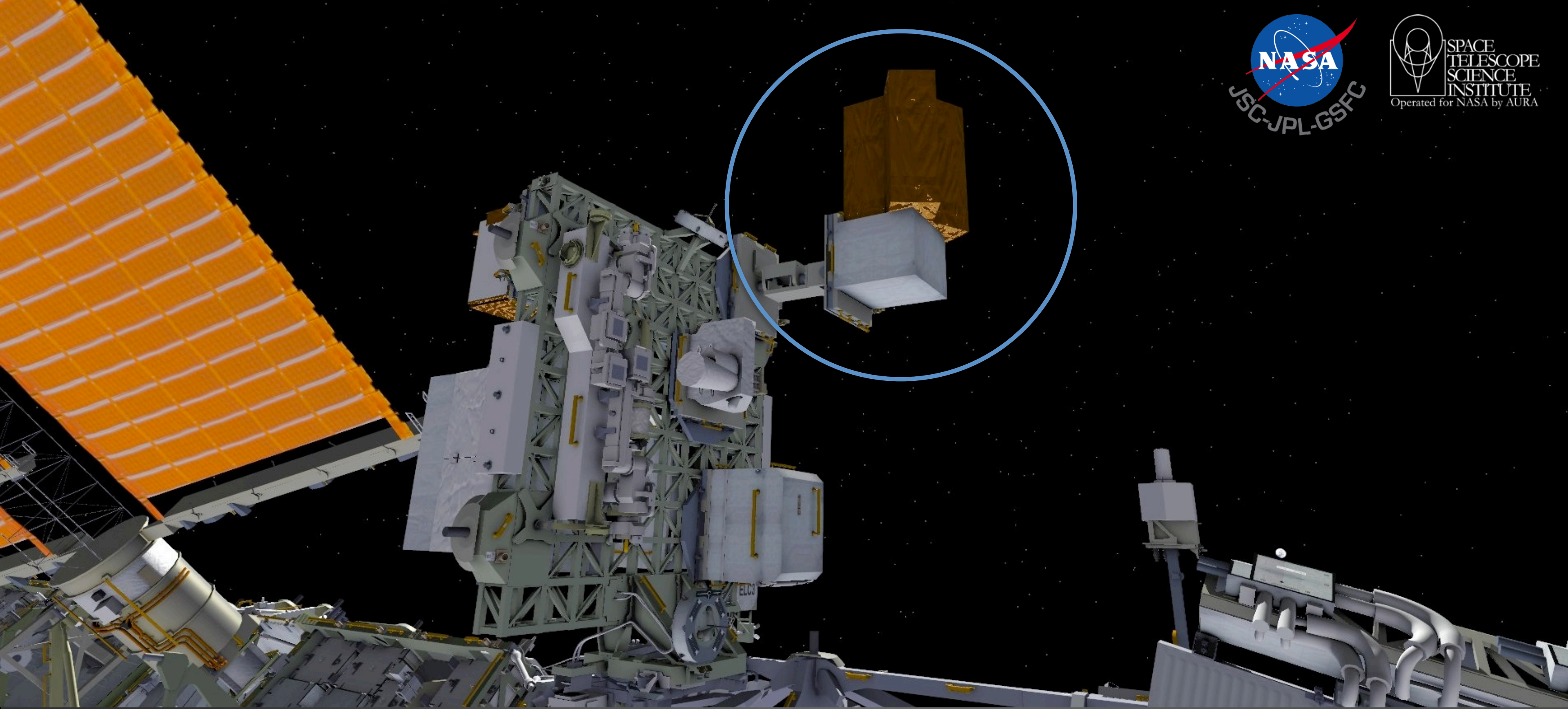


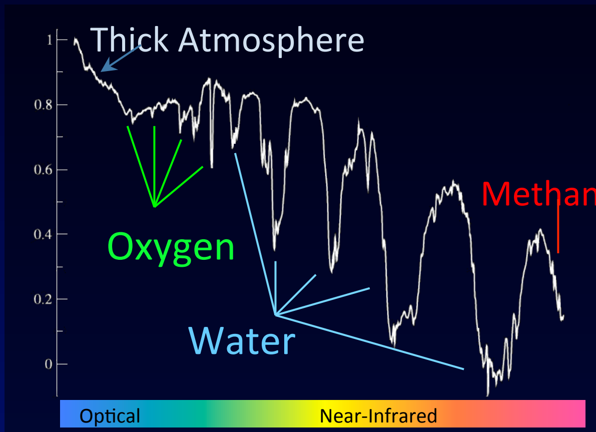
Technology demonstration for next-generation segmented large apertures

Renaud Goullioud (JPL), Mark Boyles (JPL), Fengchuan Liu (JPL), Marc Postman (STScI), Harley Thronson (NASA-GSFC), Kim Ess (JSC)

