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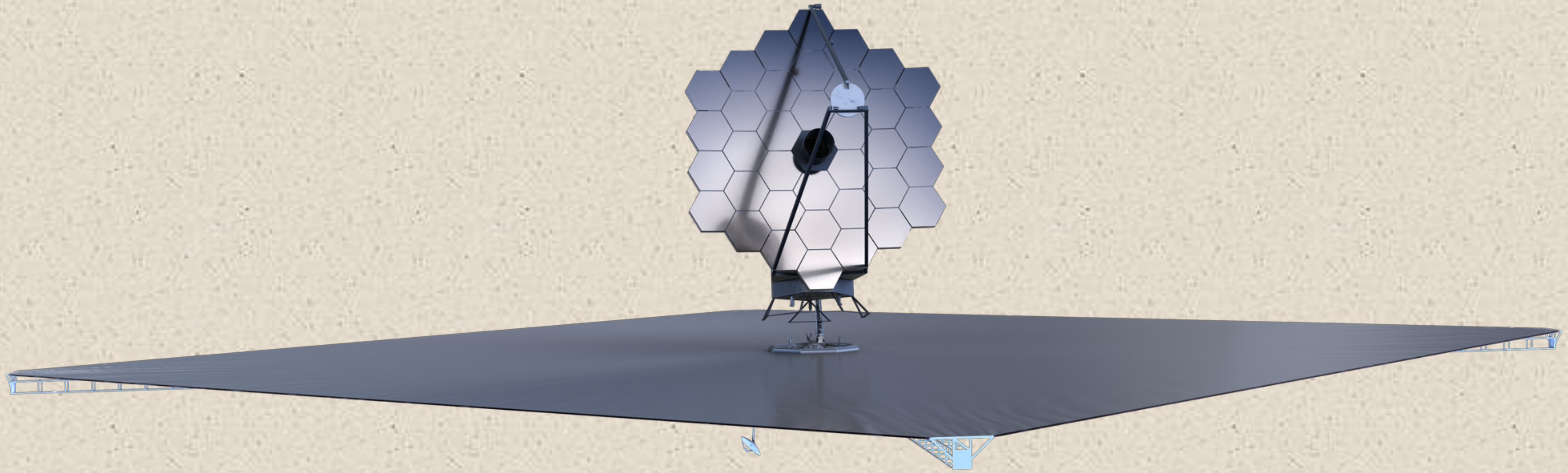
SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

Continuing the Legacy of the Hubble Space Telescope

Advanced Technology Large-Aperture Space Telescope (ATLAST)

-AKA-

The Large UV/Optical/IR Observatory (LUVOIR)



The ATLAST Study Team

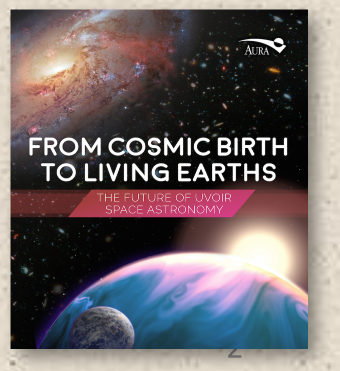
July 9, 2015

CONCEPT OVERVIEW

- A four-institution design study of a 10-m class UVOIR observatory
  - Detailed conceptual engineering design studies traceable to science goals
  - Identification of technology priorities and requirements
  - Room temperature telescope avoids complex cryogenic design and I&T
  - Serviceable and upgradable, also allows ready access during I&T

- Better together: concept provides for both exo-earth survey/characterization and for cutting-edge general astrophysics, as recommended by
  - *Enduring Quests, Daring Visions* (NASA 30-Year Roadmap, 2014)
  - *From Cosmic Birth to Living Earths* (AURA report, 2015) →

Public release at AMNH on July 6



AURA

FROM COSMIC BIRTH TO LIVING EARTHS

THE FUTURE OF UVOIR SPACE ASTRONOMY

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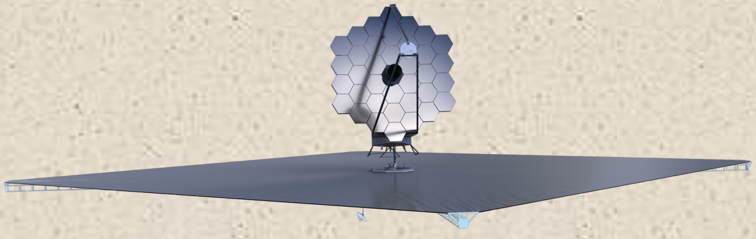
The Advanced Technology Large-Aperture Space Telescope (ATLAST)

