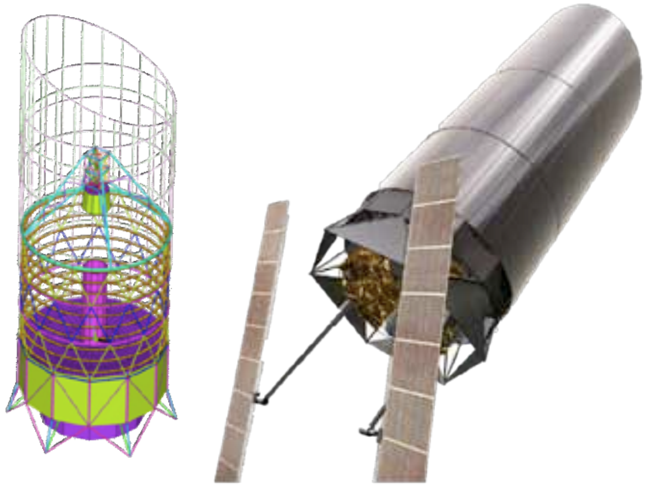
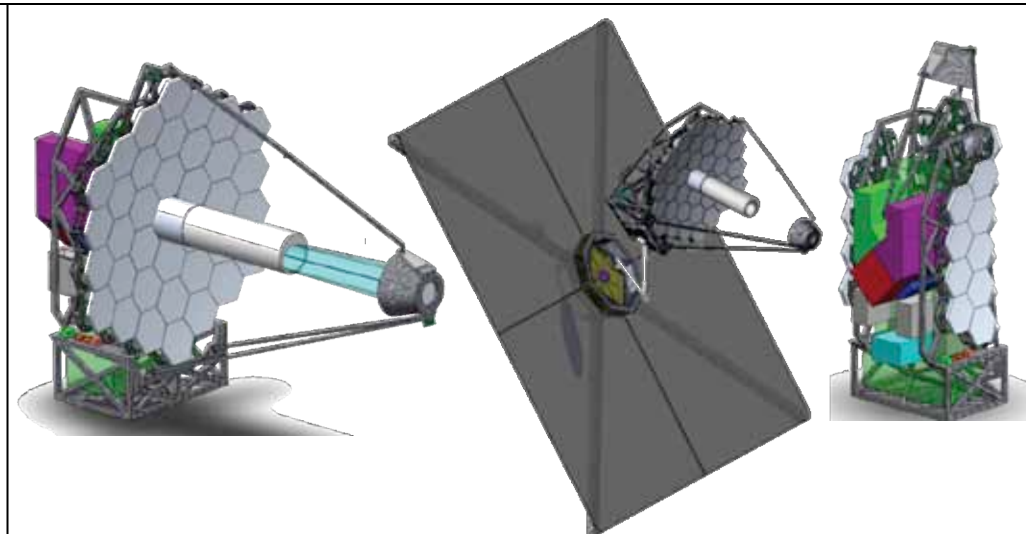
“8-meter Class” Space Telescope Concepts



8-m Monolithic Primary
(shown with on-axis SM configuration)



9.2-m Segmented Telescope
36 1.3-m hexagonal mirror segments

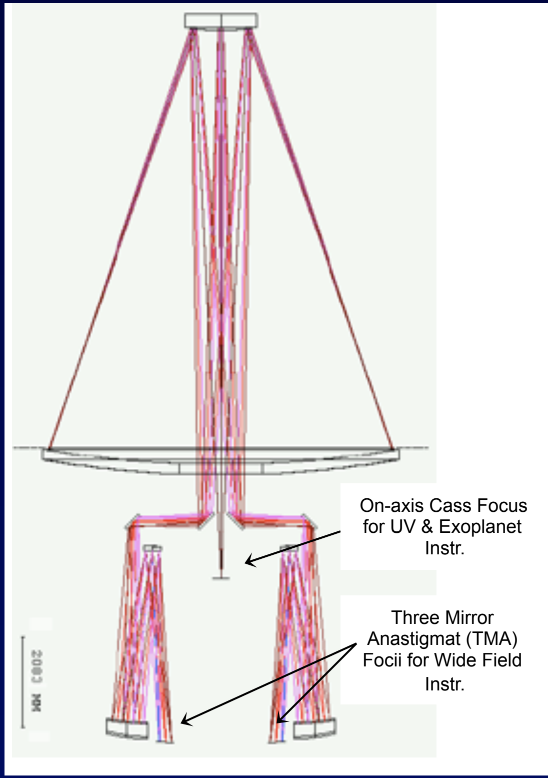
Marc Postman, STScI
COPAG, Sept. 22, 2011

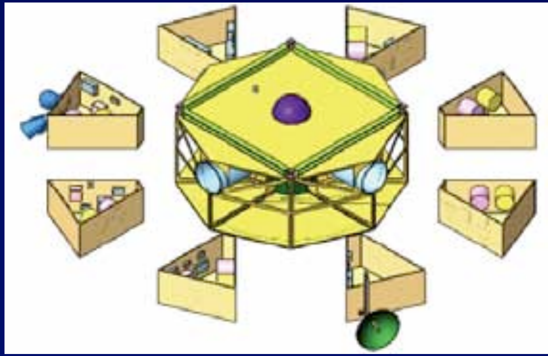
Two architectures for an 8-meter class telescope: monolithic vs. segmented mirror telescopes

- Monolithic Primary
  - Could use existing ground-based mirror materials – would survive launch loads. But mirror would be 20 mT.
  - This is still, potentially, enabled by large lift capacity of the proposed **SLS** launch vehicle (70 mT to LEO with upgrade to 140 mT capacity).
  - For 8-meter design: a ULE massive mirror (~20 mT) has ~7 nm rms surface (exquisite intrinsic quality) but requires big rocket to launch.
  - Very long thermal time constant (~500 hours) at SE-L2.
- Segmented Primary
  - Requires use of (relatively) lightweight mirror materials (15 - 25 kg/m^2) & efficient fabrication.
  - 9.2m observatory would have 36 segments (each 1.3m edge-to-edge) and a total mass of ~14 mT.
  - Segmented observatory can fly in slightly upgraded Delta IV Heavy EELV.
  - Requires active WFS&C system with sunshield to reduce scattered light.

