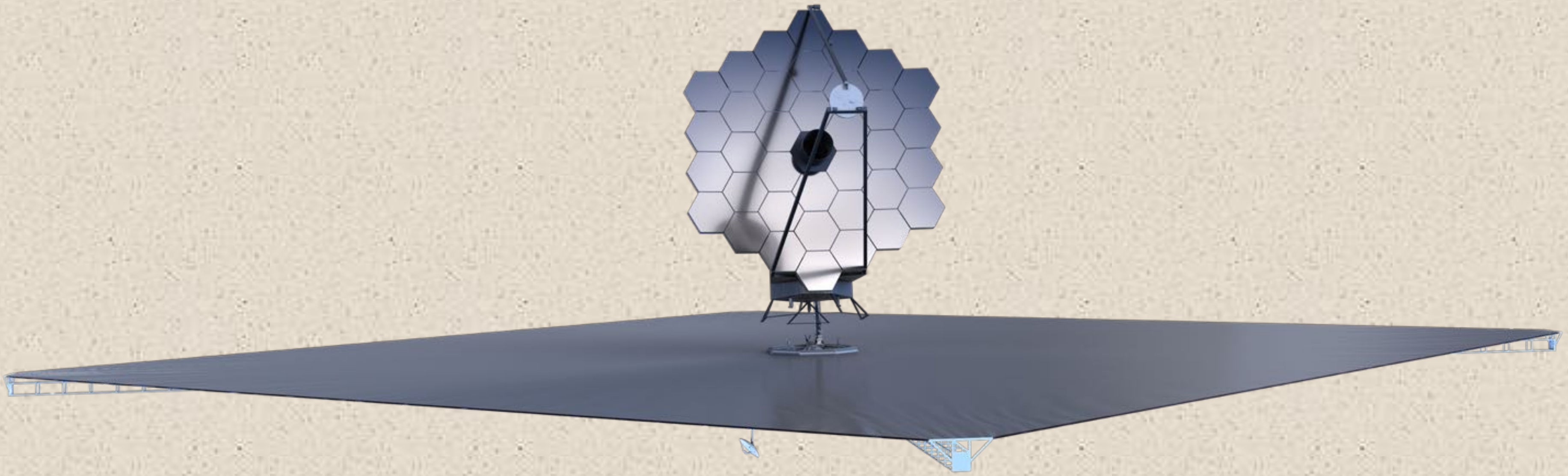
A Future Large-Aperture UVOIR Space Observatory: Reference Designs



Norman Rioux

NASA Goddard Space Flight Center

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SPIE Optical Engineering + Applications Symposium

Broad Consensus - Large Telescope Aperture Enables Breakthrough Science

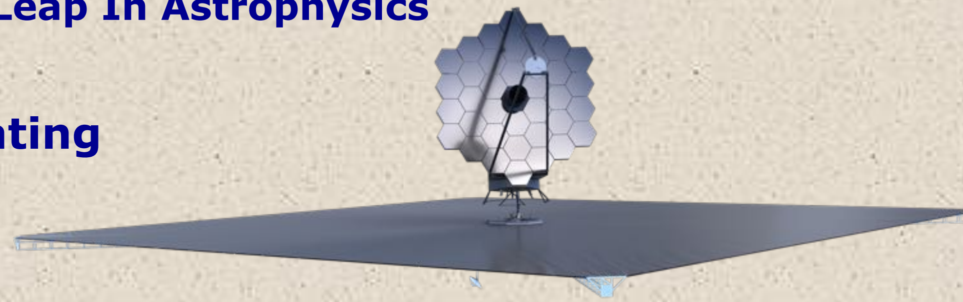
- ATLAST – Advanced Technology Large Aperture Space Telescope
  - Proposals submitted to 2010 NRC Decadal Survey
  - GSFC, MSFC, JPL, STScI
    - 8m monolith, 9.2m deployed, 16m deployed
  - 2010 Decadal Survey elevated technology investment for a mission to search for exo-Earths as its highest-priority "Medium Activity" for the decade
- LUVOIR – Large Ultraviolet Optical Infra-Red telescope
  - NASA's 30-year vision for astrophysics
    - Enduring Quests, Daring Visions
    - Highlighted a Large UV/Optical/IR observatory as a priority mission for the 2020s.
- HDST – High Definition Space Telescope
  - Associated Universities for Research in Astronomy (AURA)
  - Report - From Cosmic Birth to Living Earth
  - Recommends large UVOIR telescope - www.hdstvision.org/report/

