Fast steering mirror disturbance effects on overall system optical performance for the Large Ultraviolet/Optical/Infrared Surveyor (LUVOIR) concept using a non-contact vibration isolation and precision pointing system

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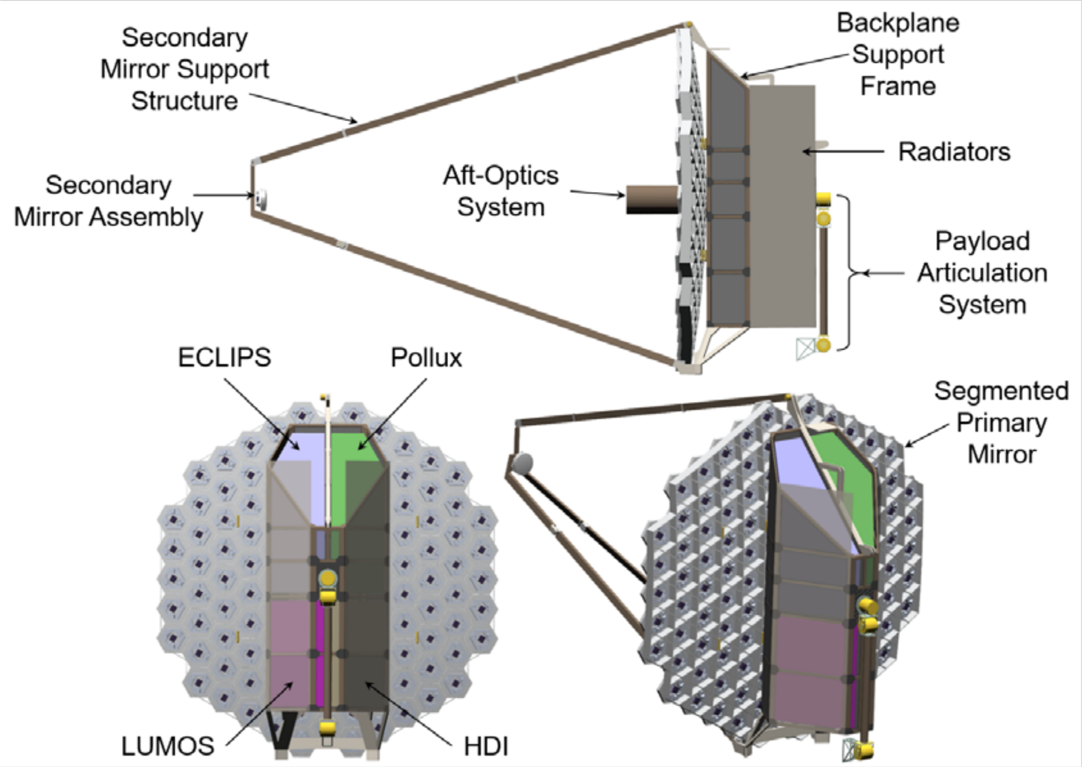
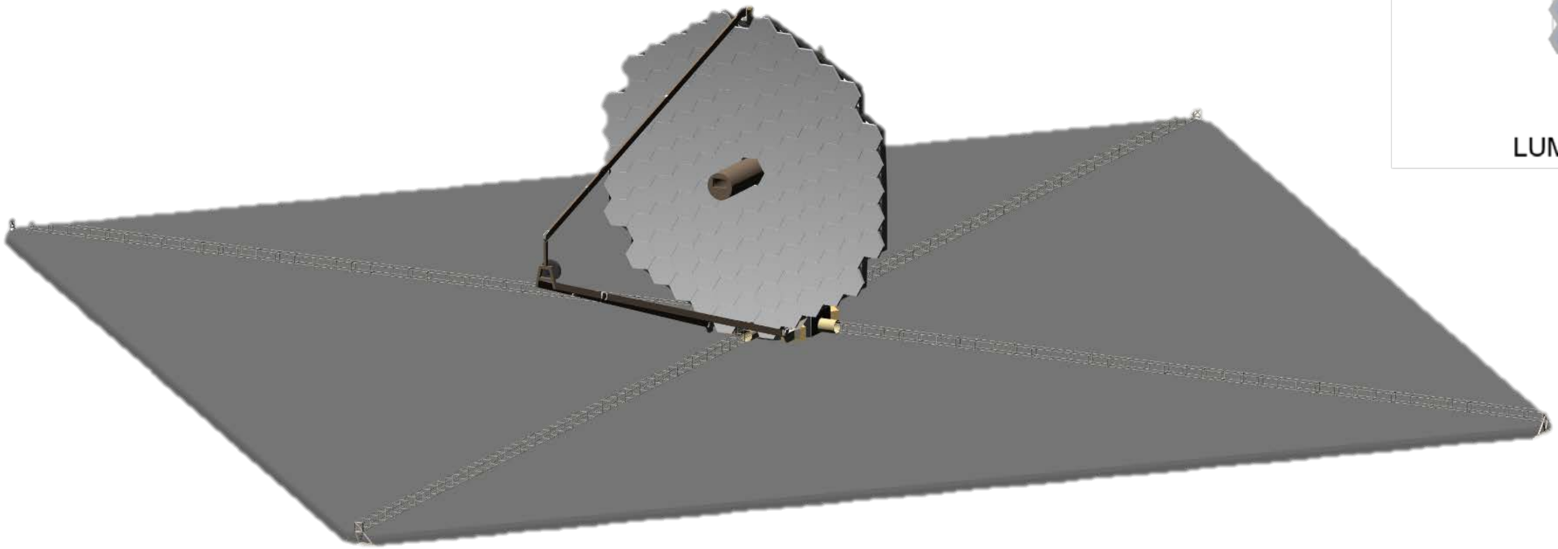
Overview

