Large UV / Optical / Infrared Surveyor

Telling the story of life in the universe

LUVOIR

NASA

Technologies to Enable the Next Great Observatory

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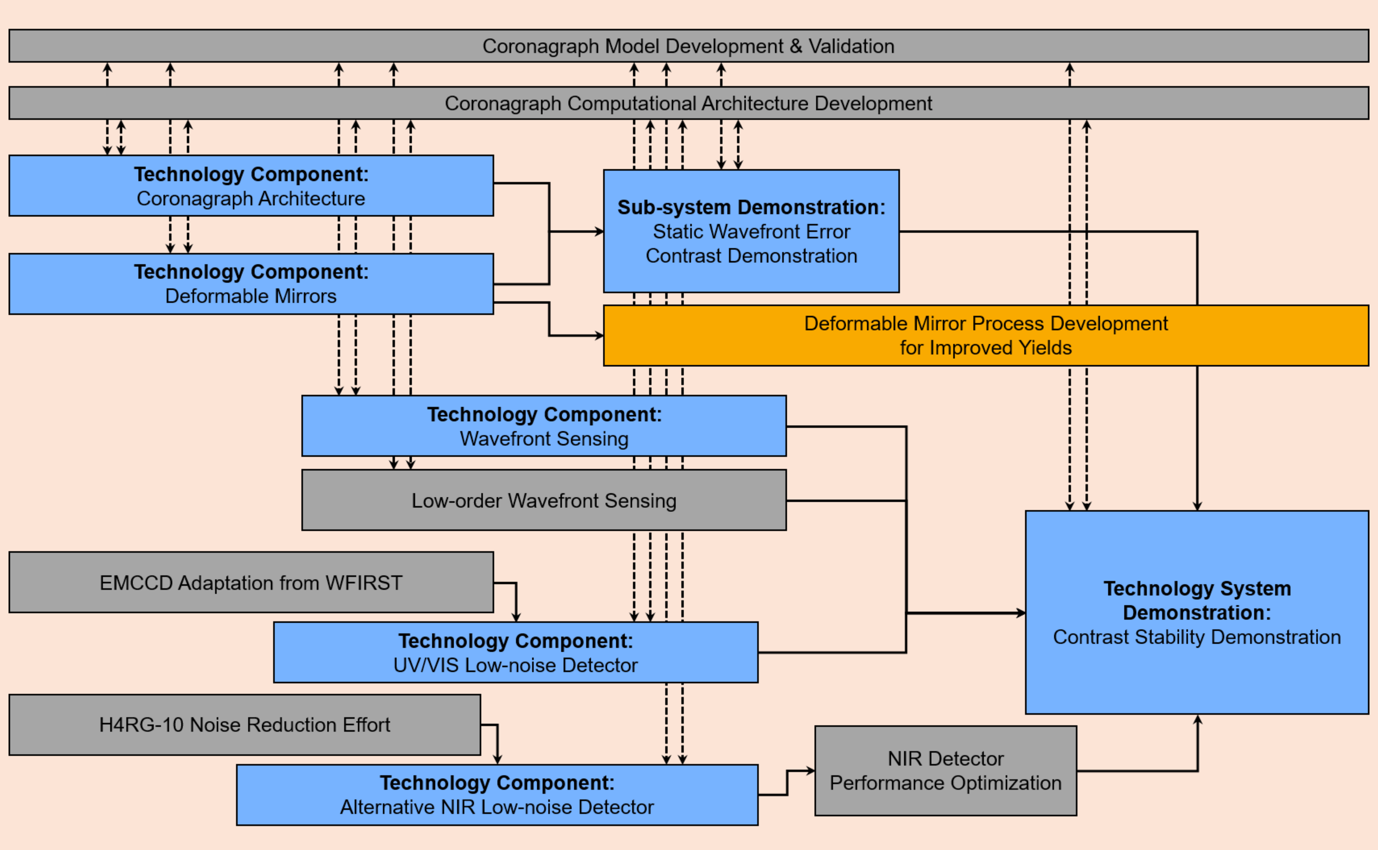
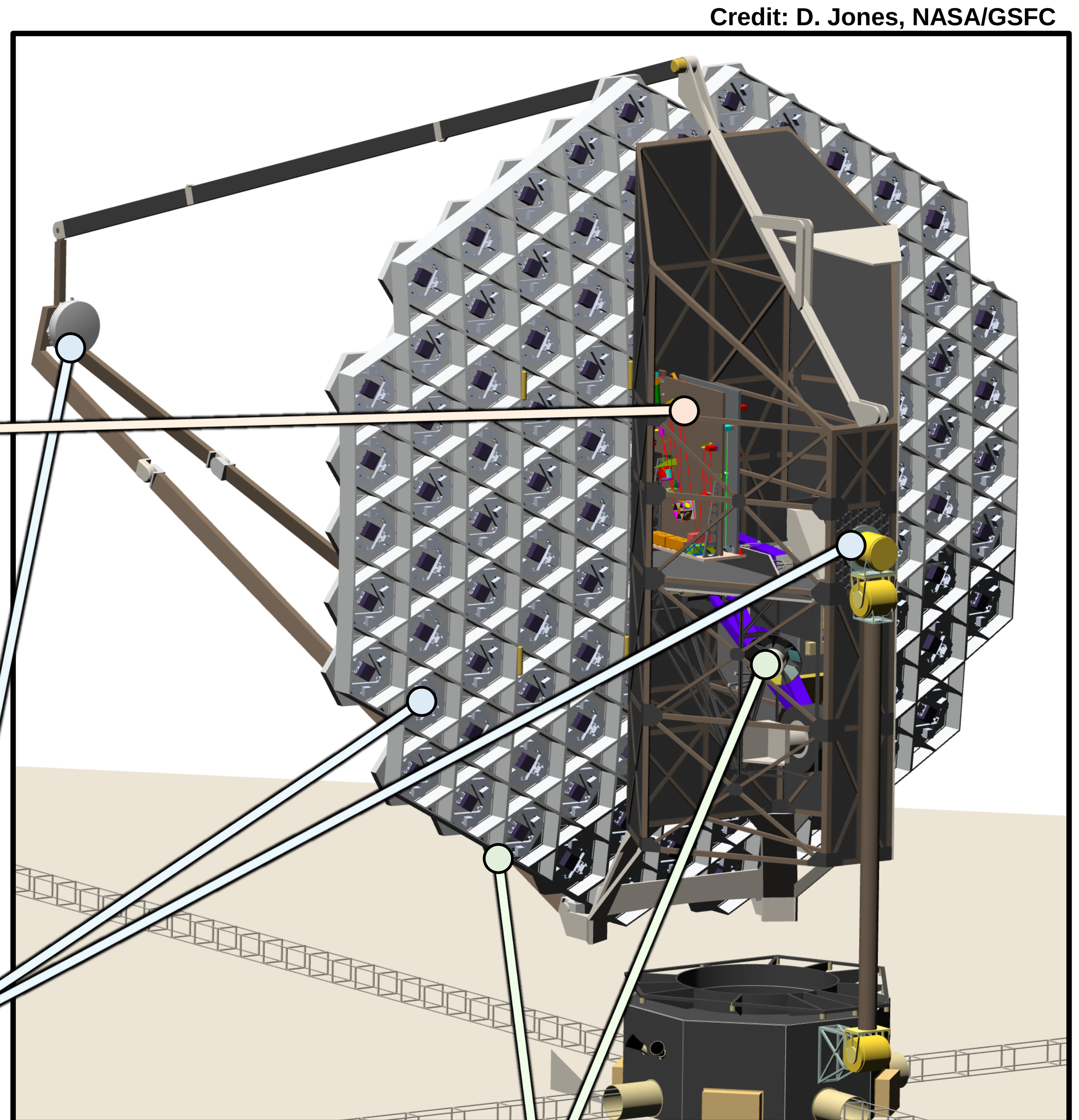
The Large Ultraviolet/Optical/Infrared Surveyor (LUVOIR) is one of four mission concepts being studied by NASA for the 2020 Decadal Survey in Astronomy and Astrophysics. Enabling a mission as ambitious as LUVOIR requires an array of technologies. Critically, a systems-level approach must be taken to developing these technologies, guided by architecture studies to place each technology in the appropriate system context.