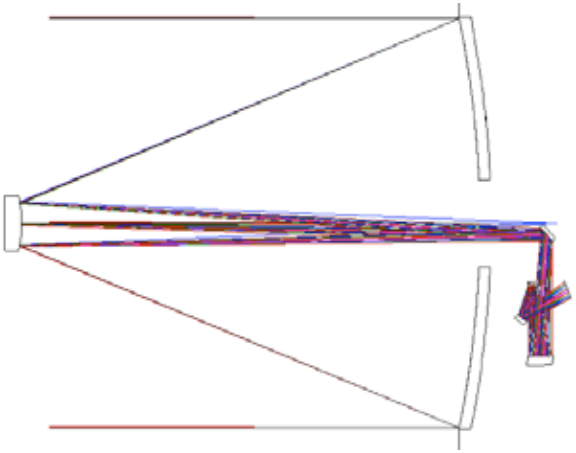
Common Features for all Designs

- Diffraction limited @ 500 nm
- Designed for SE-L2 environment
- Non-cryogenic OTA at ~280° K
- Thermal control system stabilizes PM temperature to ± 0.1° K
- OTA provides two simultaneously available foci - narrow FOV Cassegrain (2 bounce) for Exoplanet & UV instruments and wide FOV TMA channel for Gigapixel imager and MOS
- Designed to permit (but not require) on-orbit instrument replacement and propellant replenishment (enables a 20+ year mission lifetime)





Optical Design Summary

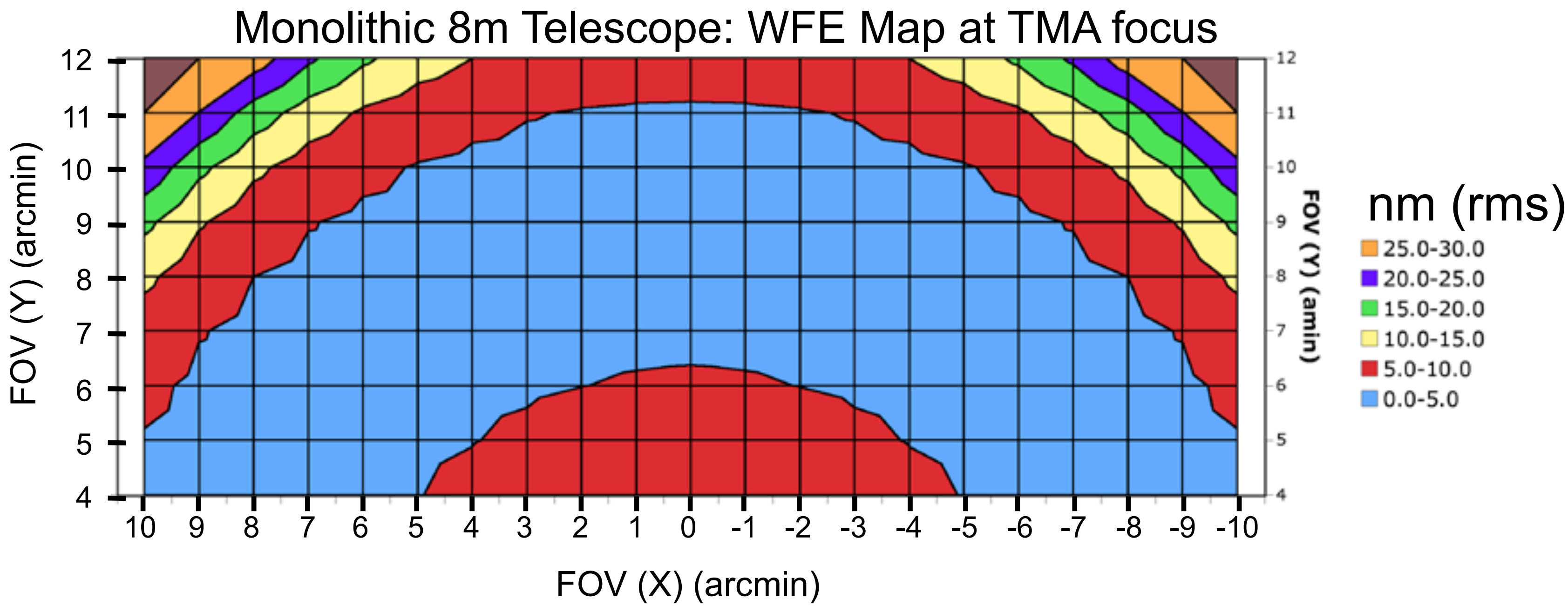


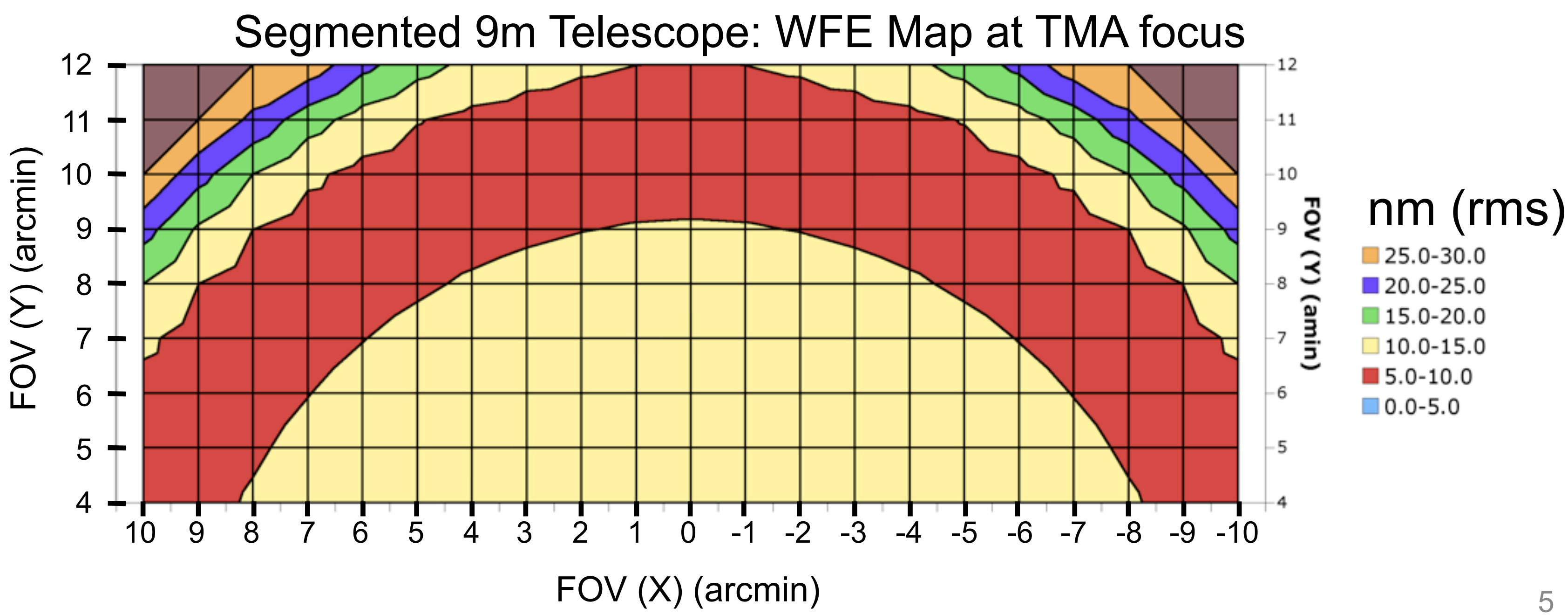
Architecture	Primary Mirror	TMA Focus	Cass Focus	Angular Resolution at 500 nm
8m Monolith	f/1.5	f/15, 8 x 20 arcmin FOV	f/13.6, 1 arcmin FOV	15.7 mas
9.2m Segmented	f/1.25 (36 x 1.3m segments)	f/18, 8 x 20 arcmin FOV	f/12.6, 1 arcmin FOV	13.7 mas