- LUVOIR Payload
- Control Architecture
- Integrated Model
- Overall Results
- Targeted Results
- Conclusion

LUVOIR Payload

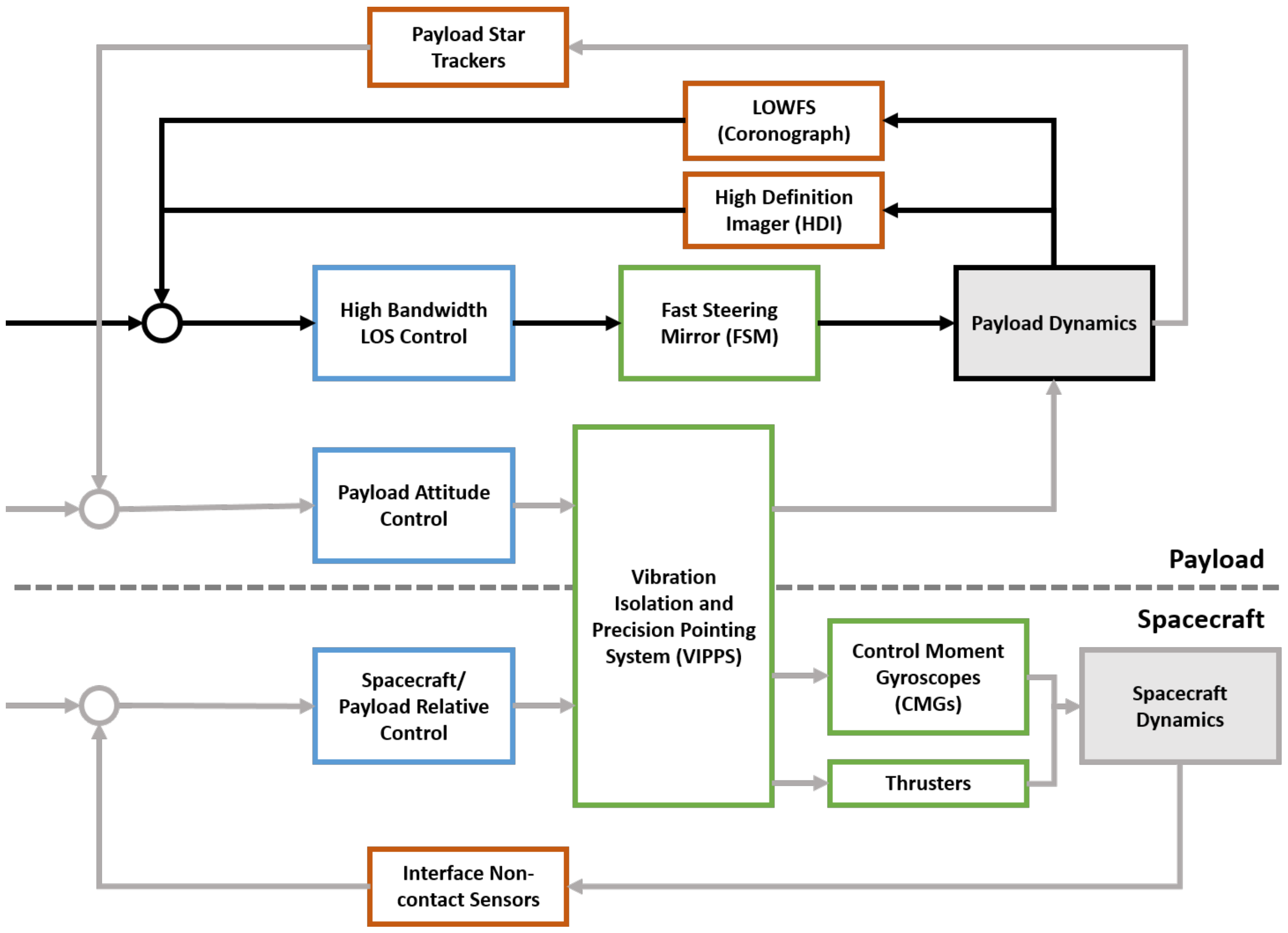
- 120 Primary Mirror Segments
  - Attached to Backplate Support Frame
- Secondary Mirror Assembly
- Aft-Optics System
  - Houses the Fast Steering Mirror (FSM)
- Payload Articulation System (PAS)





