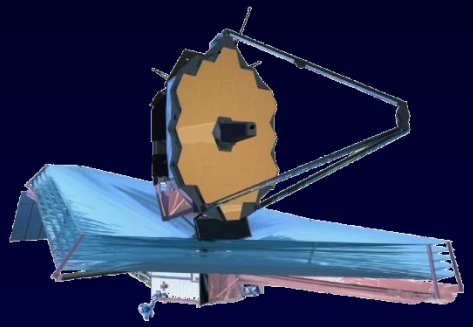
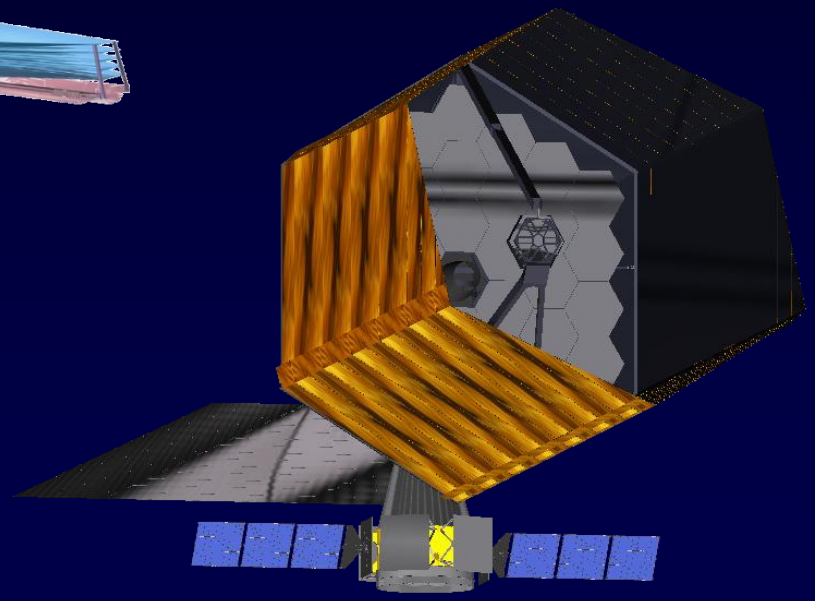
The Science Rationale for Servicing and Considerations for Existing and Future Space-based Astronomical Observatories





Marc Postman, STScI

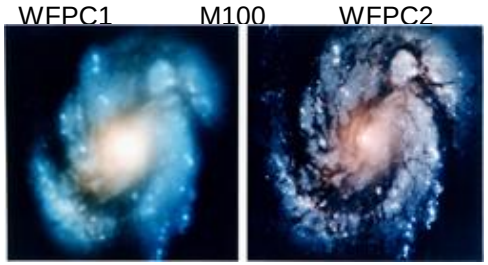
International Workshop on On-Orbit Satellite Servicing

University of Maryland, College Park
March 24 - 26, 2010

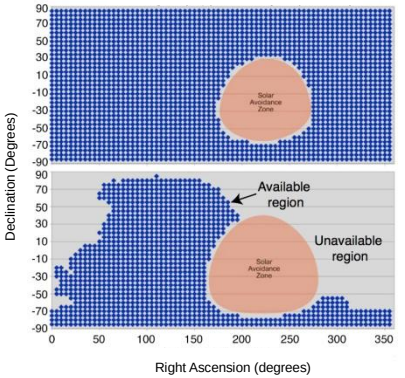
Science Gain & Servicing

- On-orbit servicing provides three key functions that directly extend or magnify the scientific impact of space observatories:

–***Restoration*** ***of observatory operation*** through the replacement or repair of degraded or failed components;



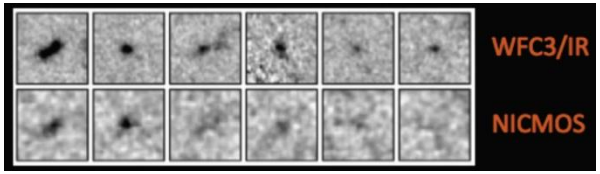
–***Extension*** ***of observatory lifetime*** through replenishment of expendables and replacement of limited-lifetime items;



3-gyro sky coverage

2-gyro sky coverage

–***Expansion*** ***of observatory capability*** by upgrading to newer technology.



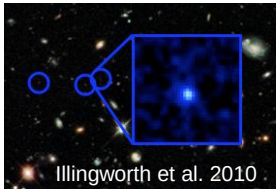
Science Gain & Servicing

Scientific benefits to a longer observatory lifetime and upgraded instrumentation:

– Perform observations not possible with the initial suite of instruments.

