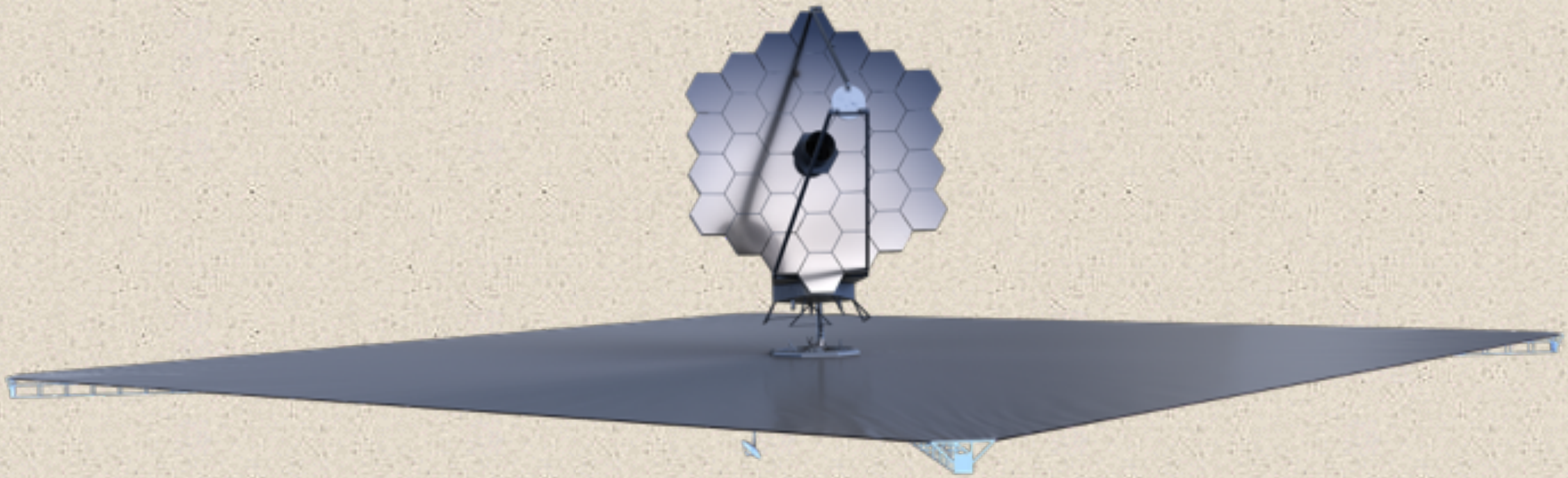
Continuing the Legacy of the Hubble Space Telescope

The Advanced Technology Large-Aperture Space Telescope (ATLAST)



