The Next Great Observatory

A Future Advanced Technology Space Telescope and The Search for Life-Bearing Planets

"[This goal would be] one of the most romantic and successful of NASA's [programs]: the search for Earth-like planets in habitable orbits around other stars."
--- NY Times, May 16 2013

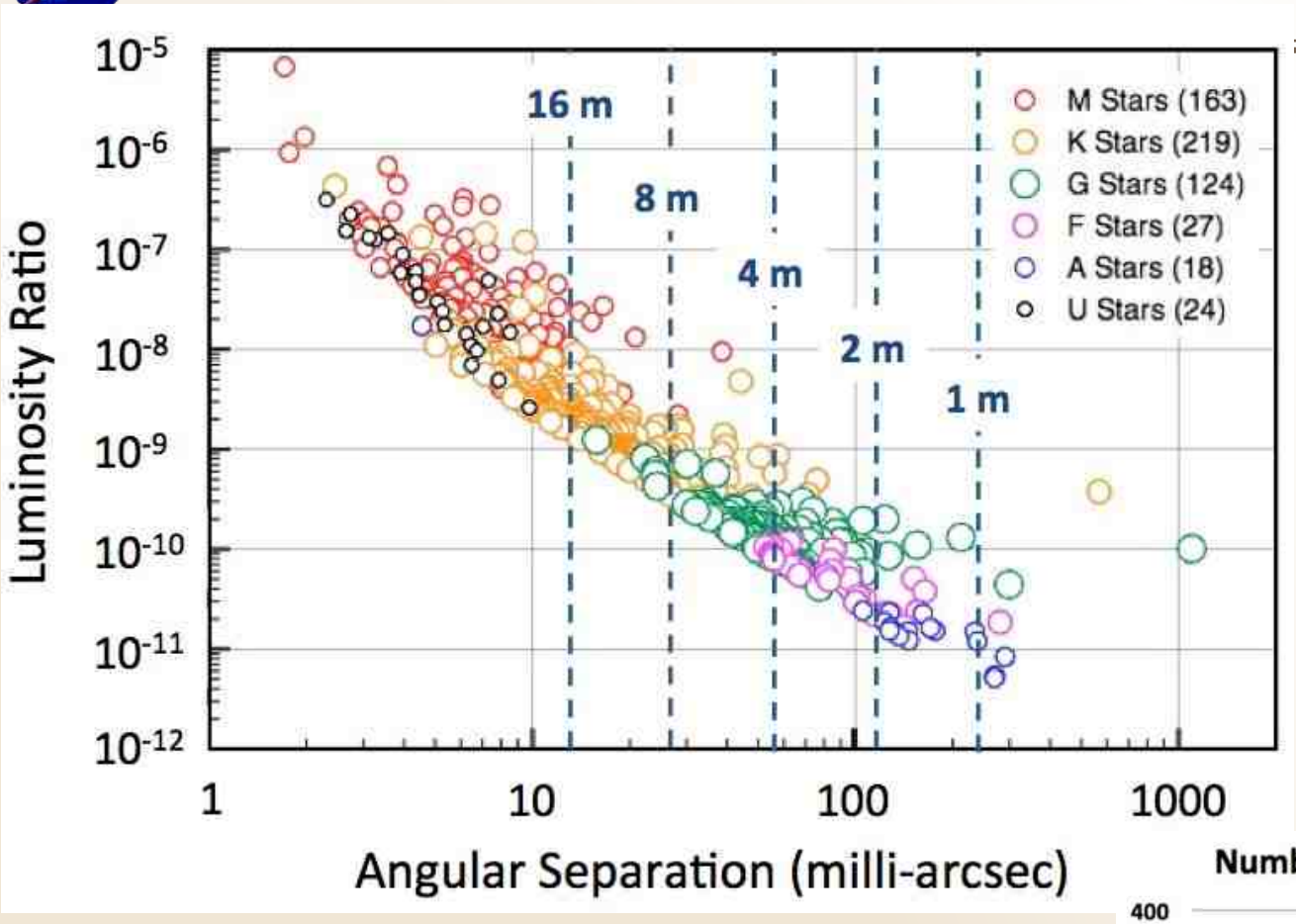
17 May 2013

Competition Sensitive: GSFC & STScI Internal Only

Candidate Priority Science Goals for a Future Large-Aperture UVOIR Observatory

- Search for Earth 2.0: direct spectroscopy of terrestrial exoplanets in Habitable Zones around solar-type stars: Detection of "bio-signatures"
- Direct detection of main sequence turn-off in resolved stellar populations in hundreds of galaxies within 15 Mpc of the Milky Way: reconstruct precise star formation histories across a broad range of environments, enabling a comprehensive theory of star formation and evolution
- Direct detection of intrinsically faint supernova progenitors
- Measure stellar proper motions in Local Group dwarf galaxies: provides direct constraint on dark matter density profiles.
- Direct measurement of warm gas kinematics in the circumgalactic environments in *all* galaxies within 15 Mpc of the Milky Way: providing a comprehensive understanding of galaxy evolution