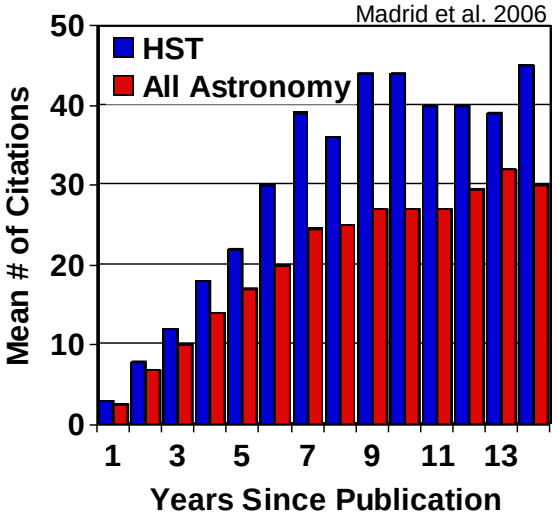
– Undertake investigations not conceived of when observatory was initially built.

– Provide long-term access to space-based coverage of a broad set of wavelengths.

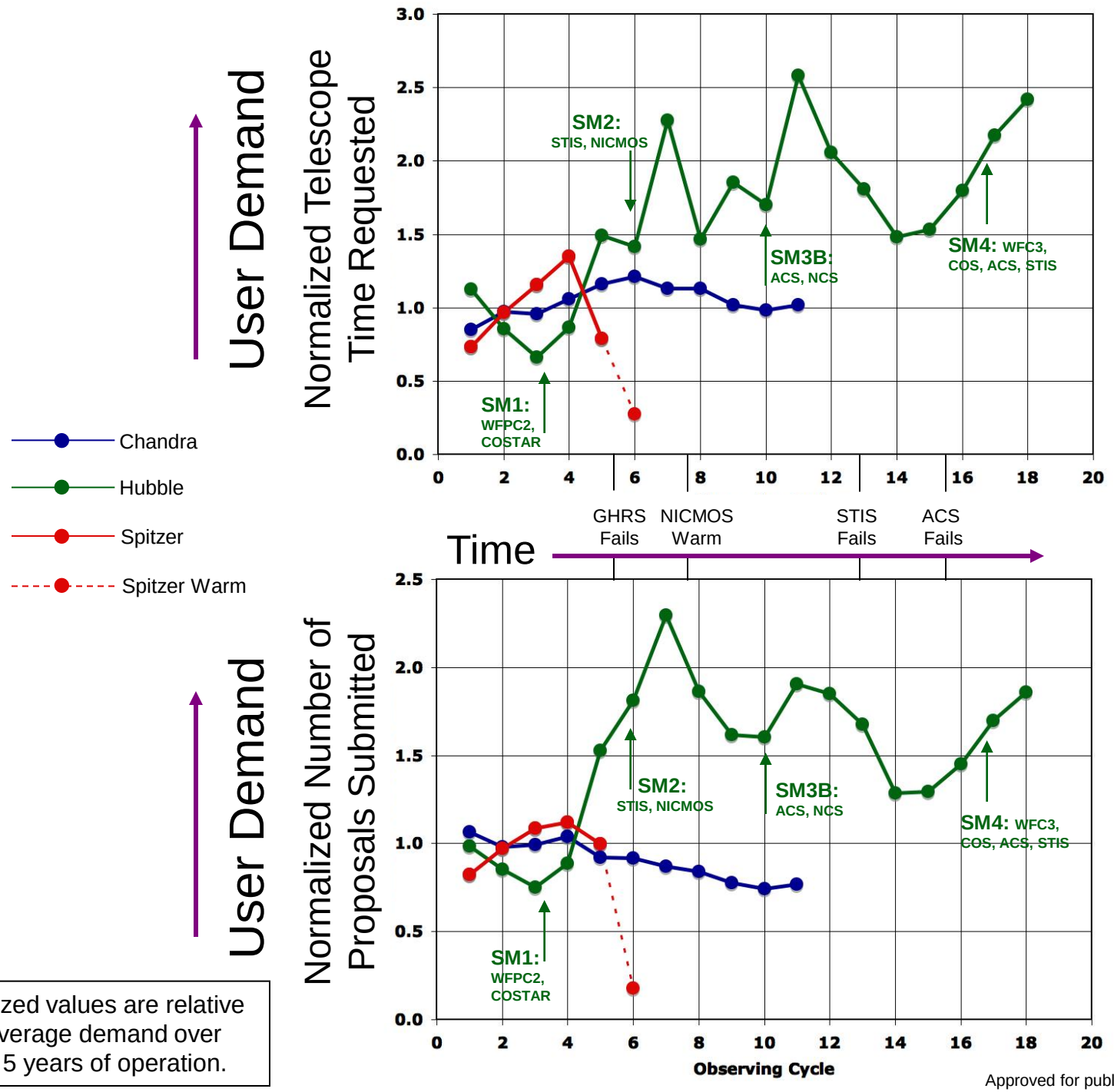


SM4 WFC3/IR Cam: Direct detection of galaxies ~13 billion light years away.

SM2 STIS: Spectroscopy of Exoplanet Atmosphere around star HD209458.



These benefits **keep the observatory at the forefront of research** well beyond the nominal mission life of most unserviceable facilities.