Mark Clampin
and
The ATLAST Study Team

June 25, 2015

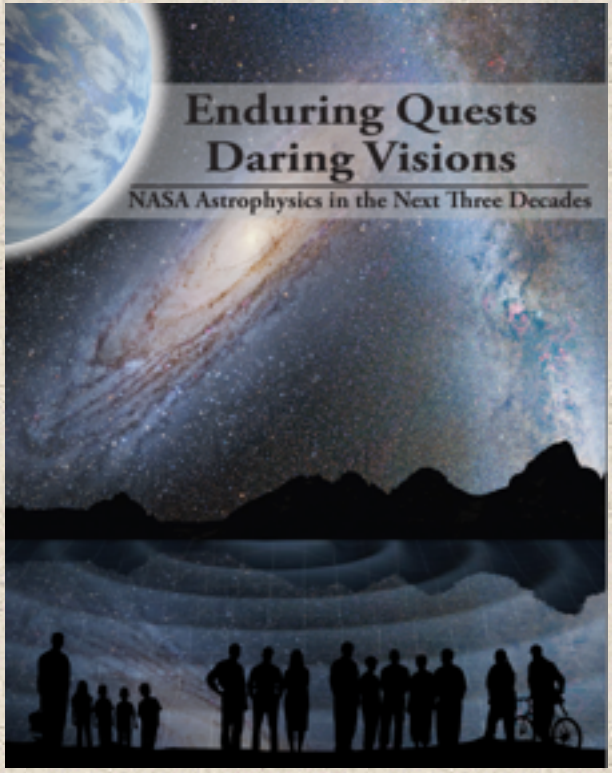
CONCEPT OVERVIEW

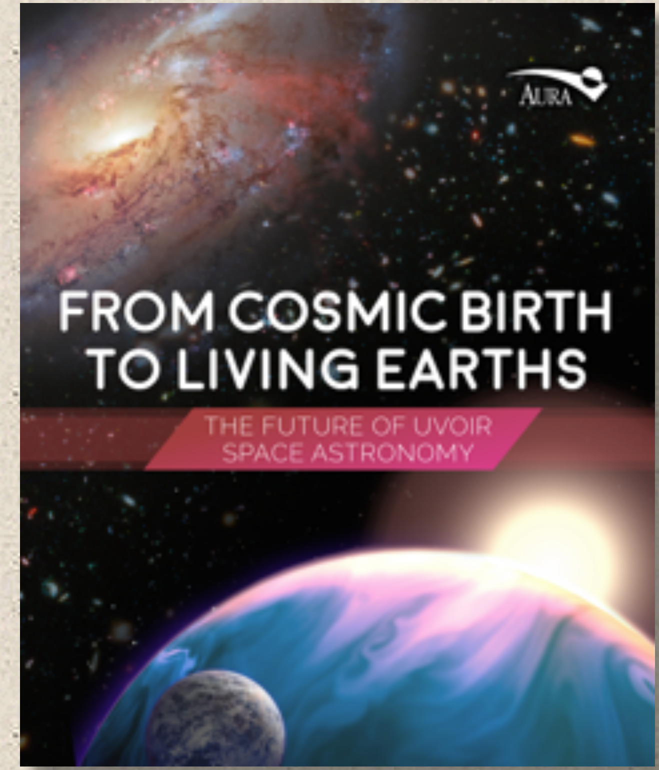
- **A four-institution design study of a 10-meter class UVOIR observatory**
  - **Architecture is scalable to larger (up to ~14 m) apertures depending upon availability of launch vehicle**
  - **Architecture is not cryogenic, and easier to manufacture, integrate and test (I&T): $T_{telescope} \approx 273 - 293$**
  - **Serviceable and upgradable, modularity permits access during I&T**
  - **Broad wavelength coverage: 90 nm – 1.8+ μm; longer wavelength operation under assessment**
- **Adopted 9.2-meter segmented aperture, derived from JWST experience as reference design . . .**
  - **Allows increasingly detailed engineering design – thermal/ mechanical stability, estimated system scientific performance, deployment technique, etc.**
    - **Verifies that science goals can be achieved with margin**
  - **Allows identification of technology priorities common to wide range of segmented aperture diameters**
  - **Largest aperture within existing launch vehicle fairing that deploys similarly to JWST**

-

CONCEPT OVERVIEW

- **ATLAST architecture provides both cutting-edge general astrophysics *and* search for ExoEarths as recommended by**
  - ***Enduring Quests, Daring Visions***
    (NASA Thirty-Year Roadmap, 2014)
  - ***From Cosmic Birth to Living Earths***
    (AURA report, 2015)





Goddard SPACE FLIGHT CENTER

JPL

marshall

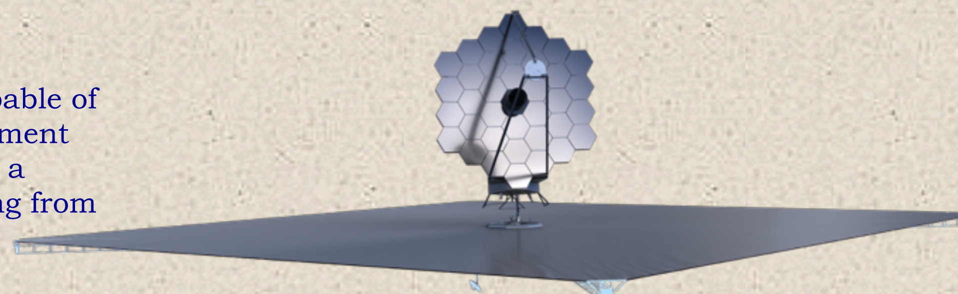
SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

The Advanced Technology Large-Aperture Telescope (ATLAST)

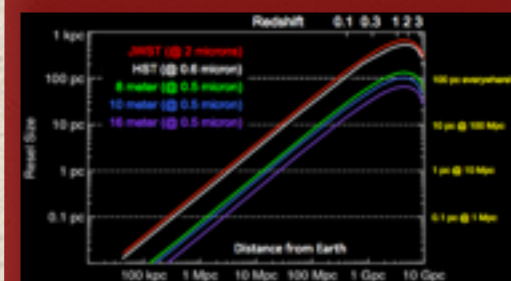
The Next Great Leap In Astrophysics

The ATLAST Reference Design

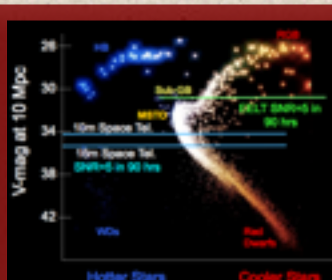
The ATLAST reference design is a 10 m-class observatory capable of being launched by a Delta IV Heavy vehicle and using deployment systems and designs developed for JWST. It is designed to be a powerful general-purpose non-cryogenic observatory operating from 0.1 µm to 1.8+ µm with a suite of instruments capable of breakthrough science to carry on the legacy of HST.
The segmented design is capable of being expanded to fit future launch vehicles and is capable of being serviced on orbit.