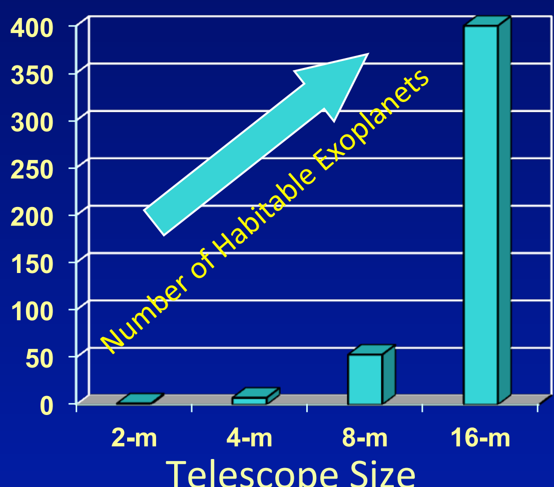
NASA Town Hall, May 6 2013

A Large Space Observatory is ***Required*** to Understand the Earliest Universe and to Detect Life on Exoplanets

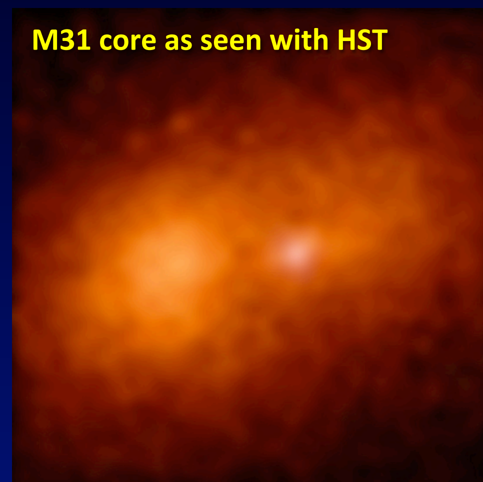
Is There Life Elsewhere in the Galaxy?

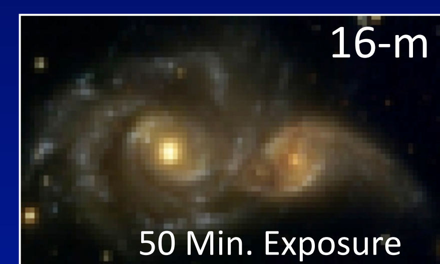


The signature of life is encoded in the spectrum of the Earth



What are the Fundamental Processes that Govern Early Galaxy Formation?





Distant Galaxy in UDF

Reveal >10x more detail than HST in <5% of the time: Discover astrophysical knowledge that would otherwise be infeasible from any other facility.

The Conventional Paradigm

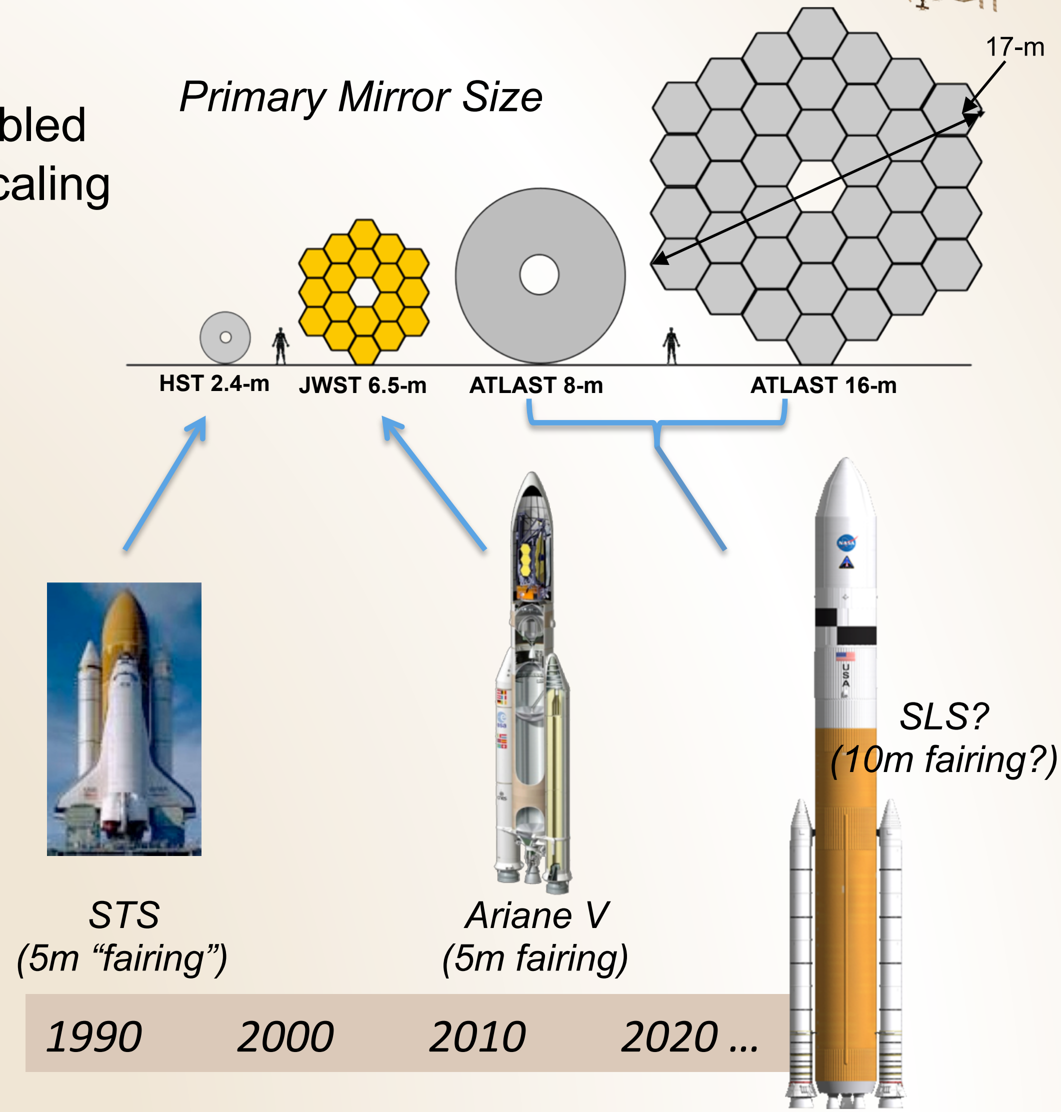
Future large space telescopes with conventional monolithic or pre-assembled segmented mirrors face substantial scaling challenges including:

- Testing in 1-g,
- Launch Vehicle throw weight & fairing size,
- Complex precision deployments on-orbit,
- Long term performance,
- Not forgiving of anomalies.

The conventional paradigm relies on future heavy L/V, large fairings and complex geometry.

Increasing aperture drives cost and complexity geometrically.

We believe there is a better way!



The New Paradigm

- Build a modularized, actively controlled, segmented *scaleable* telescope by robotically assembling components in space and autonomously phasing it up to diffraction-limited performance:
  - Modules launched separately to ISS and robotically assembled,
  - Uses lightweight, low-cost, deformable mirror segments,
  - Uses active wavefront sensing and control and laser metrology,
  - Assembled to mechanical tolerances (~sub-mm precision) and aligned, figured and controlled to optical tolerances (~nm level),
  - Will be an on-orbit testbed for future NASA telescope and science instrument development and a centerpiece for outreach.

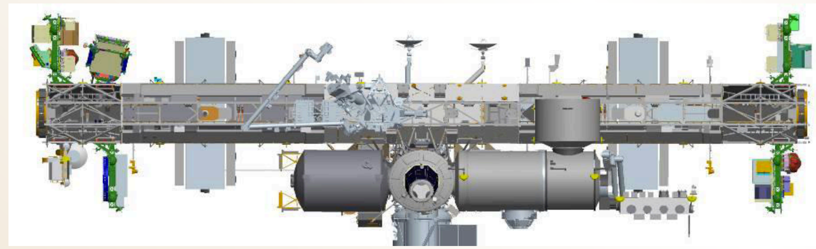
These 3 capabilities are already developed & demonstrated to TRL 4-6 through ongoing non-NASA funded technology development at JPL.

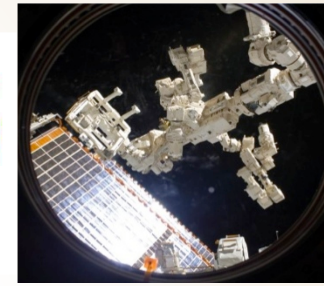
- Aperture size is no longer limited by manufacturing, ground testing, launch and deployment constraints.
- Intrinsically tolerant to imperfections anywhere in the optical chain arising during manufacturing, launch, assembly or operation.
- Eliminates need for large system-level ground I&T facilities.
- Causes a significant shift in the space telescope cost curve similar to what has already been realized on the ground.
- Enables new possibilities for affordable space telescopes.

What Enables This Concept?