Earthlike Exoplanet distribution drives Telescope Size



Assumes:

$\eta_{EARTH1} = 1$

Planets all Earth diameter

V-band 500 – 600 nm

IWA = 2 λ/D

See:

Lyon, Clampin, JOE 51 (2012)

Large Apertures Required for Earth-like Exoplanets

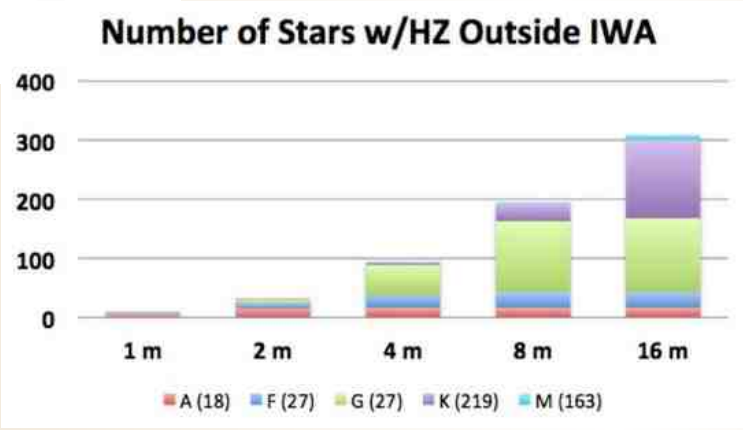
Most G-stars beyond 30 mas

Aperture must be ≥ 8m, Area ≥ 50 m^2

yields ~10 photons/sec in V-band

Spectral resolution R=100

=> ~0.1 photon/sec/spectral channel

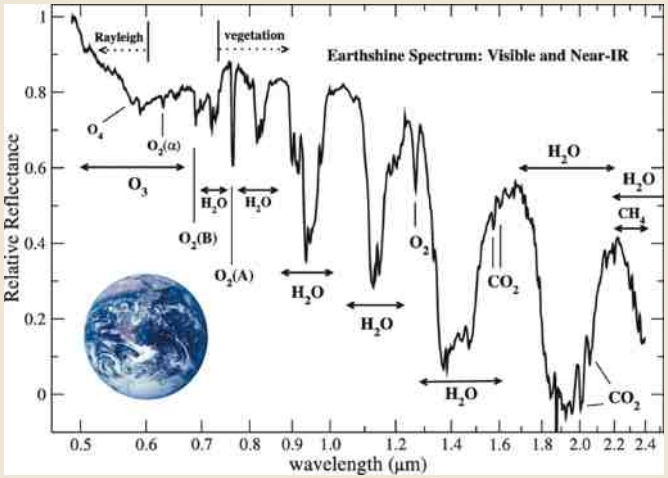


Observatory Requirements for a Search for Earth 2.0: Aperture

Number of observable habitable zone planets depends on several to-be-determined astrophysical (η_{Earth}, exozodi dust levels) and facility parameters (aperture size, instrument performance): priority study goal

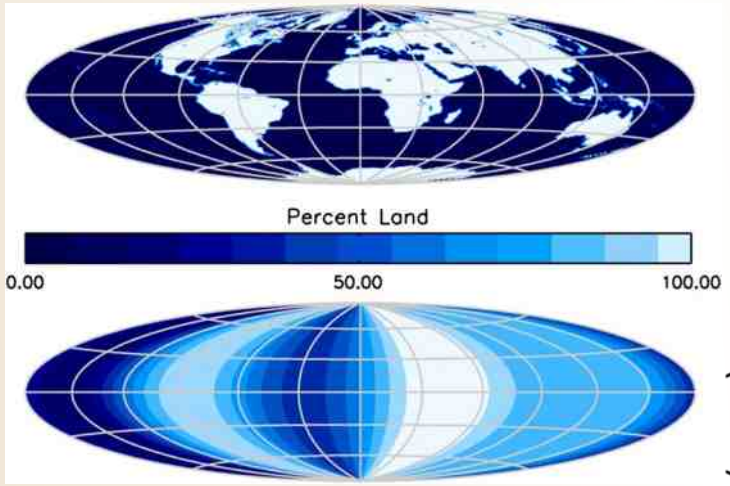
The importance of a large telescope aperture lies not in the greater quantity of data collected, but in greater quality. Characterization studies enabled by 8 – 16 meter apertures include …