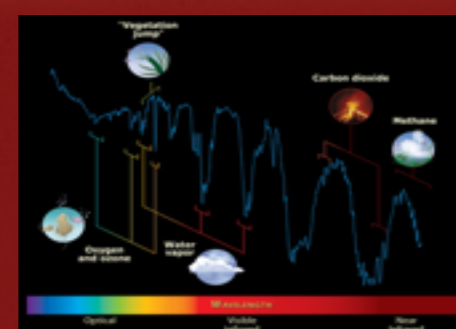
Breakthrough in UVOIR Resolution and Sensitivity throughout the Universe



Resolve 100 pc Star-Forming Regions Everywhere in the Universe

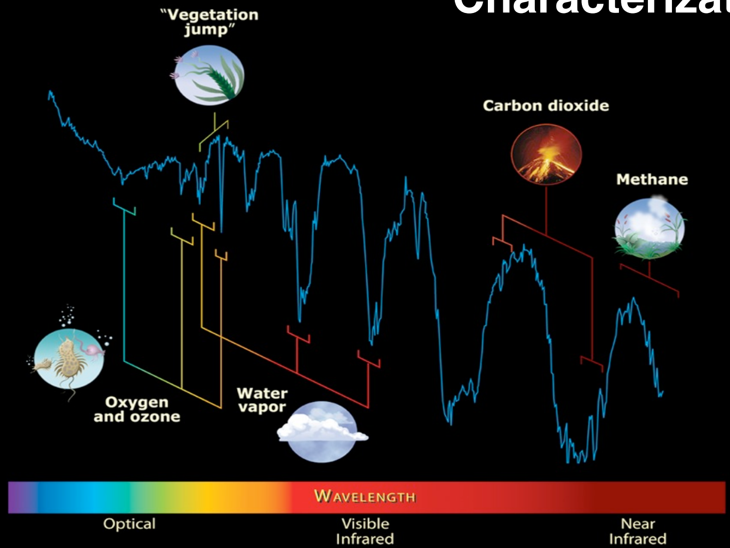


Tracing the History of Star Formation in all Types of Galaxies up to 10 Mpc

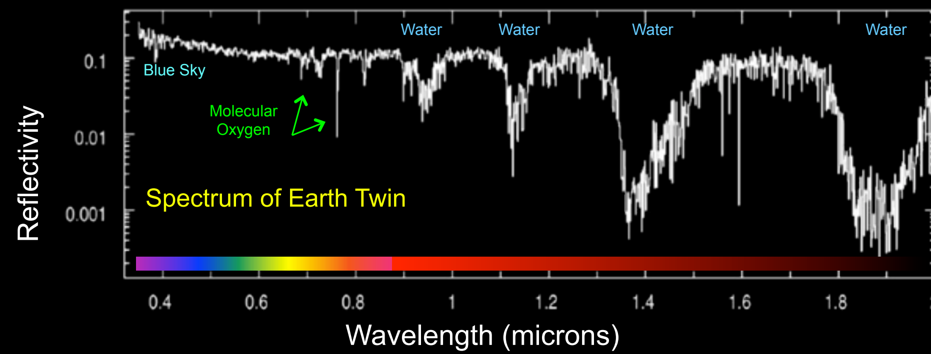


Detection of Biosignatures in Habitable Zone Planets

Characterization of Habitable Zone Planets

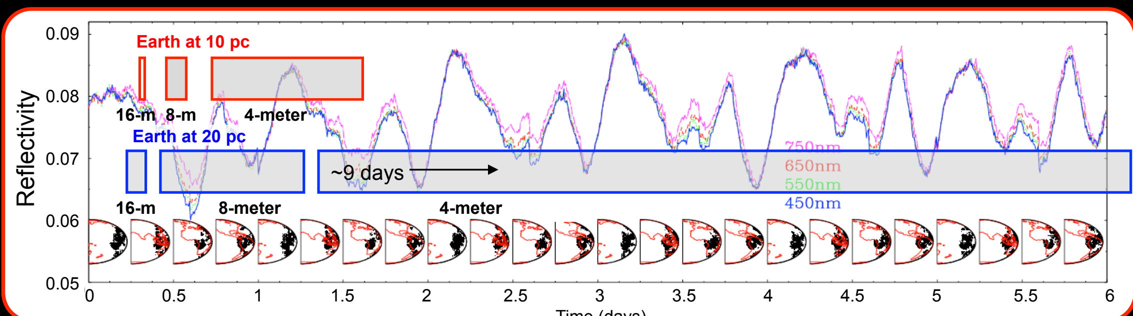


Detection of Biosignatures in Habitable Zone Planets

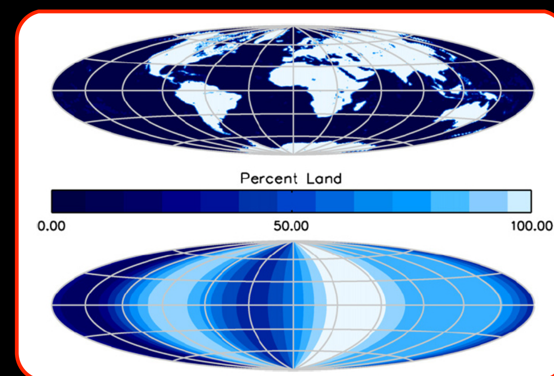


Oxygen and water in the atmosphere of an Earth-like planet can be detected in its spectrum.

