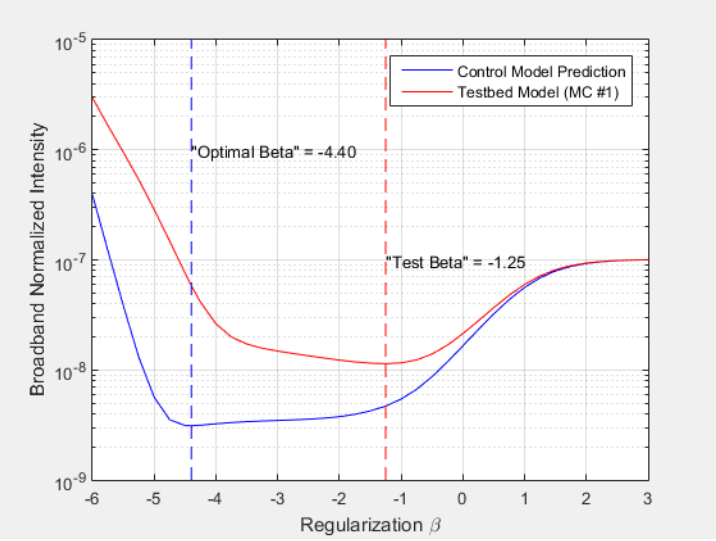
- **Add Calibration Errors to Numerical Model for Testbed**

Name	Parameter	Unit	Nominal Value	MC Error σ
Pupil	Pupil Diameter	pix	305.3	0
DM1	X-Decenter	um	-94.1	50
	Y-Decenter	um	-475.1	50
	X-Rotation (Tip)	deg	8.25	0
	Y-Rotation (Tilt)	deg	-0.07	0
	Z-Rotation (Clocking)	deg	-0.86	0.05
DM2	X-Decenter	um	799	50
	Y-Decenter	um	-83.5	50
	X-Rotation (Tip)	deg	2.37	0
	Y-Rotation (Tilt)	deg	0.004	0
	Z-Rotation (Clocking)	deg	0.45	0.05
Lyot	X-Decenter	um	0	25
	Y-Decenter	um	0	25
FPM	X-Decenter	um	0	0.5
	Y-Decenter	um	0	0.5
Pupil	Amplitude Variation	rel. int.	Measured	Intensity Noise
	Phase Variation	rad (rms)	Measured	0.05