The optical design provides a Three Mirror Anastigmat (TMA) channel for wide FOV instruments and a Cassegrain channel that minimizes reflections in the UV.

The primary mirror is fast to minimize length of the OTA. Primary and secondary mirrors are coated with Al+MgF_2 (or better coating?) for good UV response at Cass focus.

Both the monolithic and segmented primary mirror designs are diffraction-limited at λ = 500 nm over an 8 x 20 arcmin FOV.


Monolithic 8m Telescope: WFE Map at TMA focus
FOV (Y) (arcmin)
12
11
10
9
8
7
6
5
4
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10
FOV (X) (arcmin)
FOV (Y) (amin)
nm (rms)
25.0-30.0
20.0-25.0
15.0-20.0
10.0-15.0
5.0-10.0
0.0-5.0

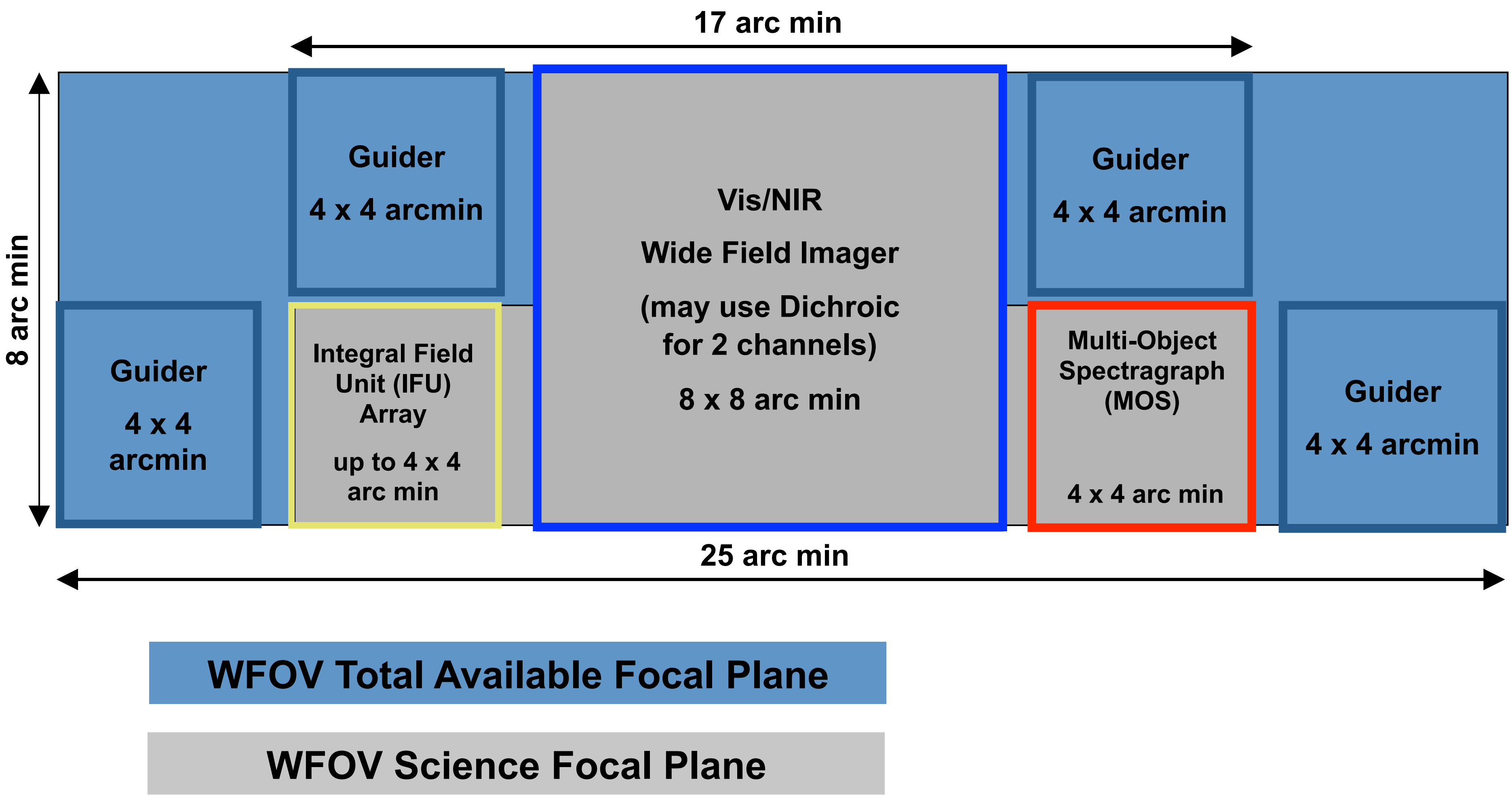

Segmented 9m Telescope: WFE Map at TMA focus
FOV (Y) (arcmin)
12
11
10
9
8
7
6
5
4
10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10
FOV (X) (arcmin)
FOV (Y) (amin)
nm (rms)
25.0-30.0
20.0-25.0
15.0-20.0
10.0-15.0
5.0-10.0
0.0-5.0

Instruments

- A suite of possible instruments were considered for ATLAST to address specific science goals
- Unlikely that more than ~4 of these would be implemented at launch. Others could be swapped in during a subsequent servicing mission.
- Optical designs of varying fidelity were produced for the instruments below.