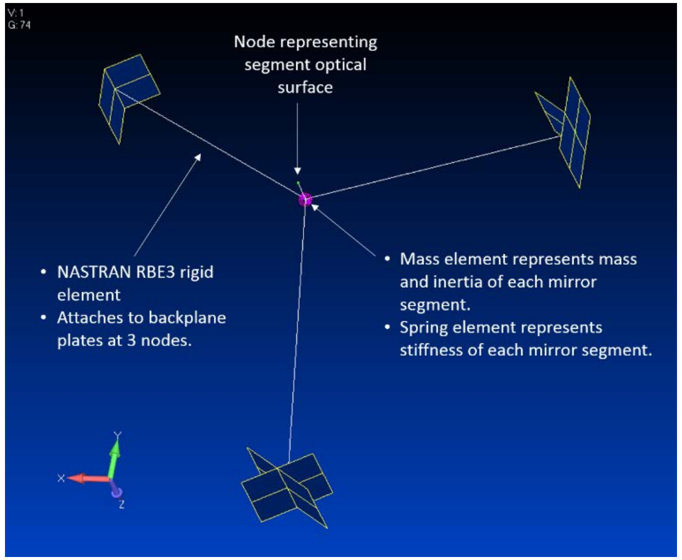
Control Architecture

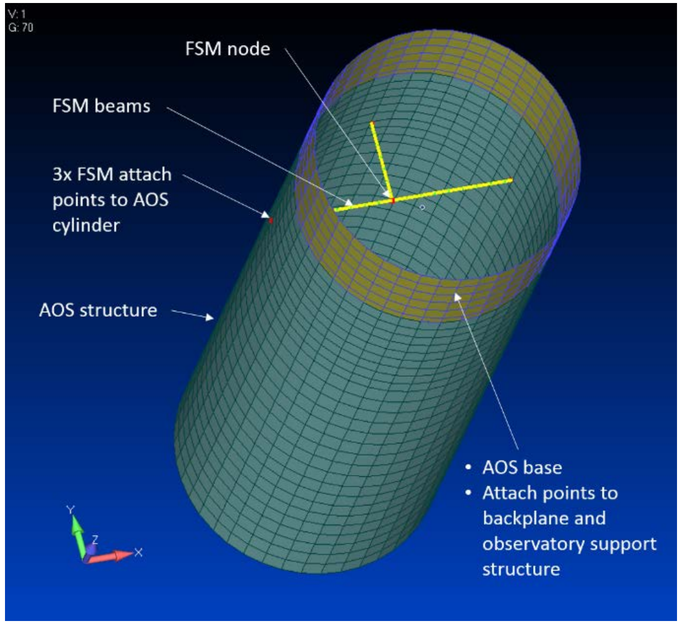
- Multi-loop control architecture
  - Payload Attitude Control
  - Spacecraft/Payload Relative Control
  - **Line-Of-Sight Control**



Integrated Model - Finite Element Model (FEM)