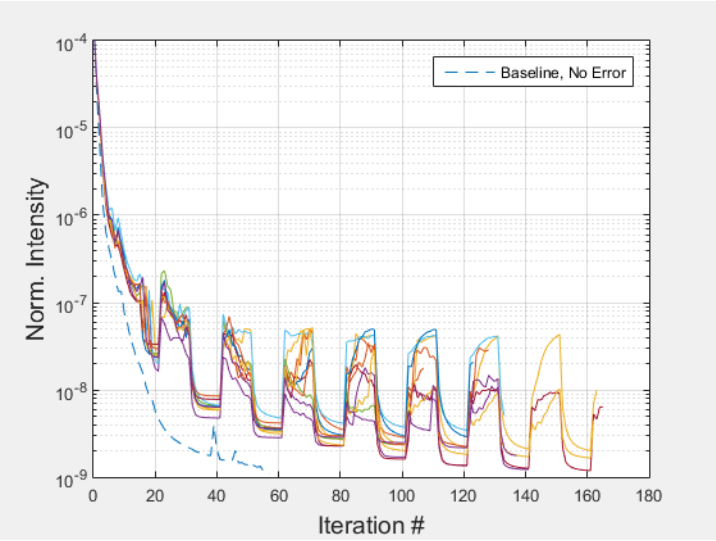
EFC With Calibration Errors

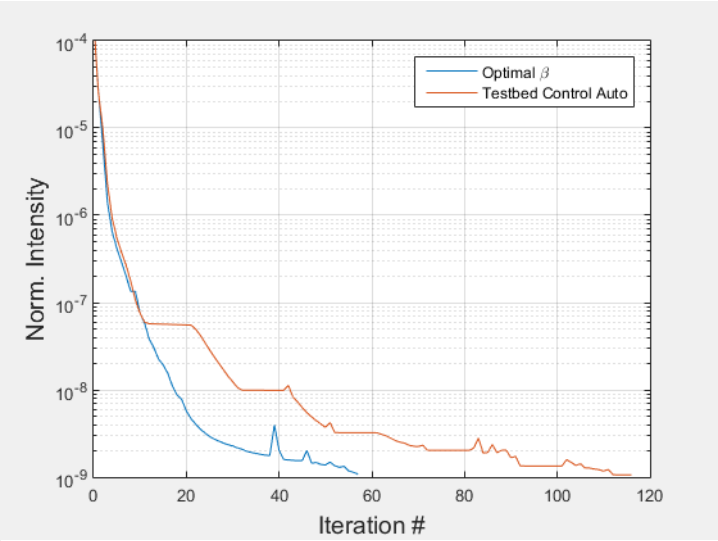


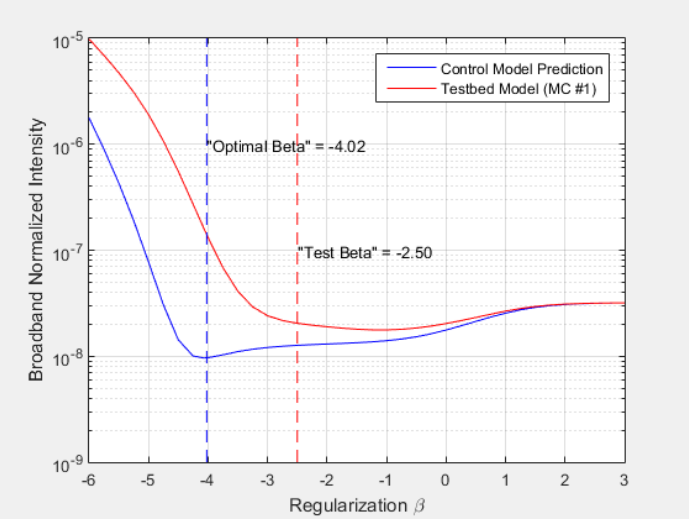
Effect Of Calibration Error

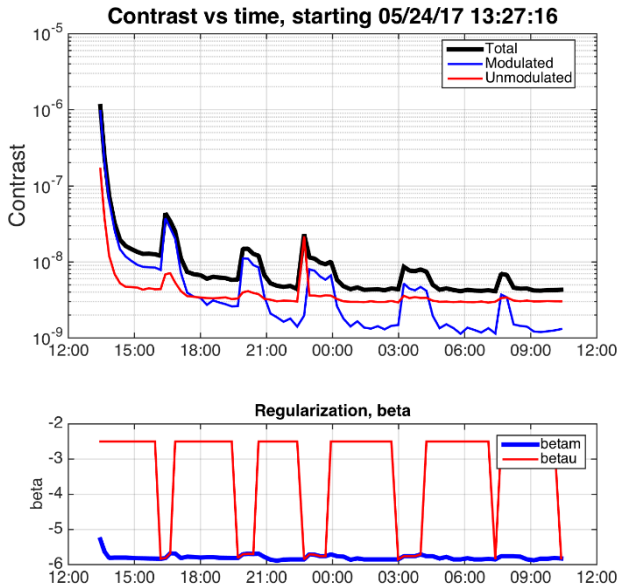


New Control Strategy








Contrast vs time, starting 05/24/17 13:27:16
Contrast
Total
Modulated
Unmodulated
10^-5
10^-6
10^-7
10^-8
10^-9
12:00
15:00
18:00
21:00
00:00
03:00
06:00
09:00
12:00
Regularization, beta
beta
betam
betau
-2
-3
-4
-5
-6

Conclusions

- Calibration Error: Knowledge Error of Coronagraph

- Model Error: Difference Between
  - Coronagraph Output
  - Model Output
- EFC Relies On Model:
  - Calculate Jacobian
  - Choose Regularization
- Cost of Calibration Error:
  - Slow Convergence
  - Require Regularization "Control Strategy"
- See Poster, "Optimizing the regularization in broadband wavefront control algorithm for WFIRST coronagraph," Sidick, E., 10400-74
  - Further Discussion of Regularization β.