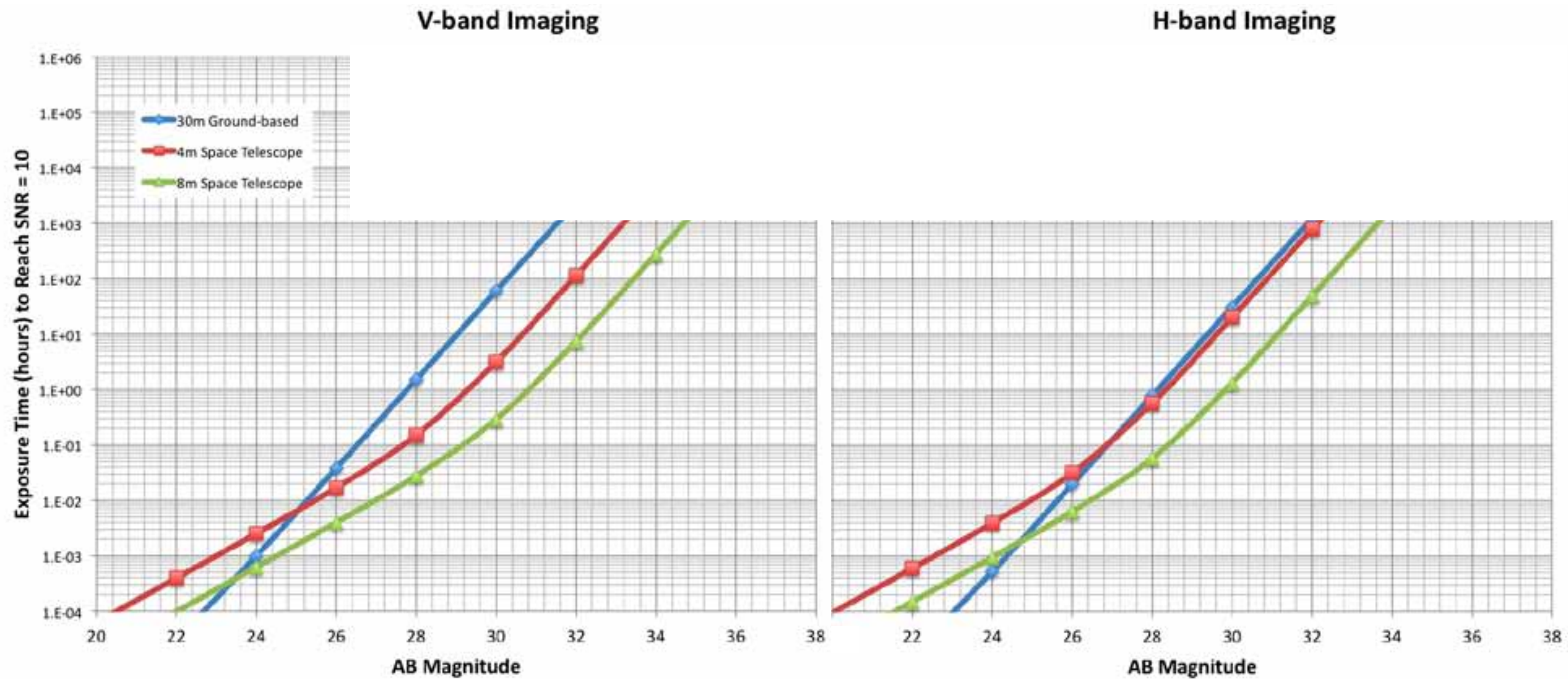
Instrument (Chan)	FOV	Resolution	Waveband
WF Cam (TMA)	8' x 8'	4	450-2500 nm
MOS (TMA)	4' x 4'	1000 - 3000	450-2500 nm
Vis IFU (TMA)	<10" x 10"	1000	450-2500 nm
UVSpec (Cass)	1" x 1"	30000-100000	110-300 nm
UV IFU (Cass)	2" x 2"	1000 - 3000	110-300 nm
ExoCam (Cass)	10" x 10"	4	250-1700 nm
ExoSpec (Cass)	1.3" x 1.3" x 4	100 - 3000	250-1700 nm