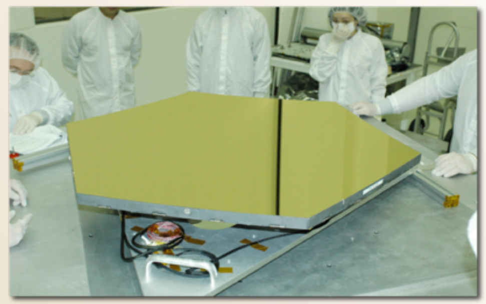
Well Established ISS Interfaces and Robotics

- A completed International Space Station and it's supporting infrastructure – (NASA and International investment)

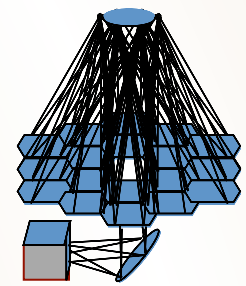




Actuated Hybrid Mirror Technology



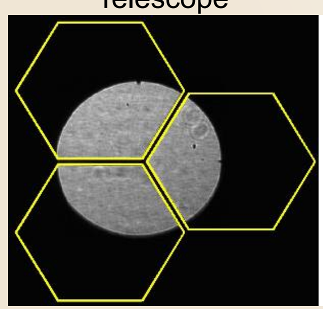
Compact Laser Metrology



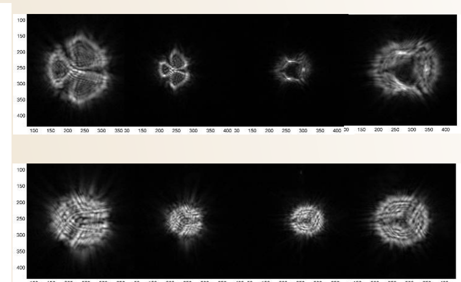
- Nanolaminate Active Mirrors and Laser Metrology – (DOD investment)

- Multi-segment telescope wave front detection and correction capability – (NASA and DOD investment)

JWST Wavefront Control Testbed with Segmented Telescope



Wavefront Sensing Camera Measurements



Wavefront

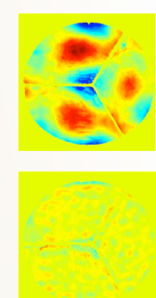
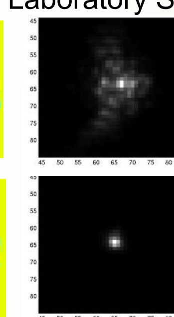


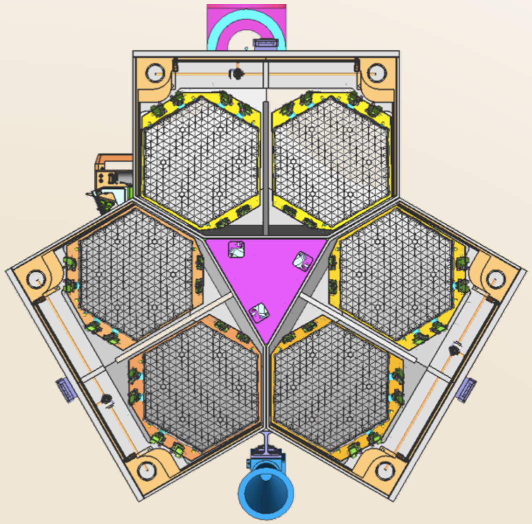
Image of Laboratory Star



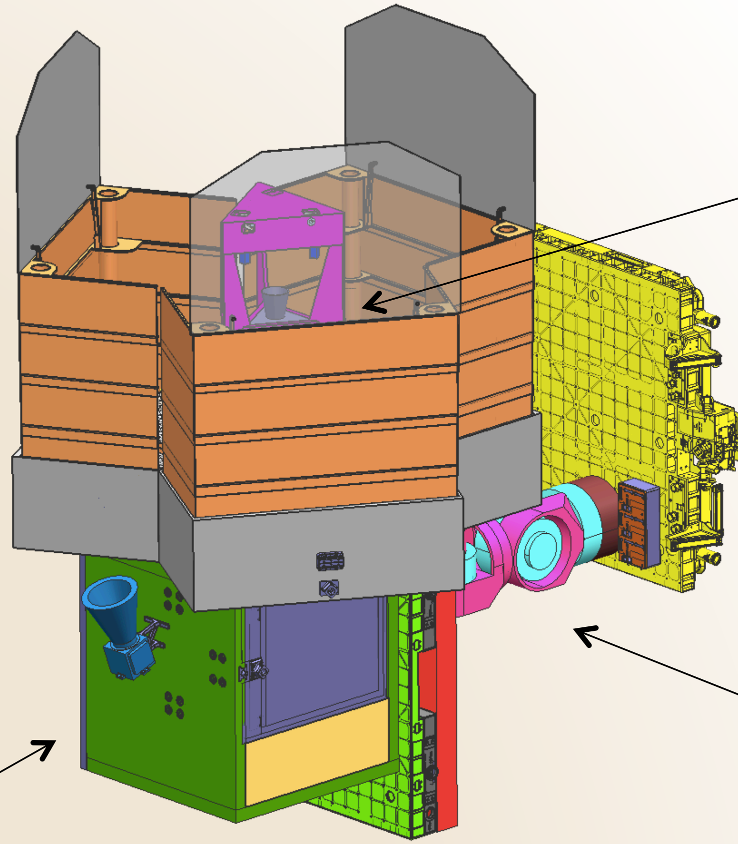
What, Why, and When?