Three technology systems enable the LUVOIR science objectives: the **High-contrast Coronagraph Instrument** system, the **Ultra-stable Segmented Telescope** system, and the **Ultraviolet Instrumentation** system. Each of the technology systems comprise the individual technology components that must be developed and demonstrated as a system. Supporting engineering manufacturing development efforts are also identified for early risk reduction.

It is important to note that the high-contrast coronagraph instrument and ultra-stable segmented telescope technology systems are tightly coupled; the performance capabilities of one system drive the requirements of the other. Similarly, the ultraviolet instrumentation technology system is loosely coupled to the other two; while the relative performance affects each system, they do not necessarily drive one another. This coupling between systems requires continuous cross-validation between the technology development paths. It is therefore critical that the technology development plan be executed in parallel with a detailed Pre-Phase A Architecture Study to provide the necessary systems-level perspective and cross-validation.

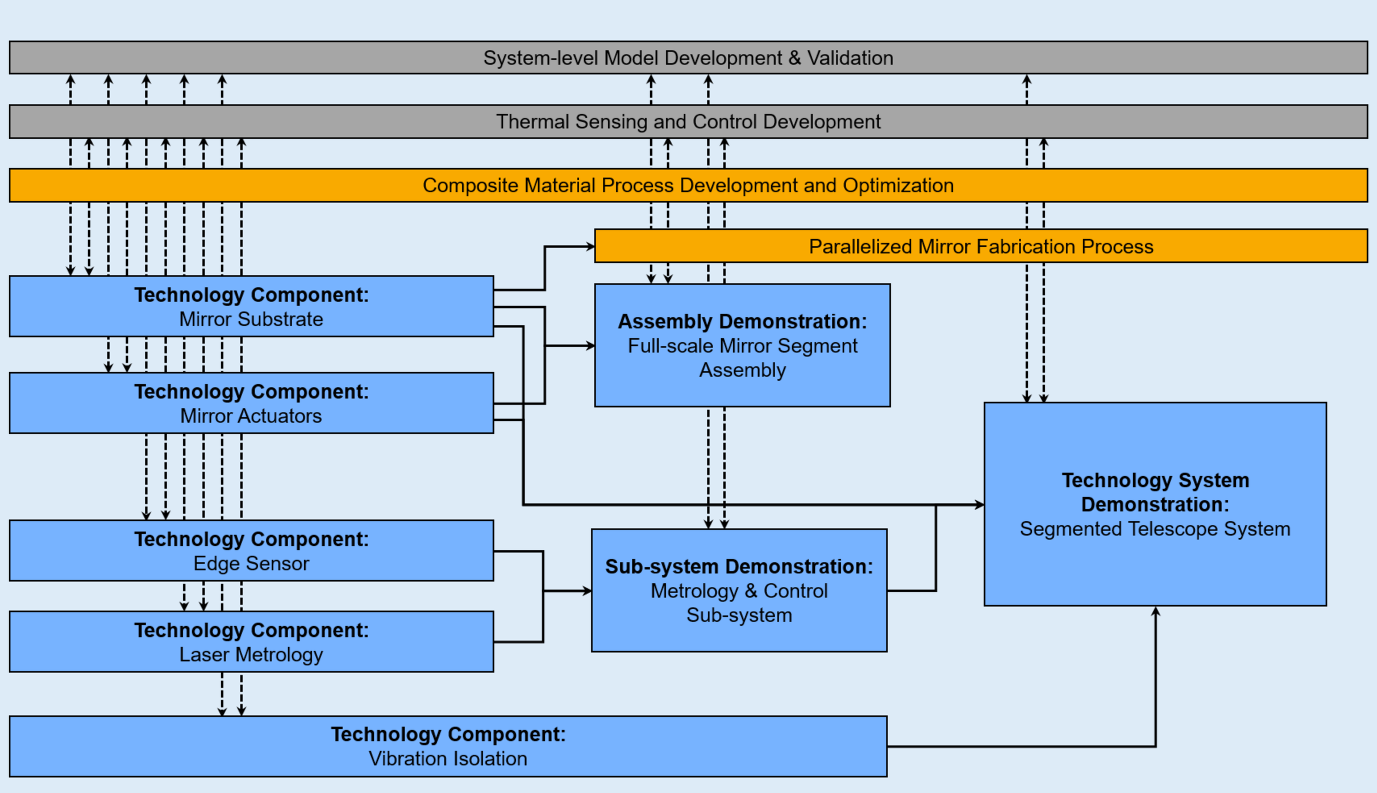
High-contrast Coronagraph Instrument System