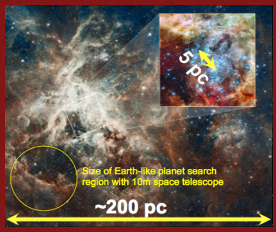
The Next Great Leap In Astrophysics

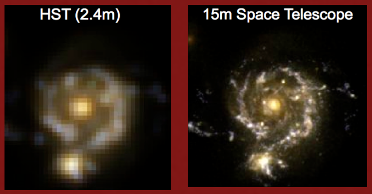
The ATLAST Reference Design

This ATLAST reference design is a 9.2-m observatory under assessment as a candidate for selection by the 2020 Decadal Survey. It is designed to be a powerful general-purpose non-cryogenic observatory operating from 0.1 µm to 1.8+ µm and able to search for biomarkers in the spectra of candidate exoEarths in the Solar neighborhood.

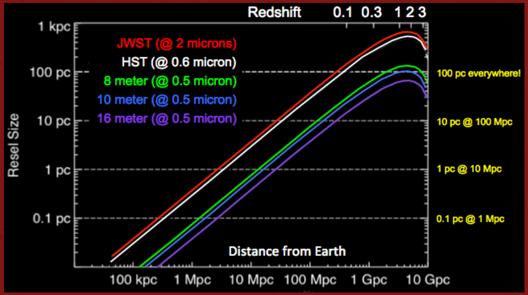


Breakthrough in UVOIR Resolution and Sensitivity throughout the Universe

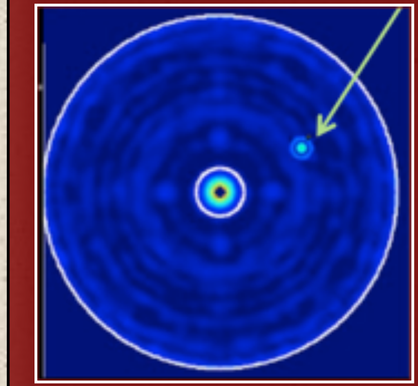


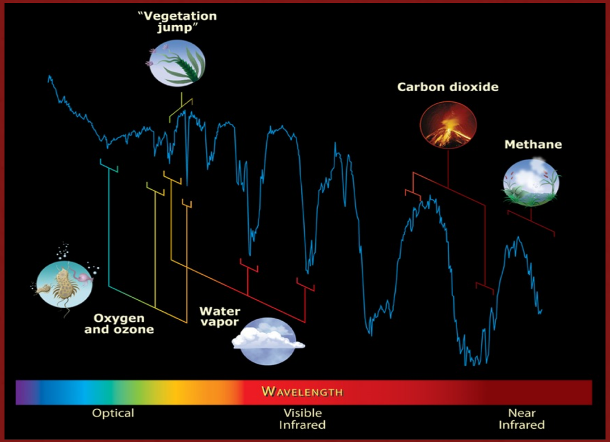


Resolve 100 pc Star-Forming Regions Everywhere in the Universe

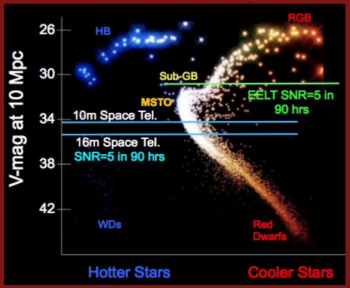


Identification of Habitable Zone Planets and detection of Biosignatures

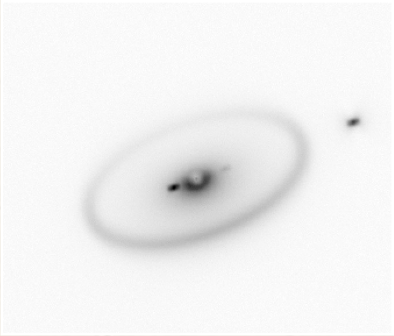




Tracing the History of Star Formation in all Types of Galaxies up to 10 Mpc



Engineering Progress: I



Starlight suppression via coronagraph

- Coronagraph
  - Multiple concepts for segmented mirror coronagraphs in early development stages (e.g. Guyon, Pueyo and Lyon)
  - Phase-Occulted Nuller could reduce requirements on system dynamic stability since it interferes telescope pupil against itself via rotational shearing
  - Starshade could be employed in second generation for spectroscopic followup

Interface Development:

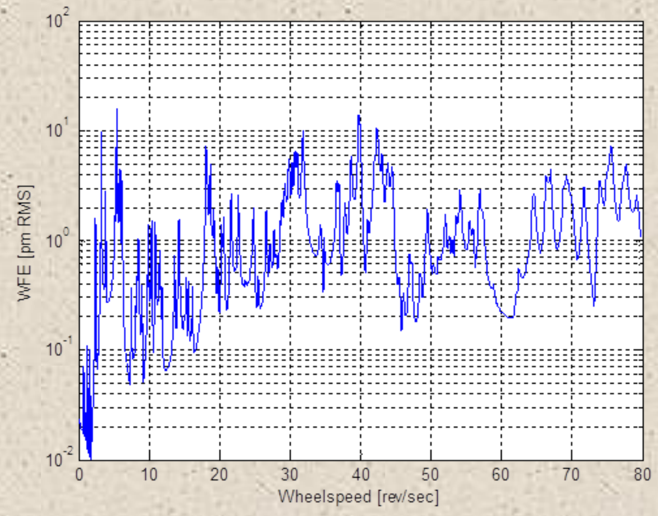
- Bounding Instrument Interfaces
  - Initiating study of observatory constraints on instrument complement
  - Mass, power, thermal, physical volume, max data rate and volume, etc.

- SLS and ATLAST Synergy
  - Engineer-to-engineer conceptual interface development meetings ongoing
  - Meetings held in December 2014 and May 2015

Engineering Progress: II

Dynamic Stability

- Bounding analysis via integrated modeling indicates feasibility for achieving 10 pm over a reasonable band pass of reaction wheel speeds with a state of the art non-contact isolation system



Thermal Stability

- Goal of <5 pm analytically demonstrated with 1 mK control from rear-side radiative heater plate without taking advantage of time variation
    - Analysis based on realizable ULE or SIC mirrors leveraging existing mirrors and real radial CTE data

MMSD Lightweight ULE Segment Substrate (GSFC/MSFC)