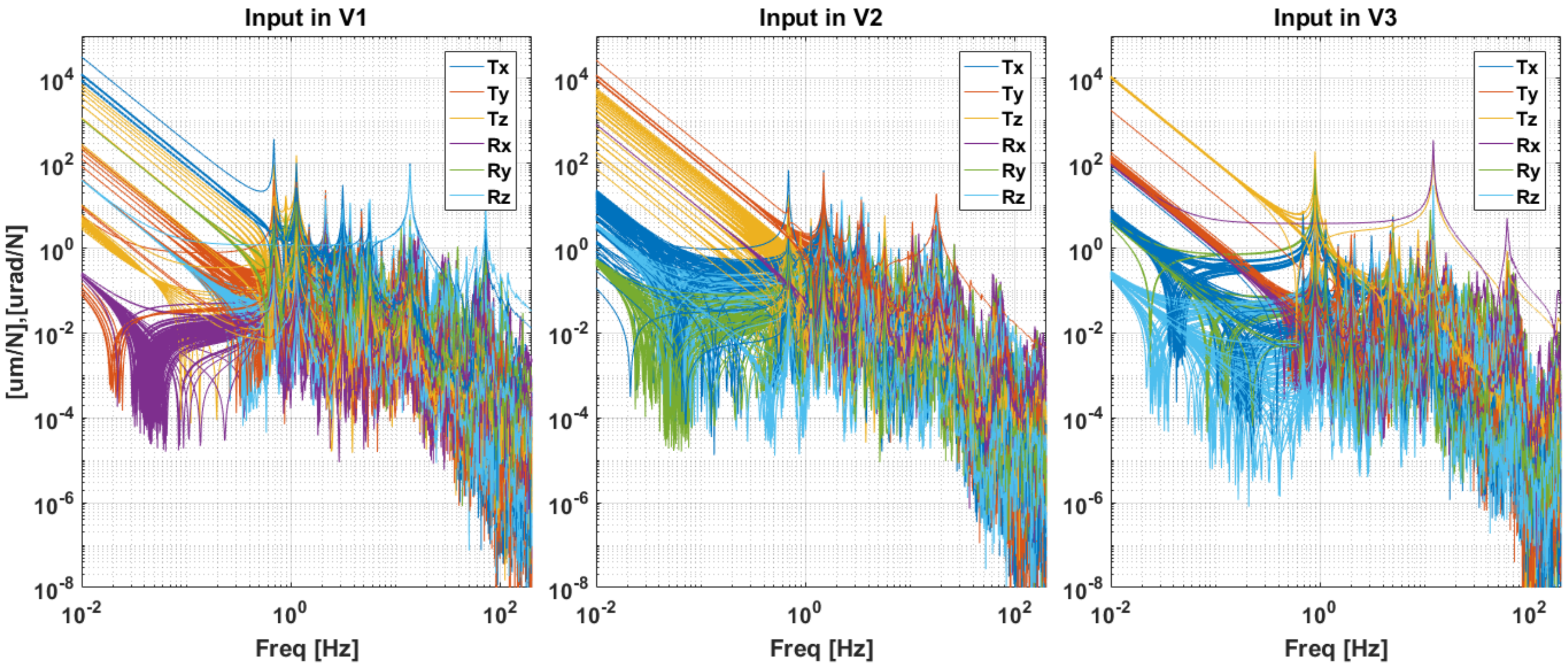
- Payload only FEM begins at the PAS
- Each primary mirror segment is modeled using a mass element connected to an optical node which is located at the center of the optical surface of each segment.
- Each mass element is coincident with a spring element attached to the backplane structure using a rigid body element (RBE).
- RBE uses interpolation to calculate the motion of the segment node form the motions of the three backplane nodes to which it is attached.
- Inertia and stiffness values comparable to flight heritage mirror segments used on the JWST observatory
- FSM housed inside the AOS cylinder and modelled using beam elements attached directly to the walls of the AOS in three places
- AOS is connected to the backplane through rigid elements so any disturbance injected into the FSM node will propagate through the rest of the primary mirror assembly





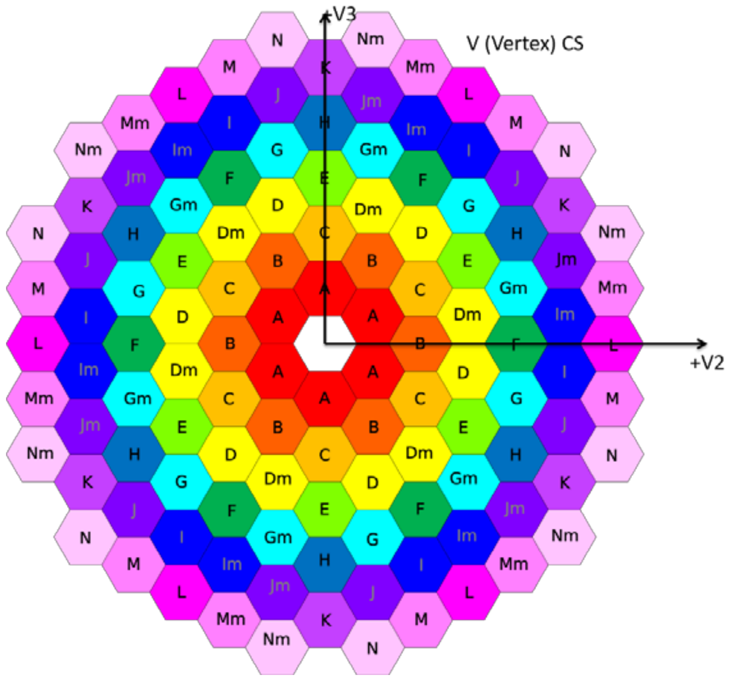
Integrated Model – FSM Input Distrubances