Possible TMA Focal Plane Allocation



From Lloyd Purves, GSFC

Broadband Imaging Comparisons

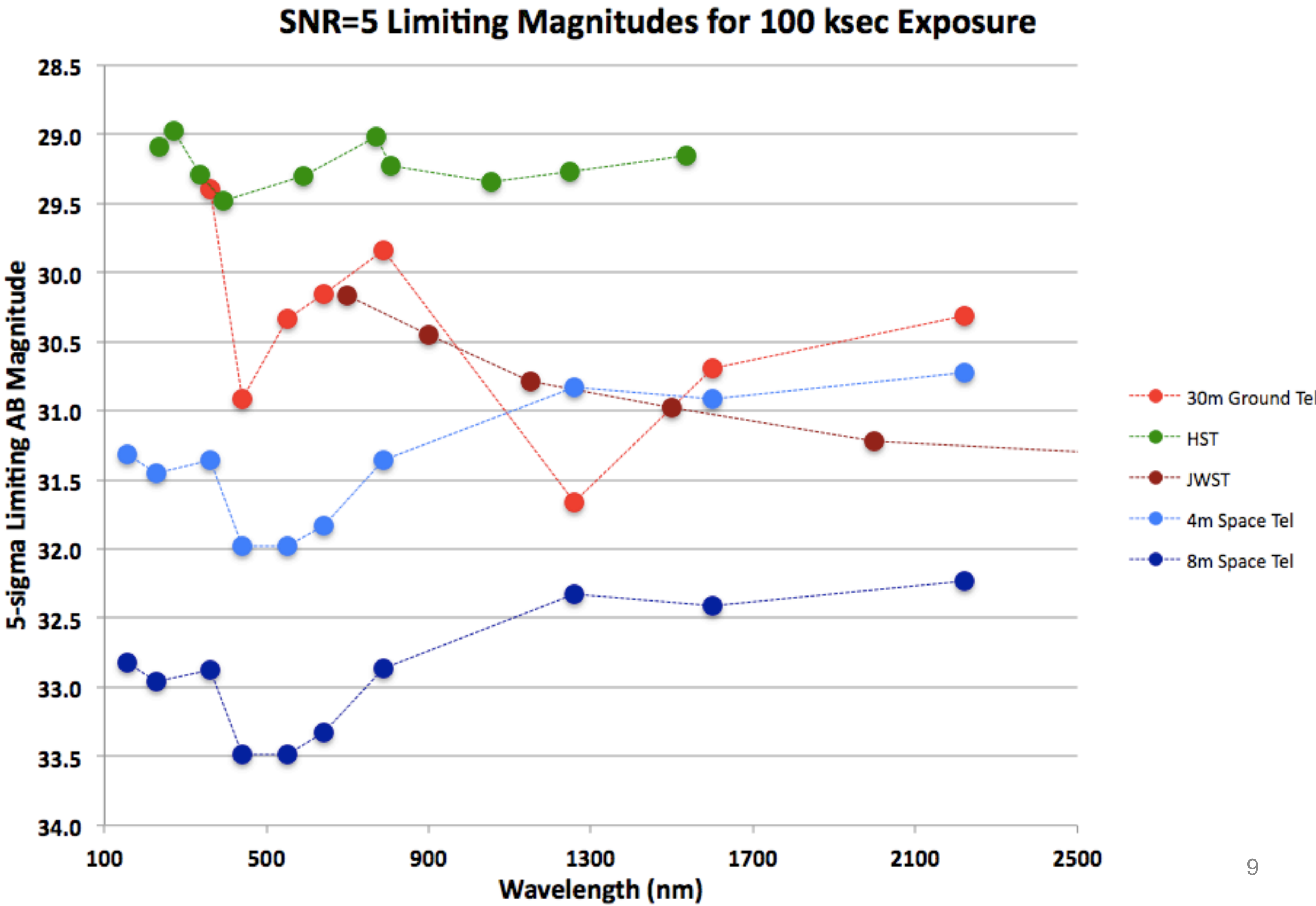


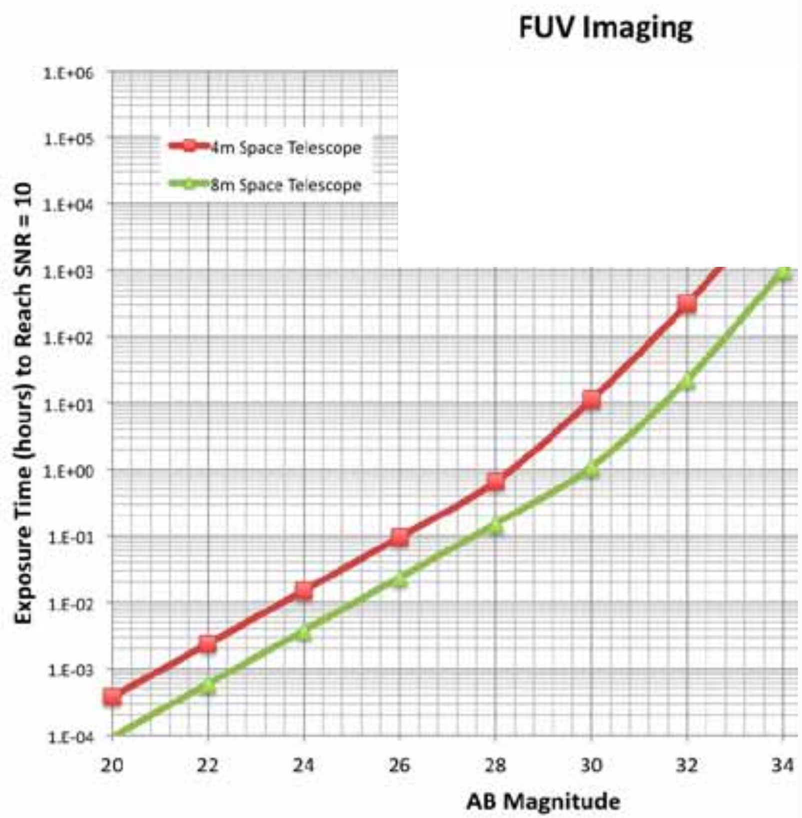
Future UDF ~ 1000 hours total in ~4 passbands

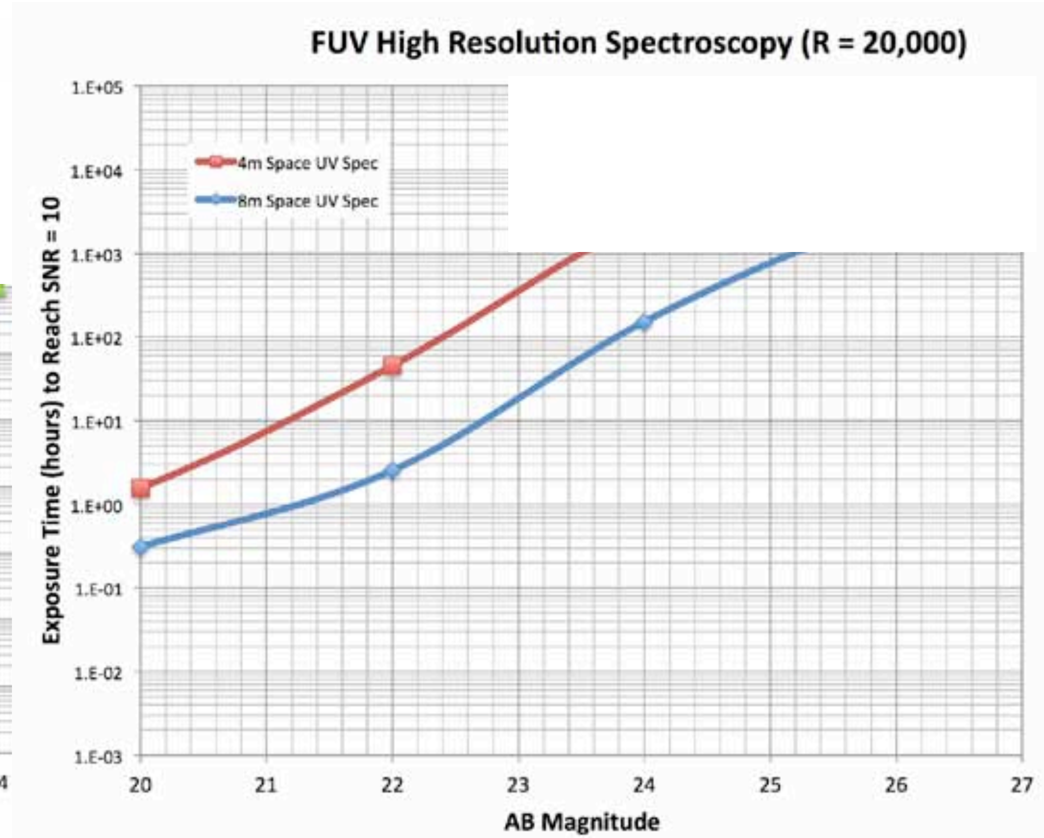
4m: 32.5 (V), 31.4 (H) (SNR = 10)