Broader bandpass & higher S/N => more atmospheric gasses detected; that is better chance of finding biomarkers



Turnbull et al. (2006)

Time-resolved imaging => see diurnal and seasonal variations => get hints of oceans/continents/ice caps



Cowan et al. (2009)

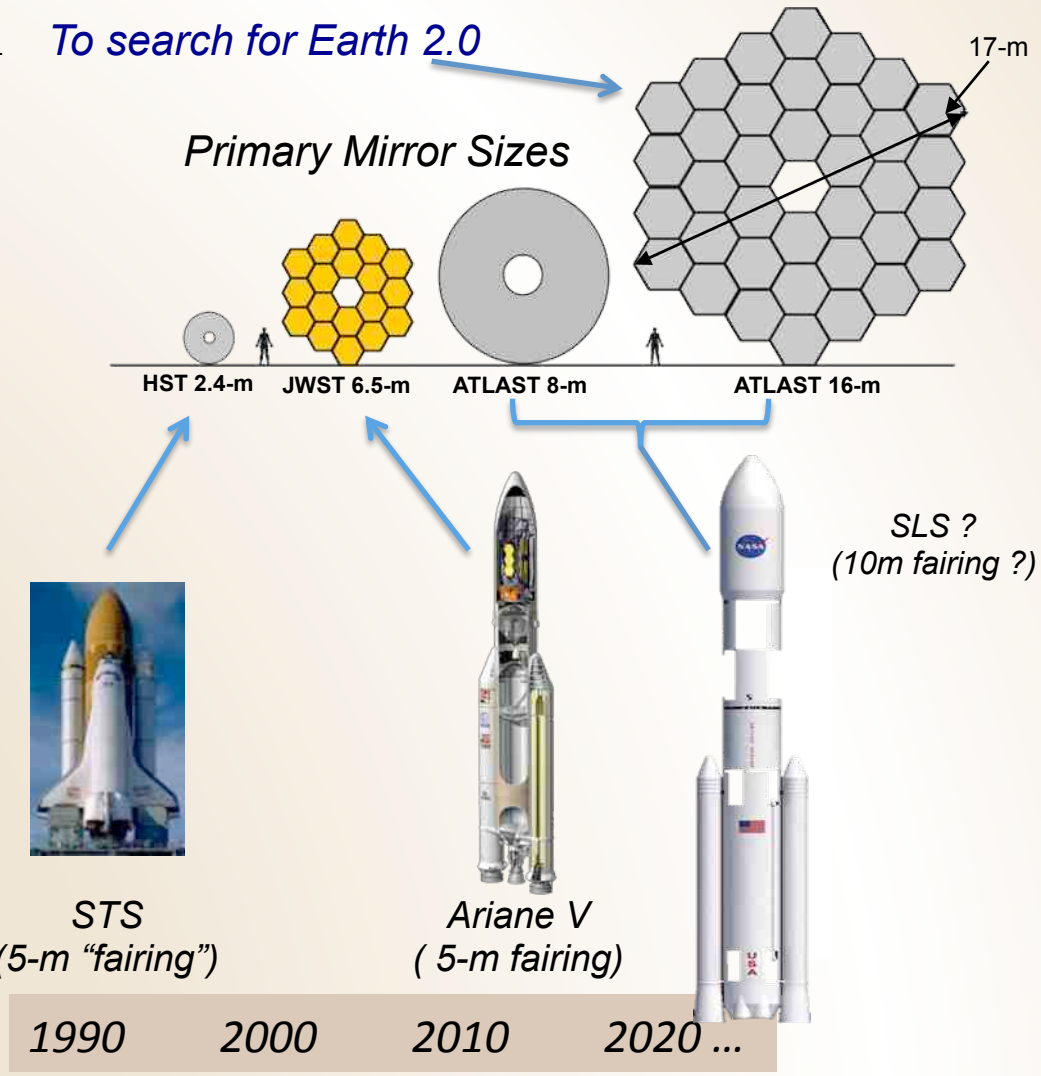
Conventional Launch Vehicle Requirements

Large space telescopes with conventional monolithic (*a la* HST) or pre-assembled segmented mirrors (*a la* JWST) face substantial challenges in scaling to even larger sizes, including

- Testing in 1 g
- L/V throw weight & fairing size
- Complex, precision deployments on-orbit
- Long-term performance
- Prohibitive cost

