The Current State of Assembly and Servicing of Space Observatories

John Mace Grunsfeld
NASA Goddard Space Flight Center

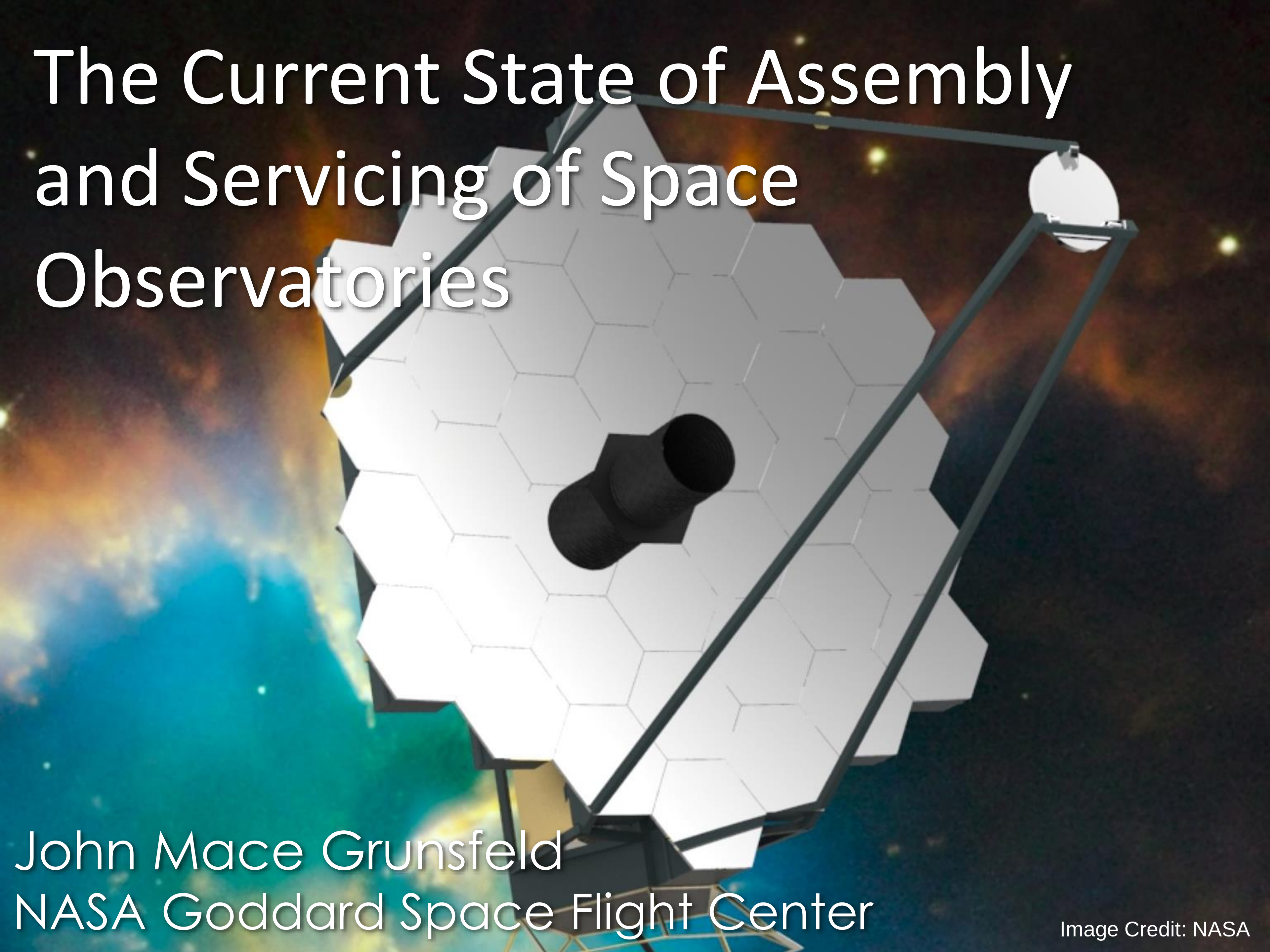
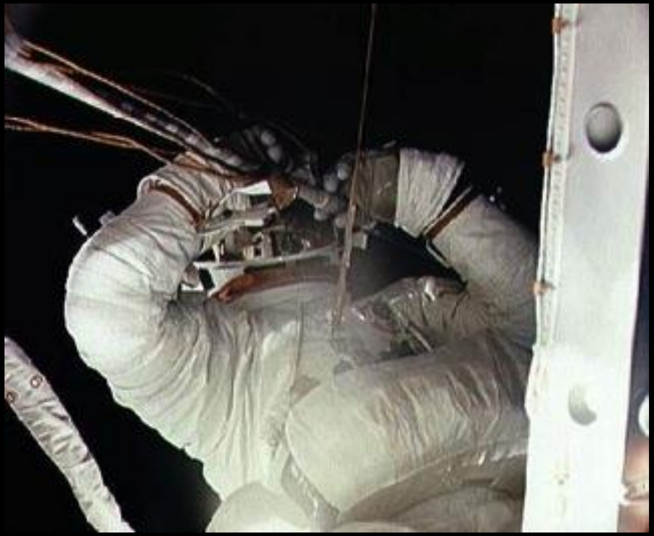


Image Credit: NASA

40+ Years of On-Orbit Servicing

1973

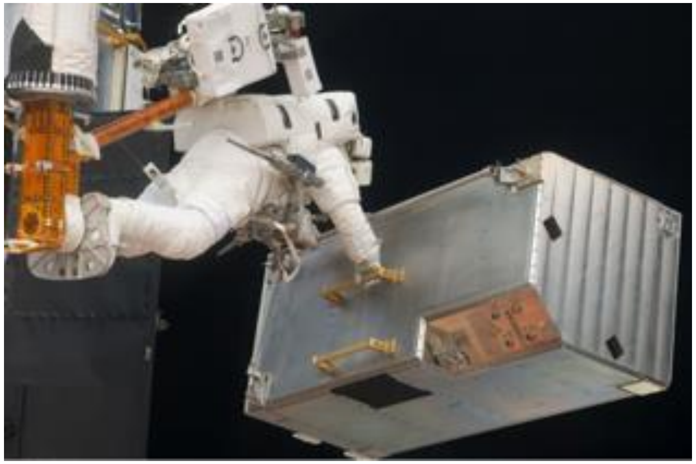


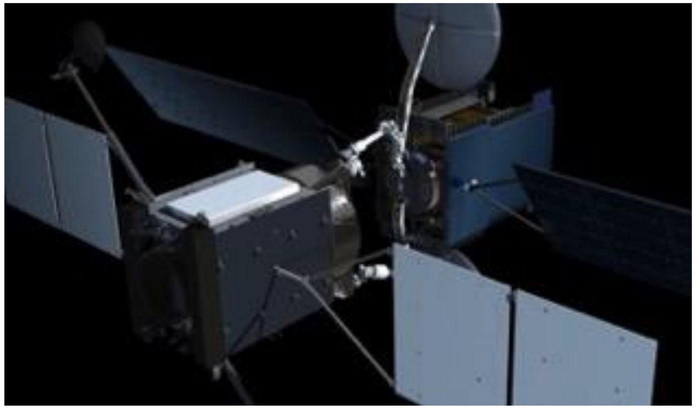
2018

Satellite Servicing Capabilities

Servicing provides capabilities for resilient architectures.

- Remote Inspection
- Relocate
- Refuel
- Replenish
- Repair
- Replace
- Assemble



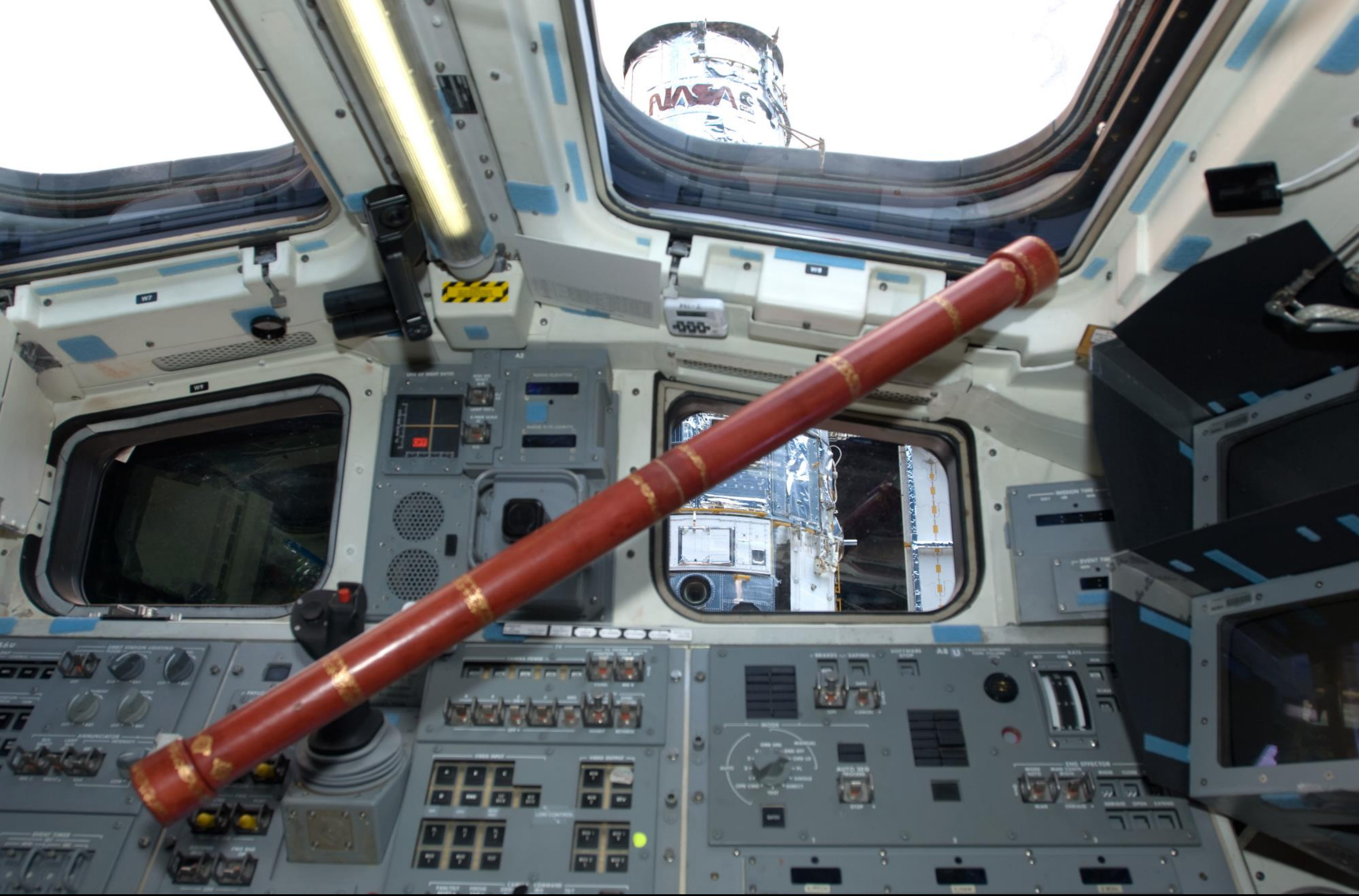


Big Scientific Questions:

Where did we come from?

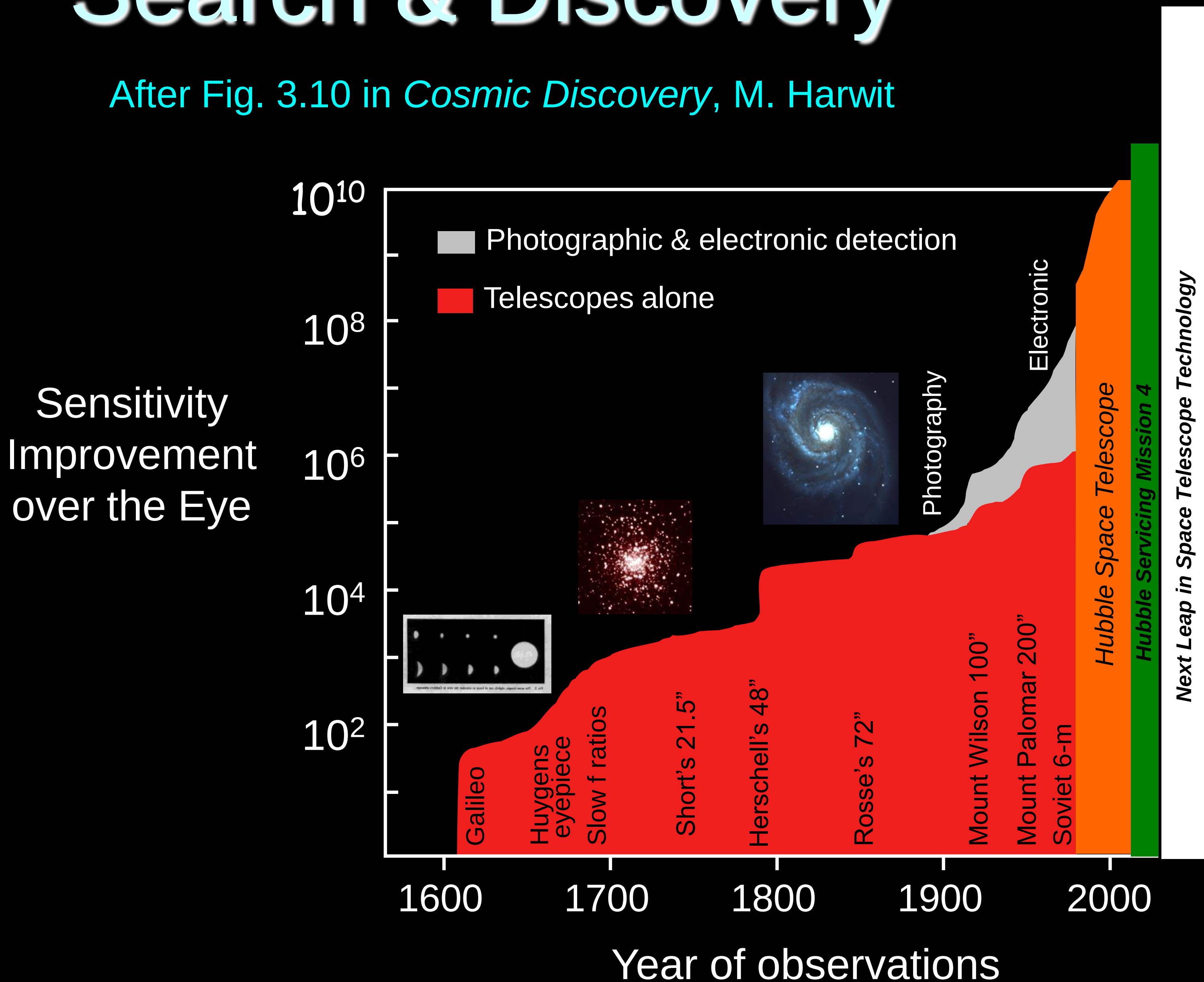
Where are we going?

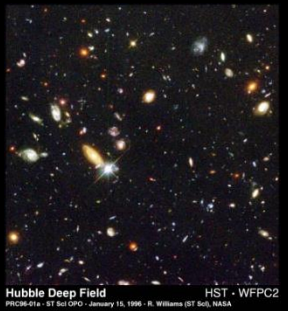
Are we alone?