- Input at the FSM node with outputs at the optical nodes (PM Segments, PM, SM, TM, FSM, FPA)
- Frequencies, damping, and mode shapes up to 200Hz imported to Matlab and frequency response functions (FRFs) to give the amplitude of the response of displacement and rotational responses at the optical nodes for an input of 1N in the V1, V2, and V3 axes.
- Generic modal damping of 0.5% included



Integrated Model – Linear Optical Model (LOM)

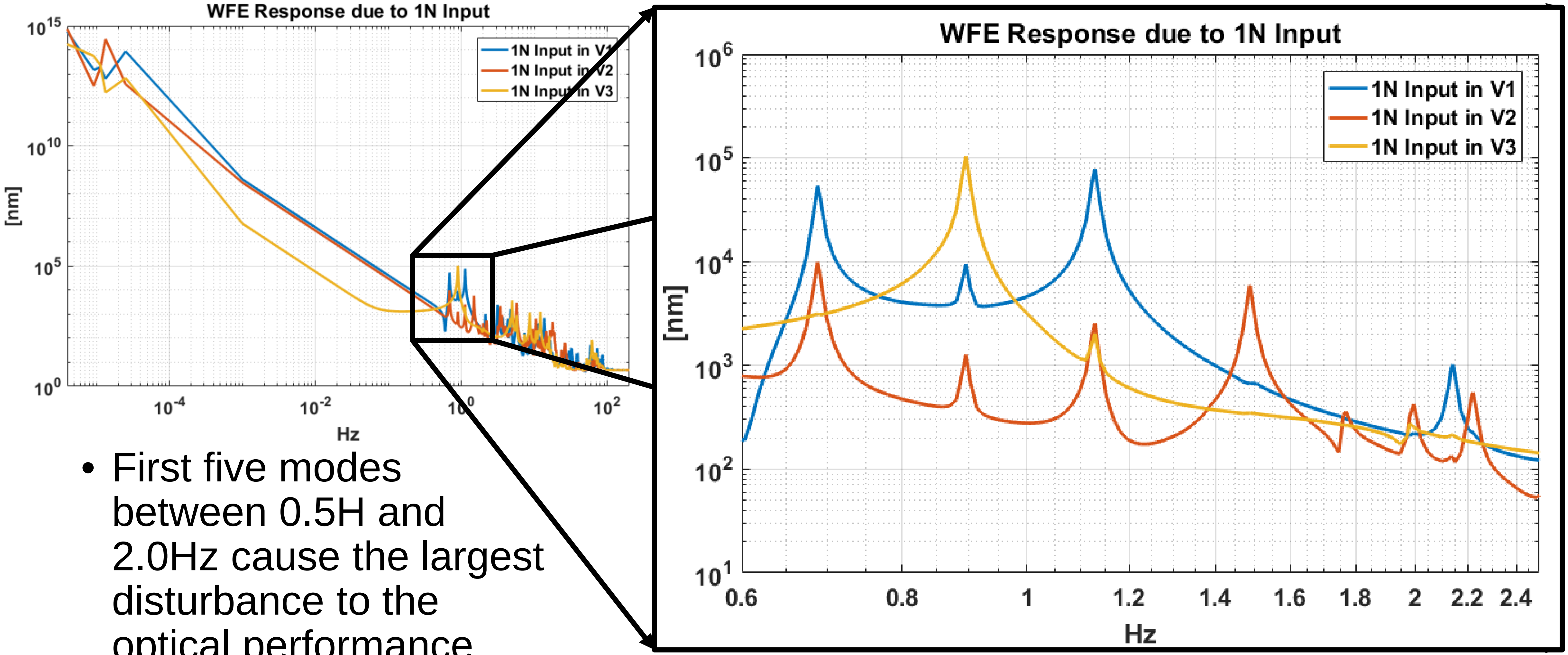
- Multidimensional matrix of sensitivity data created by perturbing each degree of freedom in the optical model and recording the change system performance divided by the perturbation amount.
- Original LOM used included a monolithic primary mirror modelled as a rigid body
- Using an optical description of the 120 segmented primary mirror, each optical surface was independently moved in three rigid body translation and rotation degrees of freedom
- Fed into Sigmadyne's SigFit along with the primary mirror prescription to create 720 (6 DOFs by 120 segments) Code V interferogram files (.int or INT) for the optical path difference (OPD).