Monitoring for Diurnal Photometric Variations



Require S/N ~ 20 (5% photometry) to detect ~20% temporal variations in reflectivity.



Reconstruction of Earth's land-sea ratio from disk-averaged time-resolved imaging with the EPOXI mission.

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	-

Ongoing Engineering Formulation

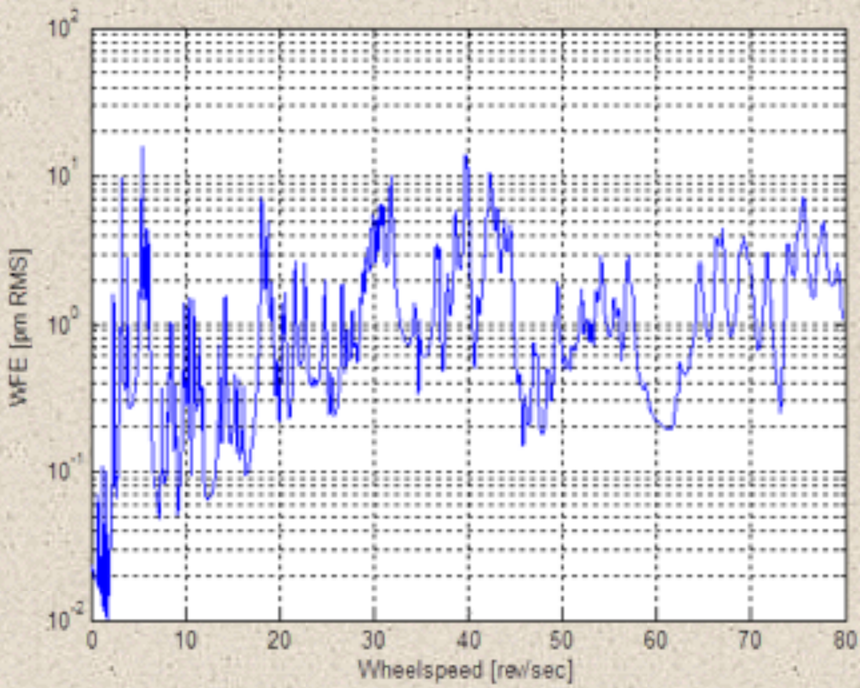
- **Highest-priority engineering formulation activities**
  - **Dynamic stability analysis**
    - ***Jitter modeling for initial estimate of jitter-induced WFC***
    - ***Primitive Finite Element Model (FEM) of observatory being validated***
  - **Thermal stability analysis**
    - ***Validate milli-kelvin-level control of mirror segment assembly***
    - ***Validate control of thermally induced wave front error control***
  - **Starlight suppression via coronagraph or starshade**
    - ***Multiple concepts for coronagraphy, although in early stage***
    - ***Successful concept may reduce demanding requirements on system's dynamic stability***

- **Mass estimation proceeding within limitations of available resources**
- **Work begun on bounding observatory instrument interfaces**
  - **Too early to down-select to final instrument suite**
  - **Bound mass, power, optical geometries, data rates, data volume, thermal, etc.**

- **SLS + ATLAST/LUVOIR engineering working group ongoing**
  - **Engineer-to-engineer development of conceptual interfaces and requirements**

ATLAST Integrated Modeling

- **Integrated modeling to predict effects of disturbance sources on telescope wave front error**



- **Ongoing model development and validation**

- **Recent refinements include effects of non-rigidity in SM support structure and the inclusion of a stiffer telescope pointing boom**

- **Initial integrated modeling indicates that 10pm can be achieved over a reasonable bandpass of reaction wheel speeds with a state of the art non-contact isolation system**