NASA

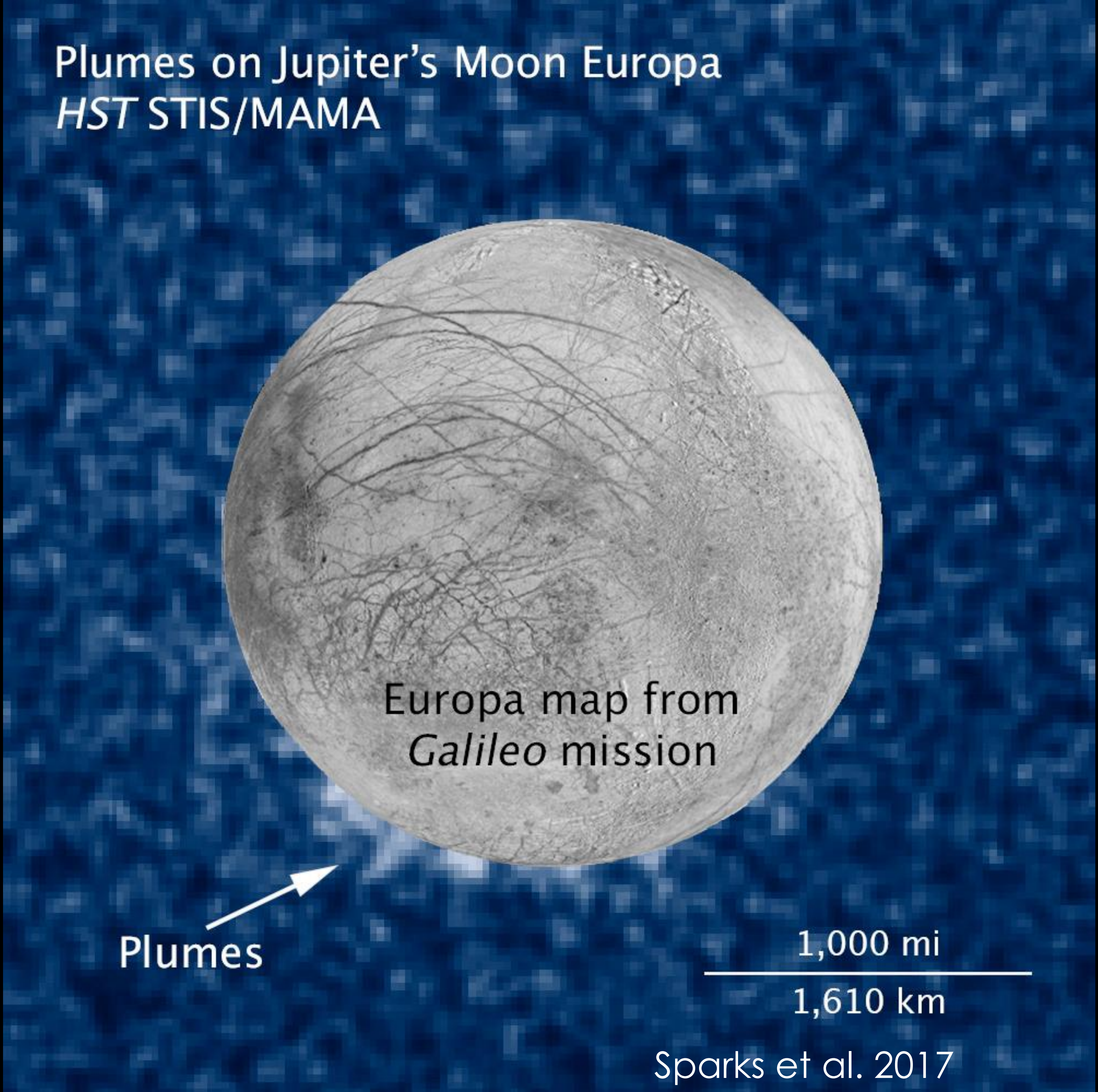
Search & Discovery

After Fig. 3.10 in *Cosmic Discovery*, M. Harwit

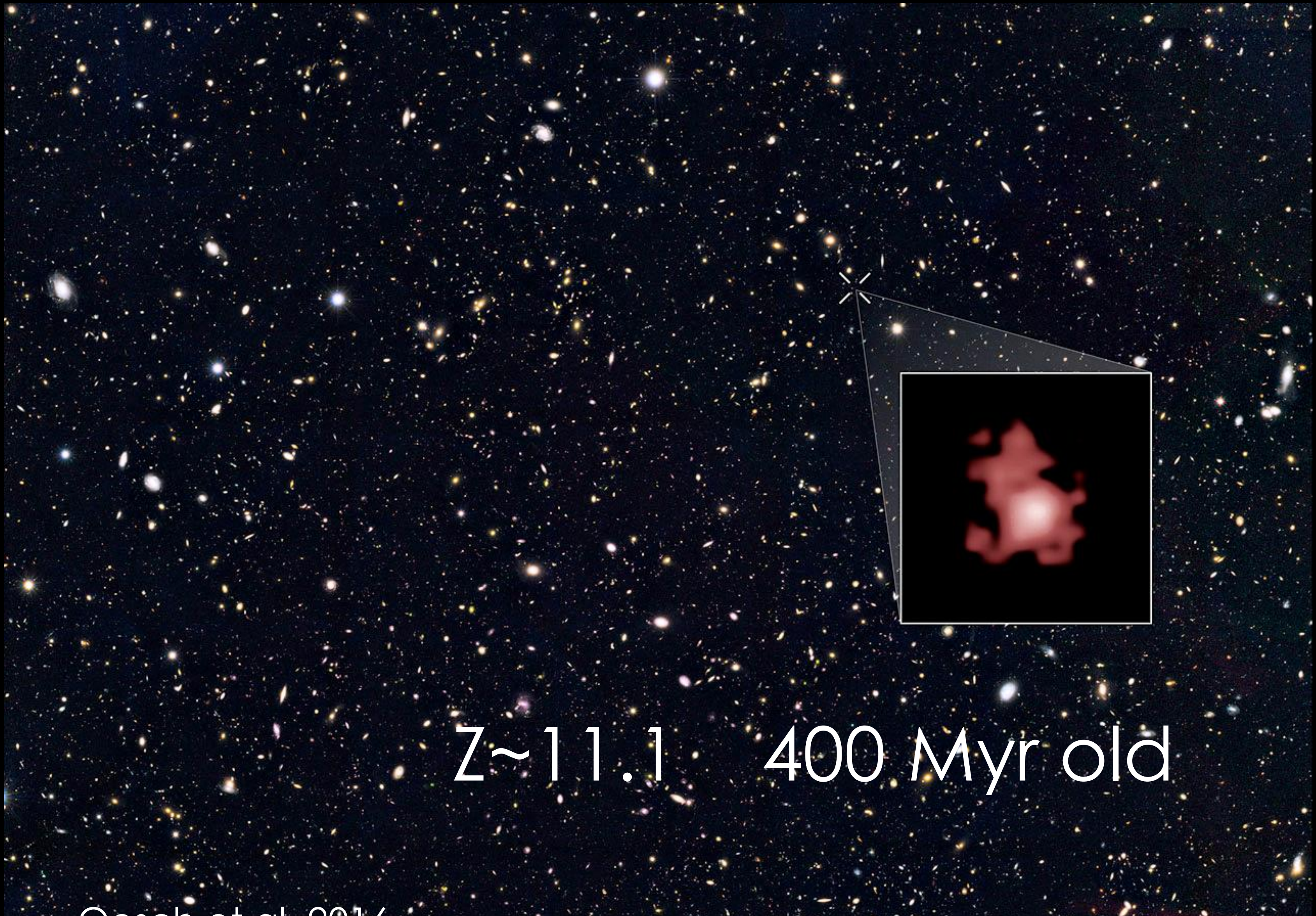




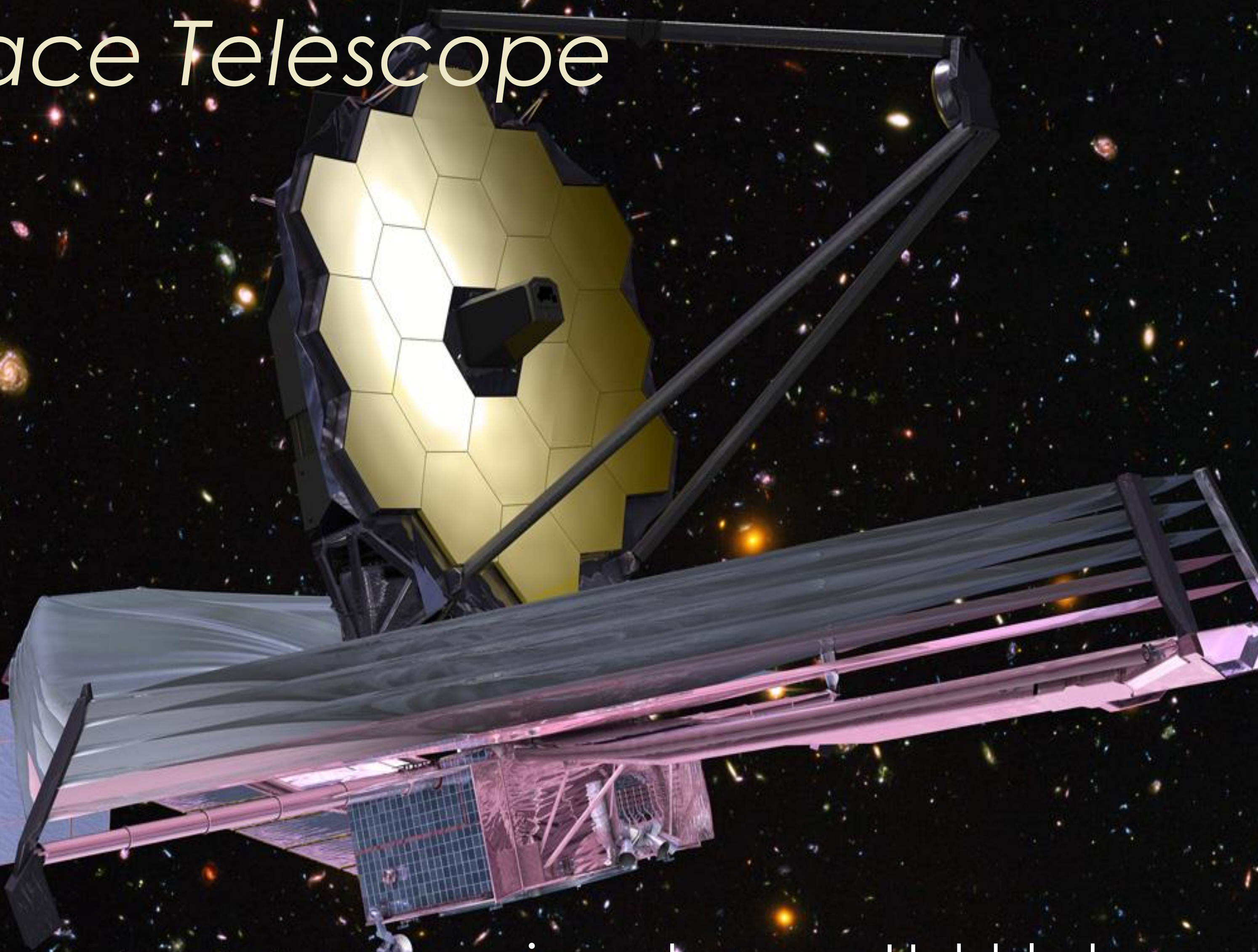
Wonder and Awe…


Plumes on Jupiter's Moon Europa
HST STIS/MAMA
Europa map from
Galileo mission
Plumes
1,000 mi
1,610 km
Sparks et al. 2017