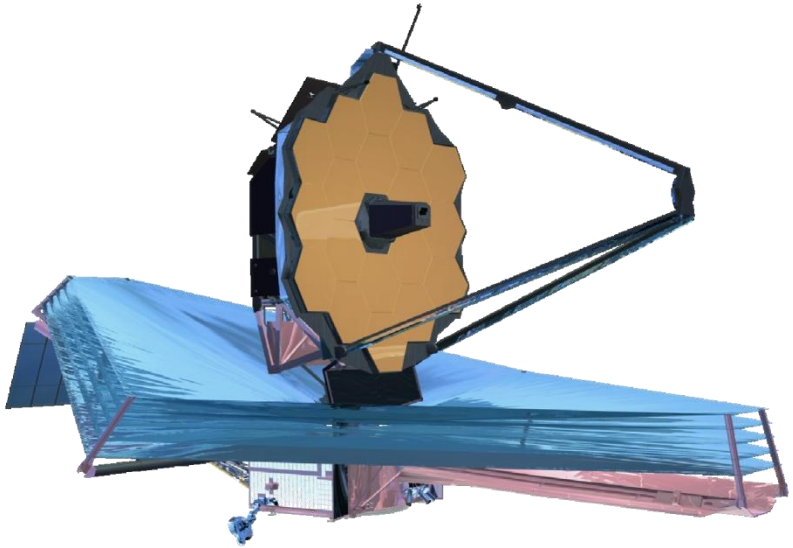


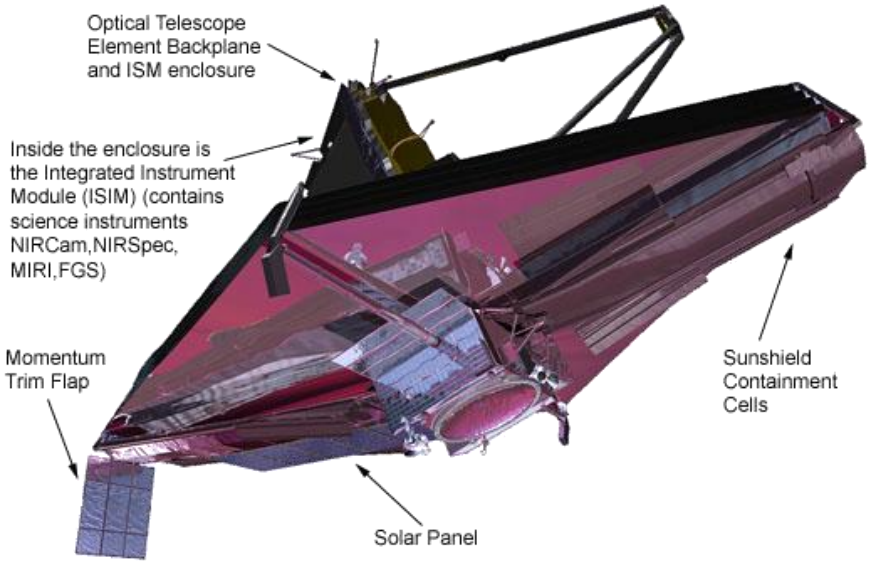
Are there scientific and cost benefits to servicing HST again

?

Normalized values are relative to the average demand over the first 5 years of operation.

James Webb Space Telescope & Servicing





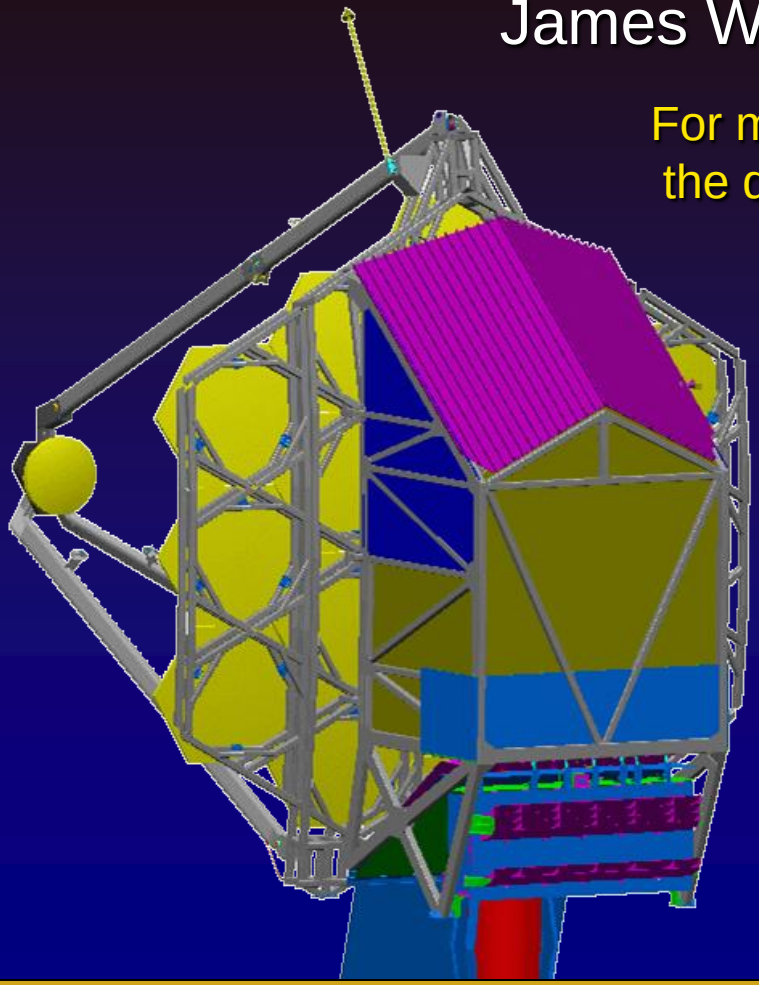
Refueling of JWST would allow it to operate beyond its nominal 10-year lifetime:

- Continue operation if facility is still functional
- Augment capabilities (e.g., extended operations with free-flying starshade for exoplanet detection and characterization)

Repair of sunshield damage due to micro-meteor impacts would also extend the usable lifetime of the observatory.

James Webb Space Telescope & Servicing

For more complex repairs, JWST poses a challenge to the design of servicing technologies and methods that work with non-cooperative targets



Region 1: Access extremely difficult; Cold side of sunshade

Science Instrument Optics Assemblies

Near Infrared Camera (NIRCam)
Near Infrared Spectrograph (NIRSpec)
Mid Infrared Instrument (MIRI)
Fine Guidance Sensor w/Tunable Filter (FGS/TF)

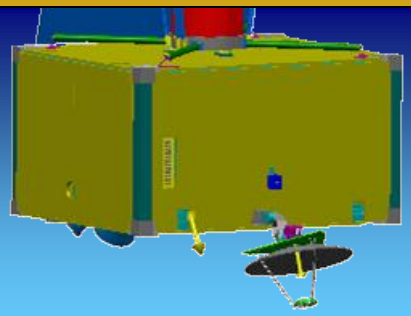
Optical Bench Structure

Radiators and support structure

Region 2: Access difficult; Cold side of sunshade

ISIM Electronics Compartment

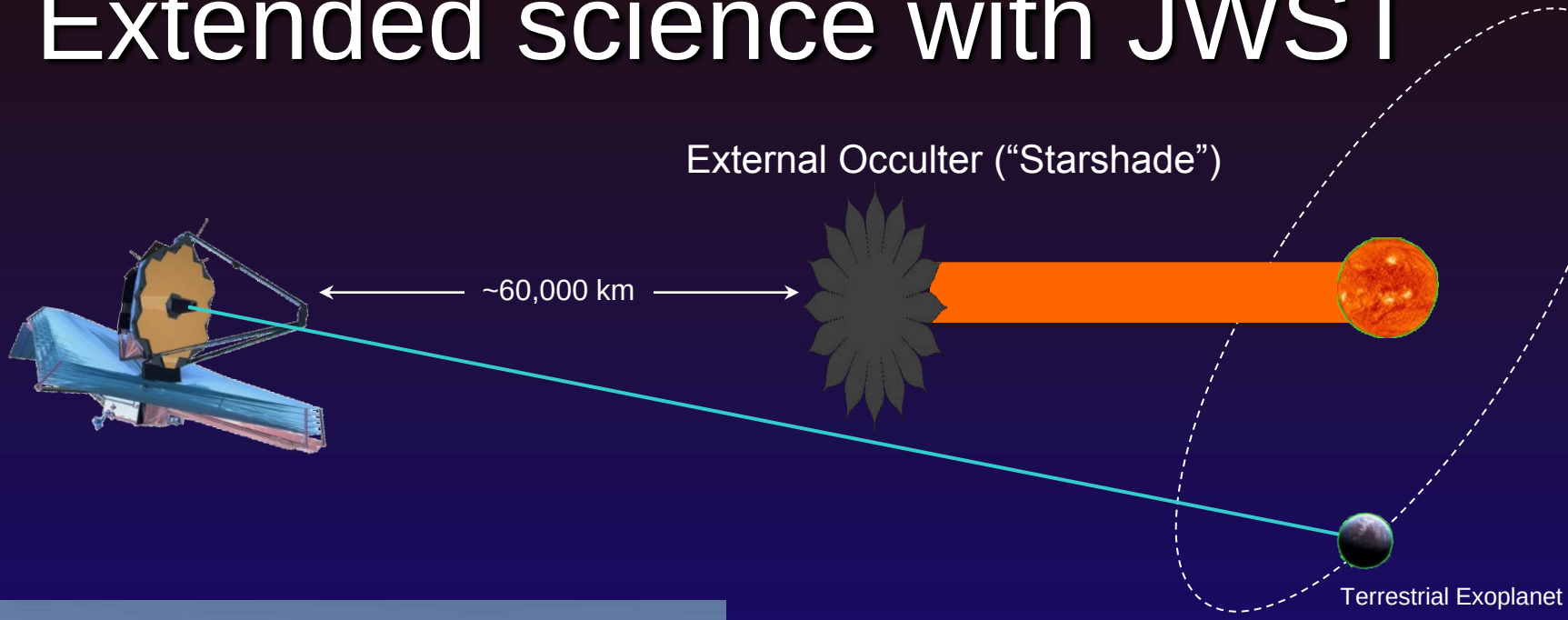
Focal Plane Electronics (FPE)
Instrument Control Electronics (ICE, MCE)
ISIM Remote Services Unit (IRSU)