When using the 720 INT files, only the translational DOFs were able to be verified when compared to the monolithic LOM and therefore were the only DOFs used in this analysis. Further work is needed to verify the rotational DOFs to include in this analysis.

Overall Results

- Wavefront Error due to a 1N input force at the FSM node

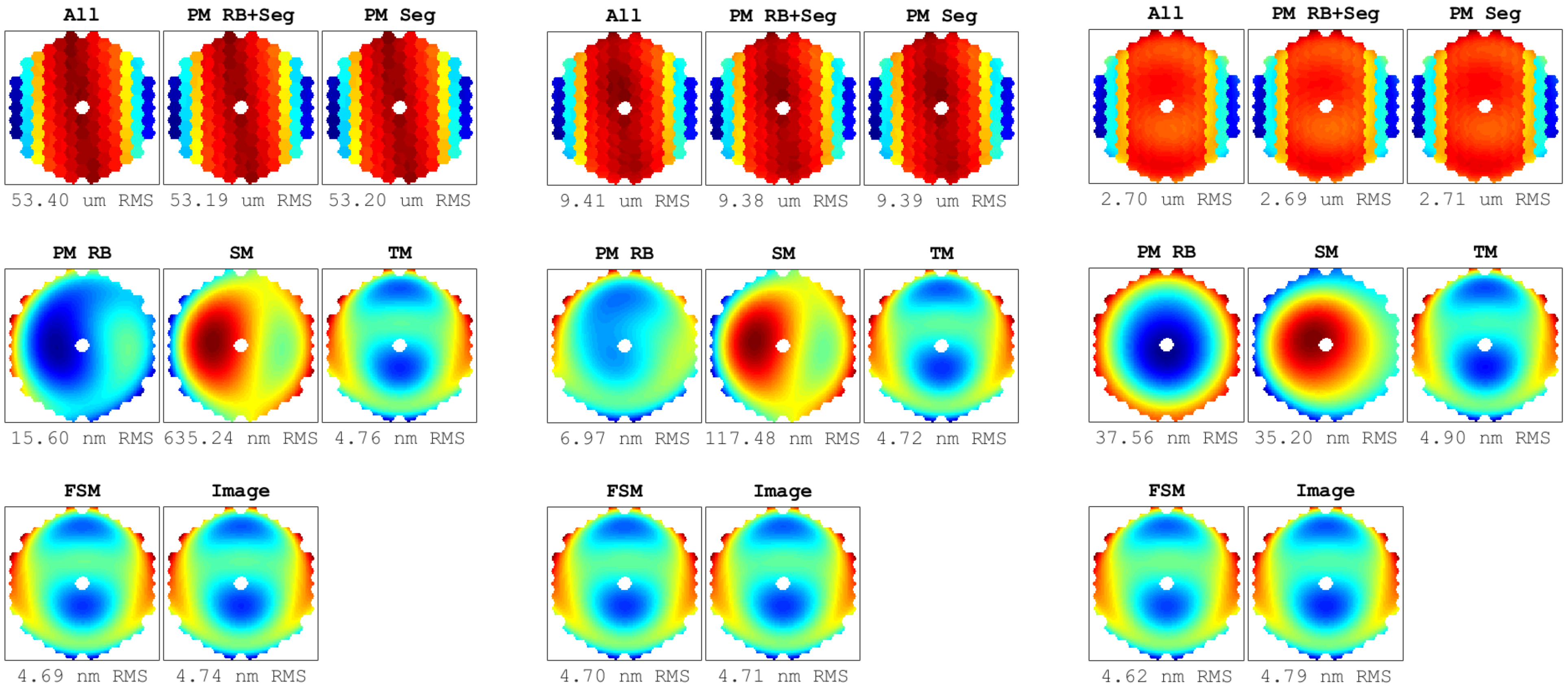


- First five modes between 0.5H and 2.0Hz cause the largest disturbance to the optical performance