Hubble breaks cosmic distance record



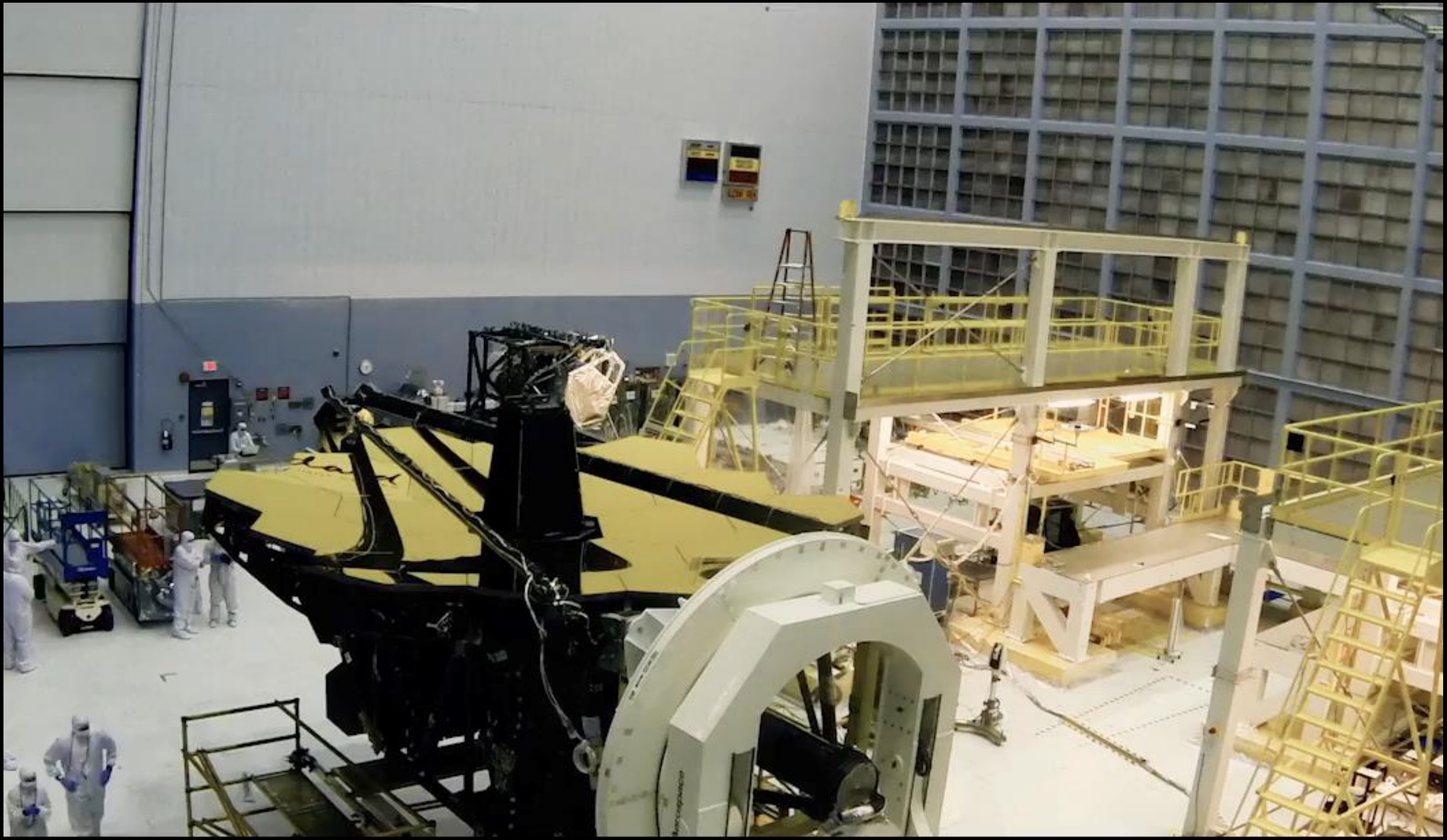
James Webb Space Telescope



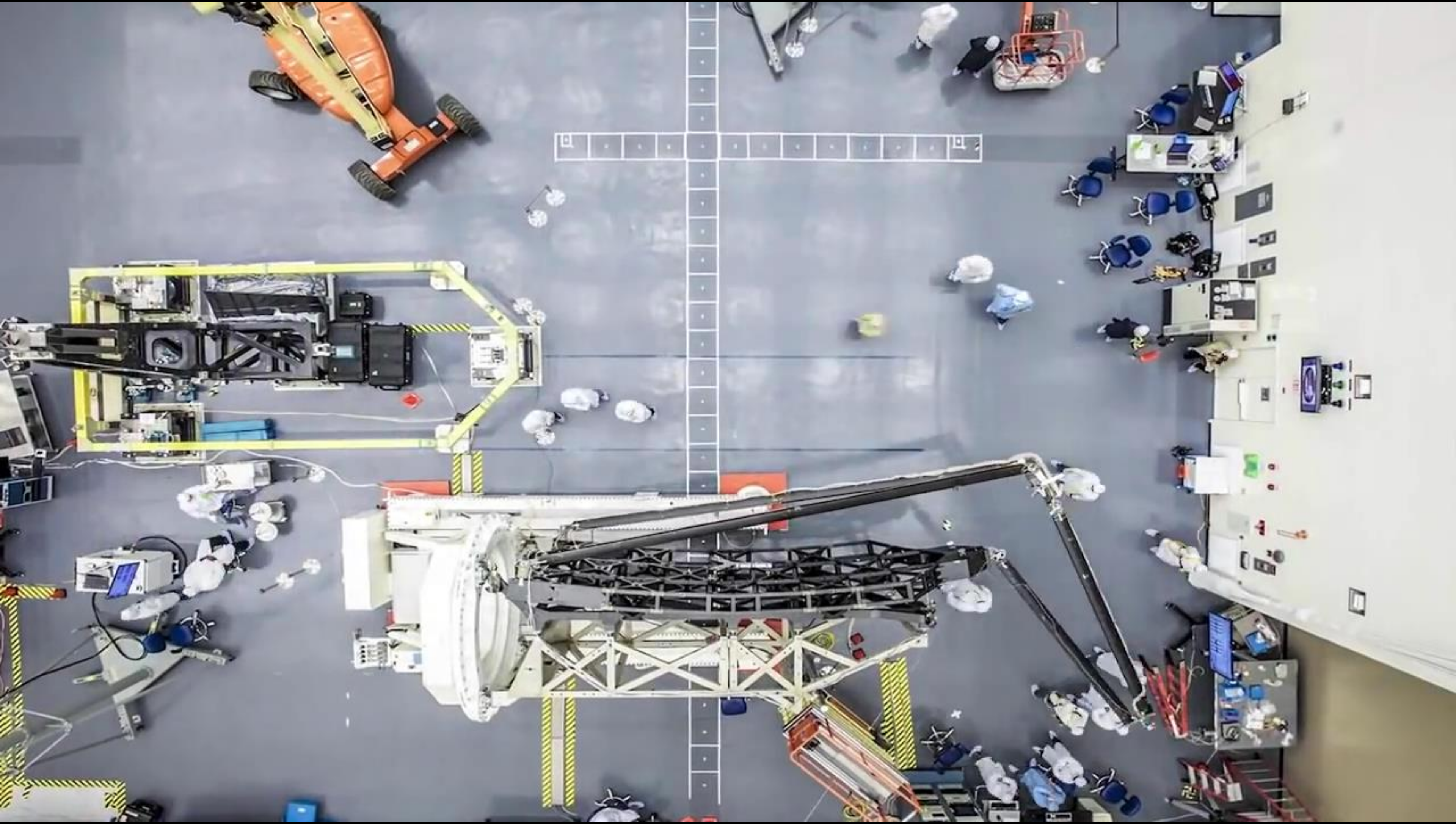
…going where no Hubble has gone before

NASA's James Webb Space Telescope at Goddard Space Flight Center

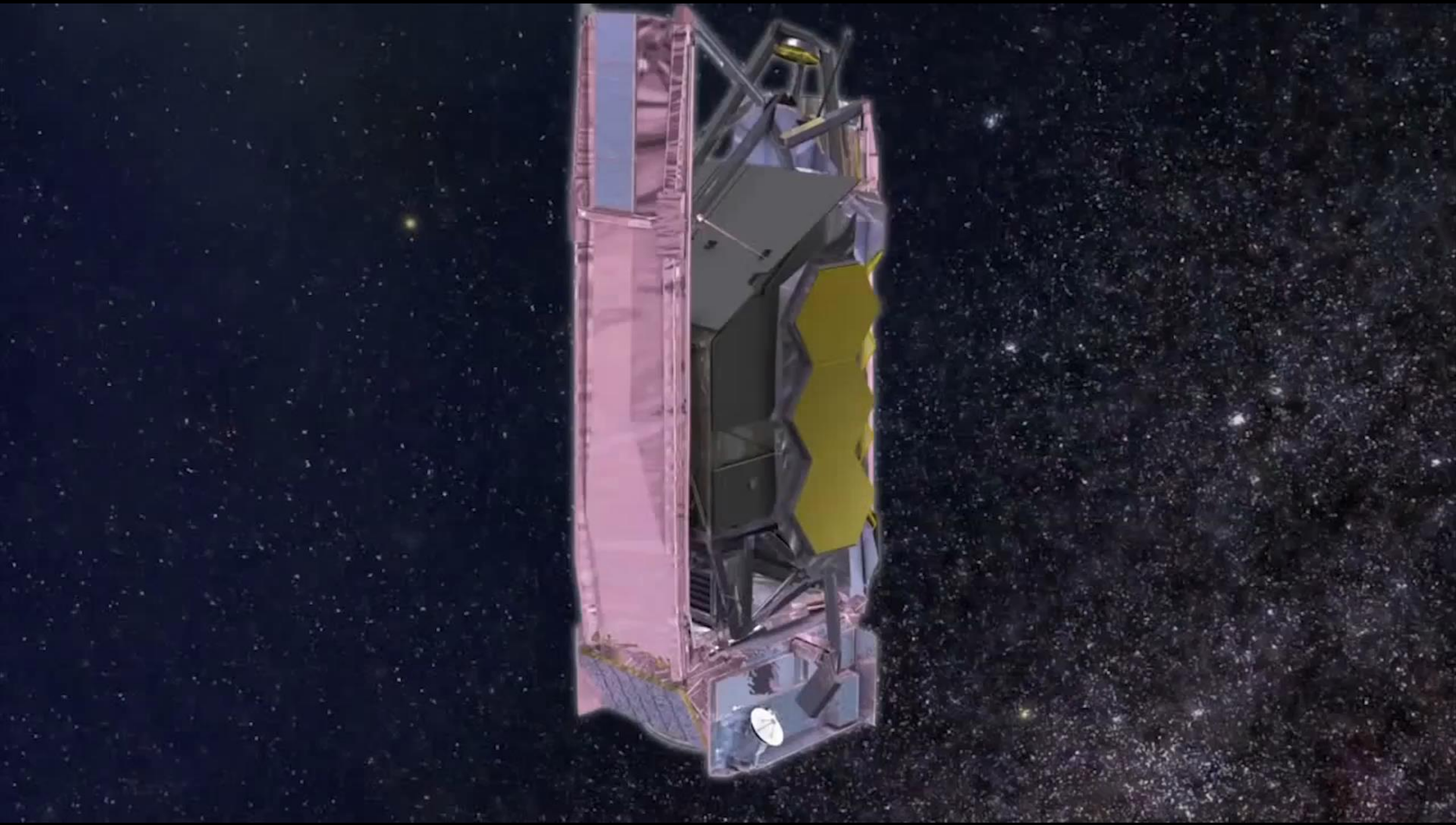
NORTHROP GRUMMAN



Video Credit: NASA/GSFC

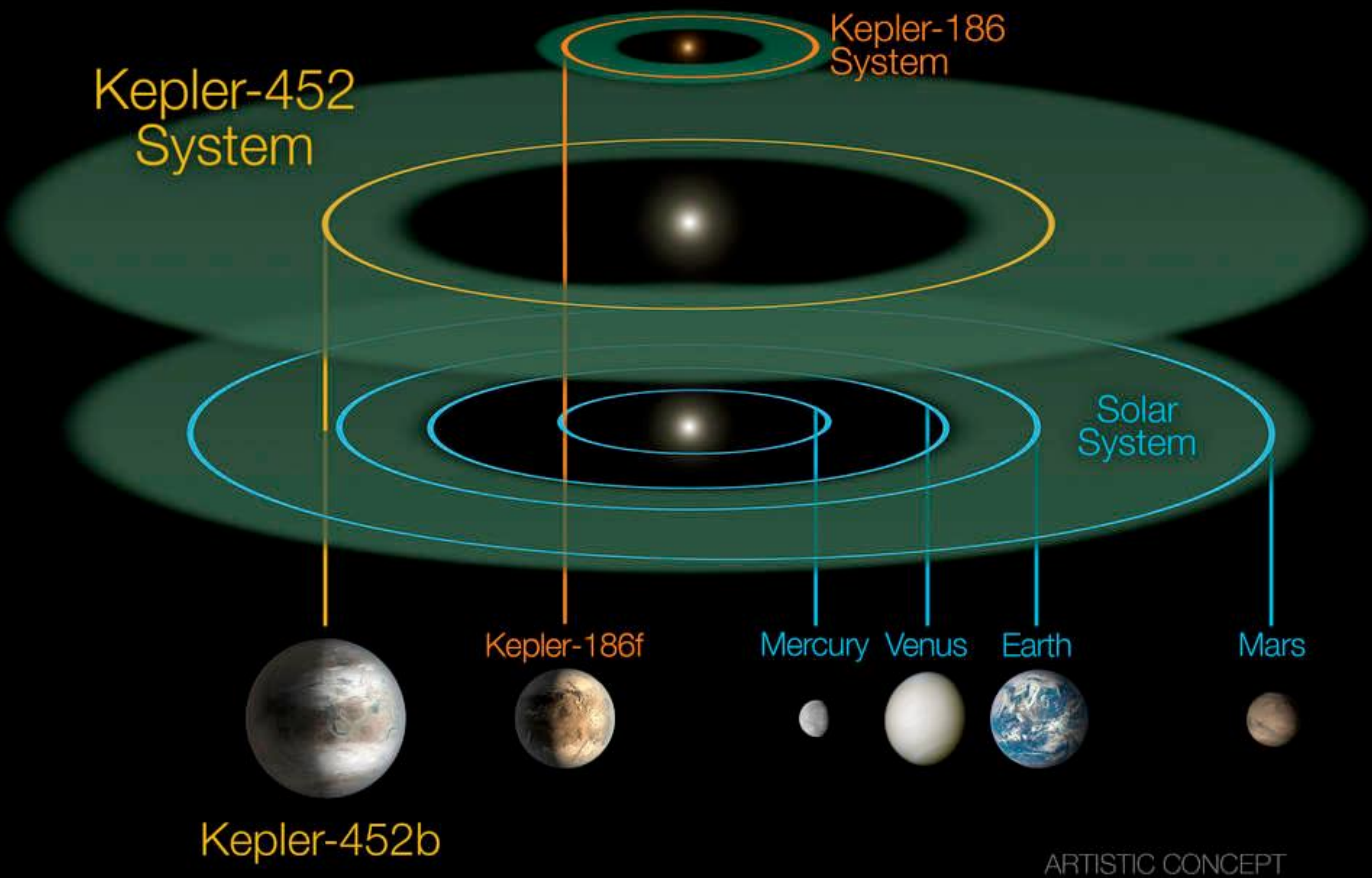


James Webb Space Telescope Deployment



James Webb Space Telescope Servicing

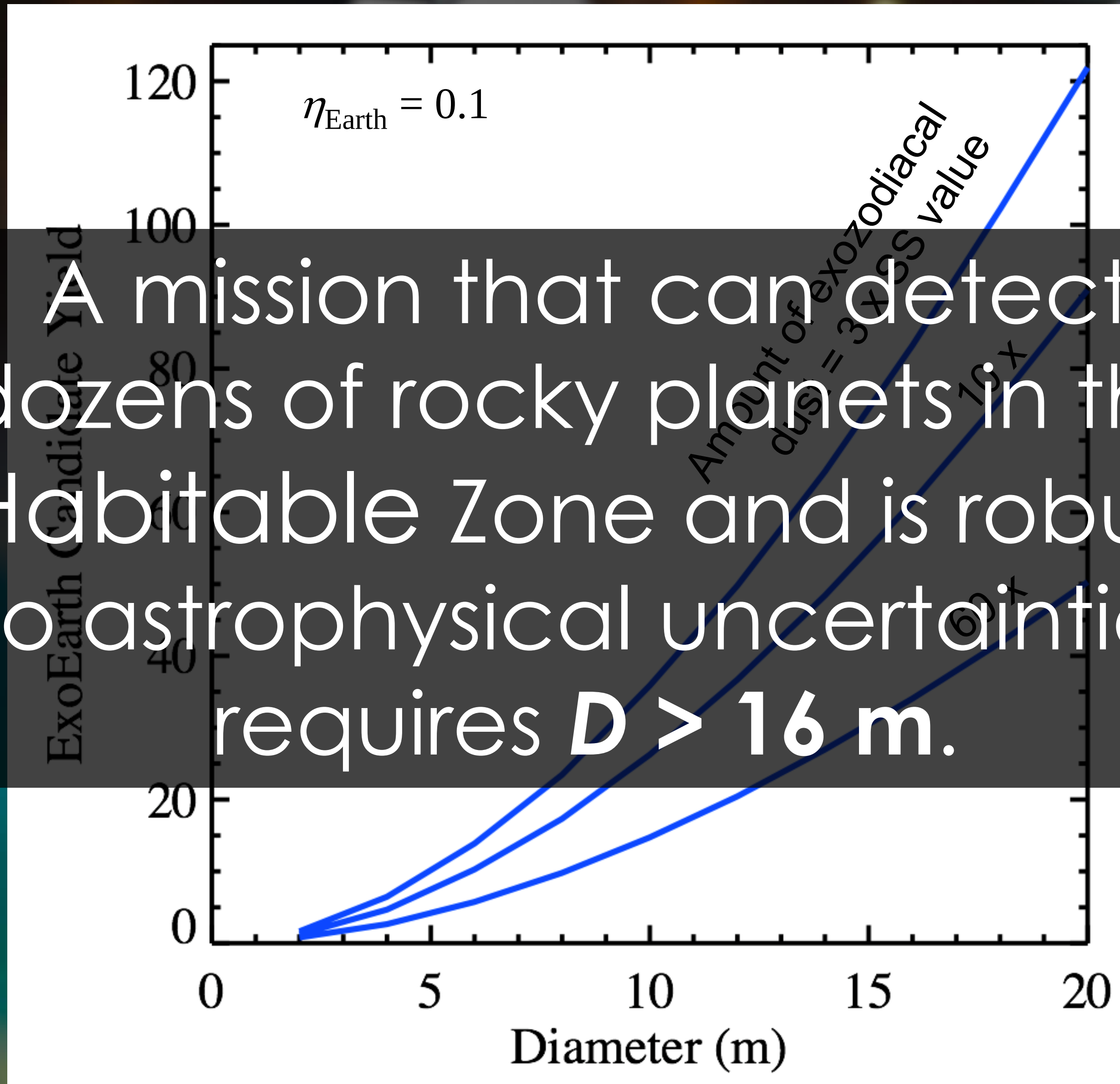
imagine the moment...