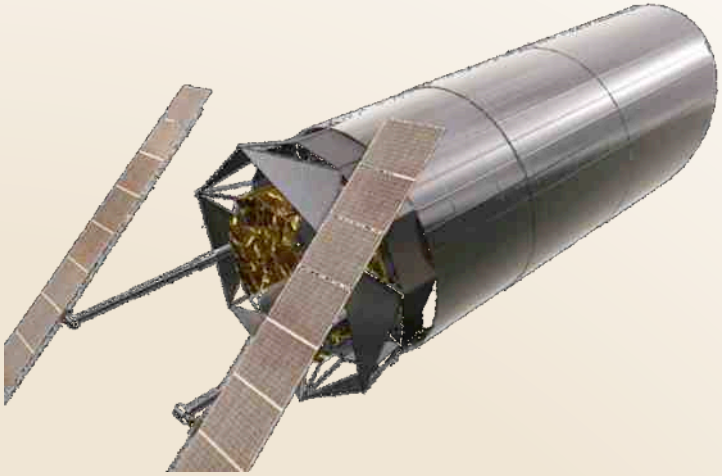
This relies on future heavy L/V, large fairings and complex geometry.

A major element of the proposed GSFC-led trade studies will be to assess alternatives: assembly in space with astronauts/robots, replication of multiple elements and economies of scale, etc.

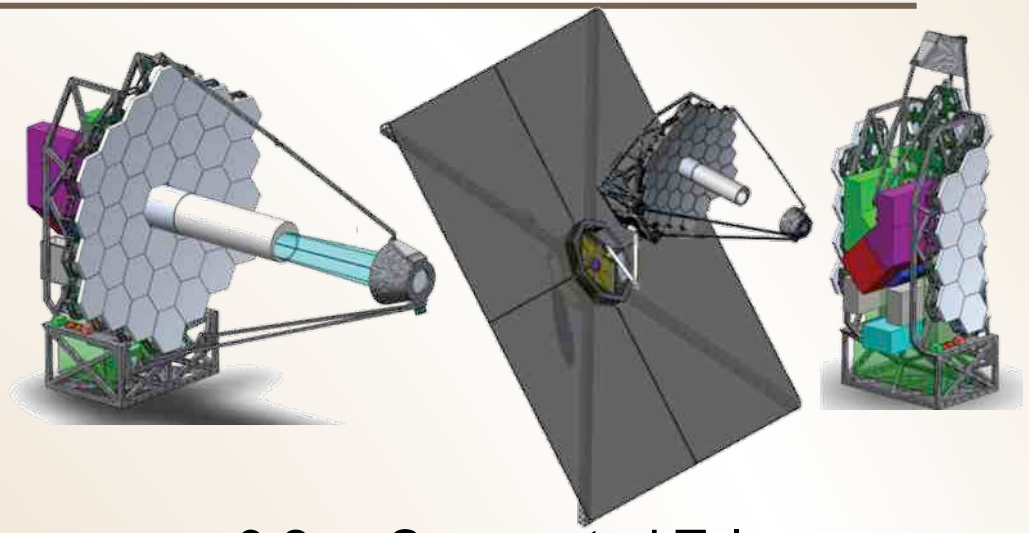


Existing Design Work: Advanced-Technology Large-Aperture Space Telescope (ATLAST)

Marc Postman *et alia*, $1M 2-year NASA Astrophysics Strategic Mission Concept Study
Joint STScI/GSFC/JPL/MSFC/academia assessment