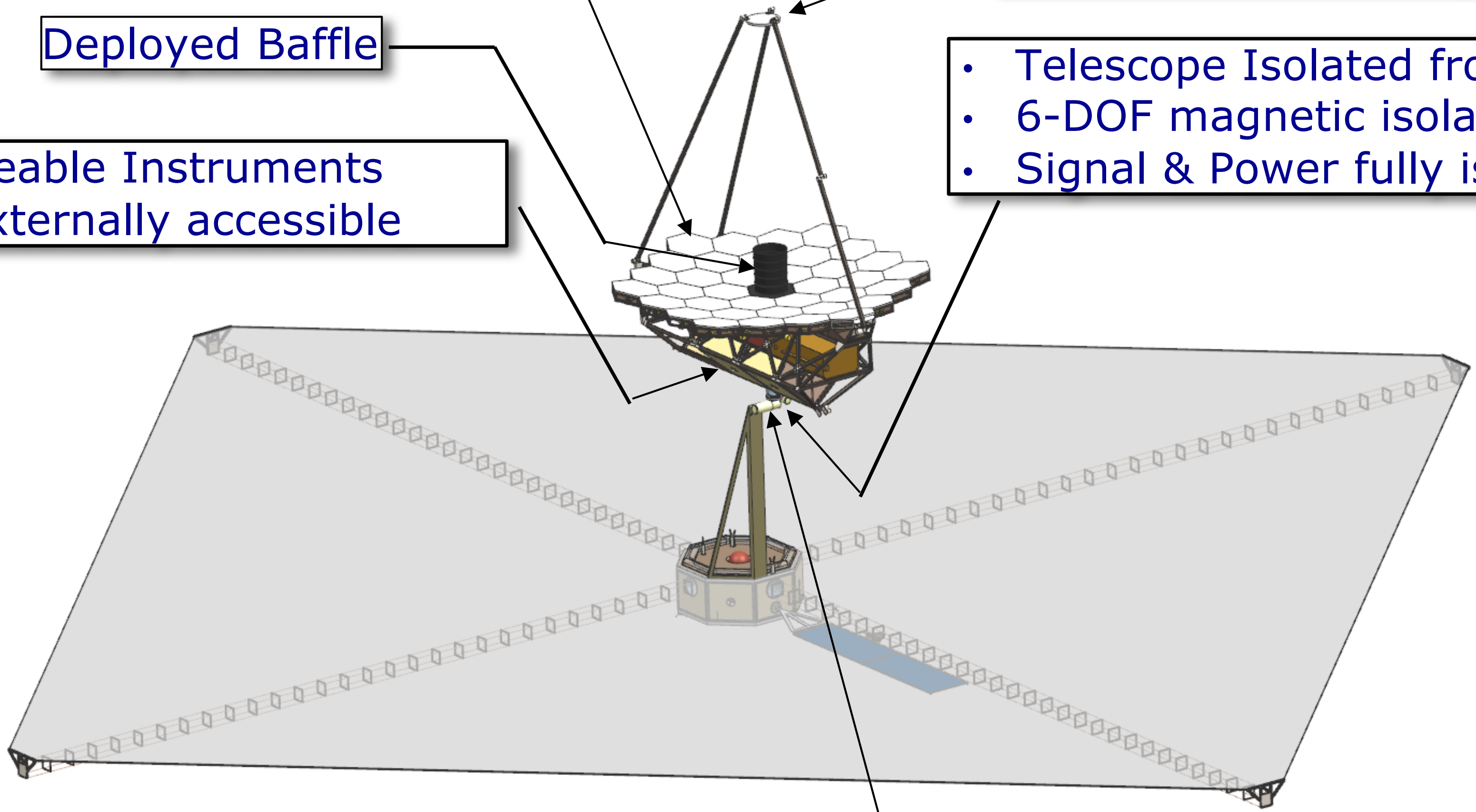
Key Technical Tall Poles: I

- Starlight suppression requires contrast at 10^{-10}. Key contributors are:
  - Coronagraph: Significant ongoing investment in starlight suppression via STMD, WFIRST and SAT programs.
  - Telescope: Primary mirror thermal stability and backplane structure
    - Mirror segments: <5 pm analytically demonstrated with 1 mK control
    - Telescope support structure
      - Slow instabilities can be actively controlled, although high-speed motions have to be isolated
      - Ultra stable, low-mass structures require technology investment
      - Complements investments being made in starlight suppression and isolation systems
- Ultra stable low-mass structures
  - Design of ~zero CTE composite structures has to address three issues:
    - Temporal instability:
    - Single events (micro-lurches): occurs whenever stress state changes
    - Moisture desorption:
  - Solution is to mature nano-particle composite technology
    - Material is already in commercial use

Key Technical Tall Poles

- New technology composite structures will have to be tested to pm levels
    - Requires new metrology approach and sub scale testbed
    - Build upon dynamic testing at nm level on JWST mirror segments
- ATLAST has assembled a telescope structures team
    - Ball Aerospace, Orbital ATK, GSFC, JPL & MSFC
- Development Goals:
    - Demonstrate an ultra-stable nano-composite structure and the associated actuator and hexapod mount needed for a segmented telescope with picometer class dynamic stability
    - Build a breakthrough high-speed speckle interferometer capable of <50 picometer-class spatial dynamic measurements of an ultra-stable composite structure and mirror system along with a laser metrology system for measuring motions
    - Develop an ultra-stable spatial dynamics testbed for model validation to the picometer level that will bound and characterize the picometer scale non-linearities
- Ultrastable structures have cross-cutting applications
    - Other astrophysics missions: e.g., gravity wave detection
    - Optical communications

ATLAST 9.2 m Scalable Architecture



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

Actively controlled SM
6-dof control metrology to SI

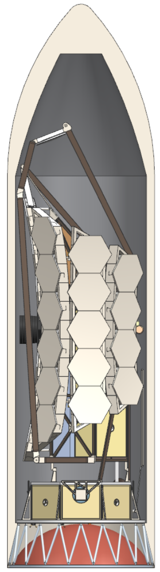
Deployed Baffle

- Telescope Isolated from SC
- 6-DOF magnetic isolation
- Signal & Power fully isolated

Serviceable Instruments
are externally accessible

- 3-layer sunshield,
- Constant angle to sun ➡□ stable sink
- Sunshield deployed using 4 booms