Goddard Space Flight Center · JPL · Marshall · Space Telescope Science Institute (Operated for NASA by AURA)

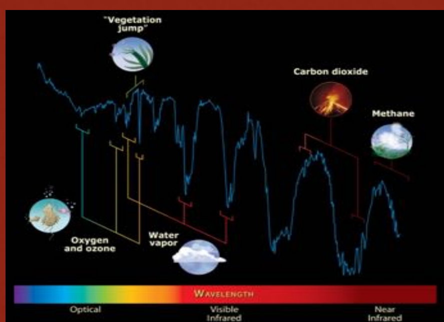
The Advanced Technology Large-Aperture Telescope (ATLAST)

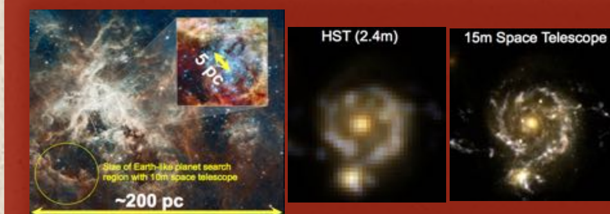
The Next Great Leap In Astrophysics

A powerful, general-purpose non-cryogenic observatory operating from 0.1 μm to 1.8+ μm.

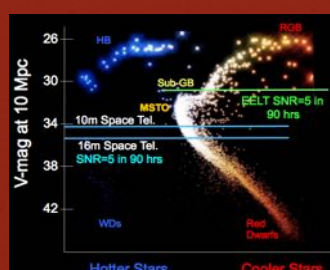


Detection of Biosignatures in Habitable Zone Planets

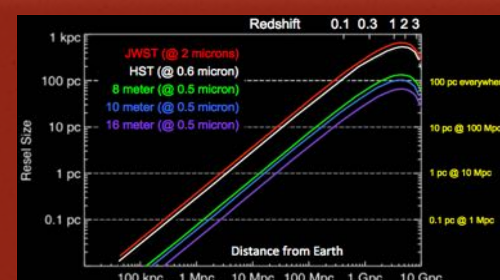




Breakthrough in UVOIR Resolution and Sensitivity throughout the Universe



Tracing the History of Star Formation in all Types of Galaxies up to 10 Mpc



Resolve 100 pc Star-Forming Regions Everywhere in the Universe

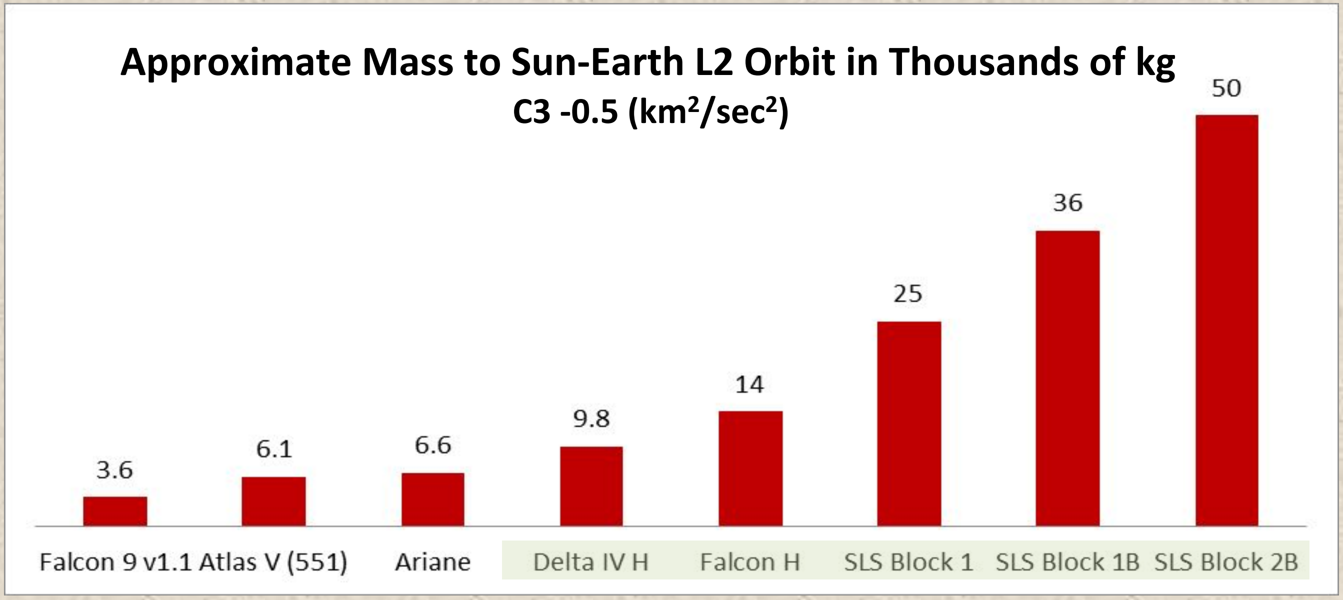
ATLAST Telescope Parameter Table

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, 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 to 5.0 µm under evaluation	Transit Spectroscopy
Image Quality	UV	< 0.20 arcsec at 150 nm	-	
	Vis/NIR/MIR	Diffraction-limited at 500 nm	-	
Stray Light		Zodi-limited between 400 nm – 1.8 µm	Zodi-limited between 200 nm – 2.5 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	-	