Region 3: Access difficult; Warm side of sunshade

ISIM Command & Data Handling (C&DH) Electronics

Extended science with JWST



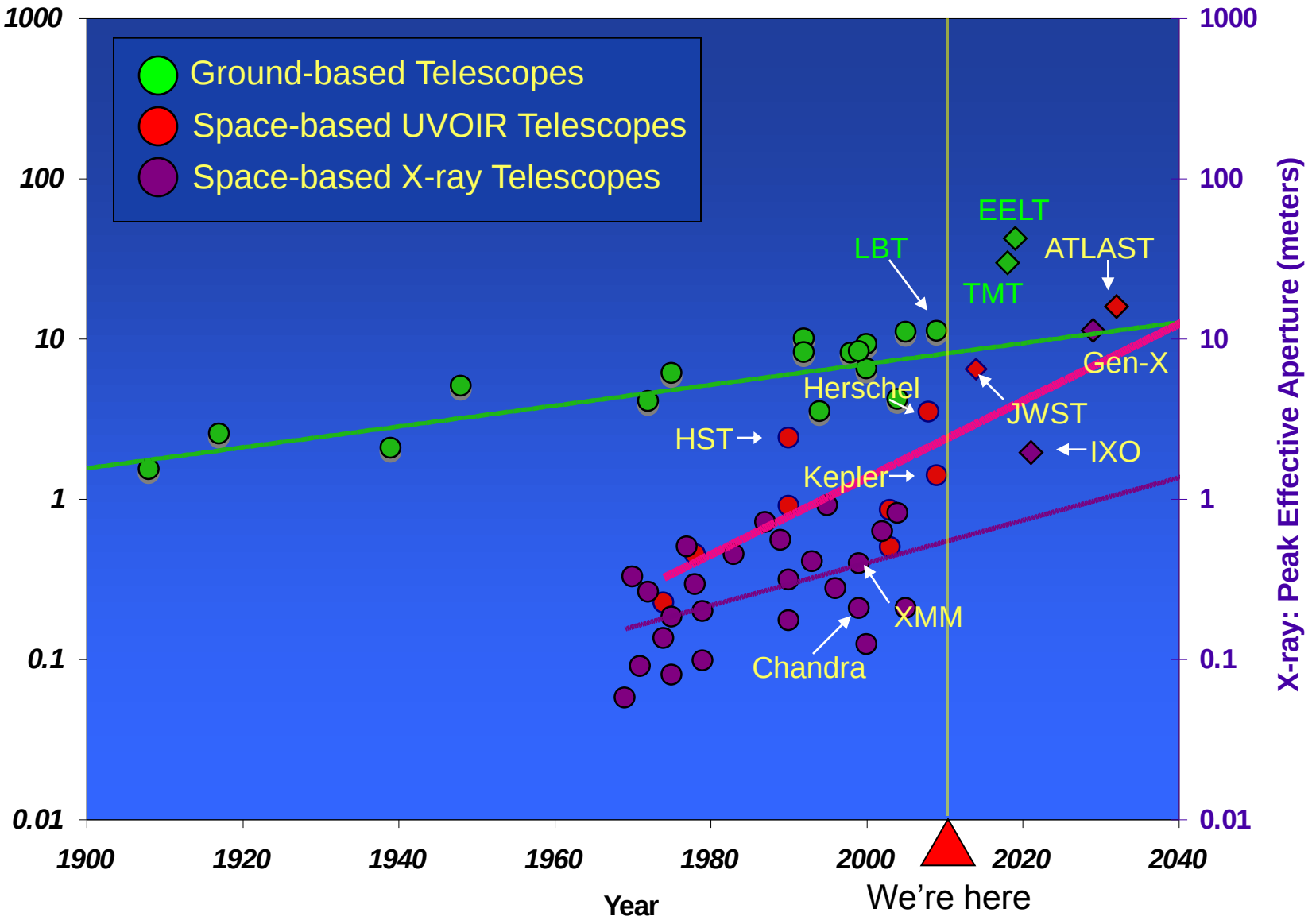
42-m EELT
First light 2019?

Astrophysics is a photon-limited field.