- **What?**
  - An ISS-based testbed to demonstrate that a large optical system can be robotically assembled in space from separate elements launched using existing modest-sized launch vehicles and autonomously phased-up via active optics to produce diffraction-limited images (intrinsically tolerant to ground-based figure errors).
- **Why?**
  - To demonstrate that the mission cost curve and risk can be lowered substantially by use of innovative new technologies, so that future large space telescopes can be enabled ~10 years sooner than otherwise possible.
    - A powerful ISS asset for testing advanced optical systems. After the initial technology demonstration, SALMON-type RFPs are possible for further new technology/science investigations.
    - A potential opportunity to obtain limited but unique science from ISS.
    - An inspiring and broad Education/Public Outreach opportunity.
- **When?**
  - Initial concept study conducted by JPL, JSC, GSFC, STScI in 2012; could be launched by 2017.

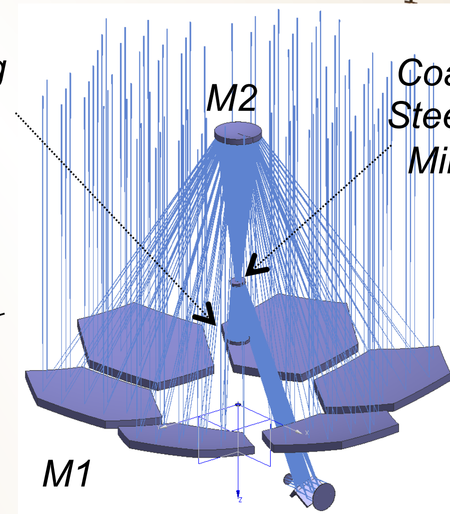
System Configuration



1.45m aperture.
Six
510mm point to point
light-weighted
segments



Fine
Steering
Tertiary



Three-Mirror Anastigmat Telescope

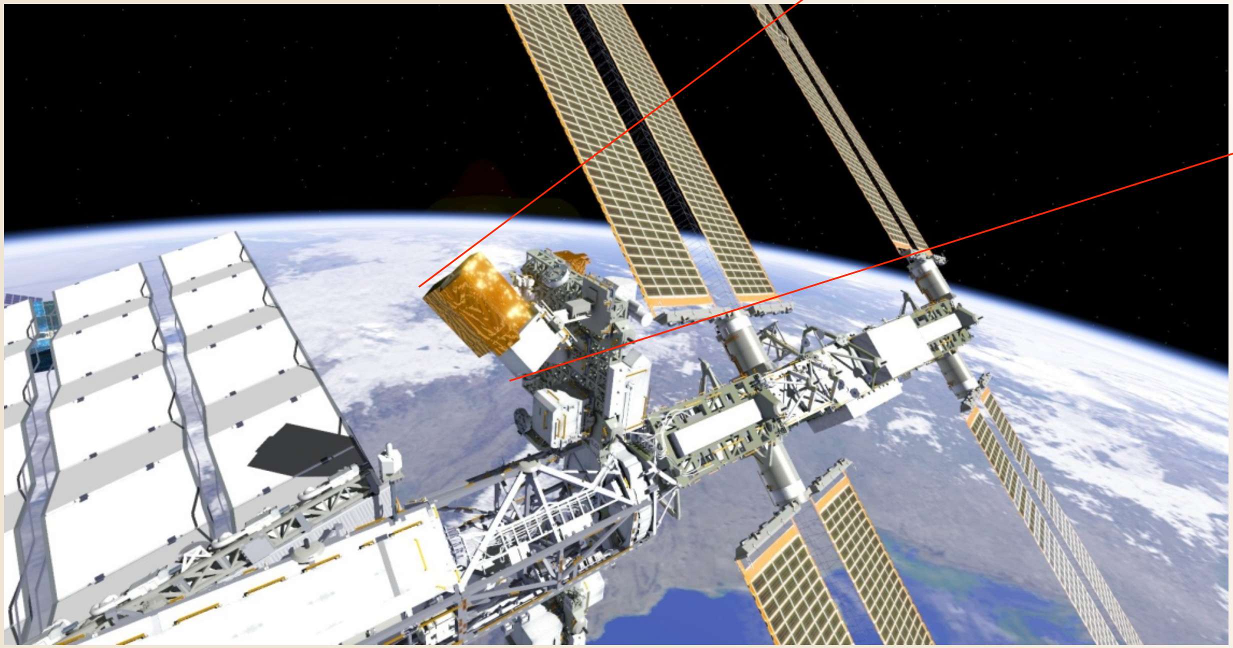
3-axis gimbal, attached to the Instrument Module on orbit; FRAM I/F on each end