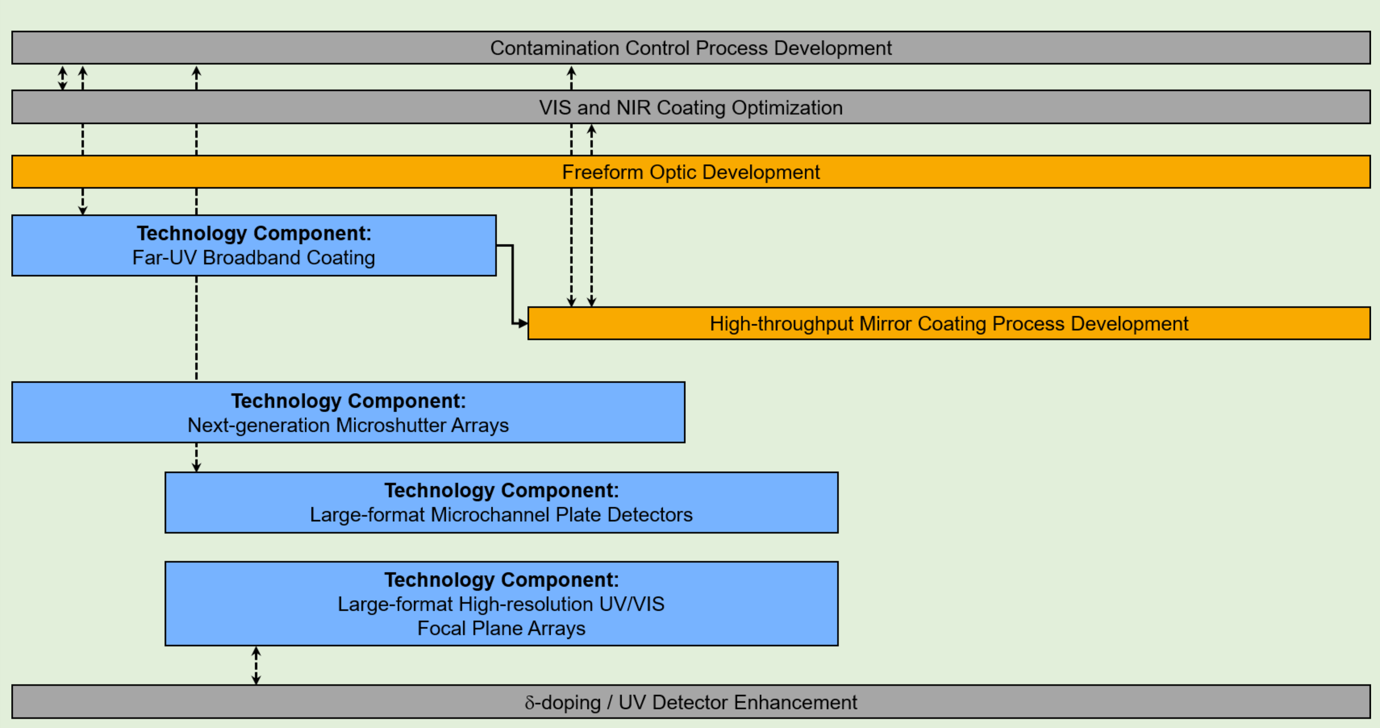
Credit: D. Jones, NASA/GSFC

Ultra-stable Segmented Telescope System



Technology Development | Engineering Development | Manufacturing Development

Ultraviolet Instrumentation System



Technology Component	Implementation Options	State of the Art	Capability Needed	FY19 TRL	In LUVOIR Baseline?
Coronagraph Architecture	Apodized Pupil Lyot Coronagraph (APLC)	6.3x10^{-6} over 6% bandpass in air. Validated models with WFIRST CGI SPC demonstrations	1x10^{-10} raw contrast >10% bandpass <4 λ/D inner working angle Robust to stellar diameter and jitter	4	✓
	Vortex Coronagraph (VC)	8.5x10^{-9} contrast over 10% band with unobscured pupil. SCDA modeling for unobscured, segmented pupil		3	✓
	Phase-Induced Amplitude Apodization (PIAA)	SCDA modeling results for unobscured, segmented pupil		3	
	Hybrid-Lyot Coronagraph (HLC)	3.6x10^{-10} contrast over 10% band in DST. SCDA modeling for unosbcured segmented pupil		3	
	Nulling Coronagraph (NC)	5x10^{-9} narrowband at 2.5 λ/D		3	
Deformable Mirrors	Micro-Electro-Mechanical Systems (MEMS)	Available up to 64 x 64 actuators; 8.5x10^{-9} contrast demonstrated with 32 x 32 actuators	Minimum 64 x 64 actuators (>100 x 100 actuators is enhancing)	4	✓
	Lead-Magnesium-Niobate (PMN) Macro-scale	<1x10^{-8} contrast demonstrated with 48 x 48 actuator Xinetics DMs (WFIRST CGI Testbed)		5	
Wavefront Sensing	Out-of-band Wavefront Sensing	Model predicting <10 pm residual error with nonlinear ZWFS, Mv = 5 source	Wavefront stabililty ~10 pm RMS ~1 Hz bandwidth with Mv < 9 source	3	✓
	Low-order Wavefront Sensing	<0.36 mas RMS line-of-sight residual error; <30 pm RMS focus, Mv = 5 source (WFIRST CGI Testbed)		6	✓
	Artificial Guide Star	Concept study for guide star spacecraft and wavefront sensing control loop completed.		3	
UV/VIS Low-noise Detector	Electron-Multiplying CCD	1k x 1k WFIRST Detector: 7x10^{-5} e-pix/s dark current 0 e- read noise 2.3x10^{-3} CIC	3x10^{-5} e-/pix/s dark current 0 e- read noise 1.3x10^{-3} e-/pix CIC >80% QE at all detection wavelengths 4k x 4k array size	4	✓
	Hole-Multiplying CCD	Prototype devices fabricated with gains > 10x (>20x in at least one device)		3	
NIR Low-noise Detector	HgCdTe Photodiode Array	H4RG-10 currently meets needed capability @ 170 K	< 1x10^{-3} e-/pix/s dark current < 3e- read noise 4k x 4k array size	6	✓
	HgCdTe Avalanche Photodiode	1.5x10^{-3} e-/pix/s dark current < 1 e- read noise 320 x 256 array size Requires < 100 K temperatures		4	
Mirror Substrate	Closed-back ULE (rigid body actuated)	7.5 nm RMS surface figure area with no actuated figure correction < 200 Hz first free mode ~10 kg/m^2 areal density	~5 nm RMS surface figure error > 400 Hz first free mode 19 kg/m^2 areal density	5	✓
	Closed-back ULE (surface figure actuated)			4	
