Continuing the Legacy of the Hubble Space Telescope

A Large-Aperture UVOIR Space Telescope

H. A. Thronson (NASA GSFC), M. Clampin (NASA GSFC), M. Postman (STScI),
D. Redding (NASA JPL), & H. P. Stahl (NASA MSFC)
Point of Contact: Harley.A.Thronson@nasa.gov

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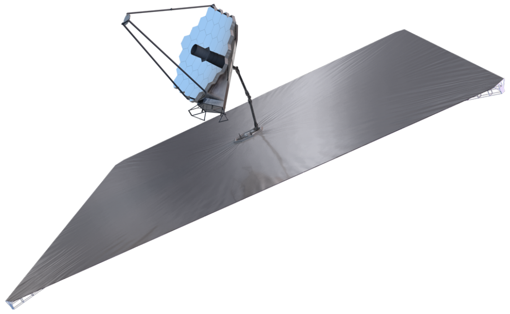
Overview: A large-aperture (~10+ m) non-cryogenic UVOIR space observatory that builds upon engineering elements and technologies developed for JWST will achieve major science goals highlighted by both the Cosmic Origins and Exoplanet Exploration Program Analysis Groups, as well as some goals of the Physics of the Cosmos Program Analysis Group (PAG). The priority science goals for such a mission have been identified by the NASA 30-year astrophysics roadmap, *Enduring Quests, Daring Visions*, and the soon-to-be-released AURA *From Cosmic Birth to Living Earths* report. Here we summarize the key design characteristics of the mission.



Conception of our current reference design for the Advanced Technology Large-Aperture Space Telescope (ATLAST) version of LUVOIR. [NASA image]

Reference Design: This figure shows a visualization of our ATLAST reference design, a 9.2-meter diameter segmented aperture capable of being launched by existing EELV vehicles. The basic design is capable of being expanded to apertures as large as ~14 m pending availability of suitable launch vehicles (i.e., SLS with larger fairings than Block 1). This concept builds on design solutions, technologies, engineering and lessons learned from JWST and other recent and ongoing projects, as well as growing experience with ground-based segmented telescopes. This version utilizes the JWST "chord-fold" deployment approach, which we estimate can be extended to launch an aperture of ~12 m using the EELV shroud volume. Unlike JWST, however, it will operate at "room temperature," thus avoiding costly and complex cryogenic design, fabrication, testing, and integration.

Mission Design Requirements: The mission design requirements flow-down from top-level science goals.

Science requirements flow-down to telescope

Parameter		Requirement	Stretch Goal	Traceability
Primary Mirror Aperture		≥ 8 meters	12 meters	Resolution, Sensitivity, Exoplanet Yield
Telescope Temperature		273 K – 293 K	-	Thermal Stability, Integration & Test, Contamination (UV), IR Sensitivity
Wavelength Coverage	UV	100 nm – 300 nm	90 nm – 300 nm	
	Visible	300 nm – 950 nm	-	
	NIR	950 nm – 1.8 μm	950 nm – 2.5 μm	
	MIR	-	Sensitivity under evaluation	
Image Quality	UV	< 0.20 arcsec at 150 nm	-	
	Vis/NIR/MIR	Diffraction-limited at 500 nm	-	
Stray Light		Zodi-limited between 400 nm – 1.0 μm	Zodi-limited between 200 nm – 1.8 μm	Exoplanet Imaging & Spectroscopy SNR
Wavefront Error Stability		< 10 pm RMS uncorrected system WFE per control step	-	Starlight Suppression via Internal Coronagraph
Pointing	Spacecraft	≤ 1 milli-arcsec	-	
	Coronagraph	< 0.4 milli-arcsec	-	

Starlight Suppression: ATLAST is designed to be a general astrophysics observatory capable of breakthrough science in many areas. However, some of the most challenging design requirements will be imposed by the goal of also being able to detect biomarkers in the UVOIR spectra of Earth-like worlds in the solar neighborhood. Our concept uses an internal coronagraph for starlight suppression, exploiting ongoing progress by the WFIRST/AFTA Coronagraph Project in developing designs that provide high contrast, even with complex, obscured apertures. Use of deformable mirrors within the coronagraph will correct static telescope aberrations from the visible-light diffraction limit, shaping the wavefront to the picometer precision needed for extremely high-contrast (10^{-10} from 3 λ/D) exoplanet imaging. This level of contrast, combined with the large ATLAST aperture, is calculated to produce tens of exoEarth candidates (Stark *et alia* 2014, Ap. J., **795**, 122).