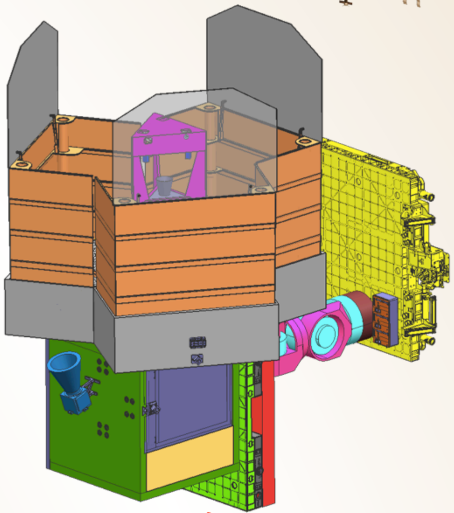
Telescope Core Module

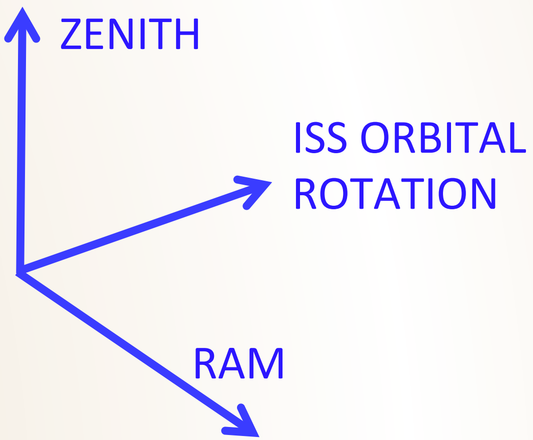
- Imaging camera
- Wavefront Sensing Unit
- Electronics, power, command & telemetry

Install Location on ISS

- Concept study identified the Express Logistics Carrier (ELC3), Zenith-looking as the best location.
- Other locations are possible as well.