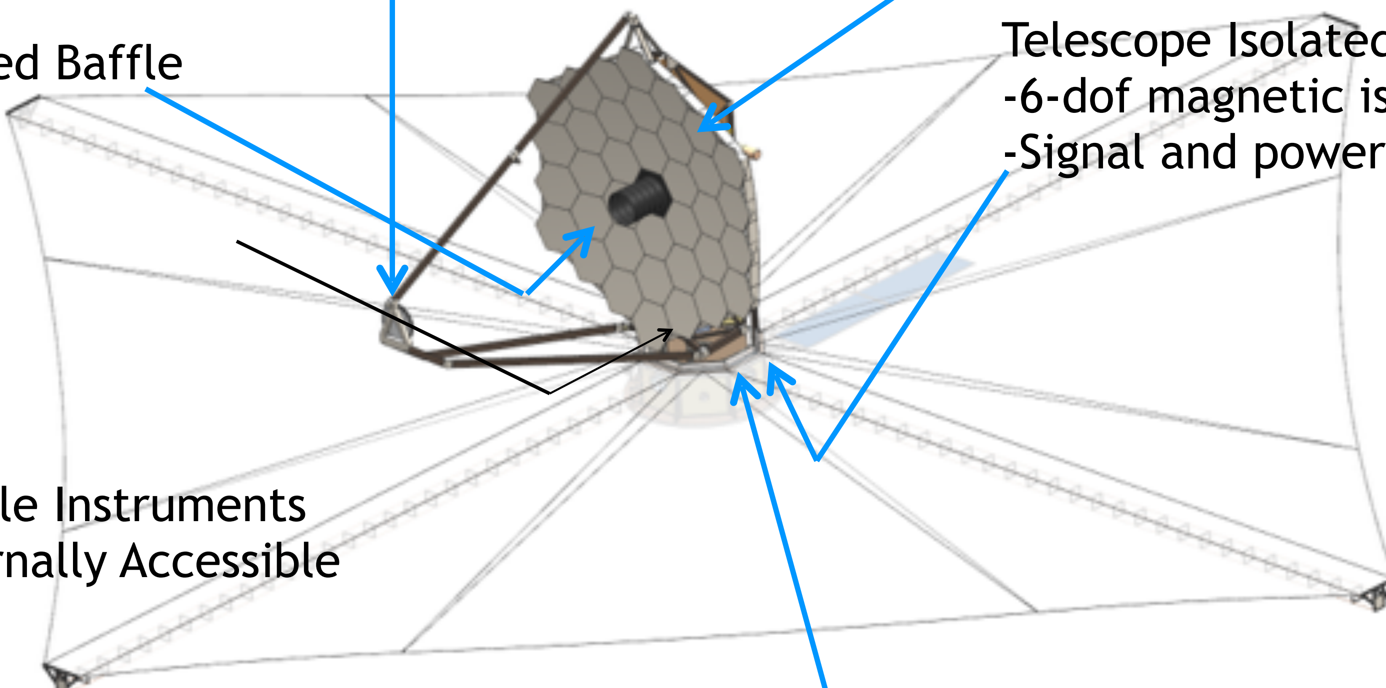
ATLAST 9.2 m Class Architecture

Actively controlled SM
6-dof control metrology to SI

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

Deployed Baffle

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

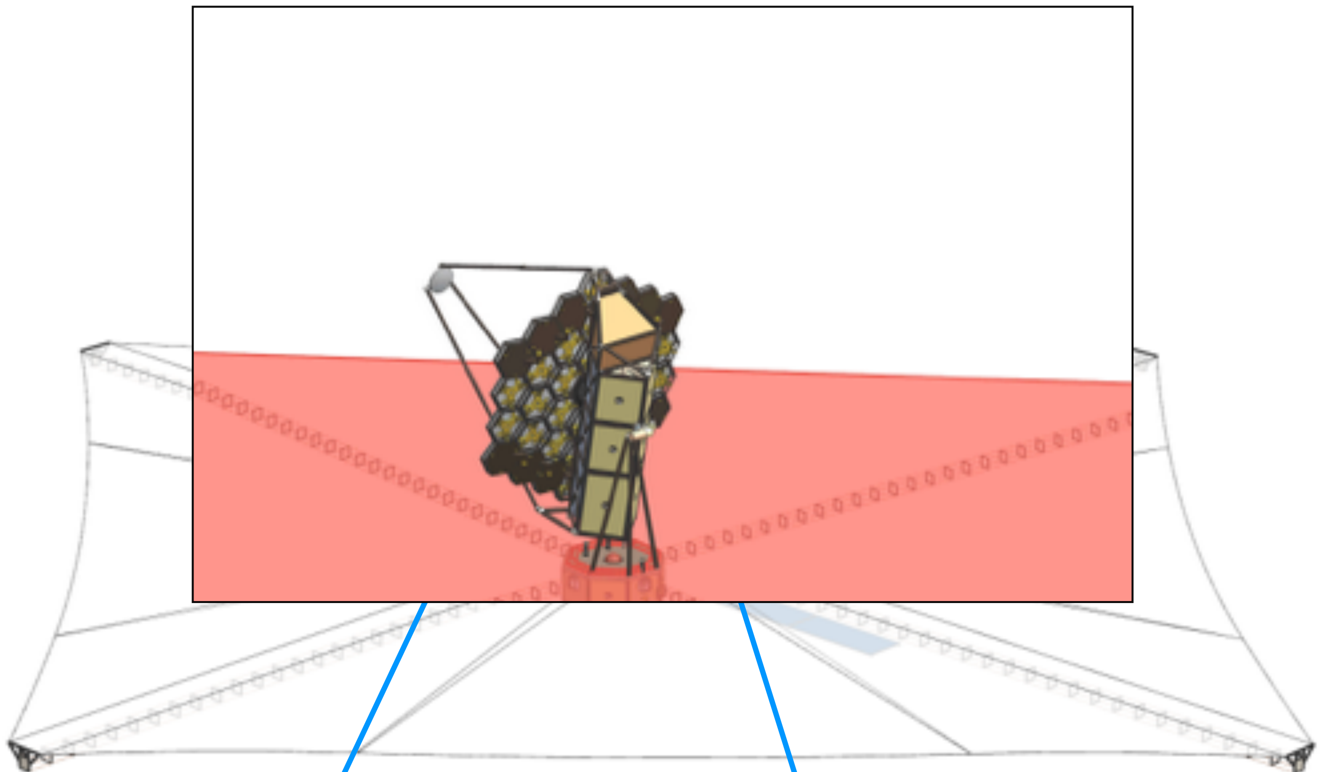


Serviceable Instruments
are Externally Accessible

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