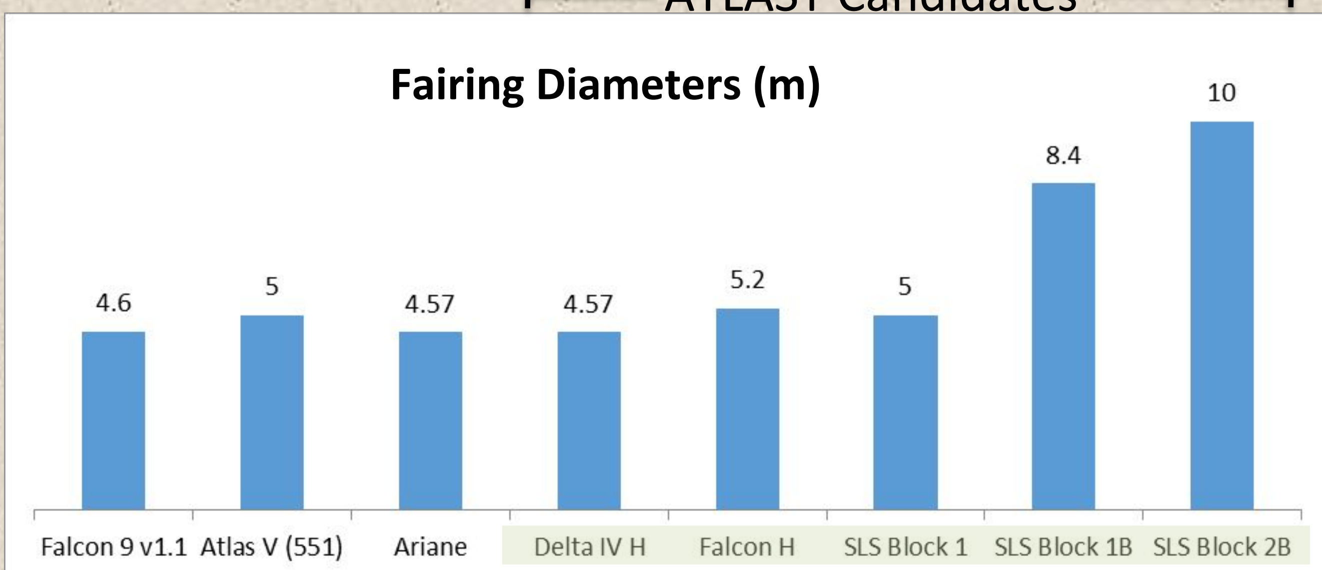
ATLAST Instrument Parameter Table

Science Instrument	Parameter	Requirement	Stretch Goal
UV Multi-Object Spectrograph	Wavelength Range	100 nm – 300 nm	90 nm – 300 nm
	Field-of-View	1 – 2 arcmin	
	Spectral Resolution	R = 20,000 – 300,000 (selectable)	
Visible-NIR Imager	Wavelength Range	300 nm – 1.8 μm	300 nm – 2.5 μm
	Field-of-View	4 – 8 arcmin	
	Image Resolution	Nyquist sampled at 500 nm	
Visible-NIR Spectrograph	Wavelength Range	300 nm – 1.8 μm	300 nm – 2.5 μm
	Field-of-View	3 – 4 arcmin	