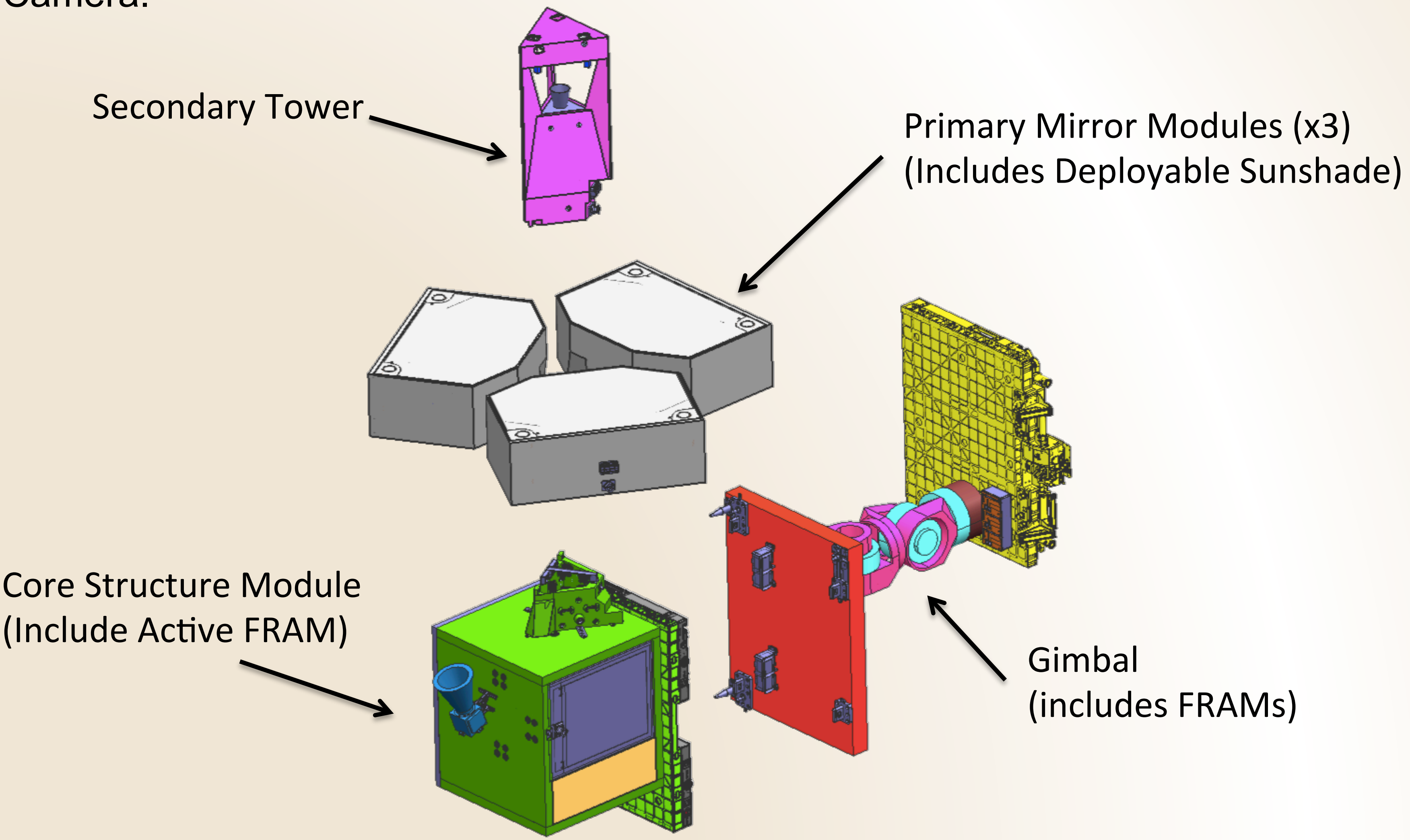




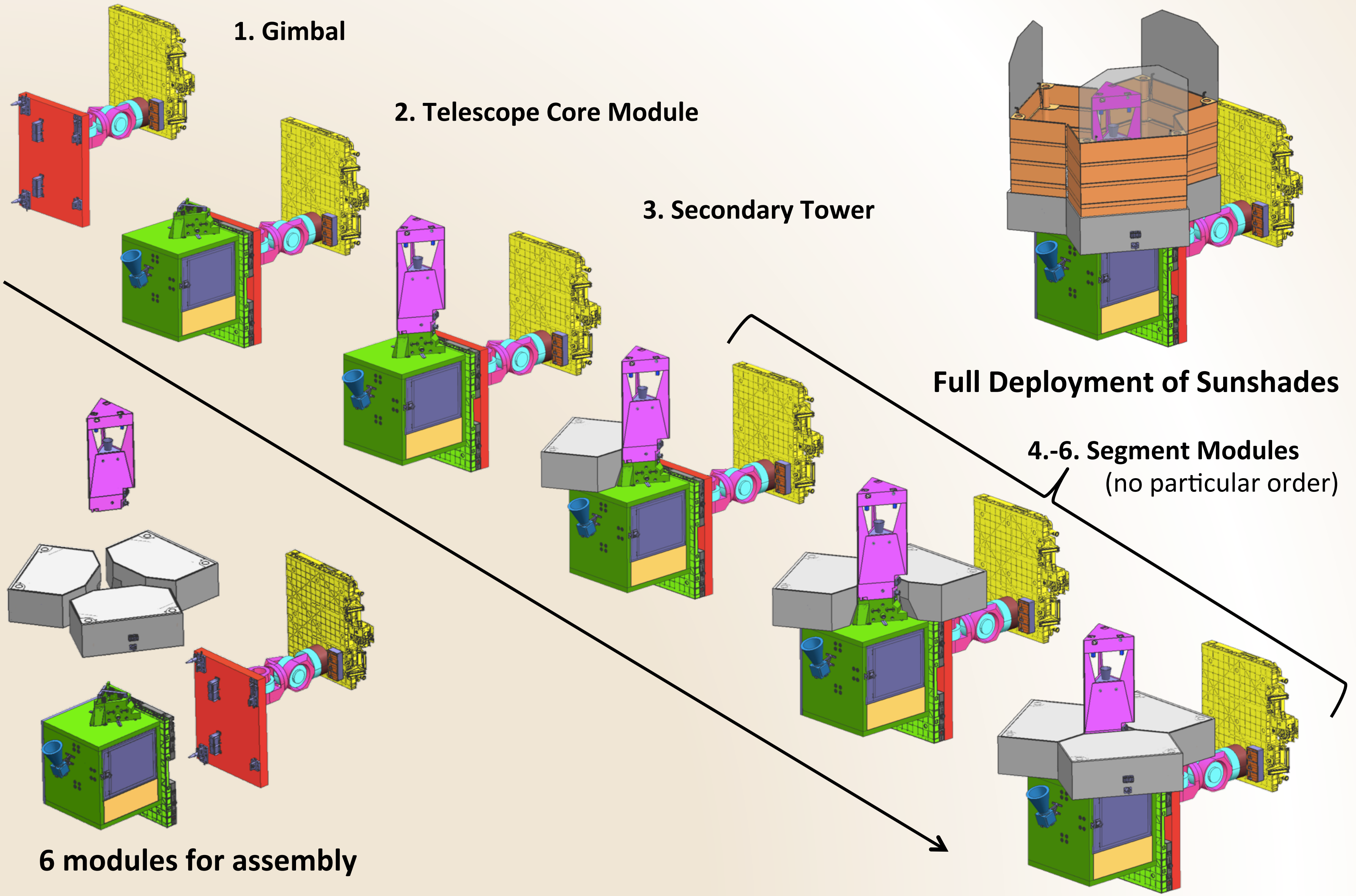


Launch Configuration

- Orbital upgradable items: Primary Mirror Segment pairs, Gimbal, Imaging Camera.