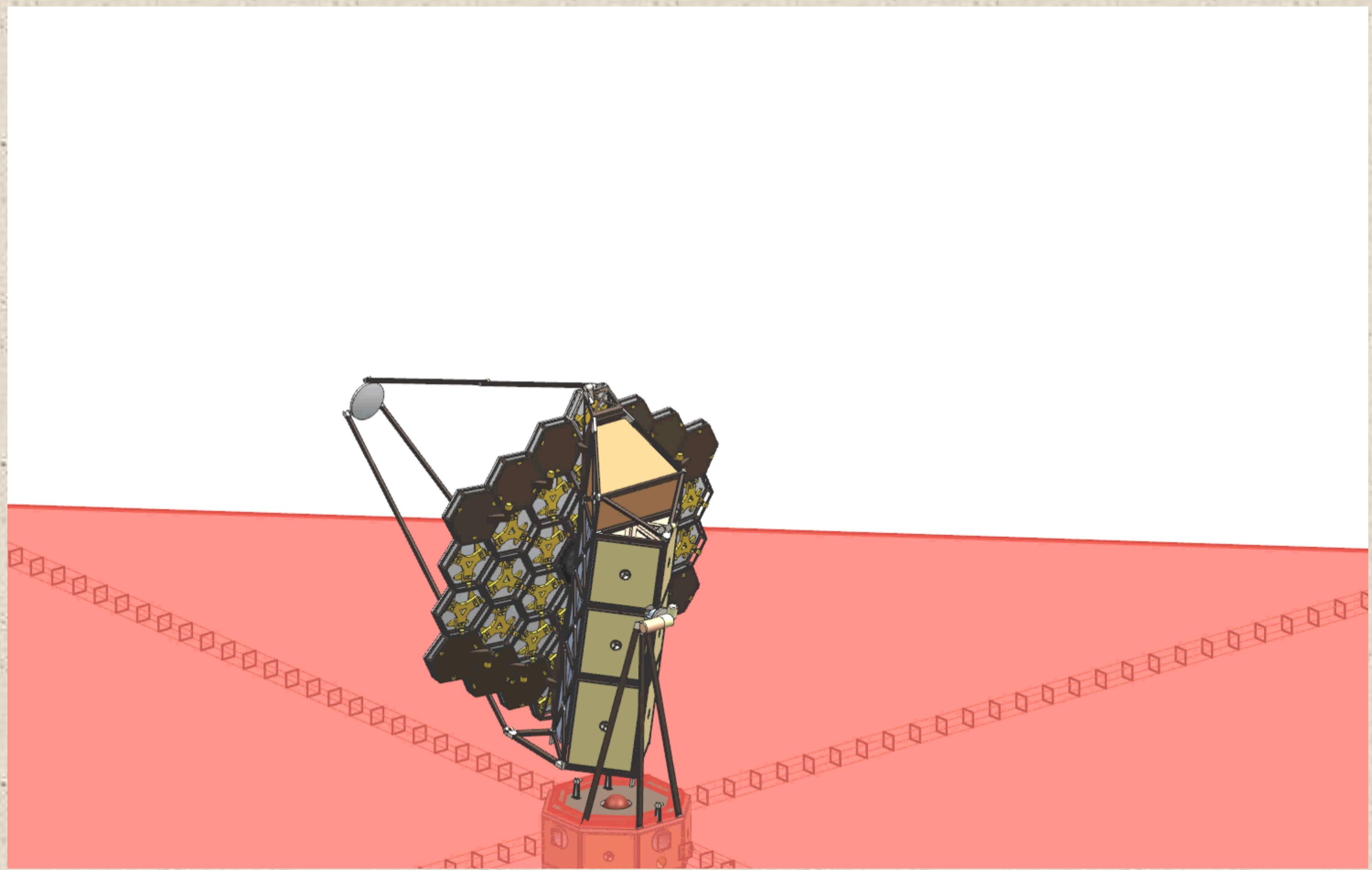
- Pointing gimbal maintains constant sun angle
- Single pointing axis



Stowed

ATLAST Gimbal Deployment

This CAD drawing sequence depicts the rotation of the science payload from its stowed position to deployment into its science-pointing configuration.