	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 – 1.8 μm	200 nm – 2.5 μm
	Raw Contrast	1×10^{-10}	
	Contrast Stability	1×10^{-11} over integration	
	Inner-working angle	34 milli-arcsec @ 1 μm	
	Outer-working angle	> 0.5 arcsec @ 1 μm	
Multi-Band Exoplanet Imager	Field-of-View	~0.5 arcsec	
	Resolution	Nyquist sampled at 500 nm	
Exoplanet Spectrograph	Field-of-View	~0.5 arcsec	
	Resolution	R = 70 – 500 (selectable)	

Launch Vehicle Capabilities



ATLAST Candidates



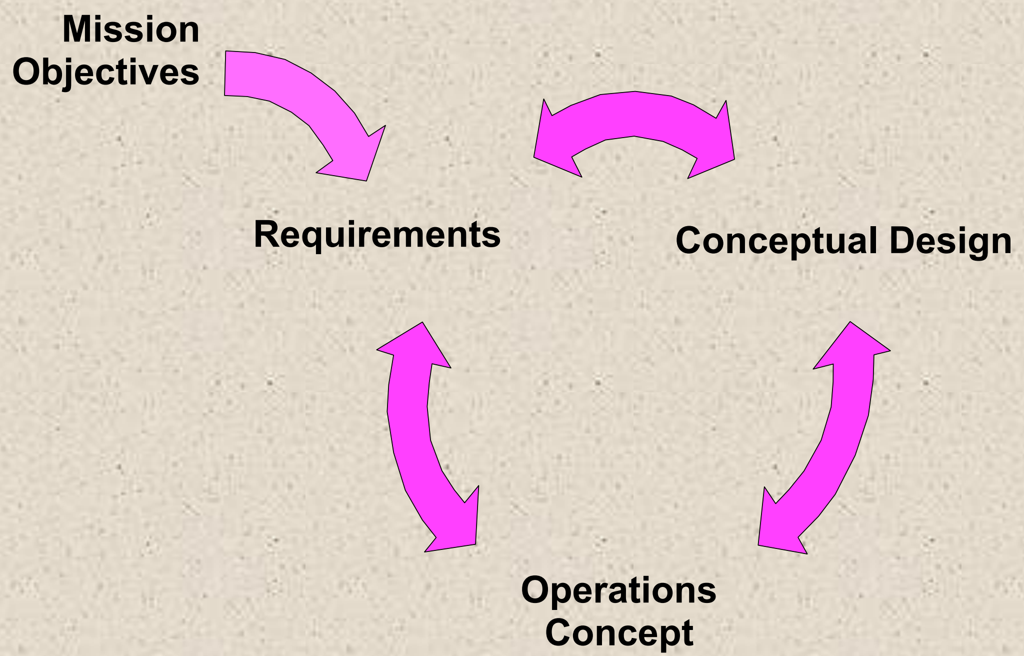
ATLAST is compatible with:

- Delta IV Heavy
- Falcon Heavy
- SLS

ATLAST and SLS engineer-to-engineer conceptual interface development meetings underway

Multiple vehicle candidates mitigate risks and associated costs

ATLAST System Formulation



- Role of Conceptual Design
  - Derive and validate requirements
  - Enable balanced, cost effective, end to end system

Engineering Design Reference Missions (EDRMs)

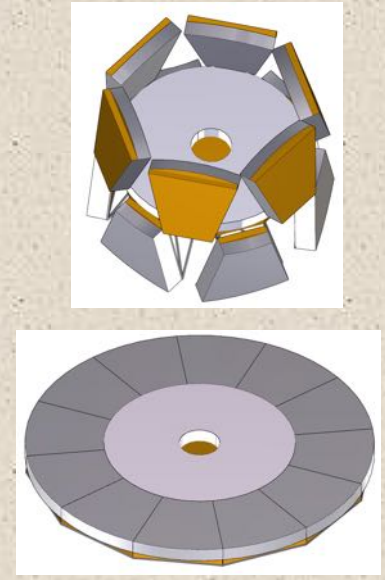
- Key design driver - Coronagraphy of exo-planets
- Multiple simultaneous science parameters
  - IWA, throughput, band pass, contrast, survey integration time, aperture, yield
  - WFE stability
    - Mechanical dynamics, jitter
    - Thermal stability
- Analyze engineering design trade space in depth and detail
  - Identify stressing requirements
  - Identify opportunities for margin against requirements
- Enable implementation trade studies to formulate most effective, well balanced, and lowest risk designs.

SLS, Block II 10m Fairing Enabled EDRMs

Stahl et al., SLS - launched missions concept studies for LUVOIR Mission

- 8-m monolith EDRM
  - Submitted to 2010 Decadal Survey
  - Largest possible monolith for space application

- 12.7 m deployed EDRM
  - Central monolith, deployed petals
  - Leverages depth in axis of primary mirror for mechanical stability