Kepler-186
System
Kepler-452
System
Solar
System
Kepler-186f
Mercury
Venus
Earth
Mars
Kepler-452b
ARTISTIC CONCEPT

An Earth 2.0 will be incredibly faint…

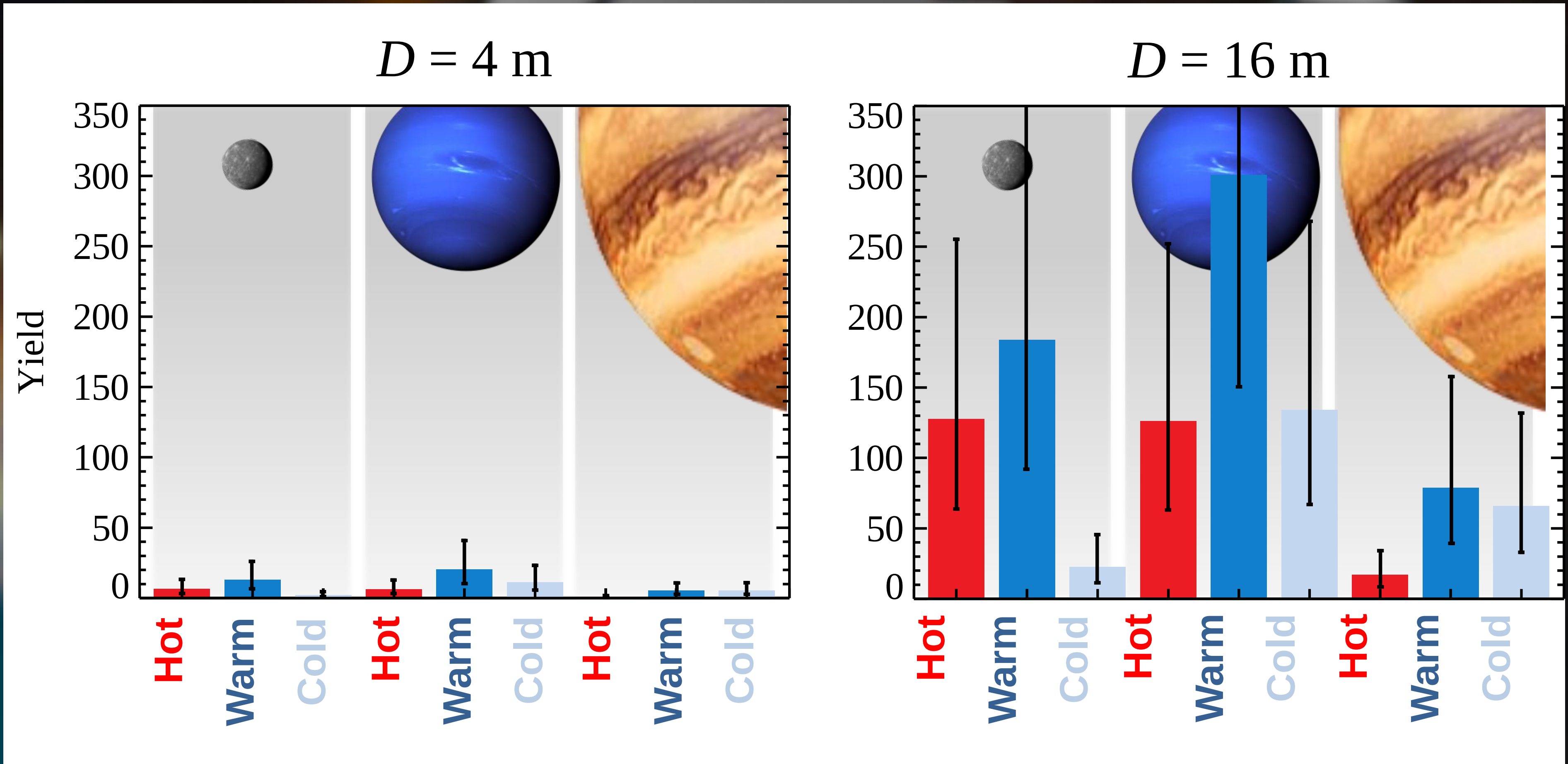
Dimmer than the faintest galaxy in the Hubble Deep Field

A Useful Sample of ExoEarth Candidates Requires a Large Aperture



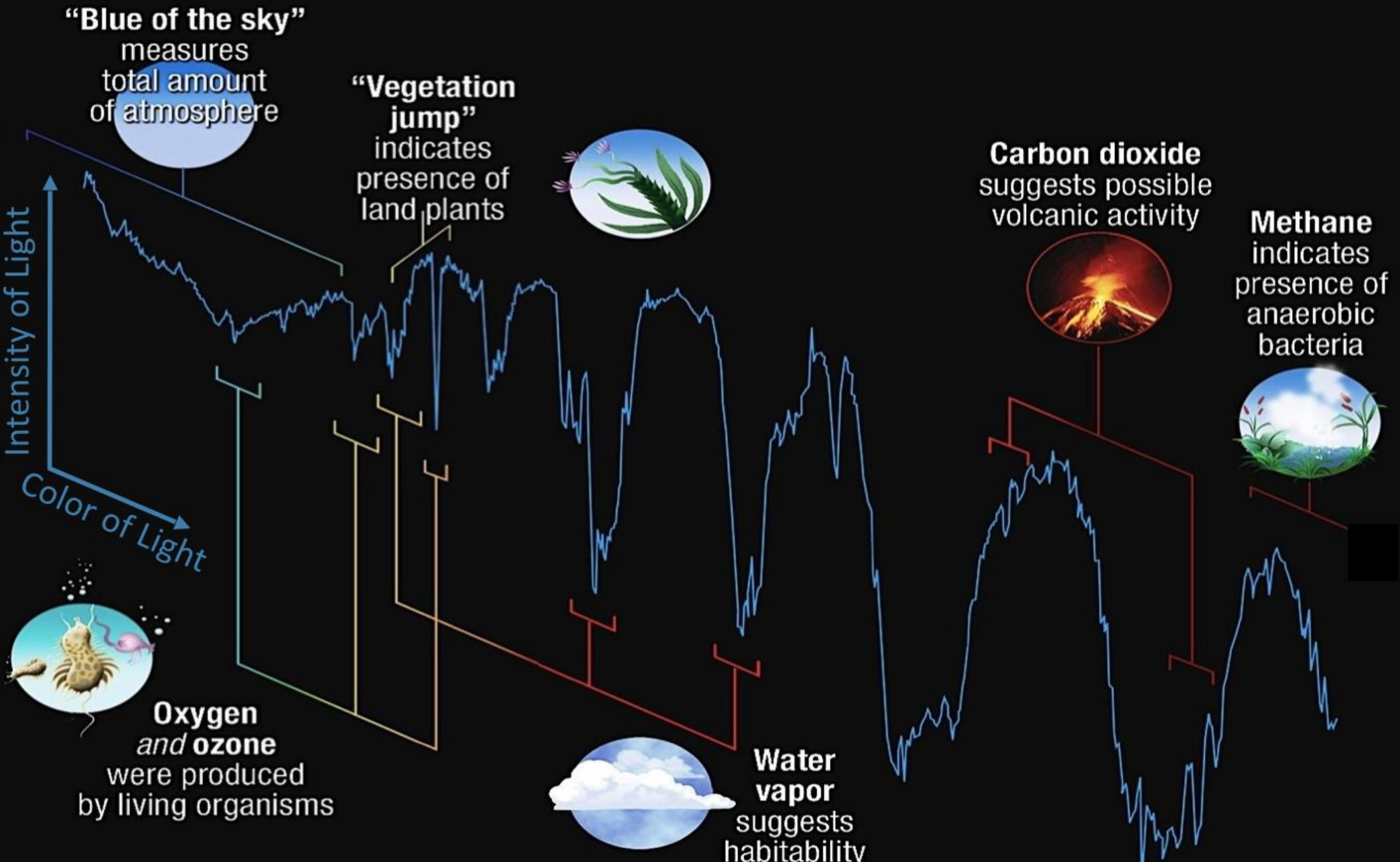
A mission that can detect dozens of rocky planets in the Habitable Zone and is robust to astrophysical uncertainties requires ***D* > 16 m**.

Comparative Planetology With Hundreds of Diverse Planets

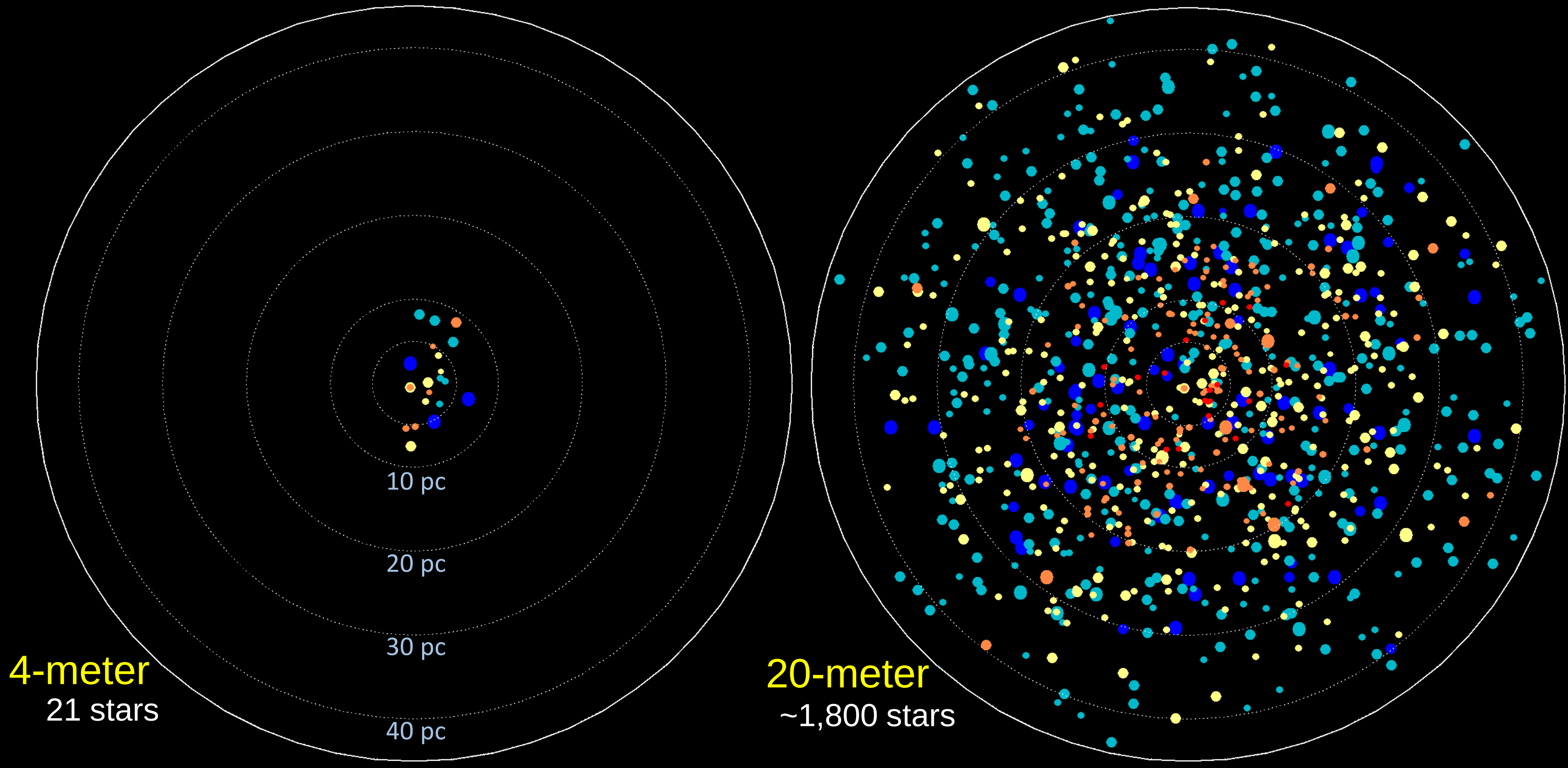


C. Stark, Using SAG13 Occurrence Rates

The Search for Life Hinges on the Detectability of Biosignatures



In how many long-lived star systems could we get exoplanet spectra?
It depends on how big a space telescope we have.

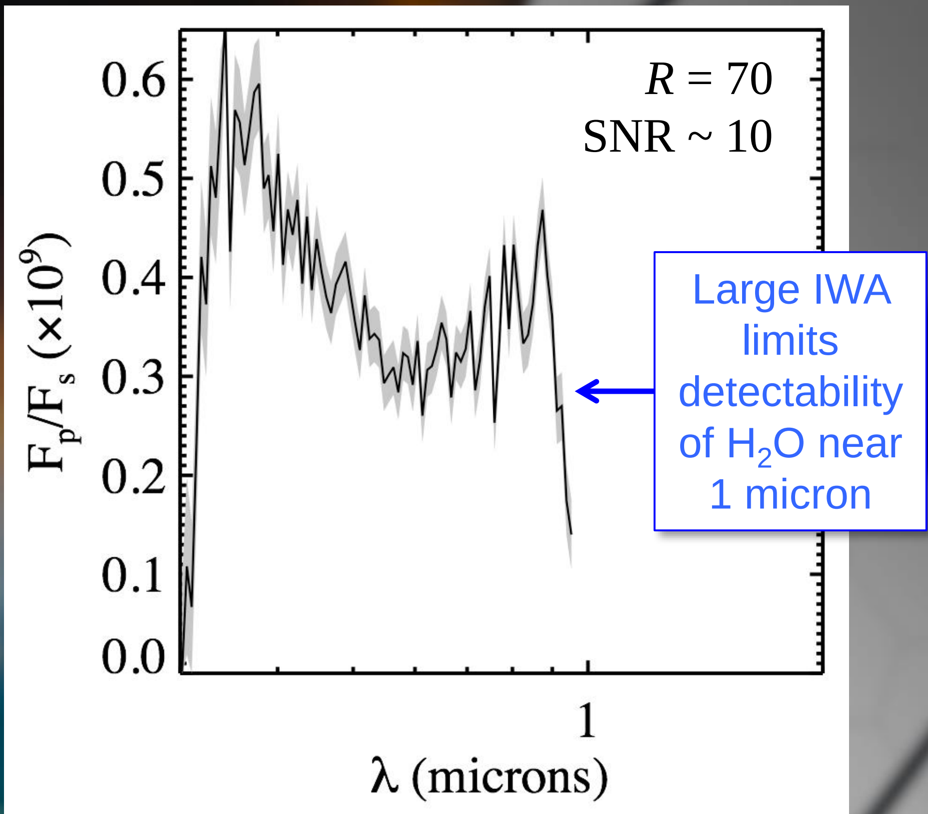


Actual map of stars within 45 parsecs of the Sun

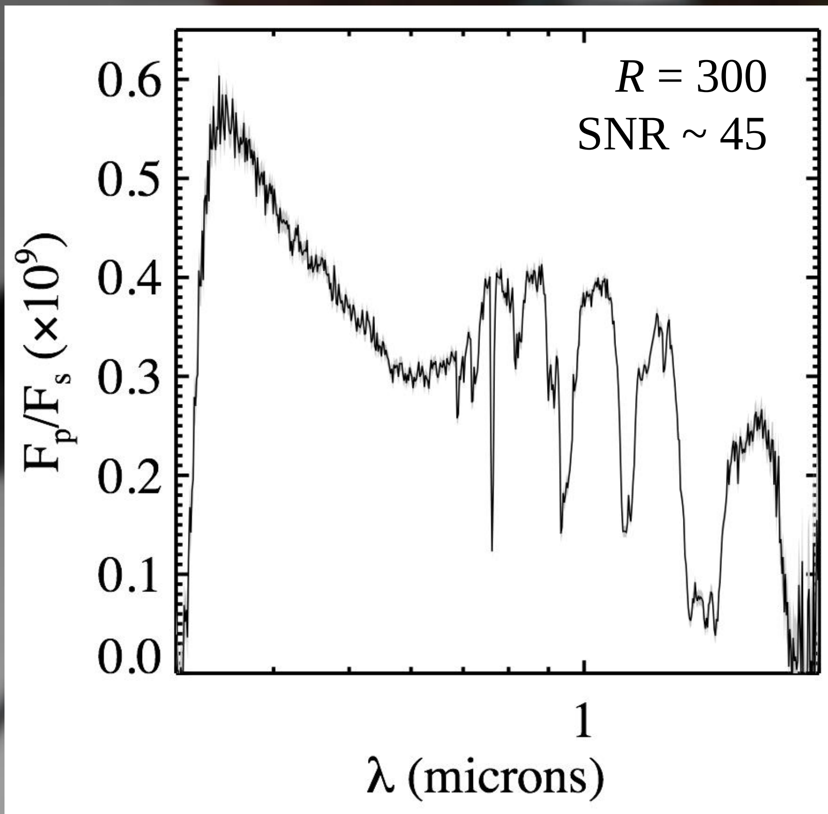
Extraordinary Claims Require Extraordinary Apertures