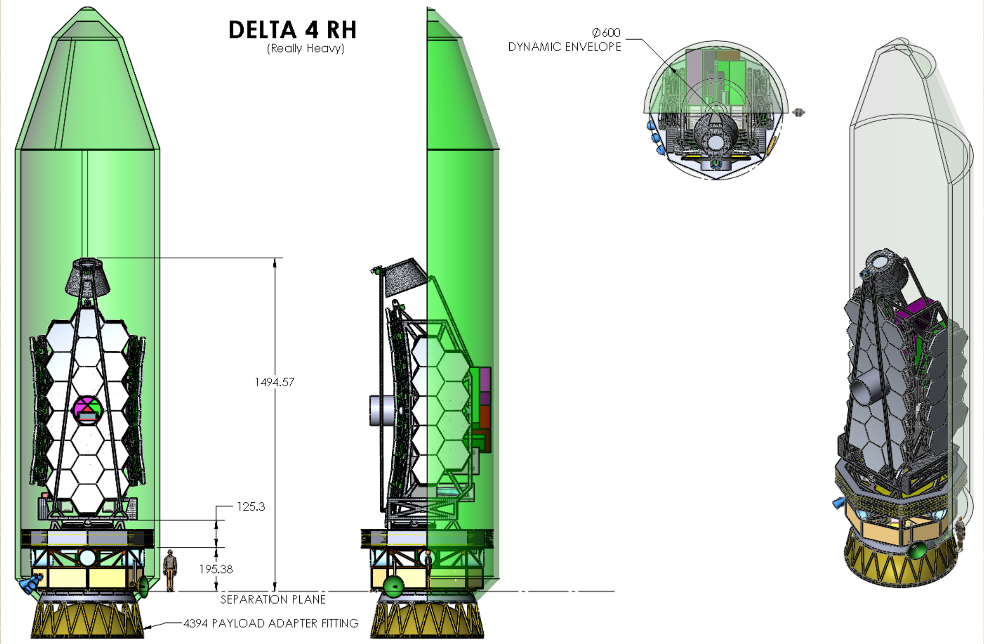
ATLAST Reference Design

Leverages Existing JWST Deployment for Large Aperture

2009 (First ATLAST Studies)

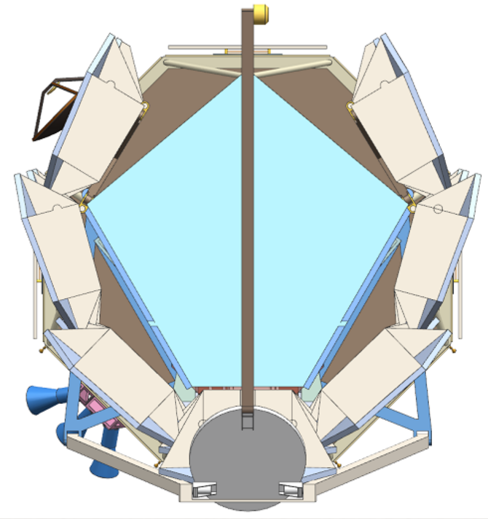
Assumed Larger EELV was Under Development

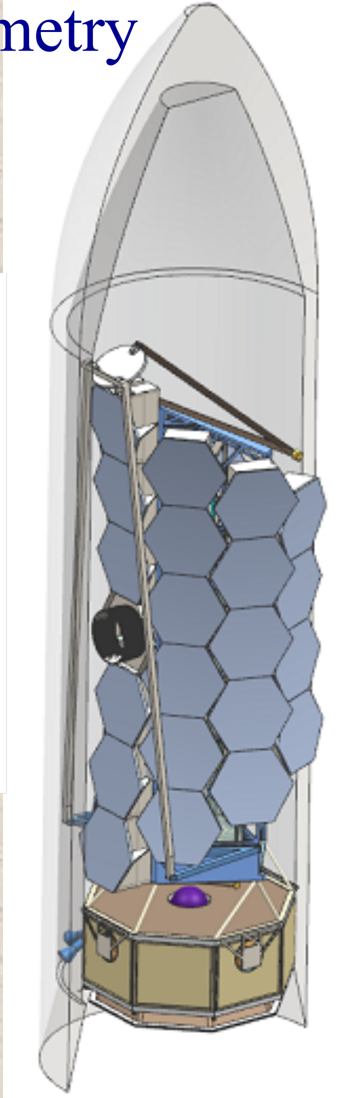
Note: JWST-Type Wings



2013 Circular Geometry

Delta IVH





Design reference mission builds upon existing investments in JWST to manage overall cost and is scalable to larger aperture sizes.

Telescope Design Parameters

Parameter		Requirement	Stretch Goal
Primary Mirror Aperture		≥ 8 meters	12 meters
Telescope Temperature		273 K – 293 K	-
Wavelength Coverage	UV	100 nm – 300 nm	90 nm – 300 nm
	Vis	300 nm – 950 nm	-
	NIR	950 nm – 1.8 μm	950 nm – 2.5 μm
	MIR	-	Capability 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 – 1.8 μm	-
Wavefront Error Stability (for Exoplanet Science)		< 10 pm RMS uncorrected WFE per control step	-
Pointing		≤ 1 milli-arcsec	-

Managing the Perception

The ATLAST/LUVOIR reference concept is designed to be *substantially* less costly than simple extrapolation from, for example, the cost of JWST. For example . . .