8m: 34.0 (V), 32.8 (H) (SNR = 10)

Broadband Imaging Comparisons





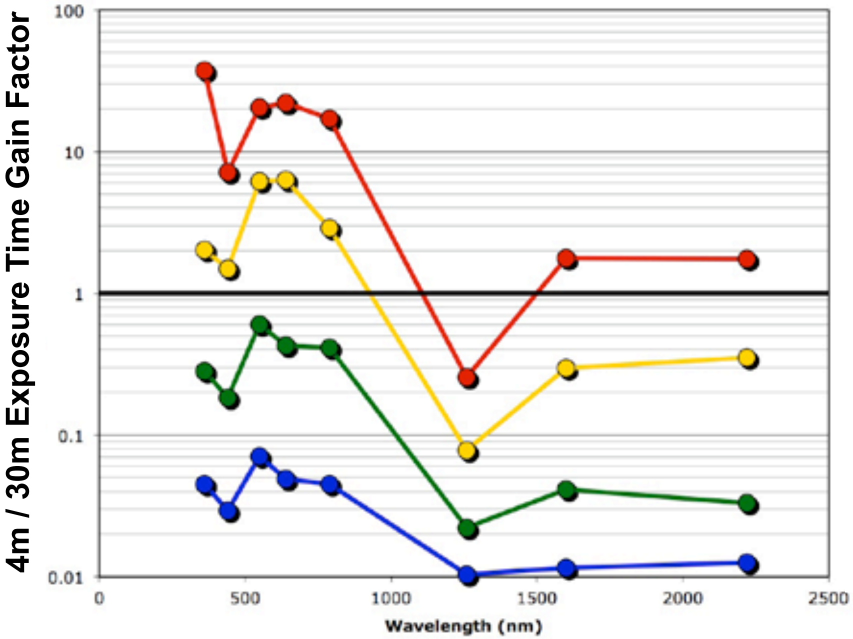


Assumed: 10% Total system QE at 155 nm
In 1 hour: 4m reaches 28.4 AB mag
8m reaches 30.0 AB mag

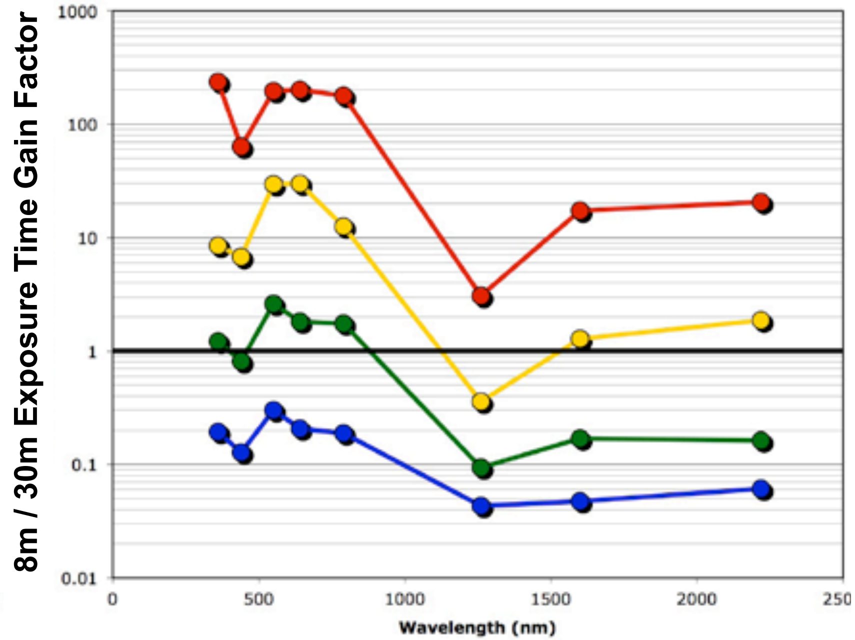
For R=20,000 spectroscopy:
In 10 hours: 4m reaches 21.2 AB mag
8m reaches 22.7 AB mag

Comparisons at Higher Spectral Resolution (in Optical / NIR wavelengths)

4-meter vs. EELT



8-meter vs. EELT



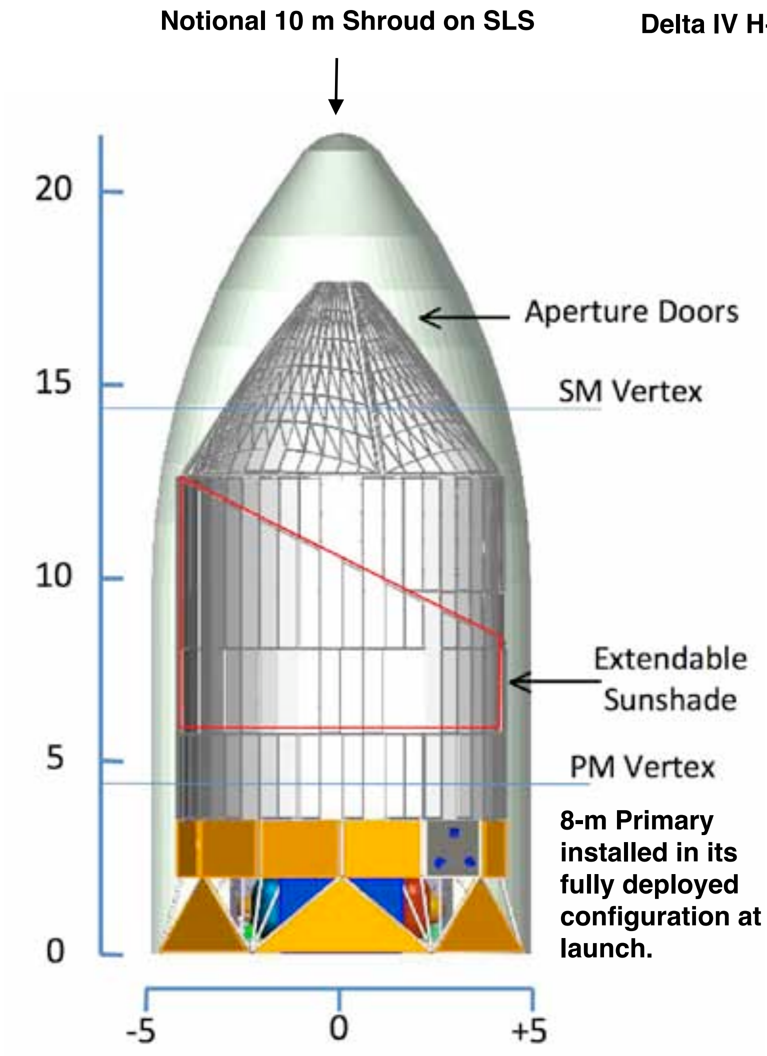
Assumes 30m ELT seeing limited below 1 micron and diffraction limited above 1 micron