Targeted Results

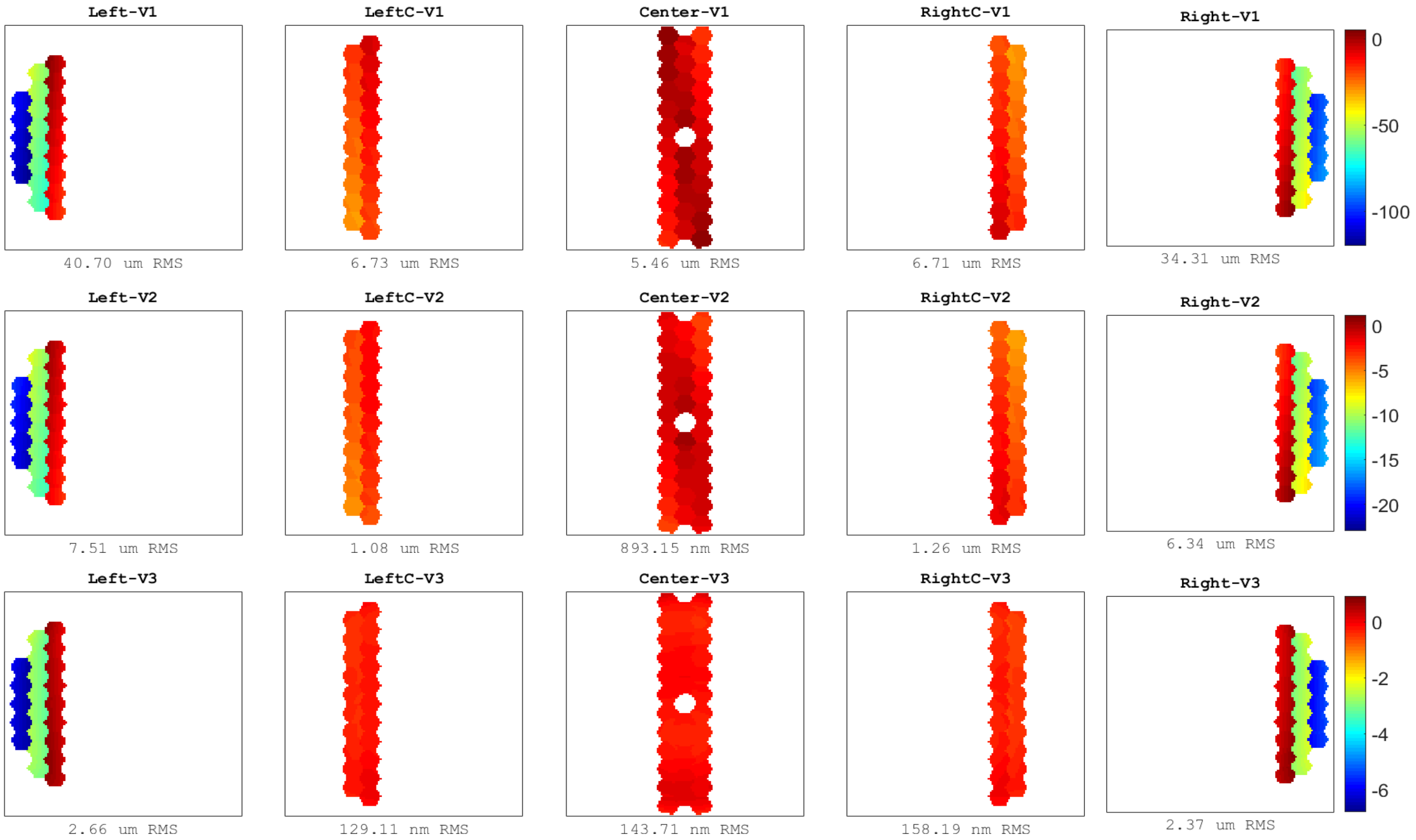
- First disturbance mode at 0.69Hz
- Response dominated by Primary Mirror Segment motion