- Unlike JWST, ATLAST/LUVOIR is non-cryogenic, thus obviating complex thermal design, technologies, and I&T
- ATLAST/LUVOIR builds upon designs, personnel, ground support equipment, facilities, and experience with JWST and other segmented optical systems
- ATLAST/LUVOIR team is identifying technology tall poles and advocating early funding of them
- ATLAST/LUVOIR, working with senior NASA managers, have identified management strategies that have been demonstrated opportunities to manage cost and schedule growth.
- Compatibility with multiple launch vehicles manages risk and associated costs: Delta IV Heavy, SLS (5,8.4,10m fairings), Falcon Heavy

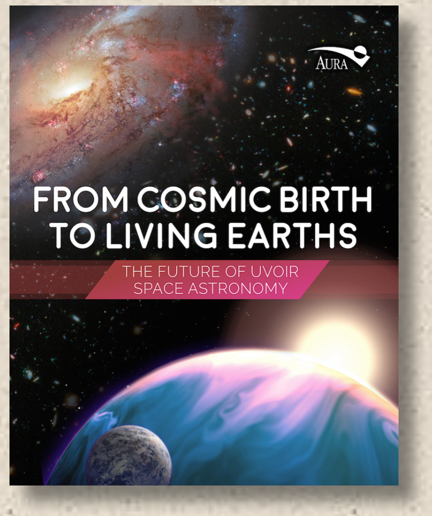
Takeaway: I

- Study just entering its third year with three priority elements:
  - o Develop an affordable large-aperture conceptual design for a broadly capable UVOIR observatory
  - o Identify and invest in the maturation of priority technology investments to ready the design for selection in the early 2020s
  - o Establish the most compelling science goals for a mission that will continue the heritage of HST

- Large aperture observatory continues to be recommended as high priority
  - *Enduring Quests, Daring Visions* (NASA 30-year astrophysics roadmap, 2014)
  - The Associated University for Research in Astronomy (AURA) report

From Cosmic Birth to Living Earths report identified
a UVOIR mission very similar to ATLAST.

⇒*Killer app will be the capability to search for the spectroscopic signatures of biological activity in the atmospheres of hypothetical Earth-like worlds in the solar neighborhood: Are We Alone?*



Takeaway: II

- ATLAST has identified key technologies and need for early investment
- Significant investment in coronagraph technology already underway
- Propose STMD investment in remaining tall-pole: ultrastable structures
  - Demonstrate ultra-stable nano-composite structure
  - Build interferometer capable of <50 pm dynamic measurements
  - Develop an ultra-stable spatial dynamics testbed for model validation including laser metrology
- Initial investment of $900 k (detailed costing is available)
- First step would be release of an RFI by GSFC for industry interest

  - Industry would like to participate, and is the main source of recent advances in materials for ultrastable structures
- Cross-cutting technology with applications in gravity-wave missions

“FLY AROUND” VIDEO HERE

BACK UP:
TECHNOLOGY ROADMAP OVERVIEW

Internal Coronagraph	**Need**	**Capability**	**Current TRL**	**Enabling / Enhancing**	**Technology, Engineering, or Manufacturing**
Segmented Aperture, High-Contrast, Broadband Coronagraph (Includes all Wavefront Sensing & Control Development)	***1×10^{-10} raw contrast*** ***IWA 2λ/D*** ***OWA 64λ/D*** ***400 nm – 1.0 µm*** ***200 nm – 1.8 µm (goal)*** ***Segmented Pupil***	***1.3×10^{-9} between 3-16λ/D*** ***720 nm – 880 nm*** ***Unobscured*** ***5.7×10^{-9} between 1.5-2.5λ/D monochromatic*** ***Segmented DM***	***3***	***Enabling***	***Technology***
Deformable Mirrors	128x128 continuous DM Electronics/harnesses, etc Environmentally robust	64x64 continuous DM Wire-dense, single point failure harnesses, etc.	3	Enabling	Engineering, Manufacturing
Autonomous Onboard Computation	***Closed-loop control*** ***Rad-hard, low power***	***Human-in-the-loop (JWST)*** ***Ground-based desktop CPUs/GPUs***	***3***	***Enabling***	***Technology***
Image Processing & Spectra Extraction Algorithms (Including PSF Calibration)	Factor of 50-100x improvement in PSF calibration	25x demonstrated 30x goal for WFIRST-AFTA	3	Enabling	Engineering
High-Contrast Integral Field Spectrometer Instrument Development	***TBD***	***TBD***	***TBD***	***Enabling***	***TBD***

Starshade	Need	Capability	Current TRL	Enabling / Enhancing	Technology, Engineering, or Manufacturing
Starshade Edge Scatter	***Edge radius ≤ 1 µm*** ***Reflectivity < 10%***	***Edge radius > 10 µm***	***TBD***	***TBD***	***Technology***
Formation Flight & Guidance, Navigation & Control	Lateral sensing err ≤ 20cm Control peak-to-peak 1 m	TBD	TBD	TBD	Engineering
Petal & Truss Construction & Deployment	***Demonstration of petal & truss construction and deployment for ATLAST-sized starshade***	***Petal prototype for 40-m class starshade meets fabrication tols.*** ***12-m Astromesh deployment on ground to tols. with 4 petals***	***TBD***	***TBD***	***Engineering, Manufacturing***
Starshade Contrast Performance & Model Validation	Contrast validation with flight-like Fresnel numbers (≤ 50) Model validation of contrast performance	Experimental contrasts at Fresnel number of ~500 Models not yet correlated to 10^{-10} level	TBD	TBD	Technology