- R = 5, mag = 30
- R = 100, mag = 28
- R = 2,000, mag = 26.5
- R = 20,000, mag = 24

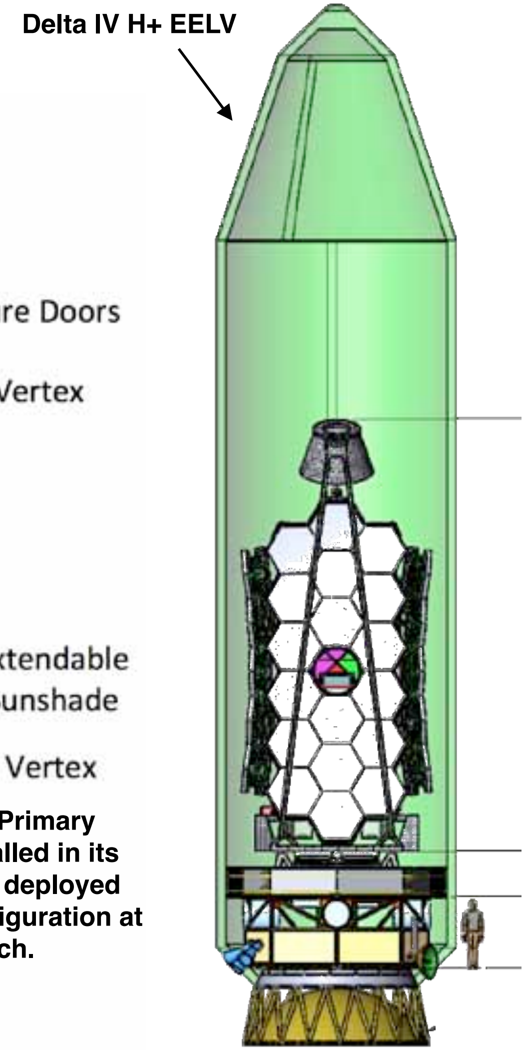
Obvious that UV is a key advantage for space-based imaging but not a sufficient science case (at least past attempts to sell LST on UV alone have not worked).

4m has ~20x speed gain for visible band imaging over TMT in optical but no advantage in NIR at any spectral resolution (except for panoramic imaging).

Launch Configurations



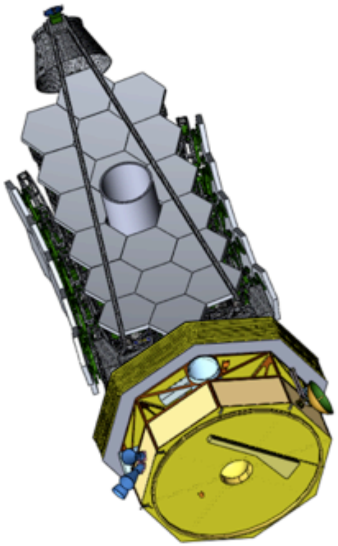
8-m Monolithic Telescope
Observatory dry mass = 44 mT



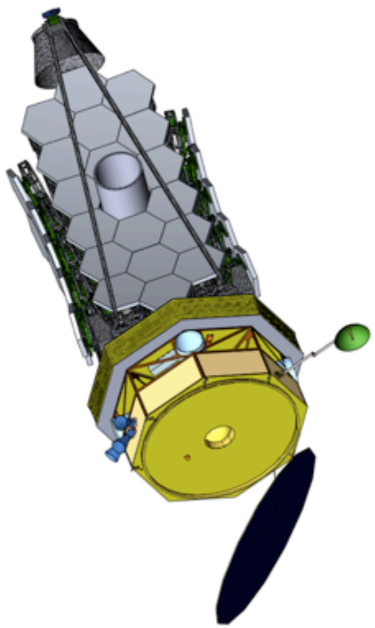
9.2-m Segmented Telescope
Observatory dry mass = 14 mT