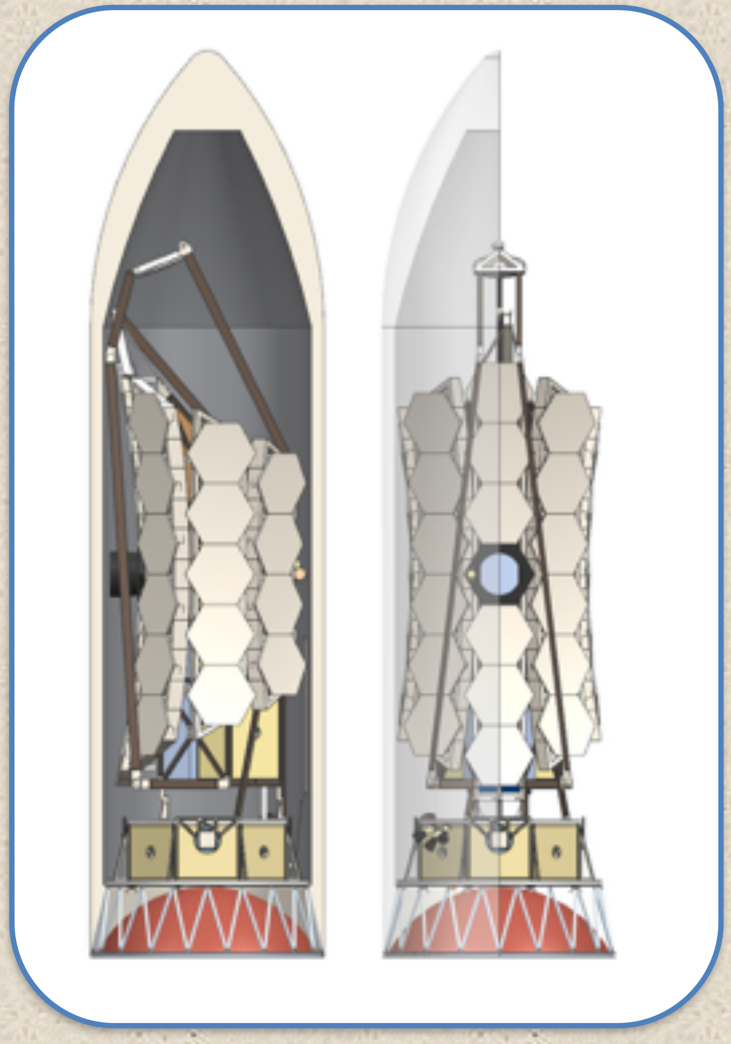
ATLAST 9.2 m Class Architecture



New backplane architecture
-Stiffer
-Matches JWST first mode and fits in volume
-Based on proven manufacturing methods
- Mass compatible with even Delta IVH budgets

Gimbal stability improved
- Stiffer
- Allows pitch
- Isolation at interface to ISIM
- Can add Yaw mechanism between isolation and gimbal if speckle removal needed