8-m Monolithic Primary

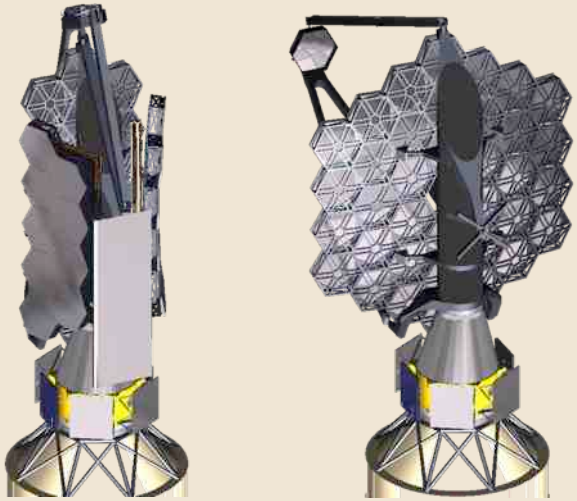


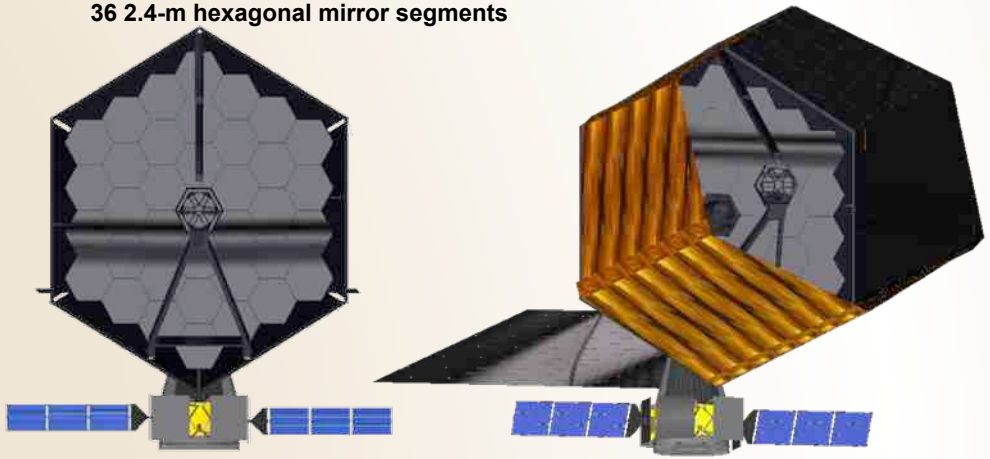
9.2-m Segmented Telescope

36 1.3-m hexagonal mirror segments

16.8-m Segmented Telescope

36 2.4-m hexagonal mirror segments



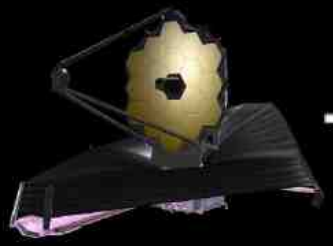


Key GSFC Capability (1): Goddard's Historic Leadership Role in Large Space Telescopes

Hubble Space Telescope

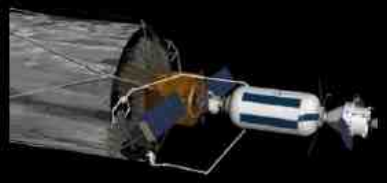
2.4m Monolithic
Precision Mirror
Servicing
Phase Retrieval

James Webb Space Telescope



6.5m PM, 18 segments
Passive Stability
Image Based WFSC
Lightweight Mirrors
Deployed

Modular Assembled Space Telescopes



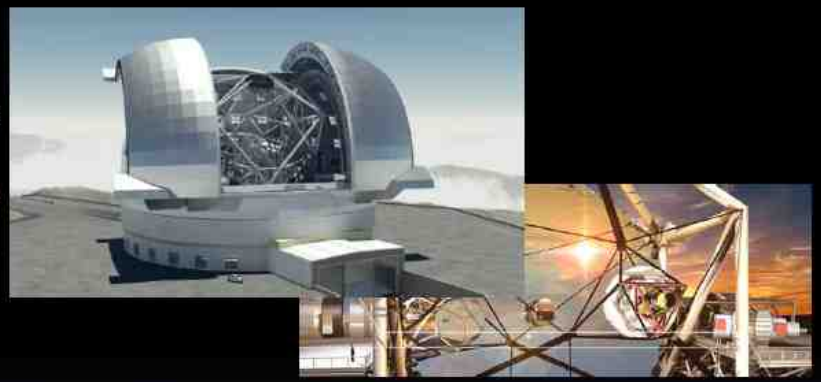
Initially 20m class
Scalable to larger – 100m+
Active Image Based WFSC
Production Fab
Assembly of Modules

Keck

36 segments
Active WFSC

Thirty Meter Telescope+EELT

30-39m PM
Hexagaonal mirrors
492/798 segments
Large Secondary
Production Fab



Gemini/ 8-m class

8m class monoliths
Active WFSC

GMT

Six 8.4m telescopes
Active WFSC

Current | **2015-2020** | **2020-2030**

WFSC = Wavefront Sensing and Control

L. Feinberg

Key GSFC Capability (2): Starlight Suppression via Visible Nulling Coronagraph

- The Visible Nulling Coronagraph (VNC) is uniquely capable of operating with segmented optics telescopes
- VNC is less susceptible to stability variations in the telescope topical system
  - WFSC is done near-real time using bright channel
  - Scaleable architecture
  - Integrated design measures pointing error simultaneously
- VNC at GSFC is funded with two SATs
  - Demonstrate contrast of 10^9 in broadband
  - Qualify large format IRIS-AO deformable mirror
- Contrast 3 x 10^9 demonstrated in narrowband in air