Scalable Segmented EDRM

36 JWST-Size Segments
(Glass or SiC, Heater Plates)

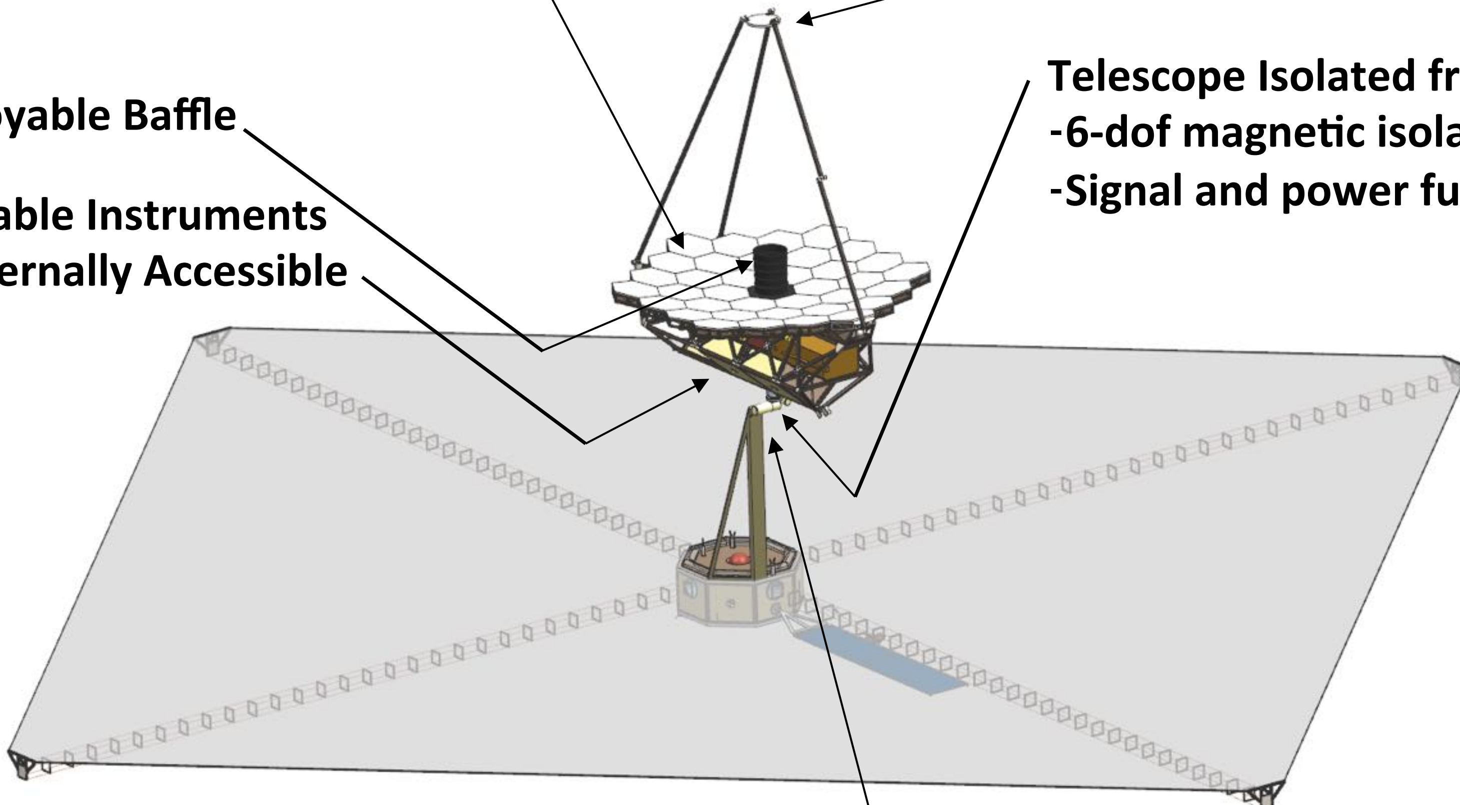
9.2 m Aperture

Actively controlled SM
6-dof control metrology to SI

Telescope Isolated from SC
-6-dof magnetic isolation
-Signal and power fully isolated

Deployable Baffle

Serviceable Instruments
are Externally Accessible

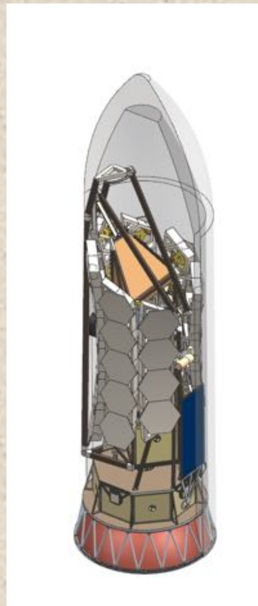


Stowed
Configuration

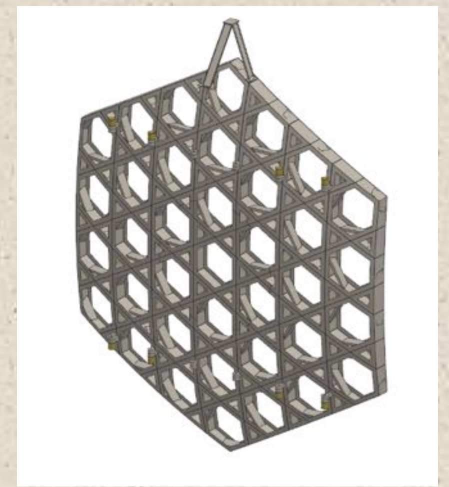
Three-layer sunshield,
Constant angle to sun, warm, stable sink
Sunshield deployed from below using four booms

Pointing gimbal maintains
constant sun angle;
Single pointing axis enhances stiffness