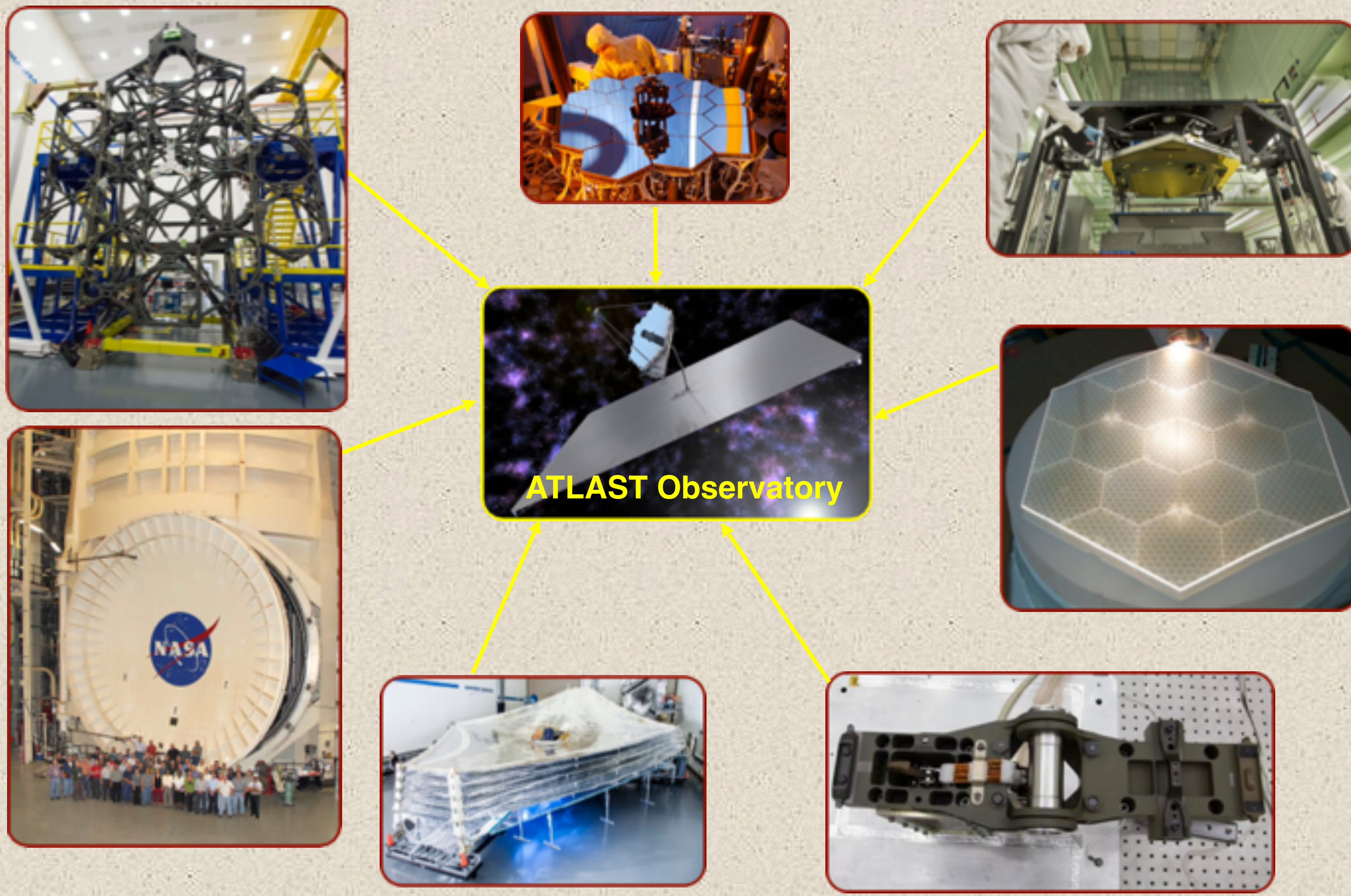
ATLAST 9.2 m
JWST-like Deployment



Highly leverages JWST deployments
- Secondary
- Wings (6 vs 2)

ATLAST 9.2m
Stowed in Existing Fairing Volume
(Delta IVH, SLS Block 1, Falcon 9)

Leveraging JWST Technology



Leveraging JWST Technology

Mirror Backplanes

Composite, primary mirror backplane structures scaleable to
≥ 10 meter apertures

Control System

Wavefront Sensing and control for large, segmented optical systems

Integration and Test

Precision high-speed interferometric testing of mirror segments with ≤ SFE precision

Segmented Mirrors

MMSD mirror program demonstrates lightweight ULE segments capable of ~pm stability with active thermal control @ 300K

TV Test Facilities

Thermal vacuum test chamber facility, optimized for large aperture telescopes

Sunshield

Large deployable, sunshield structures

Deployment Mechanisms

Mechanisms and latches employed in deployment of large structures and sunshields

ATLAST Key Technologies & Capabilities (1)

Starlight Suppression System

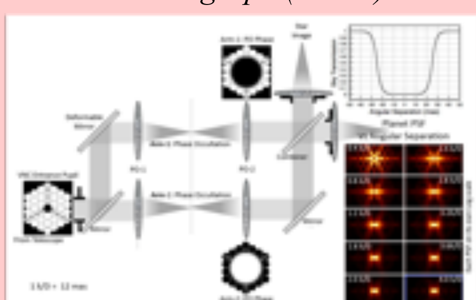
Need:

1×10^{-10} raw contrast
1×10^{-11} contrast stability
Wavelengths of 400 nm – 1.8 μm
Working angles of $2\lambda/D$ – $\sim 100\lambda/D$
Work with a segmented aperture

State of the Art:

1.3×10^{-10} raw contrast
Wavelengths of 700 nm – 880 nm
Working angles of $3\lambda/D$ – $16\lambda/D$
Unobscured aperture

Phase-Occulting Visible Nulling Coronagraph (GSFC)



Prototype Starshade Petal Structure (Princeton/JPL)

Lightweight Mirrors

Need:

<10 pm RMS wavefront error stability
<7 nm RMS static surface figure
<36 kg/m² areal density

State of the Art:

~70 nm RMS wavefront error stability
~25 nm RMS static surface figure
70 kg/m² areal density

MMSD Lightweight ULE Segment Substrate (GSFC/MSFC)

AHM SiC-based Segment Substrate (JPL)

ATLAST Key Technologies & Capabilities (2)