200 hr observations of Earth @ 10 pc

D = 4 m



D = 16 m



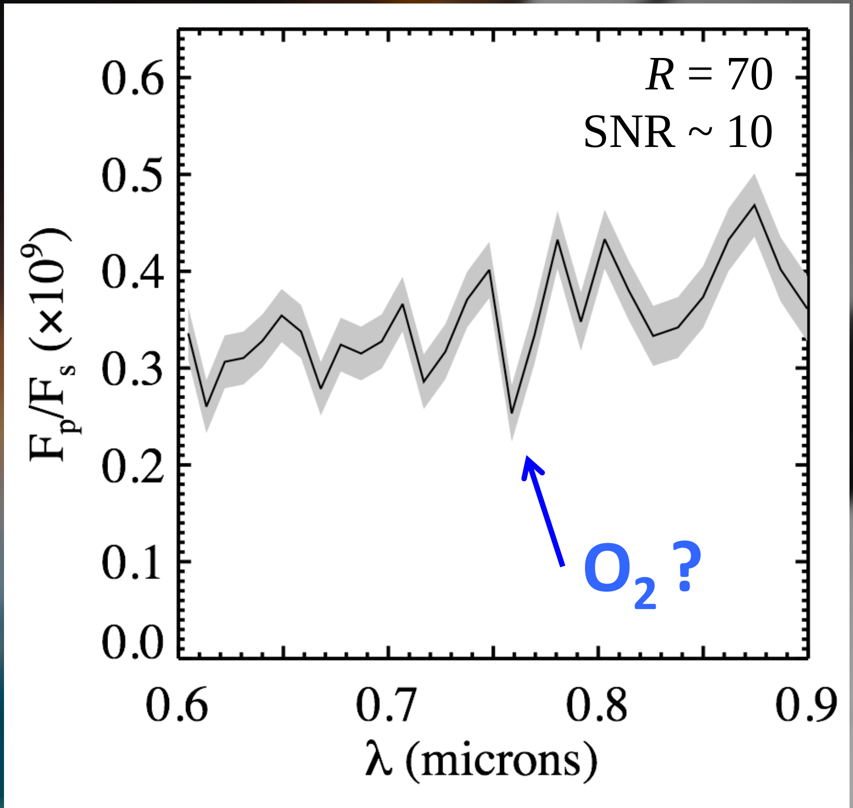
J. Tumlinson's Online Spectra Tool (Tumlinson, Robinson, Arney, et al)

In background-limited regime, exposure time of a given planet ~ D^{-4}. 16 m apertures can achieve R ~ **250 x** that of 4 m apertures in same exposure time, or take **250 x** as many spectra!

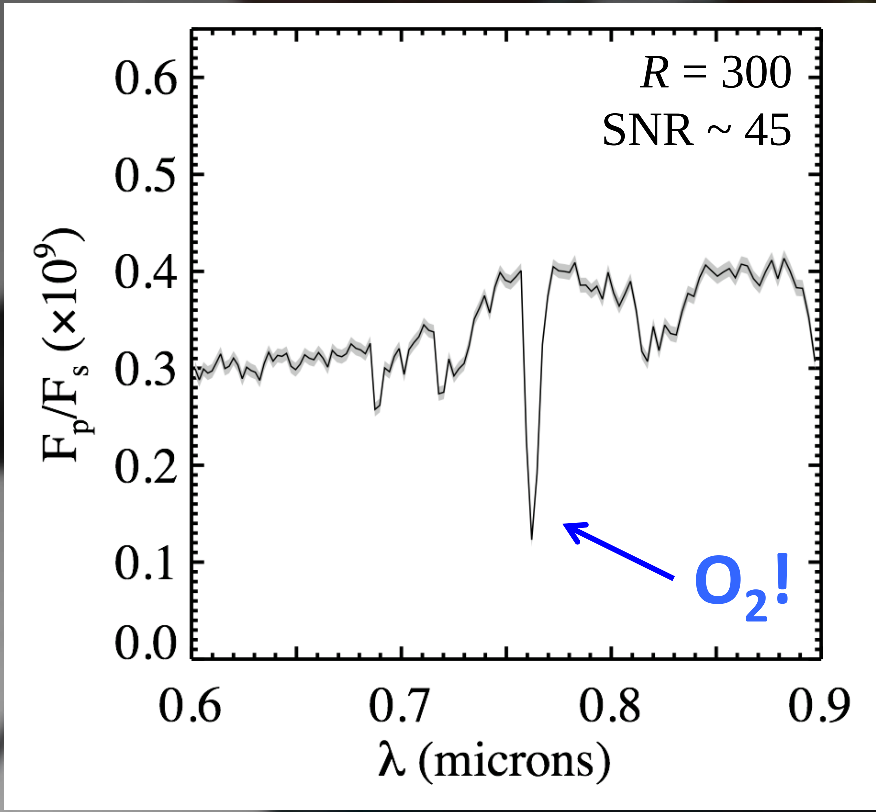
Extraordinary Claims Require Extraordinary Apertures

200 hr observations of Earth @ 10 pc

D = 4 m



D = 16 m



J. Tumlinson's Online Spectra Tool (Tumlinson, Robinson, Arney, et al)

Will the unresolved O_2 line on the left be sufficient for the most profound discovery NASA has ever made?

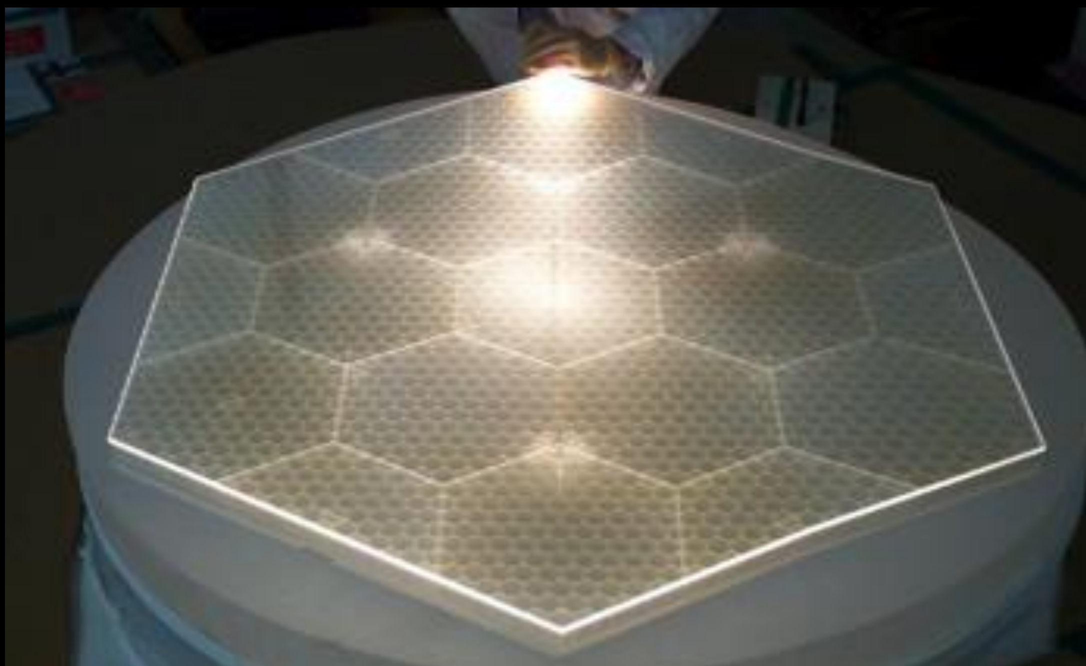
For the First Time
in Human History

We have the technology to answer the question:

"Are We Alone In the Universe"

Large Mirror Technology

For Faint Exoplanets at Small Inner Working Angles

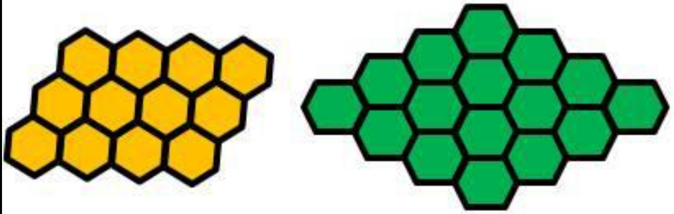


Multi-Mirror System Demonstration (MMSD) Lightweight ULE Segment Substrate (*Harris*)

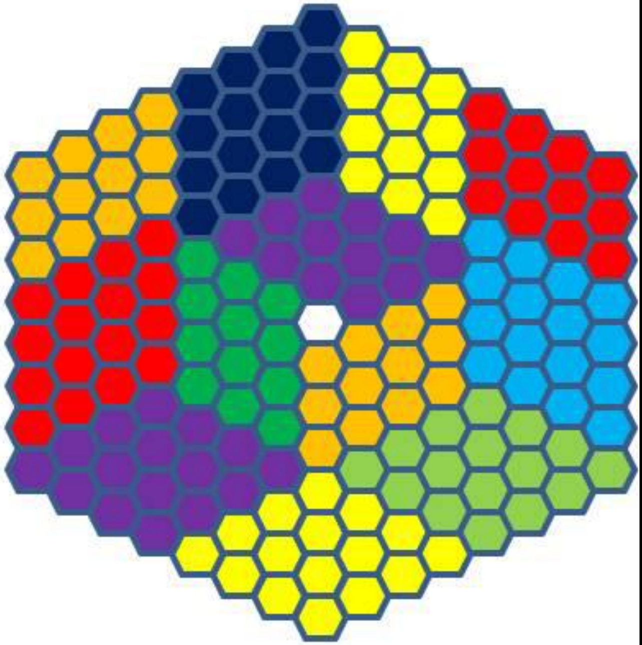
Active Hybrid Mirror (AHM) SiC-based Mirror Segment (AOA/Xinetics/JPL)