Segmented Telescope Deployment

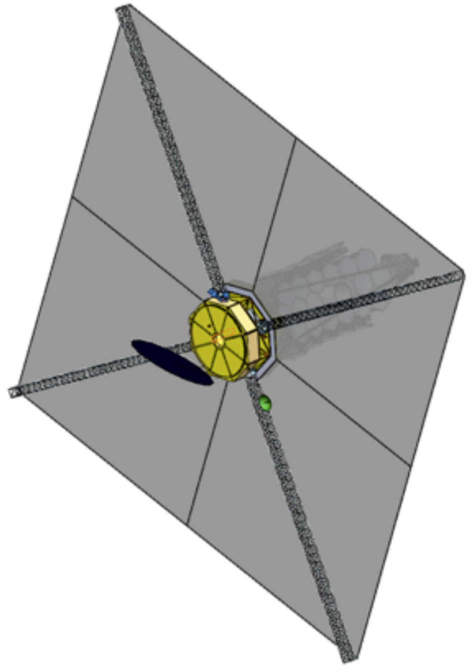
Deployment Sequence



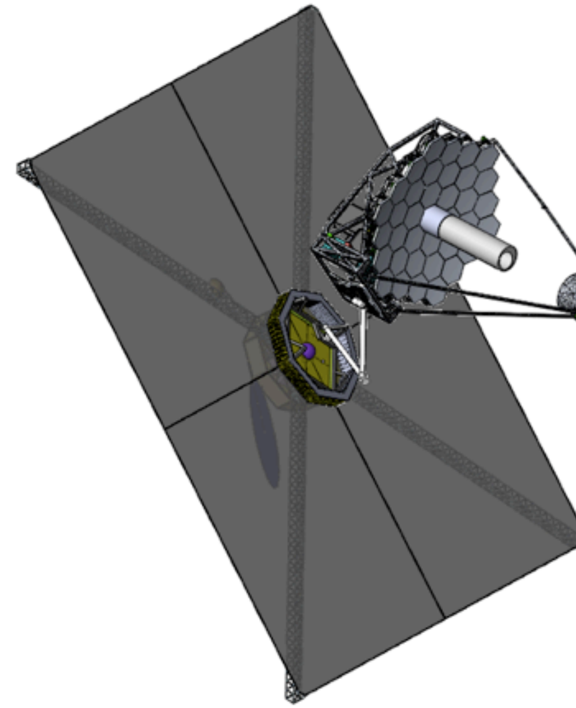
After fairing separation



Deploy solar array and antenna

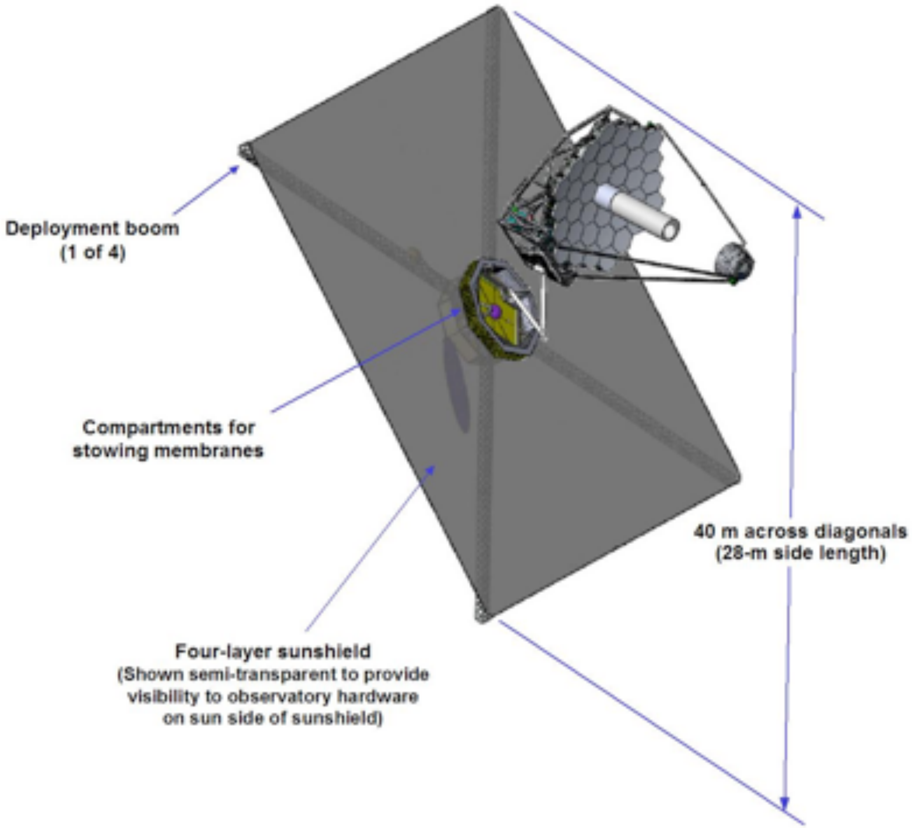


Sunshield deployed (looking from sun side; S/C bus Visible)



Pointing arm and OTA deployed (dark side of sunshield)

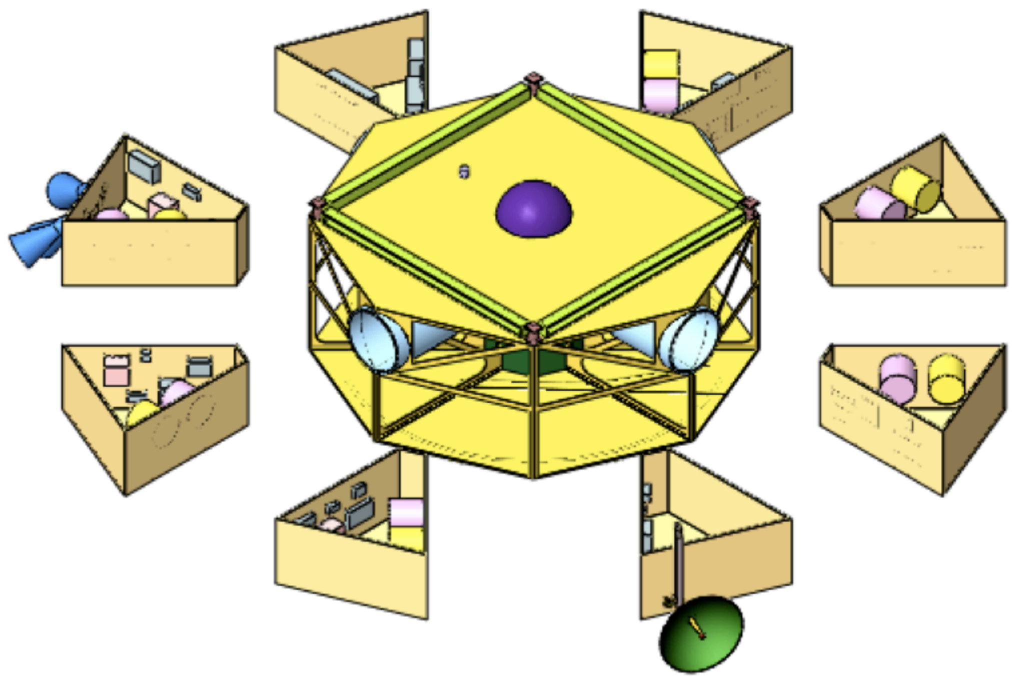
Sunshield



- Sunshield is "flat" unlike JWST - thin, with relaxed shape control
- Purpose is not to provide thermal control; only for blocking light from sun, earth and moon
- 28 x 28 m in size
- 4 layers of kapton for prevention of light leakage due to micro-meteoroid punctures
- Sunshield is divided into 4 quadrants that are deployed by 4 extendable booms
- Booms and sunshield are folded and stored in small compartment above S/C bus and below OTA at launch
- Exact deployment scenario under study

"Servicing Friendly" Spacecraft Bus

- S/C bus has modular design to permit easy replacements in I&T and for potential servicing. A modular science instrument and observatory avionics bus was incorporated in both the monolithic and segmented telescope designs.



Key Technologies Needed for 8-meter

Technology Development for:

- Optical Telescope Assembly
  - Advanced WF Sensing & Control
  - Fully Active Optics
  - Lightweight Mirror Materials
  - Lightweight Mirror Fabrication
  - Milli-arcsecond pointing control

- Gigapixel Detector Arrays
  - Photon-counting Detectors
  - High Efficiency Dichroics
  - High Efficiency UV coatings

- Systems Modeling & Verification
- Disturbance isolation systems
- Autonomous Rendezvous & Docking