Assembly Order

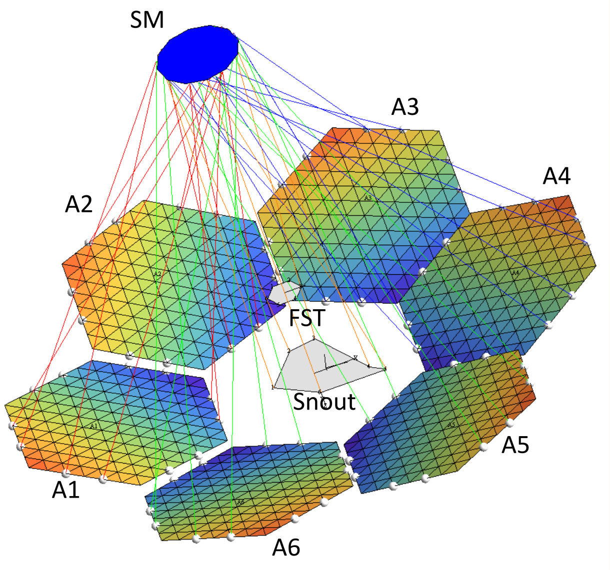


Wavefront Sensing and Control

- **Wavefront Sensing Camera:**
  - Shack-Hartmann Sensing for initial segment alignment.
  - Dispersed Fringe Sensing for segment co-phasing.
  - Phase-Retrieval Sensing for fine wavefront adjustment.
  - Performs 80% Strehl ratio demonstration.

Wavefront Sensing	Control Objective
Rigid-Body Actuator Encoders	Capture Segment Alignments
Shack-Hartmann Sensing	Segment Tilt and Figure
Dispersed Fringe Sensing	Segment Piston
Phase Retrieval	Total System Correction
Laser Metrology	Maintain Alignment

- **Fine Guidance Camera:**
  - Fast camera for Fast Steering Mirror control.
- **Relative metrology:**
  - Monitor changes in the primary mirror segment and secondary mirror motion.
- **Imaging Camera:**
  - Serviceable camera with science grade large format detector.

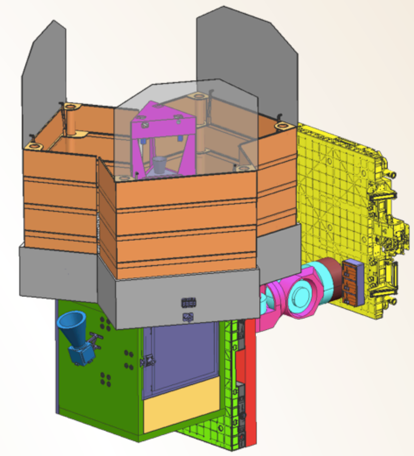


Key Technologies Needed for the Next Generation of UVOIR Space Telescopes

Technology	Needed for 8m (and larger) Space Telescopes	Technology Demonstration
Lightweight mirrors suitable for UV-optical use	Yes	Yes
Segmented primary mirror, diffraction limited in visible	Yes	Yes
Active wavefront control	Yes	Yes
1-mas pointing system	Yes	No
Disturbance isolation system	Yes	Yes
Robotic assembly	Yes (especially for systems with apertures >10m)	Yes
Servicing capability	Yes	Yes
High performance starlight suppression system for exoplanet observations	Yes	No
Giga-pixel imager	Yes	Partially

A Timely Investment

- **This type of technology demonstration could demonstrate an *affordable* approach to the launch and deployment of large space telescopes by:**
  - Integrating substantial NASA & DOD technology investments,
  - Leveraging existing ISS facilities and robotics,
  - Bringing together, for the first time, fully active telescope technologies and in-space assembly & upgrade capabilities.



- **Operating on the ISS in this decade could:**
  - Demonstrate a scalable path toward very large, high-performance, lower-cost space telescopes in time for them to be considered for the 2020 NRC Decadal Survey.
  - Advance the timescale for many ambitious space science missions by at least 10 years through major reductions in cost & risk.
  - Demonstrate technologies identified in NRC's ASTRO2010.
  - Be a centerpiece of an HEOMD/SMD/STMD collaboration providing high value, visibility and engagement with a large audience.