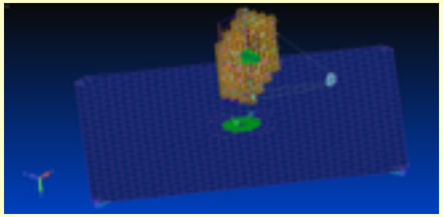
Ultra-Stable Structures

Need:
- 140 dB active attenuation > 40 Hz
- <10 nm/K thermally stable structures
- High-fidelity, efficient integrated modeling

State of the Art:
- 80 dB passive attenuation > 40 Hz
- 100 nm/K thermally stable structures
- Multi-week design iterations; low-fidelity

Lockheed 5-Degree of Freedom Disturbance Free Payload Testbed

Integrated Modeling (GSFC)

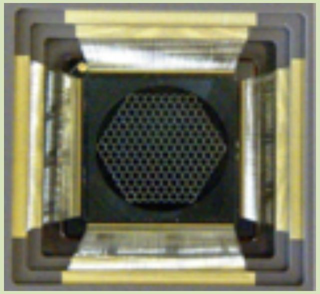


Sensing & Control System

Need:
- <1 mK thermal control
- Autonomous onboard sensing & control
- >16,000 actuator-count Deformable Mirrors (DMs)
- Picometer-level metrology & actuation

State of the Art:
- 1 mK thermal control
- Ground-based processing, human-in-the-loop
- 4096 actuators DMs, <100% yield
- Nanometer-level metrology & actuation

IrisAO 167-Segement Piston-Tip-Tilt Deformable Mirror



Xinetics 48x48 Continuous Face-Sheet Deformable Mirror

ATLAST Key Technologies & Capabilities (3)

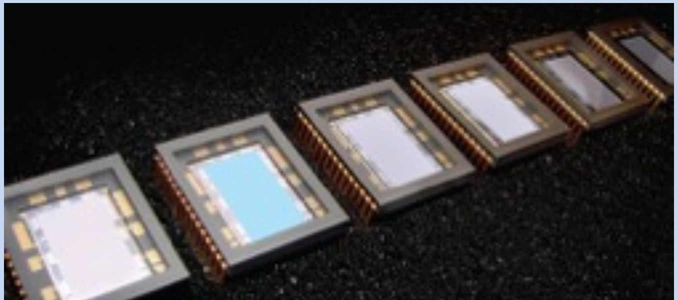
Detectors

Need:

>50% quantum efficiency UV detectors (90 nm – 300 nm)
Photon-counting Vis/IR detectors (300 nm – 1.8 μm)

State of the Art:

5-20% quantum efficiency UV detectors (150 nm – 300 nm)
Photon-counting visible detectors (300 nm – 750 nm)



Above: Six fully processed and packaged 0.5-megapixel, delta-doped EMCCD devices. The device with the multilayer AR coating (<0.3 μm thick) for FIREBall is visibly darker in the photo.

δ-doped EMCCD Devices (GSFC/JPL)

Mirror Coatings

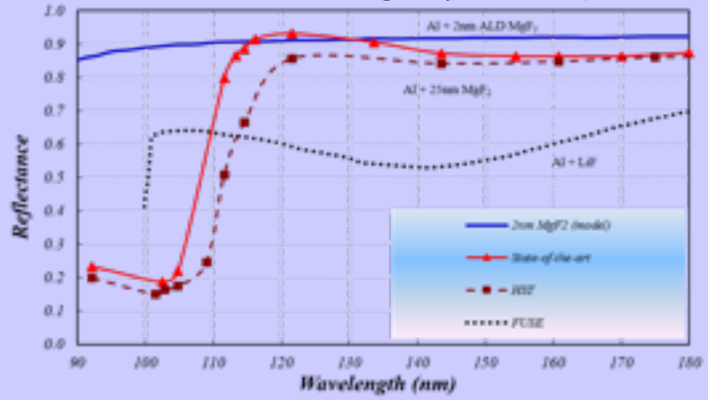
Need:

>90% reflectivity ≥ 90 nm
<1% non-uniformity ≥ 90 nm
<1% polarization ≥ 90 nm

State of the Art:

60% reflectivity between 90–180 nm
85% reflectivity ≥ 180 nm
2% non-uniformity ≥ 90 nm

Predicted & Measured Coating Performance (GSFC/JPL)



Summary

- **Compelling science goals identified in recent studies**
  - **Discovery and characterization of earth-like planets**
  - **Compelling astrophysics enabled by UV/Opt large aperture**
    - **NASA 30 year Roadmap**
    - **AURA : *From Cosmic Birth to Living Earths***

- ***ATLAST team has focused on yield drivers for ExoEarth candidates (Stark et al. 2015), and requirements for spectral characterization of biosignatures***

- **ATLAST team has identified a <u>scaleable</u> observatory architecture and started to model performance to identify "tall-poles"**
  - ***Key technologies have been identified***
  - ***Initial modeling shows pathway to required performance***
  - ***Leverage existing technology and infrastructure***