High-contrast coronagraphy requires an extremely stable telescope. Our studies indicate that picometer-level thermal stability can be achieved in a Sun-Earth L2 orbit using a JWST-like flat sunshield augmented with precision heater controls. With fewer layers of shielding, less-challenging deployment, and a constant line of sight to the sun, this sunshade will provide extraordinary thermal stability at the design temperature 273 – 293 K. It will also provide excellent stray-light suppression.

Dynamical stability can be provided using approaches such as non-contacting vibration isolation, augmented by careful structural design. Stability will be further enhanced using low-order wavefront sensing of light from the target star, perhaps augmented by high-bandwidth laser metrology-based techniques using optical controls, exploiting laser metrology-based methods.

Mirrors: The mirrors for ATLAST could be provided by multiple sources. We note in particular that lightweight Ultra-Low Expansion ULE) glass mirror segment substrates of the right size have *already* been demonstrated. Other materials and designs could also meet ATLAST specifications, leaving room for improvements in performance and cost. Studies that include testing of representative mirror segments have been proposed in response to NASA solicitations.

Serviceability: The current NASA Authorization that is in force requires all large space observatories to be serviceable, although not necessarily serviced. Our concept fulfills this requirement with externally mounted instruments and major subsystems. Not only does this offer the opportunity to upgrade instruments, but as was the case with HST, it greatly simplifies the complex integration and testing of the observatory.

Technology to enable detection of biomarkers in neighboring Earth-like worlds was identified as the highest-priority "medium activity" in the 2010 NRC Decadal Survey. Our current technology development plan has been submitted to NASA HQ to guide them in delivering on the Survey recommendations.

Instrumentation: Breakthrough potential requires breakthrough instrumentation. A notional range of options for instruments is summarized below. The high-priority enabling and enhancing (mainly detector) technologies for these instruments have been recommended for investment to NASA HQ.

Science requirements flow-down to *notional* instruments, pending engineering trade studies and further definition of the mission science goals and requirements.

Science Instrument	Parameter	Requirement	Stretch Goal
UV Imager / Multi-Object Spectrograph	Wavelength Range	100 nm – 300 nm	90 nm – 300 nm
	Field-of-View	1 – 2 arcmin	
	Resolution	< 0.20 arcsec	
	Spectral Resolution	R = 20,000 – 300,000 (selectable)	
Visible Imager / Multi-Object Spectrograph	Wavelength Range	300 nm – 950 nm	
	Field-of-View	4 – 8 arcmin	
	Image Resolution	Nyquist sampled at 500 nm	
	Spectral Resolution	R = 100 – 10,000 (selectable)	
NIR Imager / Multi-Object Spectrograph	Wavelength Range	950 nm – 1.8 μm	950 nm – 2.5 μm
	Field-of-View	3 – 4 arcmin	
	Image Resolution	Nyquist sampled at 1 μm	
	Spectral Resolution	R = 100 – 10,000 (selectable)	
MIR Imager / Spectrograph	Wavelength Range		2.5 μm – 8 μm
	Field-of-View		3 – 4 arcmin
	Image Resolution		Nyquist sampled at 3 μm
	Spectral Resolution		R = 5 – 500 (selectable)
Starlight Suppression System	Wavelength Range	400 nm – 1.0 μm	200 nm – 1.8 μm
	Raw Contrast	10^{-10}	
	Contrast Stability	10^{-11} over integration	
	Inner-working angle	36 milli-arcsec @ 1 μm	
	Outer-working angle	1.4 arcsec @ 1 μm	
Multi-Band Exoplanet Imager	Field-of-View	~1 arcsec	
	Resolution	Nyquist sampled at 500 nm	
Exoplanet Spectrograph	Field-of-View	~1 arcsec	
	Resolution	R = 70 – 500 (selectable)	