WFE Output from Input in V1, V2, V3 @ 0.69Hz



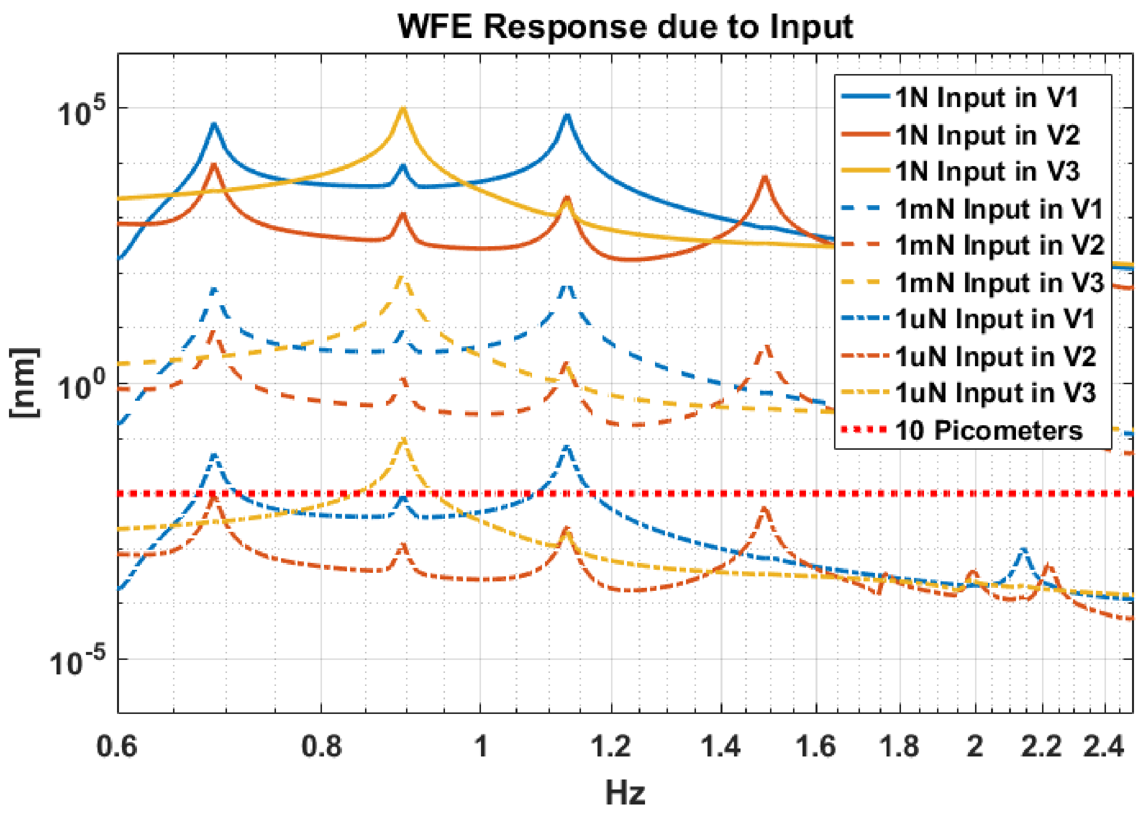
Targeted Results – Segment Motion

- Further from center the segment is, the more effected by FSM response
- See backup charts for expanded table of results



Conclusions

- LUVOIR requirement to have wavefront error stability less than 10 picometers RMS of the uncorrected system WFE per wavefront control step.
- Current analysis does not include primary mirror segment.
- Current analysis only includes contribution of the FSM disturbances.
- To achieve less than 10 picometers, the input disturbance must be less than 1 micro-Newton in all axes.



- Further analysis needed to determine exported forces from a notional FSM and how much wavefront error stability will be reduced by the active segment metrology and control system not included in this analysis

Back Up Slides

Targeted Results – Table of 0.5Hz to 2.0Hz Results

Optical Section		0.69Hz			0.90Hz			1.13Hz			1.49Hz			2.0Hz		
		V1, V2, V3[um]			V1, V2, V3[um]			V1, V2, V3[um]			V1, V2, V3[um]			V1, V2, V3[um]		
Total WFE		53	9.4	2.7	9.0	0.9	104	78	2.2	1.8	0.6	6.0	0.8	0.5	0.7	0.7
Segments		53	9.4	2.7	9.0	0.9	104	78	2.2	1.8	0.6	6.0	0.8	0.5	0.7	0.7
PM Slices	Left	41	7.5	2.6	10	1.4	116	96	3.0	2.9	0.7	7.3	0.4	0.2	0.7	0.3
	Left C	6.7	1.0	0.1	0.3	0.3	3.6	9.8	0.3	0.1	0.2	5.7	0.1	0.1	0.3	0.2
	Center	5.4	1.0	0.1	0.2	0.3	2.5	10	0.3	0.1	0.2	4.7	0.1	0.1	0.2	0.2
	Right C	6.7	1.3	0.2	0.4	0.3	4.5	9.4	0.4	0.2	0.3	5.4	0.1	0.1	0.4	0.2
	Right	34	6.3	2.4	9.2	1.2	102	105	3.4	3.1	0.9	5.9	0.4	0.3	0.6	0.3

References

- National Aeronautics and Space Administration, Goddard Space Flight Center, “Large UV/Optical/Infrared Surveyor”, https://asd.gsfc.nasa.gov/luvoir/.
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- Joseph M. Howard and Kong Ha, "Optical modeling activities for the James Webb Space Telescope (JWST) project: II. Determining image motion and wavefront error over an extended field of view with a segmented optical system," Proc. SPIE 5487, 850 (2004).
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