Tessellations of Segments as Building Blocks

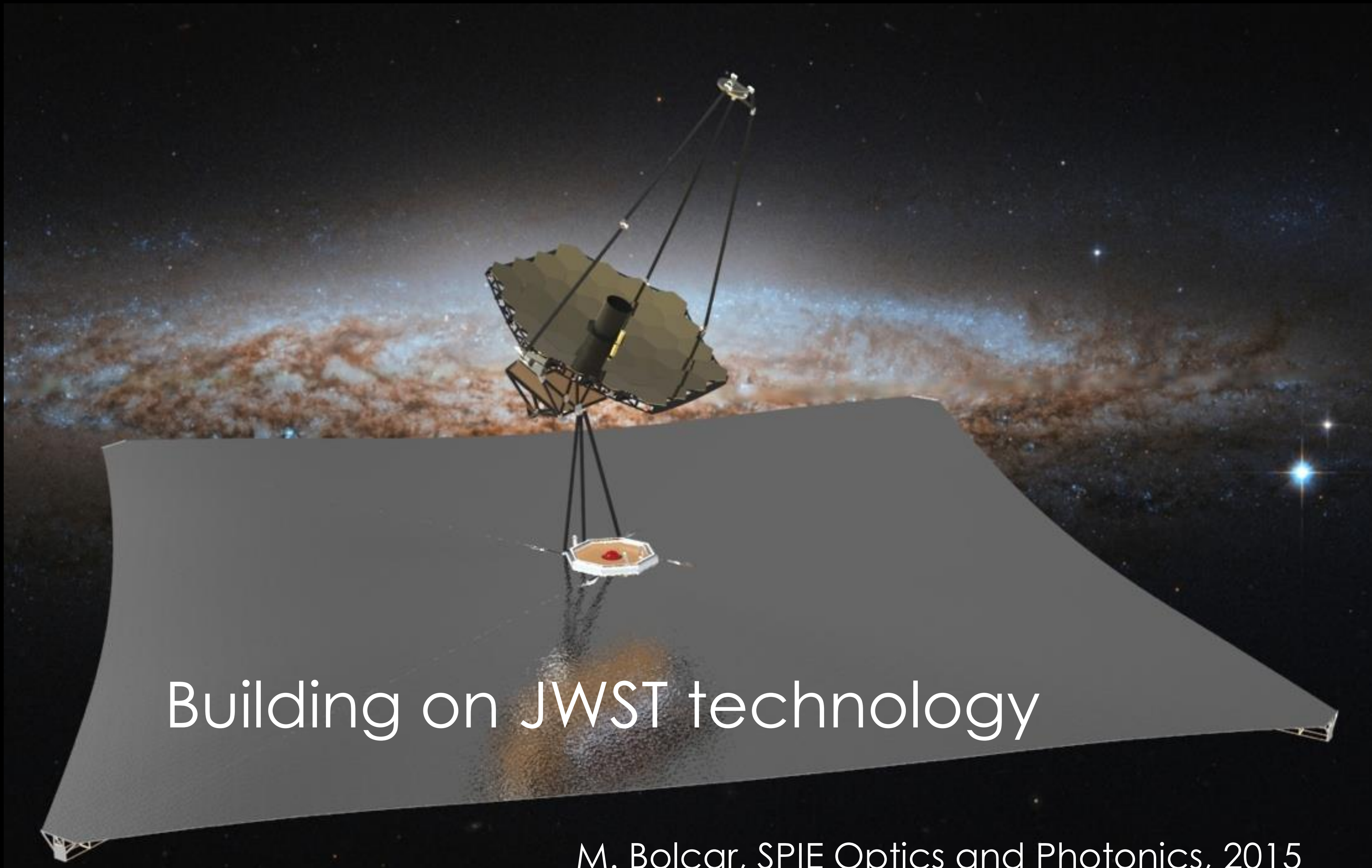
JWST Center Section



Panel Shapes



Large Segmented Space Telescope Concept

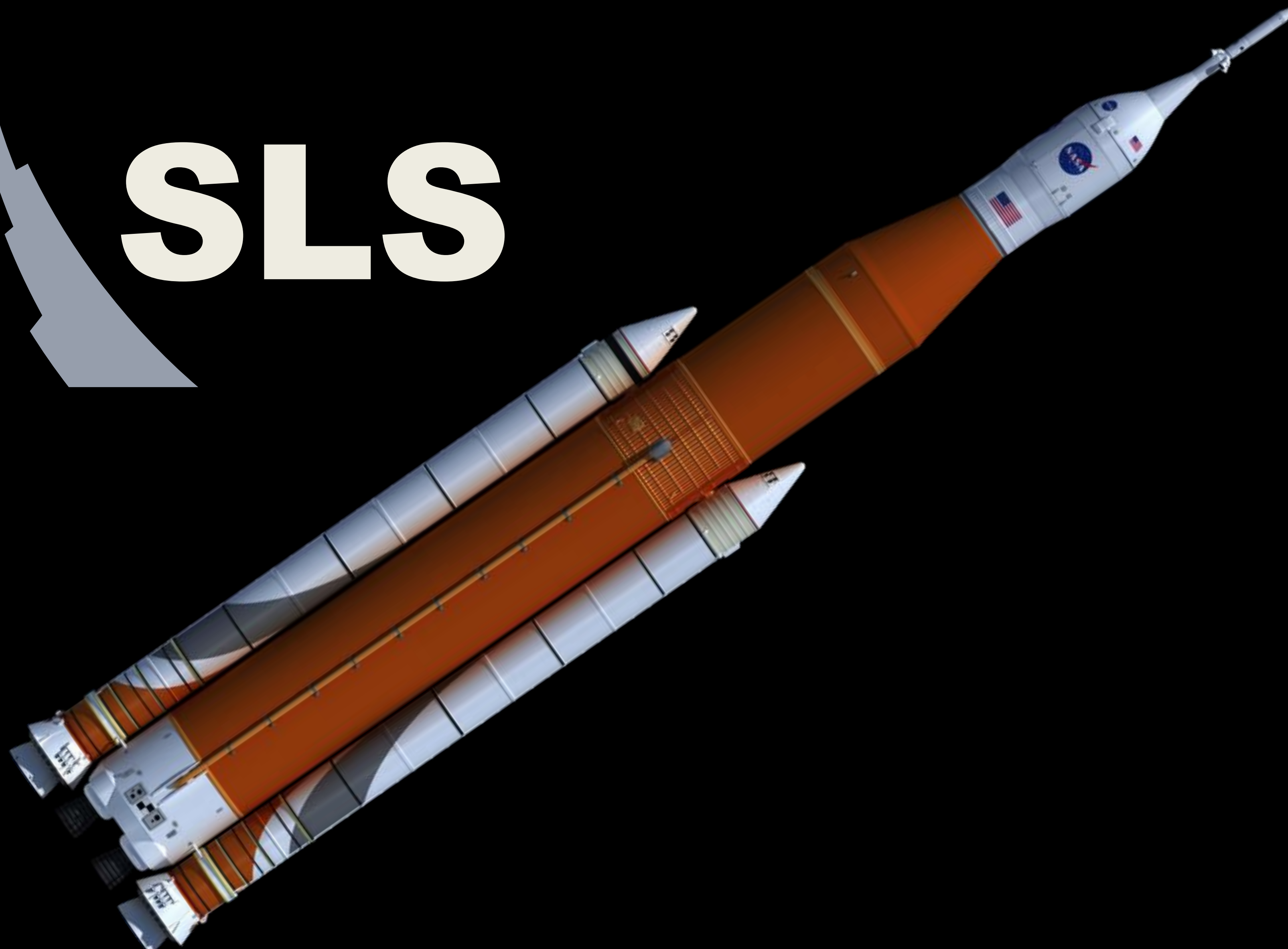


For the First Time in Human History

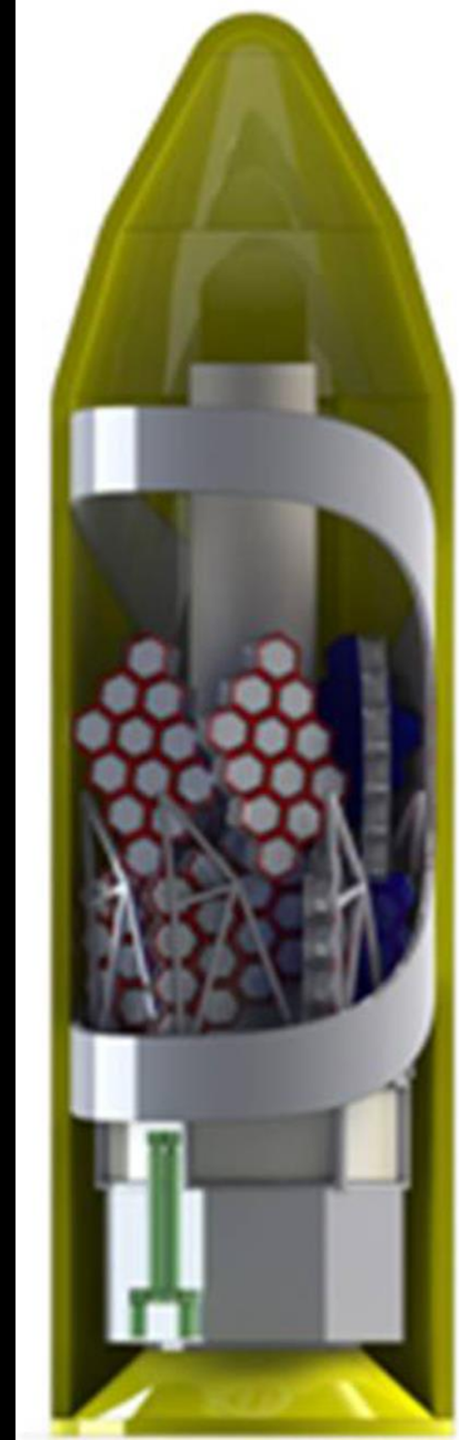
We have the means to launch transformative science missions

The Versatile Space Launch System

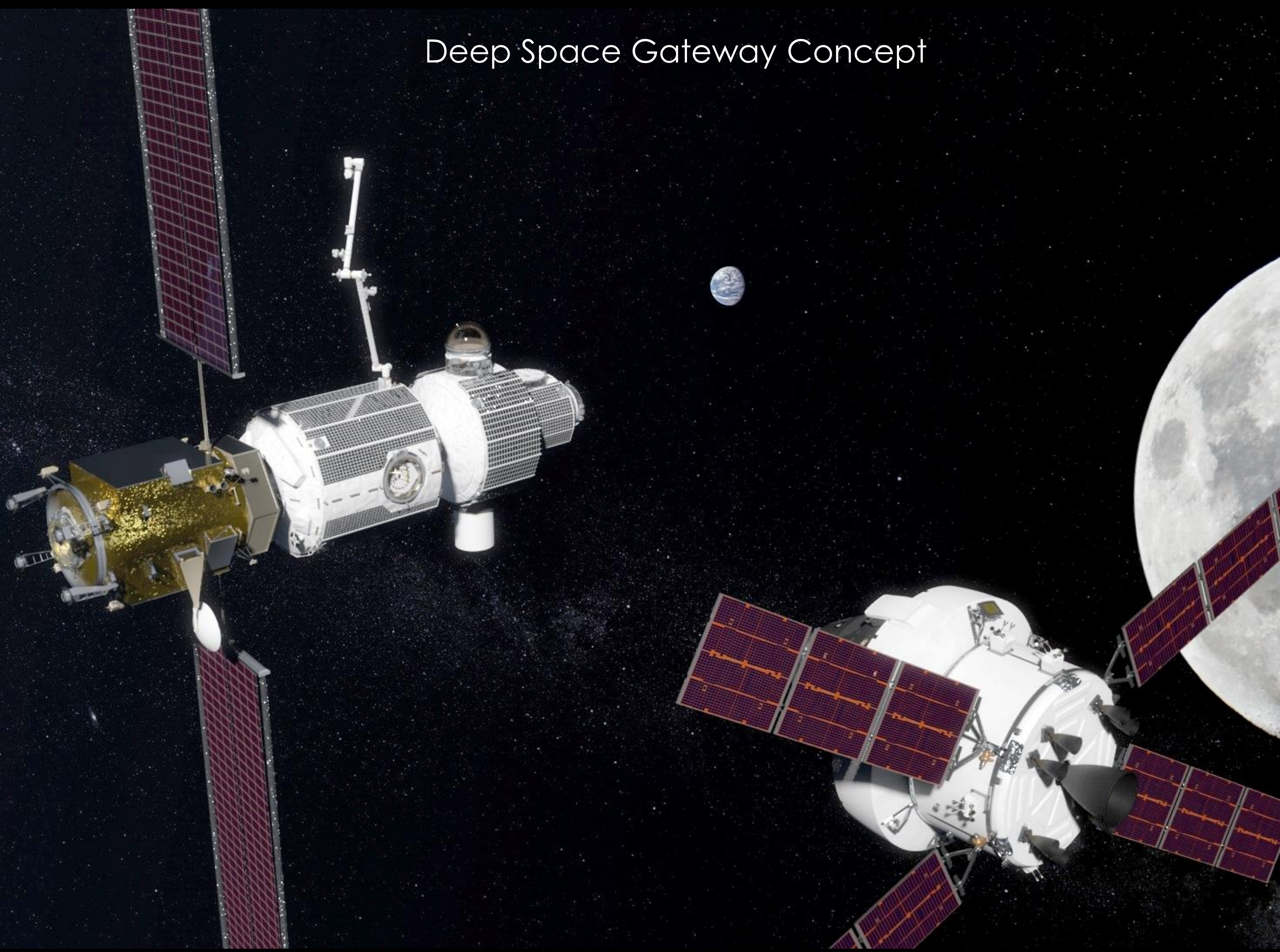
SLS

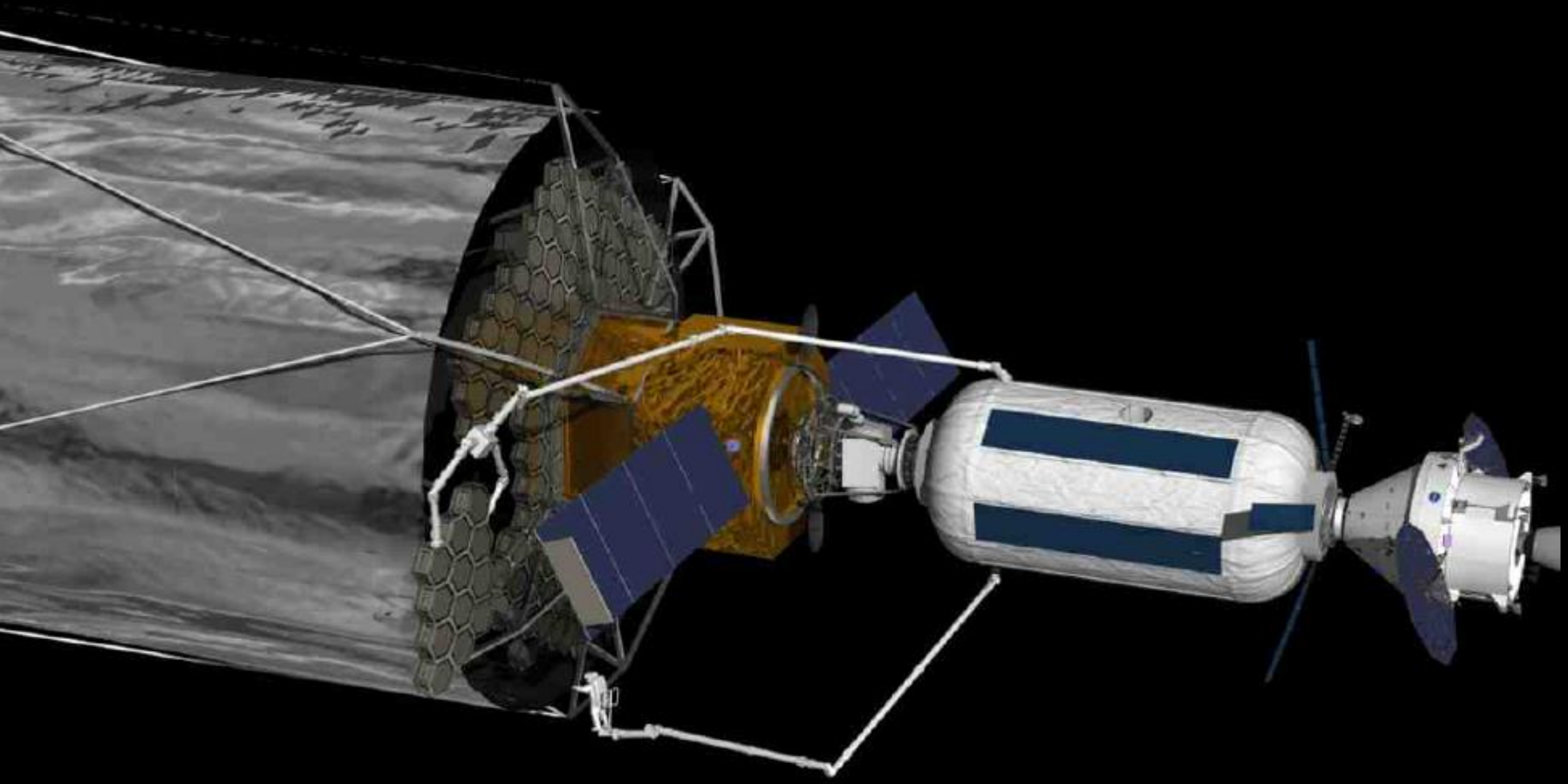



USA



Deep Space Gateway Concept





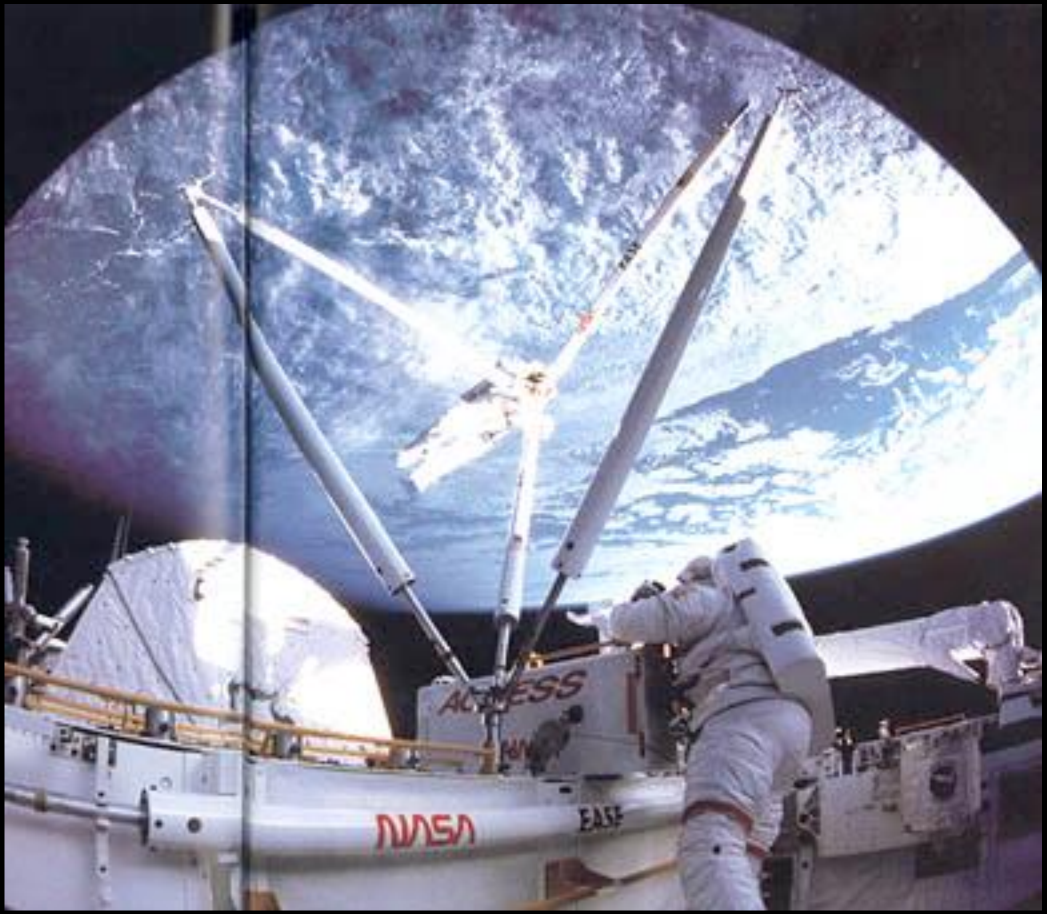
Advantages of Building a Large Telescope in Space