	Open-back Zerodur (rigid body actuated)	Meets wavefront error requirement, but first mode and areal density are challenges		4	
Actuators	Combined piezo/mechanical	JWST mechanical actuators; Off-the-shelf PZT actuator with 5 pm resolution	> 10 mm stroke < 10 pm resolution < 1 pm / 10min creep	3	✓
	All-piezo			3	
Edge Sensors	Capacitive	5 pm in gap dimension, 60 Hz readout	<4 pm sensitivity at 50-100 Hz rate (control bandwidth of 5-10 Hz)	3	✓
	Inductive	1 nm / sqrt(Hz) for 1-100 Hz in shear; 100 nm / sqrt(Hz) for 1-10 Hz in gap		3	
	Optical	20 pm / sqrt(Hz) up to 100 Hz		3	
	High-speed Speckle Interferometry	< 5 pm RMS at kHz rates; requires center-of-curvature location and high-speed computing		3	
Laser Metrology	Laser truss with phasemeter electronics	Planar lightwave circuit; 0.1 nm gauge error; LISA-Pathfinder heritage laser	< 100 pm sensitivity at 10 Hz rate (control bandwidth of 1 Hz)	4	✓
Vibration Isolati	Non-contact Isolation System	> 40 dB transmissiability isolation > 1 Hz; Requires electronics development and performance validation	> 40 dB transmissiability isolation > 1 Hz	4	✓
Far-UV Broadband Coating	Al + eLiF + MgF_2	Meets performance requirements, but requires demonstration on meter-class optics; requires validation of uniformity, repeatability, environmental stability	>50% reflectivity (100-115nm) >80% reflectivity (115-200nm) >88% reflectivity (200-850nm) >96% refelctivity (> 850nm) <1% reflectance nonuniformity (over entire primary mirror) over corongraph bandpass (200 - 2000 nm)	3	✓
	Al + eLiF + AlF_3			3	
	Al + eLiF	Meets performance requirements, but is environmentally unstable		5	
Microshutter Ar	Next-gen Electrostatic Microshutter Arrays	840 x 420 prototype demonstrated, but requires development survive vibe and acoustic testing	840 x 420 array format, two-side buttable	3	✓
Large-format Microchannel Plates	CsI	Meets requirements for 100-150 nm	200 mm x 200 mm tile size >30% QE between 100 - 200 nm	6	✓
	GaN	Meet requirements for 150-200 nm range; requries development for large tile size and integration with cross-strip readout. GaN has better solar blind performance.		4	✓
	Bi-alkali			4	
	Funnel microchannels	Demonstrated 50% improved quantum efficiency with CsI photocathode		4	
Large-format High-resolution Focal Plane Arrays	8k x 8k CMOS	4k x 4k devices exist, require development for 8k x 8k and readout optimization	8k x 8k format, <7 micron pixels, three-side buttable ~1 e- read noise ~1x10^{-4} e-/pix/s dark current at 170 K	4	✓
	4k x 4k CCD	8k x 8k devices exist with 18 micron pixels; lacks programmable high-speed region-of-interest readout for guiding capability		5	

LUVOIR is a mission concept being studied in preparation for the *2020 Astronomy and Astrophysics Decadal Survey*

https://asd.gsfc.nasa.gov/luvoir/