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?
Search & Discovery

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

Sensitivity Improvement over the Eye

- **Photographic & electronic detection**
- **Telescopes alone**

Year of observations:
- **1600** Galileo
- **1700** Huygens eyepiece, Slow f ratios
- **1750** Short’s 21.5”
- **1800** Herschell’s 48”
- **1875** Rosse’s 72”
- **1900** Mount Wilson 100”
- **1940** Mount Palomar 200”
- **1970** Soviet 6-m
- **1999** Hubble Deep Field
- **2000** Hubble Servicing Mission 4
- **2004** Hubble Space Telescope

Next Leap in Space Telescope Technology

Electronic

Photography

Telescopes alone

Sensitivity Improvement over the Eye
Wonder and Awe...
Plumes on Jupiter’s Moon Europa

*HST STIS/MAMA*

Europa map from *Galileo* mission

---

1,000 mi
1,610 km

*Sparks et al. 2017*
Hubble breaks cosmic distance record

$Z \approx 11.1$ 400 Myr old

Oesch et al. 2016
James Webb
Space Telescope

...going where no Hubble has gone before
NASA’s James Webb Space Telescope at Goddard Space Flight Center
James Webb Space Telescope Deployment
James Webb Space Telescope Servicing
imagine the moment...
An Earth 2.0 will be incredibly faint…

Dimmer than the faintest galaxy in the Hubble Deep Field
A mission that can detect dozens of rocky planets in the Habitable Zone and is robust to astrophysical uncertainties requires $D > 16 \text{ m.}$
Comparative Planetology With Hundreds of Diverse Planets

$D = 4 \text{ m}$

$D = 16 \text{ m}$

C. Stark, Using SAG13 Occurrence Rates
The Search for Life Hinges on the Detectability of Biosignatures

"Blue of the sky" measures total amount of atmosphere.

"Vegetation jump" indicates presence of land plants.

Carbon dioxide suggests possible volcanic activity.

Methane indicates presence of anaerobic bacteria.

Oxygen and ozone were produced by living organisms.

Water vapor suggests habitability.
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
In background-limited regime, exposure time of a given planet $\sim D^{-4}$. 16 m apertures can achieve $R \sim 250 \times$ that of 4 m apertures in same exposure time, or take $250 \times$ as many spectra!
Extraordinary Claims Require Extraordinary Apertures

200 hr observations of

\[ D = 4 \text{ m} \quad \text{Earth @ 10 pc} \quad D = 16 \text{ m} \]

\[ R = 70 \quad \text{SNR} \sim 10 \]

\[ R = 300 \quad \text{SNR} \sim 45 \]

Will the unresolved \( \text{O}_2 \) line on the left be sufficient for the most profound discovery NASA has ever made?

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

Building on JWST technology

M. Bolcar, SPIE Optics and Photonics, 2015
For the First Time in Human History

We have the means to launch transformative science missions
The Versatile Space Launch System

SLS
Human Space Flight and Assembly of a Future Large Aperture Telescope
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?
Assembly Concept for Construction of Erectable Space Structures
NASA/LaRC

Experimental Assembly of Structures in EVA
NASA/MSFC
We Built the International Space Station
Servicing Progress Since Servicing Mission 4

Robotic Refueling Mission (2011)

Robotic Oxidizer Transfer Test (2013)


Raven (2017)
The Future of In-Space Assembly

Artist’s Concept. NASA/SSPD
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
imagine the moment...

To create that moment...

...we need to be ambitious!

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