Ultra-Stable, Large Aperture Telescopes

	Need	Capability	Current TRL	Enabling / Enhancing	Technology, Engineering, or Manufacturing
Thermal Control System	***10 nm/K stability*** ***0.01 mK control accuracy***	***100 nm/K stability*** ***1 mK control accuracy***	***3***	***Enabling***	***Technology***
Stable Structures	Low CTE, micro-lurch characteristics	CTE TBD Experience mico-lurch at interfaces	3	Enabling	Technology
Mirrors (Surface Figure, Areal Density, Cost, Production Rate)	***< 7 nm RMS figure*** ***<36 kg/m^2 (Delta IV)*** ***<$1M/m^2*** ***30-50 m^2/year***	***~ 7 nm RMS (HST, ULE)*** ***70 kg/m^2 (JWST)*** ***$6 M/m^2 (JWST)*** ***4 m^2/year (JWST)***	***4***	***Enabling***	***Engineering, Manufacturing***
Disturbance Isolation & Damping Systems	140 dB isolation > 40 Hz	80 dB > 40 Hz (JWST passive) Disturbance Free Payload at TRL 5 with 70 dB	4	Enabling	Technology
Metrology & Actuators	***1 pm accuracy (metrology)*** ***1 pm accuracy (actuators)***	***1 nm accuracy (metrology)*** ***5 nm accuracy (actuators)***	***3***	***Enabling***	***Technology***

Detectors	**Need**	**Capability**	**Current TRL**	**Enabling / Enhancing**	**Technology, Engineering, or Manufacturing**
UV Photon-Counting Detectors For Exoplanet Imaging & Characterization	***200 nm – 300 nm*** ***Read noise << 1 e^-*** ***Dark cur. < 0.001 e^-/pix/s*** ***Rad hard; 5 year lifetime*** ***Visible blind***	***GaN-based EBCMOS*** ***Needs lifetime tests*** ***Micro-channel plates*** ***Not room temperature*** ***Limited lifetime***	***5***	***Enhancing***	***Technology***
Large-Format High-Sensitivity UV Detectors for General Astrophysics	100 nm – 300 nm (90 nm – 300 nm goal) 70% q.e. >2k x 2k format Rad hard Visible blind	δ-doped EMCCD: 50% q.e. (100 nm-300 nm) 1k x 1k format Not visible blind Not rad hard Operation at -120 C	4	Enhancing	Technology
Vis/NIR Photon-Counting Detectors for Exoplanet Imaging & Characterization	***400 nm – 1.0 µm*** ***(1.8 µm goal)*** ***Read noise << 1 e^-*** ***Dark cur. < 0.001 e^-/pix/s*** ***Rad hard, 5 year lifetime***	***EMCCD:*** ***Not proven rad hard*** ***Dark cur. may not be low*** ***Hard cutoff at 1.1 µm*** ***HgCdTe APD:*** ***Dark cur. too high***	***5*** ***4***	***Enabling***	***Technology***

Mirror Coatings

	Need	Capability	Current TRL	Enabling / Enhancing	Technology, Engineering, or Manufacturing
UV Coating Reflectivity	***>70% 90 nm – 120 nm*** ***>90% 120 nm – 300 nm*** ***>90% 300 nm – 3.0 µm***	***<50% 90 nm – 120 nm*** ***80% 120 nm – 300 nm*** ***>90% 300 nm – 3.0 µm***	***2*** ***3*** ***6***	***Enabling*** ***Enhancing*** ***Enhancing***	***Technology***
UV Coating Uniformity	< 1% at λ ≥ 90 nm	TBD 90 nm – 120 nm > 2% 120 nm – 250 nm 1-2% 300 nm – 3.0 µm	2 2 3	Enhancing	Engineering
UV Coating Polarization	***< 1% at λ ≥ 90 nm***	***Not yet assessed; needs study.***	***2***	***Enhancing***	***Engineering***
Coating Environmental Durability	Easy to use, reliable automated FUV characterization is needed for testing and cross verification.	Stable performance over a year have been made, though performance below 200 nm is low.	3	Enabling	Engineering