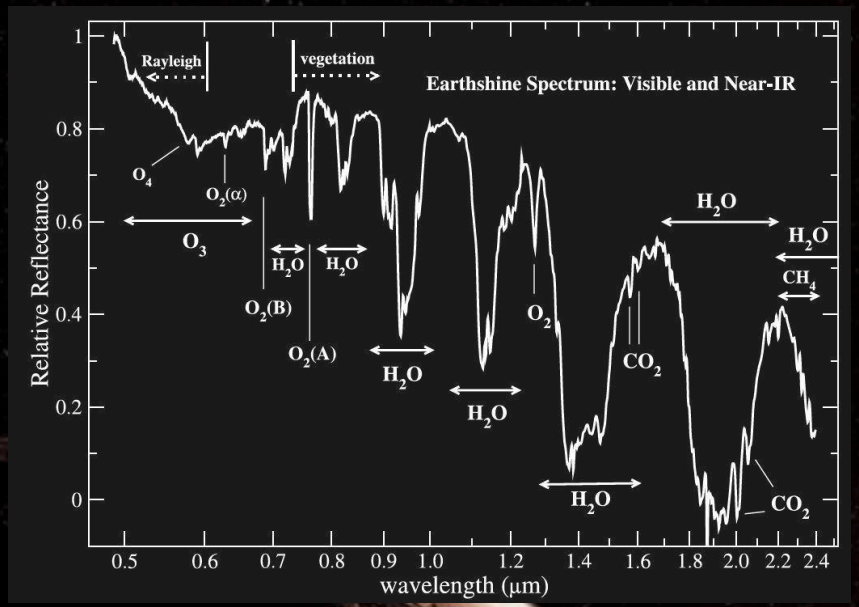
$$\frac{\text{Signal}}{\text{Noise}} \propto \frac{\text{Telescope Diameter}}{\text{Image Size}} \sqrt{\frac{QE_\lambda}{B_\lambda}}$$

The breakthroughs 20 years from now will require larger optical systems in space than are available today.

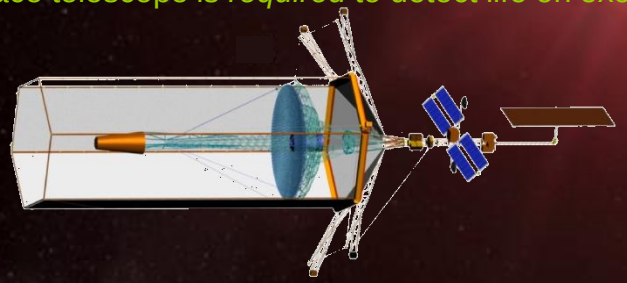
Telescope Collecting Area vs. Time



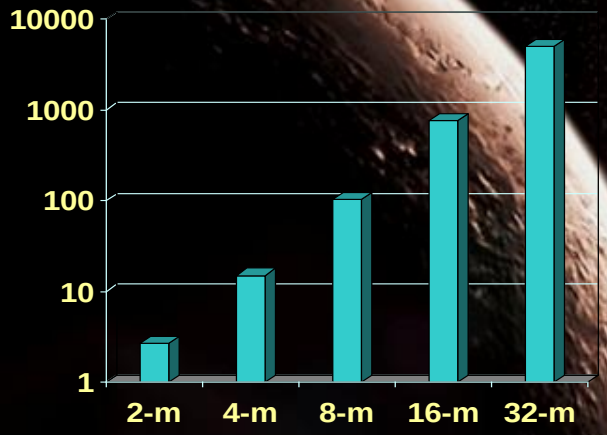
Enabled Science: "Are We Alone?"



An Earth-twin at a distance of 60 light years is 8x fainter than the faintest galaxy in Hubble's Ultra Deep Field Survey.
A large space telescope is *required* to detect life on exoplanets.