- Most direct way to study Earth sized rocky planets in detail
- Inherently serviceable for upgrades and repair
- Lower Mass, eliminating launch load survival concerns
- Potentially lower cost (ignoring infrastructure costs)
- Makes best use of many $B of investment in human space flight

Do We Really Have the Experience to Build a Large Telescope in Space?

STS-61B 1985 EASE/ACCESS

Assembly Concept for Construction of Erectable Space Structures
NASA/LaRC



Experimental Assembly of Structures in EVA
NASA/MSFC

SM1

1993

SM2

1997

SM3A

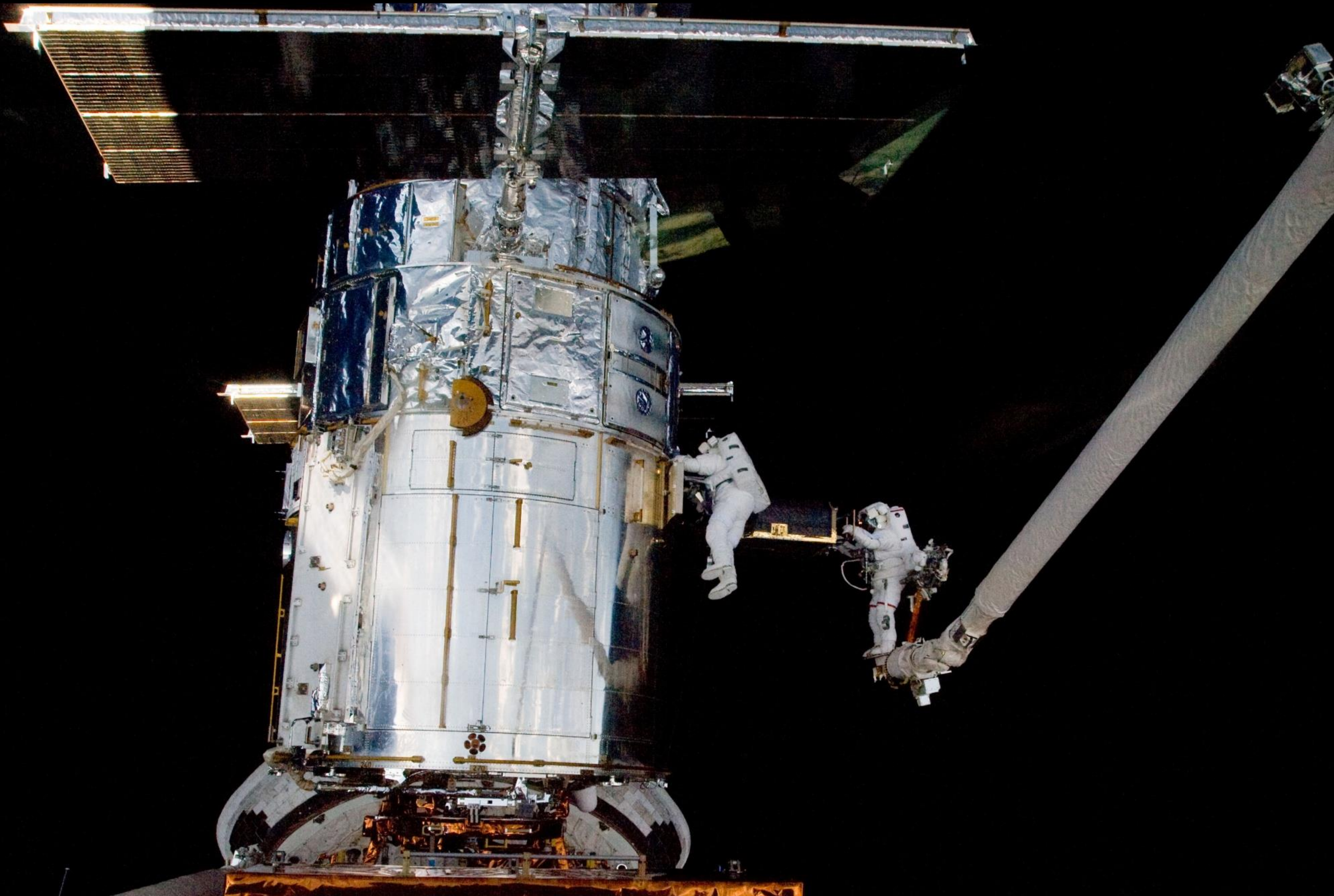
1999

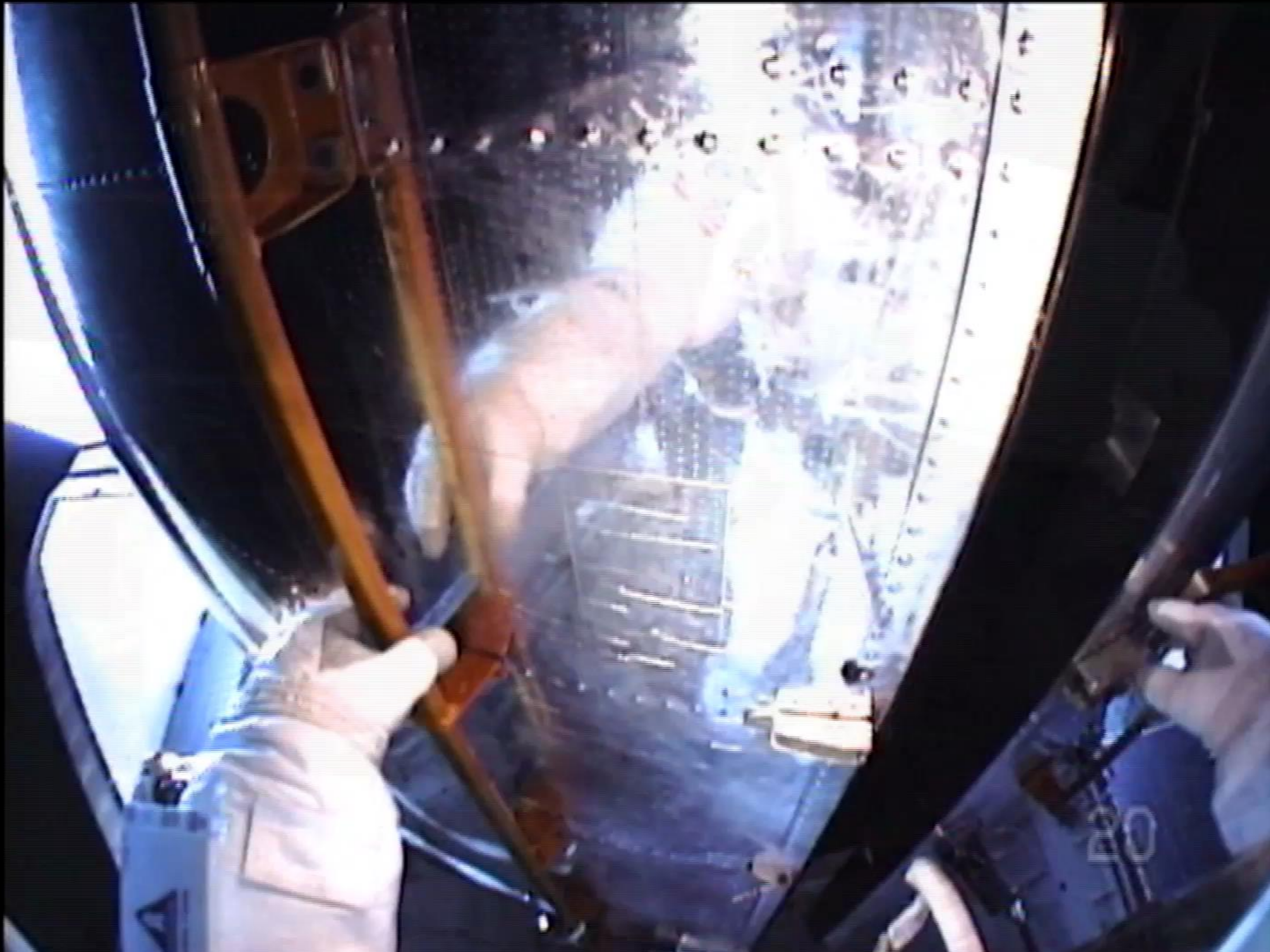
SM3B

2002

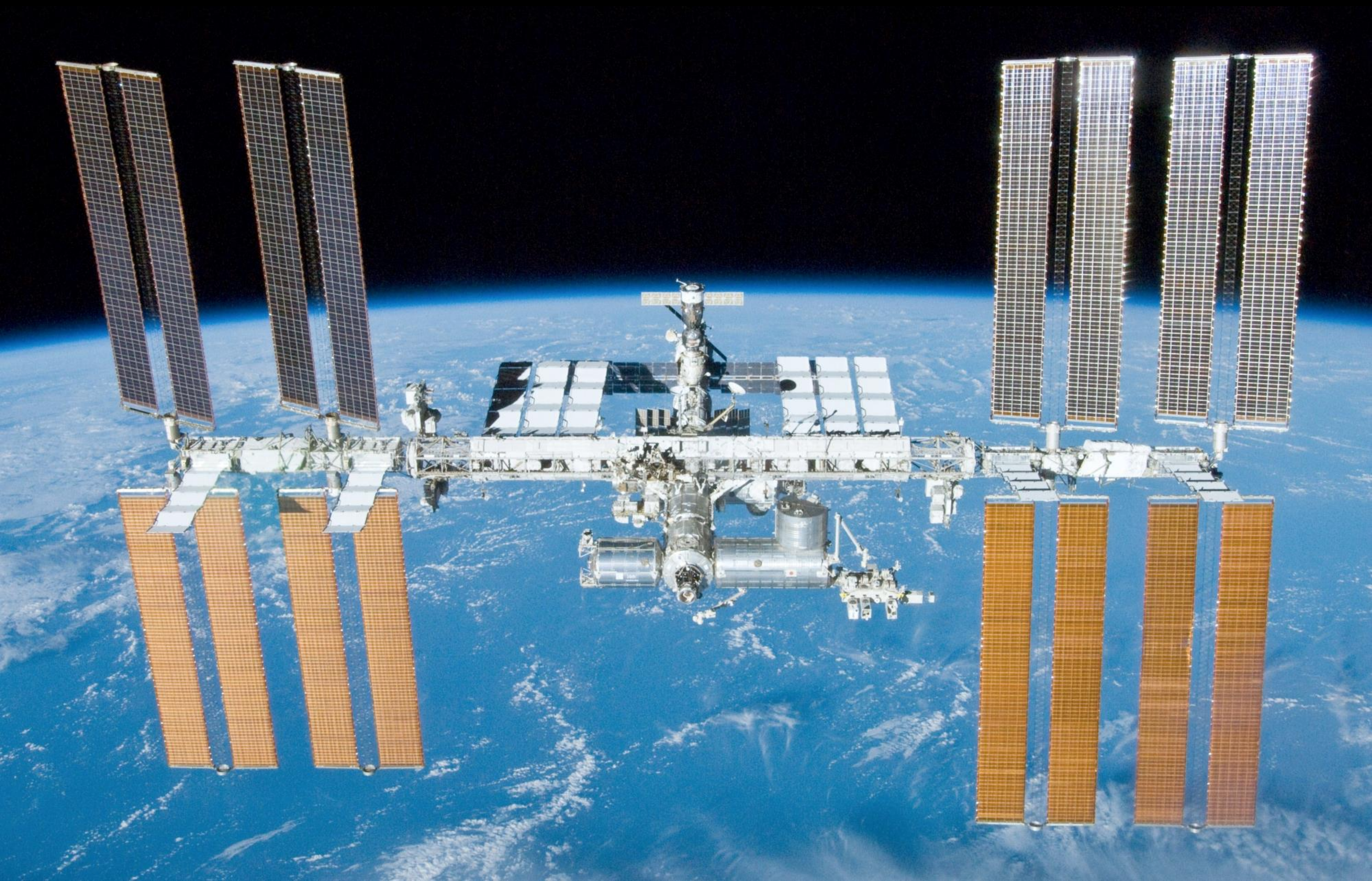
SM4

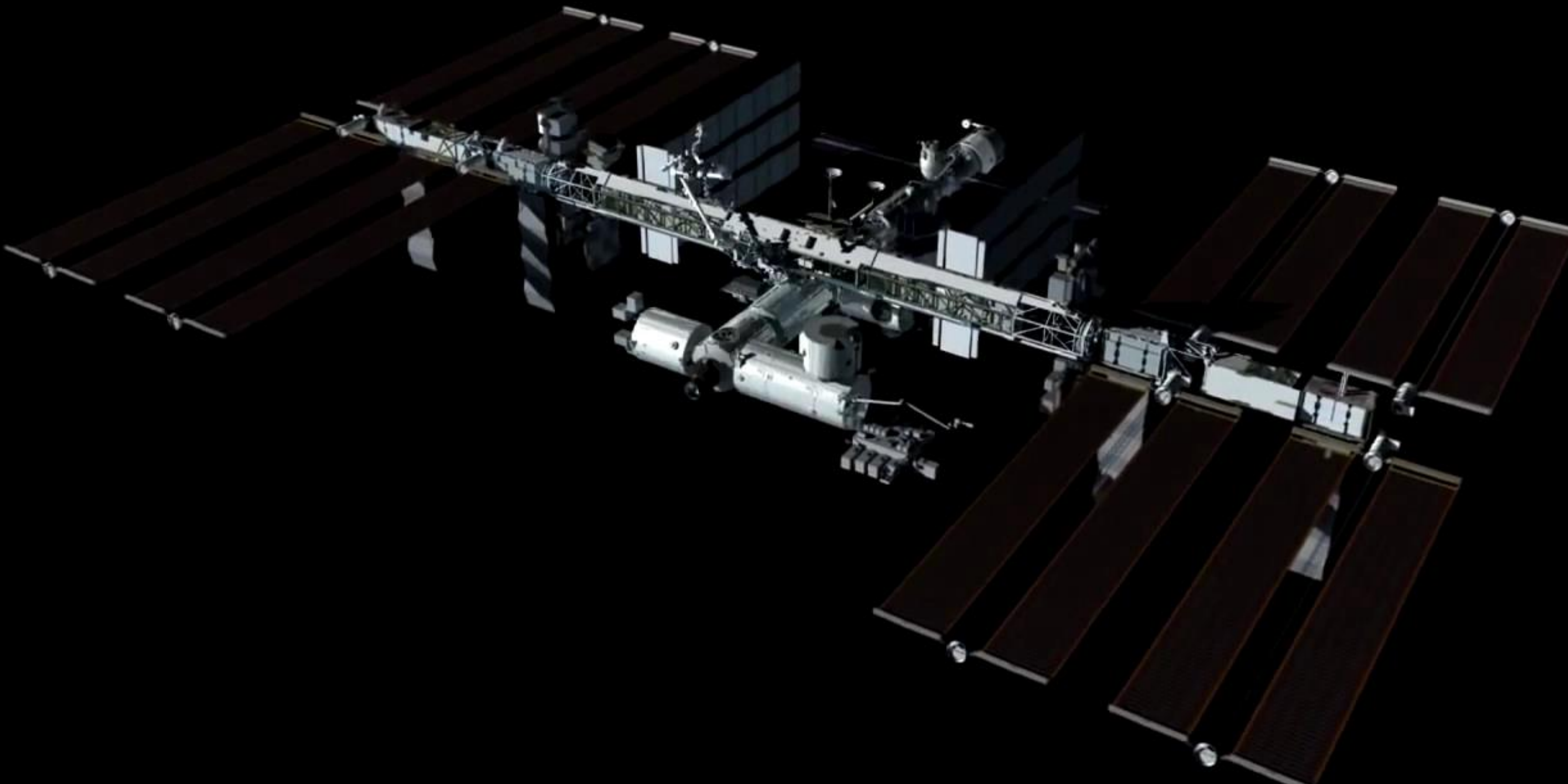
2009




20

We Built the International Space Station



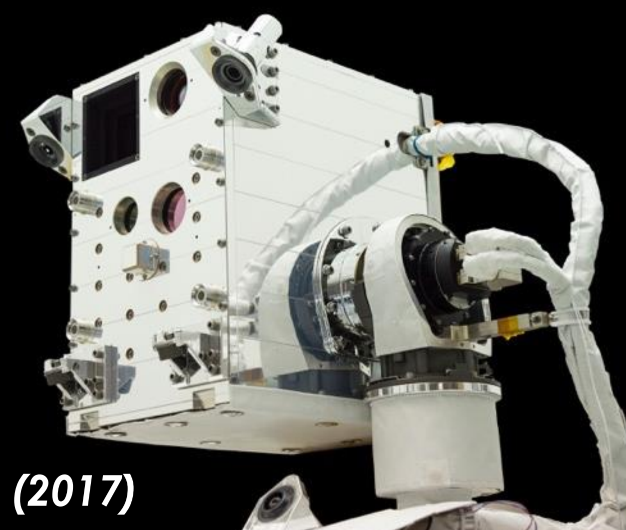