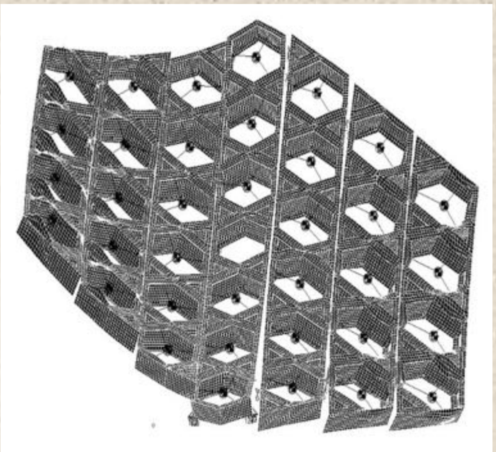
Mechanical Dynamic Stability



5m fairing packaging

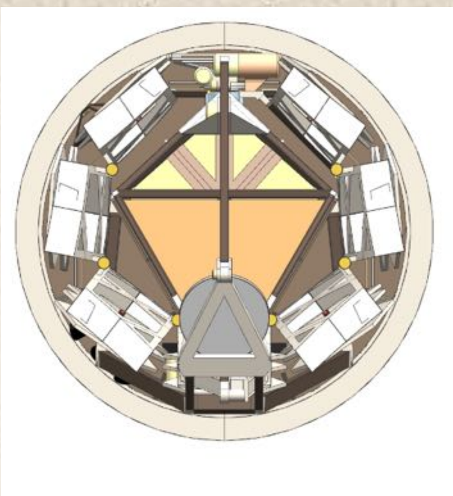


Backplane Design



Modal Analysis

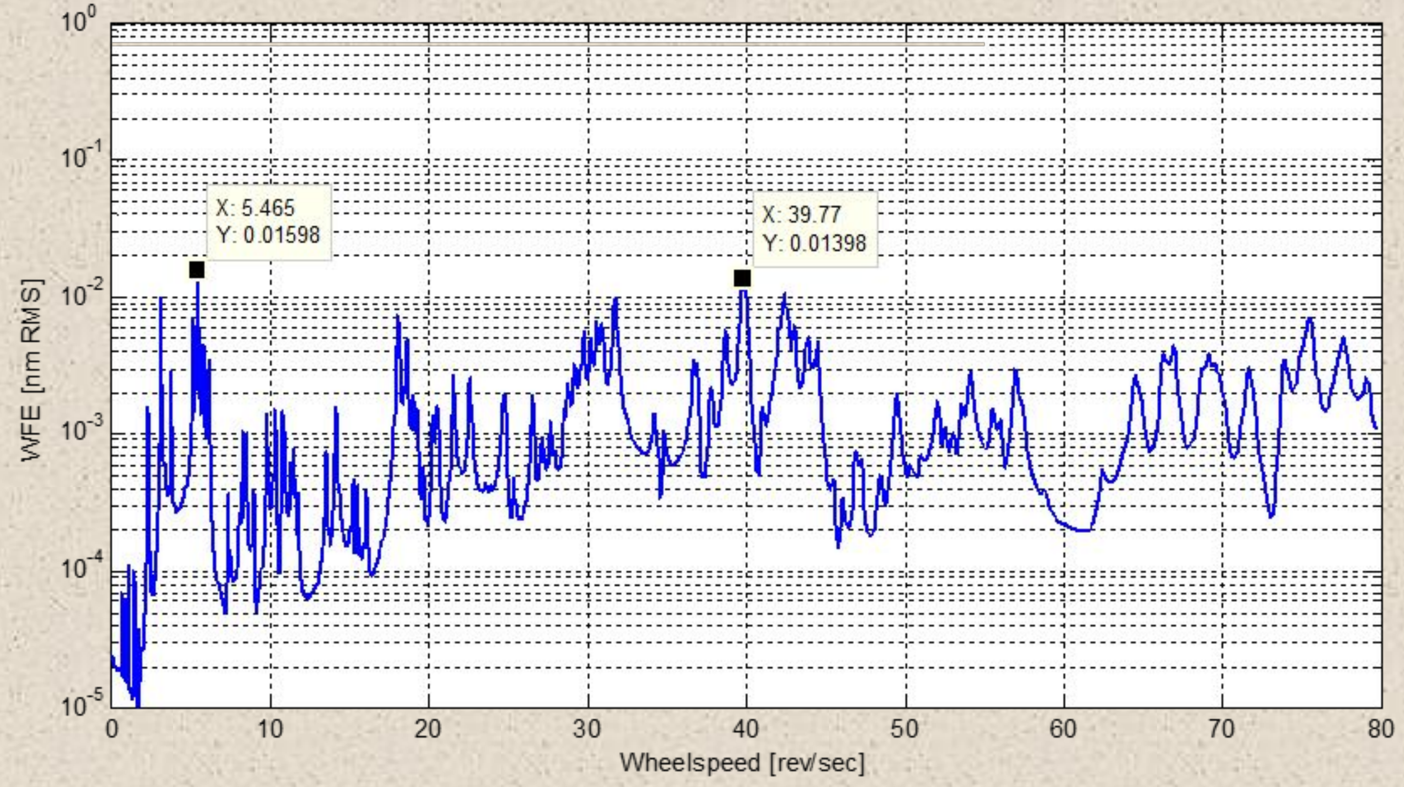
- 3 deployable mirror "wings" on each side of central strip
- Design for stiffness
- Iteration and optimization