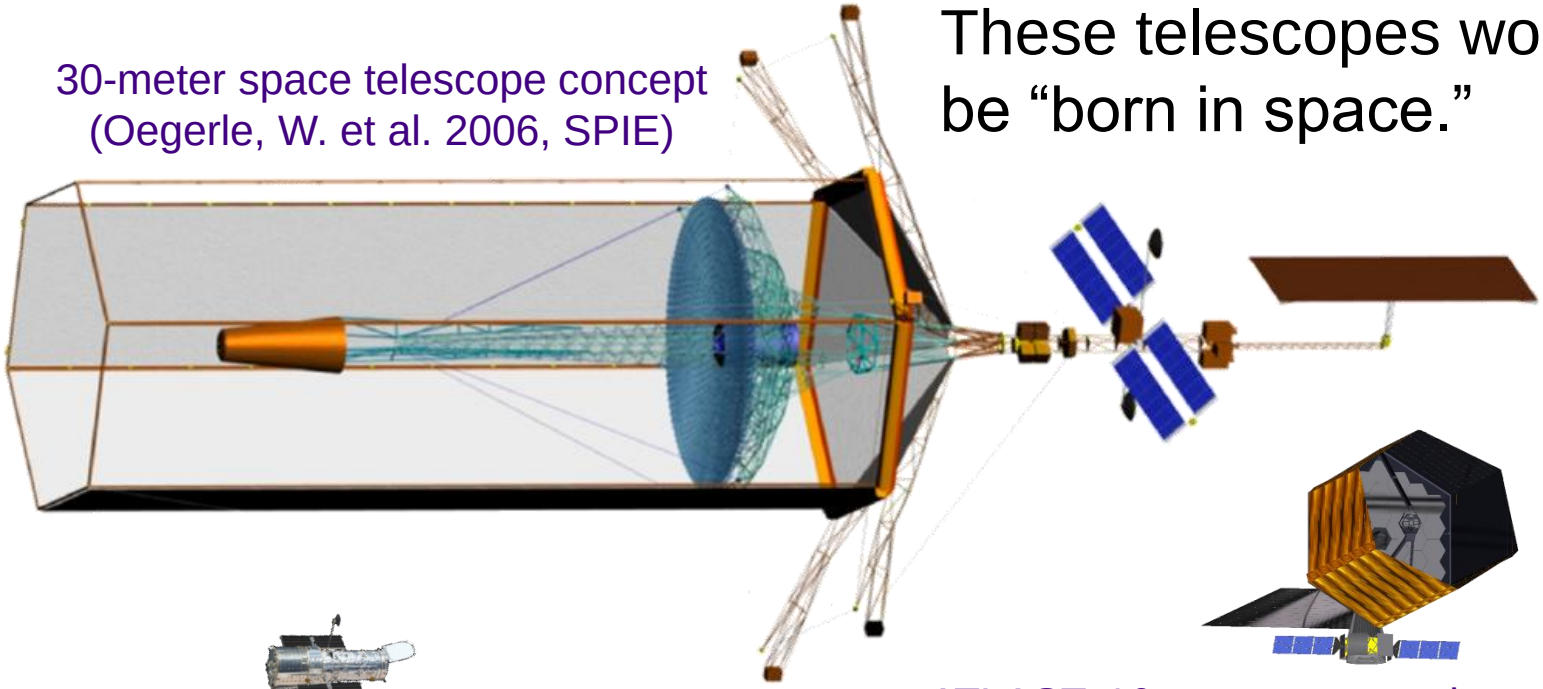
A 30-m telescope in space enables the Era of Remote Sensing of Oceans, Weather, Land and Vegetation coverage on Hundreds of Habitable Worlds Beyond Our Solar System



The number of star systems where one can search for habitable worlds increases as the cube of the telescope diameter

30-meter space telescope concept
(Oegerle, W. et al. 2006, SPIE)

These telescopes would likely be “born in space.”

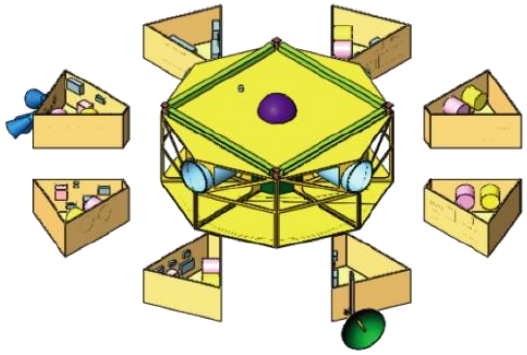


HST (to scale)

ATLAST: 16-meter space telescope concept
(Postman et al. 2009)

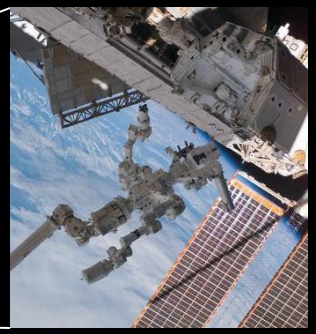
Key technology areas that need to be matured in order to realize large-aperture ***serviceable*** telescopes are:

- **Active optical systems** needed for realizing large, lightweight segmented apertures (includes mirror actuators, WFS&C, truss metrology).
- **Standardized modular designs** for spacecraft bus components.
- **Modular, replaceable** instruments, pointing and data-handling systems.
- **Expendables** that can be replenished on-orbit.
- **Computer-aided vision systems** for remote manipulator systems operating with a time delay (cf. Whitcomb’s talk at this workshop).