Servicing Progress Since Servicing Mission 4

Robotic Refueling Mission (2011)

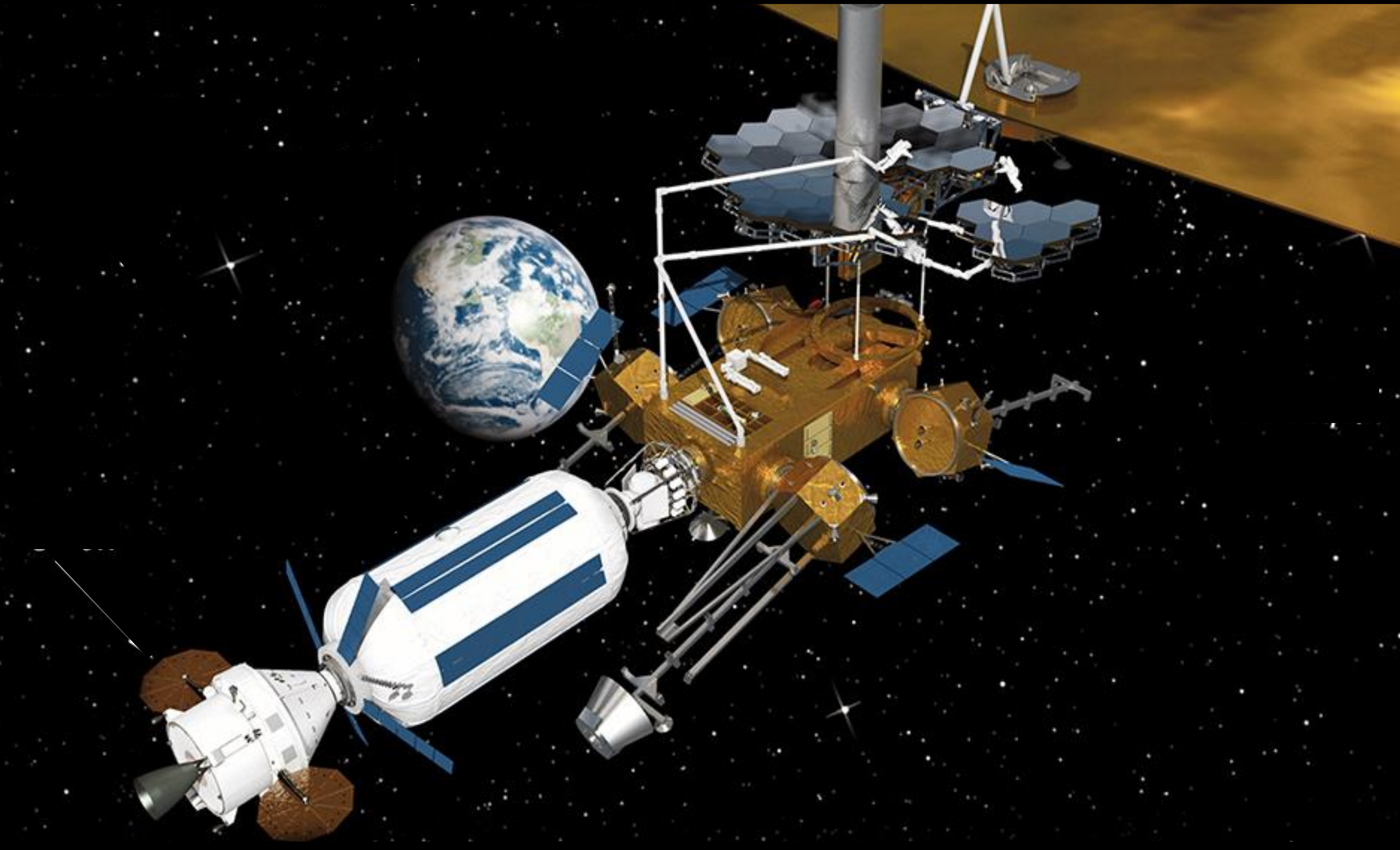
Robotic Oxidizer Transfer Test (2013)

Visual Inspection Poseable Invertebrate Robot (2015)



Raven (2017)

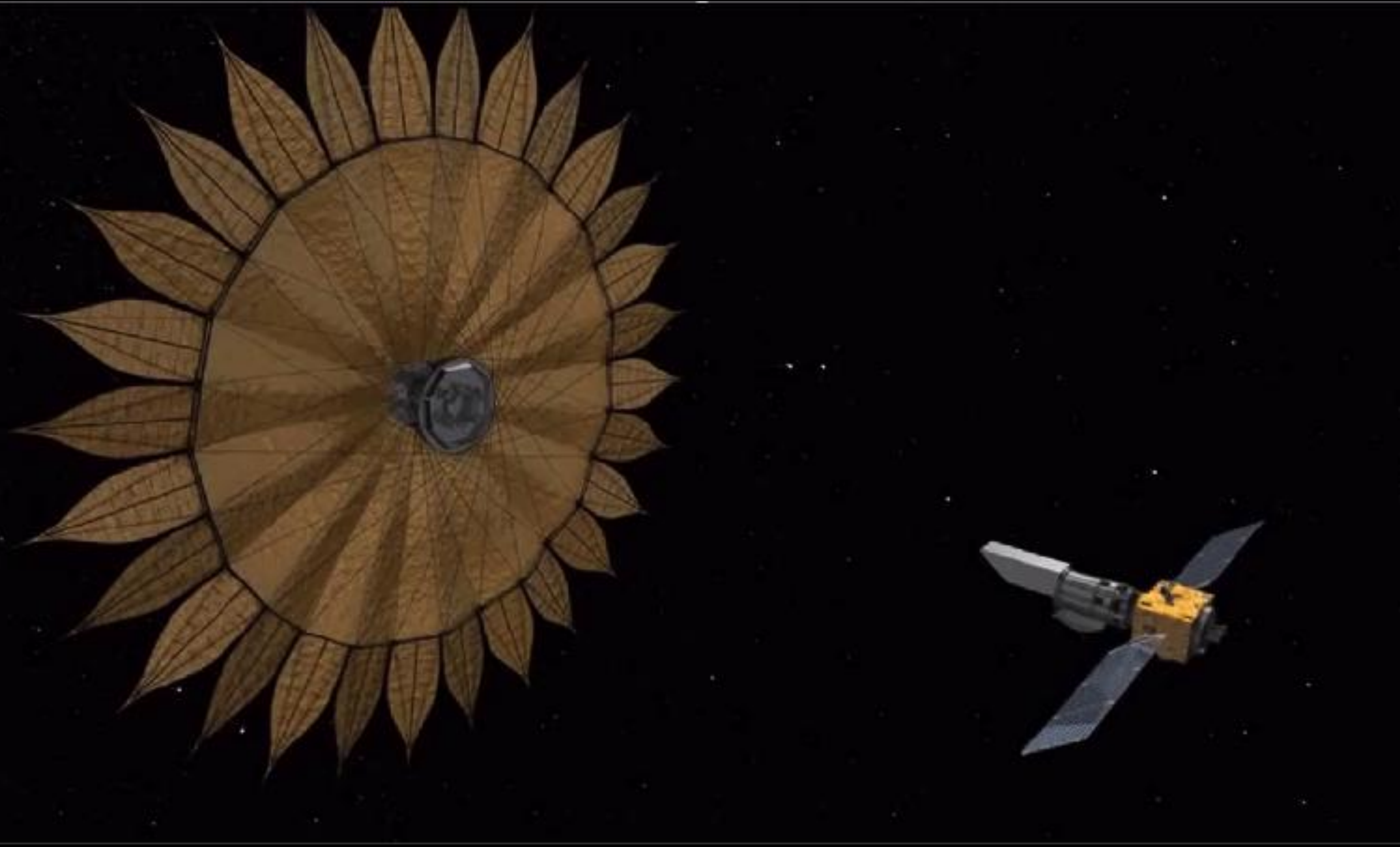
The Future of In-Space Assembly



Artist's Concept. NASA/SSPD

Servicing Near the Deep Space Gateway

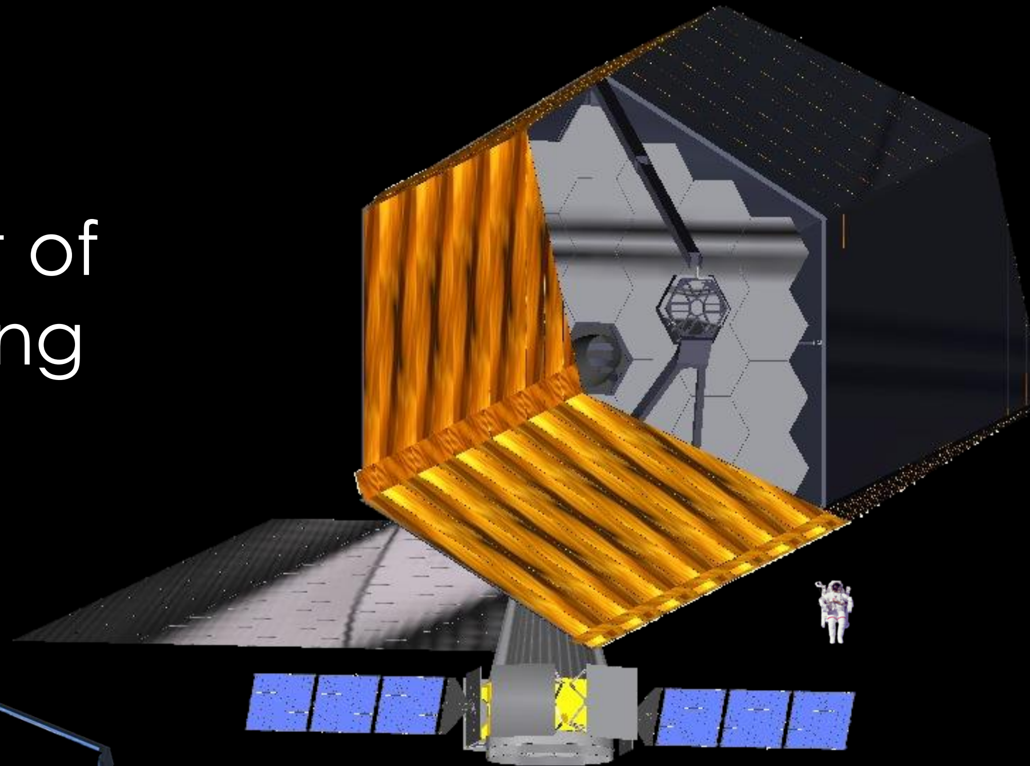
The Future

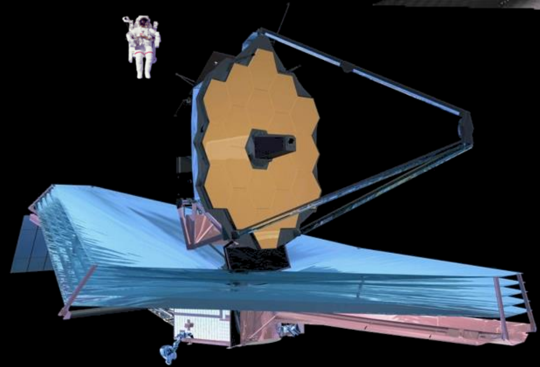


Telerobotics: Distant, Dirty, Dangerous, Dull, predictable tasks

Astronauts: Complex, Unpredictable tasks, Technically Risky, Dexterous

We Need to be Bold
to be Leaders, and
to Stay at the Forefront of
Science and Engineering





HST, JWST, Future Large Telescope

imagine the moment... 

To create that moment…

…we need to be ambitious!

https://exoplanets.nasa.gov/exep/