Axial View in Fairing

Jitter Stability

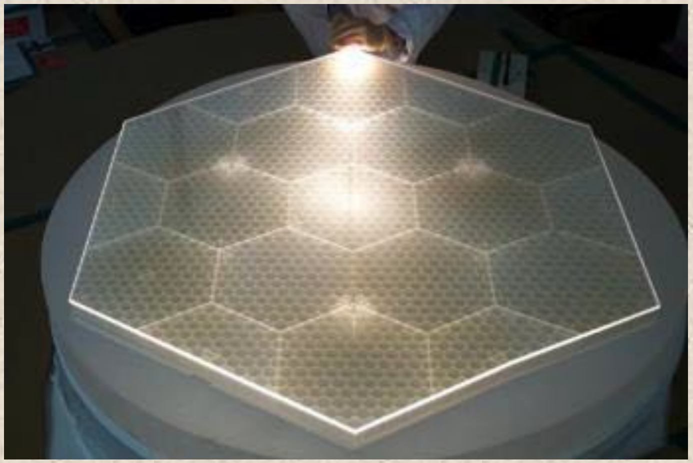
- Initiation of integrated modelling process - preliminary analysis
- Single RWA worst case forcing function
- No model uncertainty factor (MUF)
- Includes model of contact-free isolation system – 4 decades of isolation



Future improvements - Include gimbal and telescope pointing boom, MUF

Thermal Stability

- Preliminary analysis focused on feasibility of achieving picometer wave front error on individual mirror segment



- Eisenhower, Park, et al. "ATLAST ULE Mirror Segment Performance Analytical Predictions Based on Thermally Induced Distortions"
  - Analysis on a mirror segment with a high precision active heater control
- Initial results are encouraging
  - Future plans extend analysis to include the backplane

Cost Control

- Fundamental mission priorities:
  - Deliver revolutionary science that unites the science community
  - Control cost and cost uncertainty
- Develop technologies early
  - Robust technology development plan already in place
    - Bolcar et al., Technology development for the Advanced Technology Large Aperture Space Telescope (ATLAST) as a candidate large UV-Optical-Infrared (LUVOIR) surveyor
  - Actively pursuing early funding for key technologies
- Non-cryogenic telescope
- Focus on TRL-9 implementations unless mission enabling

Cost Control

- Scalable Segmented EDRM
  - Compatibility with multiple launch vehicles and fairing configurations
  - Departs from an extrapolation of previous segmented telescopes
    - Parallelization of telescope schedule
    - Economies of scale
    - High technology readiness, existing facilities and MGSE
    - Designs, hardware, mechanisms, personnel, ground support equipment, facilities, and experience with JWST