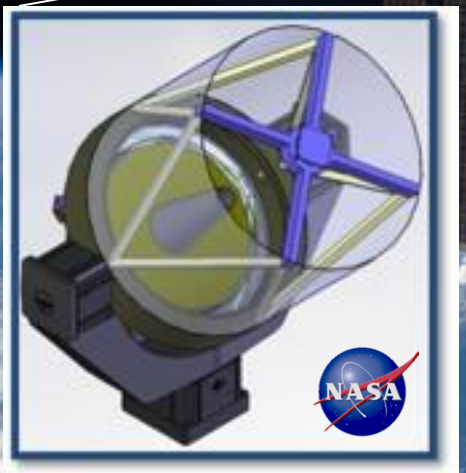
Existing HSF Infrastructure can be used to develop and mature some of these technologies

Advance the technology readiness level of human-guided robotic servicing in a space environment:
Autonomous rendezvous and capture of target
Installation of new avionics and scientific instruments
Life extension upgrades



Robotic Satellite Upgrade and Maintenance Testbed

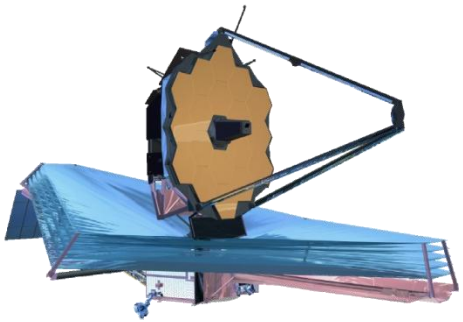
Observatory Pathfinder on the ISS



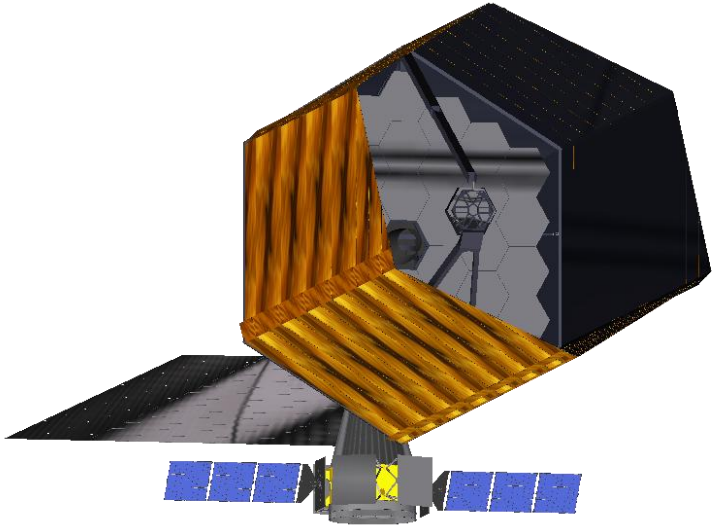
Joseph Green
Jet Propulsion Laboratory
California Institute of Technology

Pathfinder for large telescope concepts amenable to in-space assembly.
Can employ **existing** actuated primary mirror representing ultra-lightweight mirror technology that can be fabricated 4x faster than conventional glass mirrors.
High level of mirror figure actuation enables ‘test-as-you fly’ capability during I&T and provides great robustness for perfecting and maintaining the imaging performance on-orbit.
Wavefront sensing and control software allows the science focal plane be used directly to perfect the telescope, eliminating non-common-path errors.

Servicing options for HST?



Servicing options for JWST

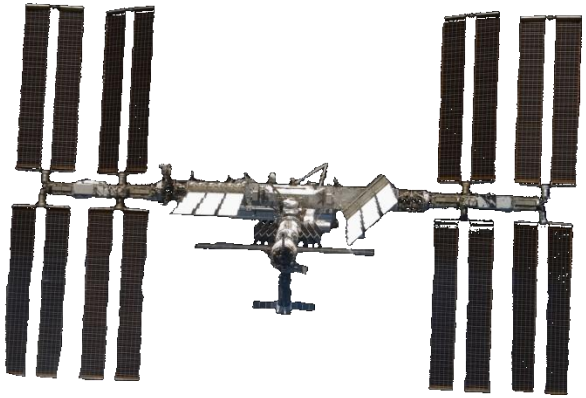


Serviceable future space telescopes

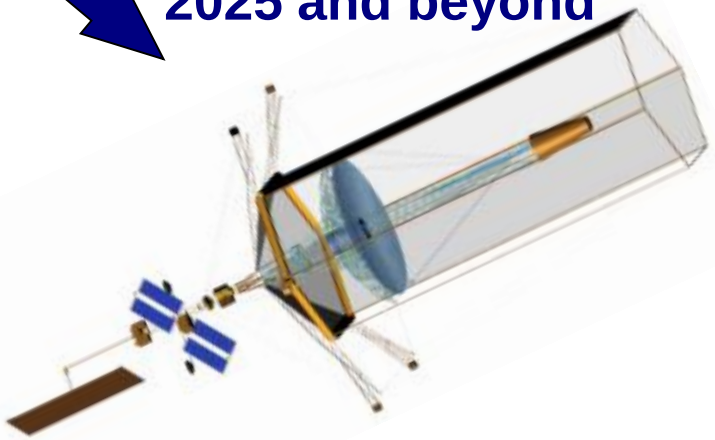
2012-2020

2019-2024

ISS demo of active space-based optical systems and advanced robotics for servicing and/or assembly



2025 and beyond



Assembly of Large Telescopes in Orbit