Planetary Science with Next Generation Large Astrophysics Missions

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Abstract

NASA's Great Observatories have pro-vided both astronomers and planetary scientists unique imaging and spectroscopic capabilities for many years. Solar System observations have typically been some of the most widely known to the community and the public. Current and new missions are now recognizing the significance in incorporating planetary science as a major role in the design, instrumentation, and operations that will reveal unprecedented science for solar system bodies. The far future astrophysics missions with on-orbit assembly for even larger space based facilities will be even more revealing and provide re-mote-sensing capabilities comparable to current in situ state-of-the-art instruments.

Introduction

Next generation airborne and space-based telescopes and instrumentation will work in con-cert with future in situ robotic crafts and large ground-based facilities to address key questions of chemical complexity, origin of life or biomolecules, and molecular inheritance throughout star and planet formation, to our own solar system. The Herschel Space Observatory, Hubble Space Telescope, Spitzer Space Telescope, and Kuiper Airborne Observatory have advanced re-search on virtually every topic in astrophysics and planetary science.

Future large telescopes offer unprecedented sensitivity and spatial resolution at wavelengths that are inaccessible from the ground due to the Earth's atmosphere, and provide global context for in situ missions. Their spectral regions host a number of significant molecular lines including: CO_2, H_2, NH_3, etc. For more complex species, disentangling the various molecular formation (and destruction) mechanisms, and therewith the origin of the chemical complexity observed in the interstellar medium and our Solar System, requires a multiwavelength approach to observe all molecular phases. Additionally, they provide broader perspectives in both targets and timelines for planetary missions that orbit, land, or fly-by a given target. Space observatories are not constrained to a specific target, and provide global context as well as source to source comparisons that are not always achieved from directed missions.

Figure 1. Summary of Astrophysics Decadal surveys and major missions from each.

James Webb Space Telescope

The James Webb Space Telescope (JWST) is an infrared-optimized observatory with a 6.5m-diameter segmented primary mirror and instrumentation that provides wavelength coverage of 0.6-28.5 microns, sensitivity 10X to 100X greater than previous or current facilities, and high angular resolution (0.07 arcsec at 2 microns) and low-moderate spectral resolution (R~100-3000) [1,2], see Figure 2. It offers multiple capabilities through 4 science instruments including: imaging, spectroscopy (slit, IFU, grism/prism), coronography, and aperture mask interferometry. JWST can observe all planets (Mars and beyond) in our solar system as well as Near-Earth Asteroids, Main Belt Asteroids, comets, satellites, as well as Trans-Neptunian Objects (TNOs). JWST is currently on schedule to launch in October of 2018 and will operate 5+ years after commissioning. This mission is timely for follow-up studies from Cassini and New Horizons and also provides unique timeline observations for the Galilean system prior to Juice, a Europa mission, etc.

Stratospheric Observatory for Infrared Astronomy

The Stratospheric Observatory for Infrared Astronomy (SOFIA) provides imaging and spectroscopic capabilities at wavelengths from 0.3-1600 microns, operating at 37,000+ ft, which is above 95% of atmospheric water vapor [3]. The observatory offers capabilities that include photometric, spectroscopic, and polarimetric observations. SOFIA provides access to the far-infrared as well as high spectral resolution that current space-based facilities do not offer, see Figure 3. The observatory is accessible, so regular upgrades to instrumentation can be made as needed. SOFIA is a unique facility that can observe a number of targets throughout the solar system (including Venus) that cannot be observed with other space telescopes. This facility can manipulate its flight plan to optimize occultation observations of satellites, TNOs, etc allowing for a perspective not always available with other observatories or missions. It also has a long lifetime that will allow for complementary studies with future planetary missions.

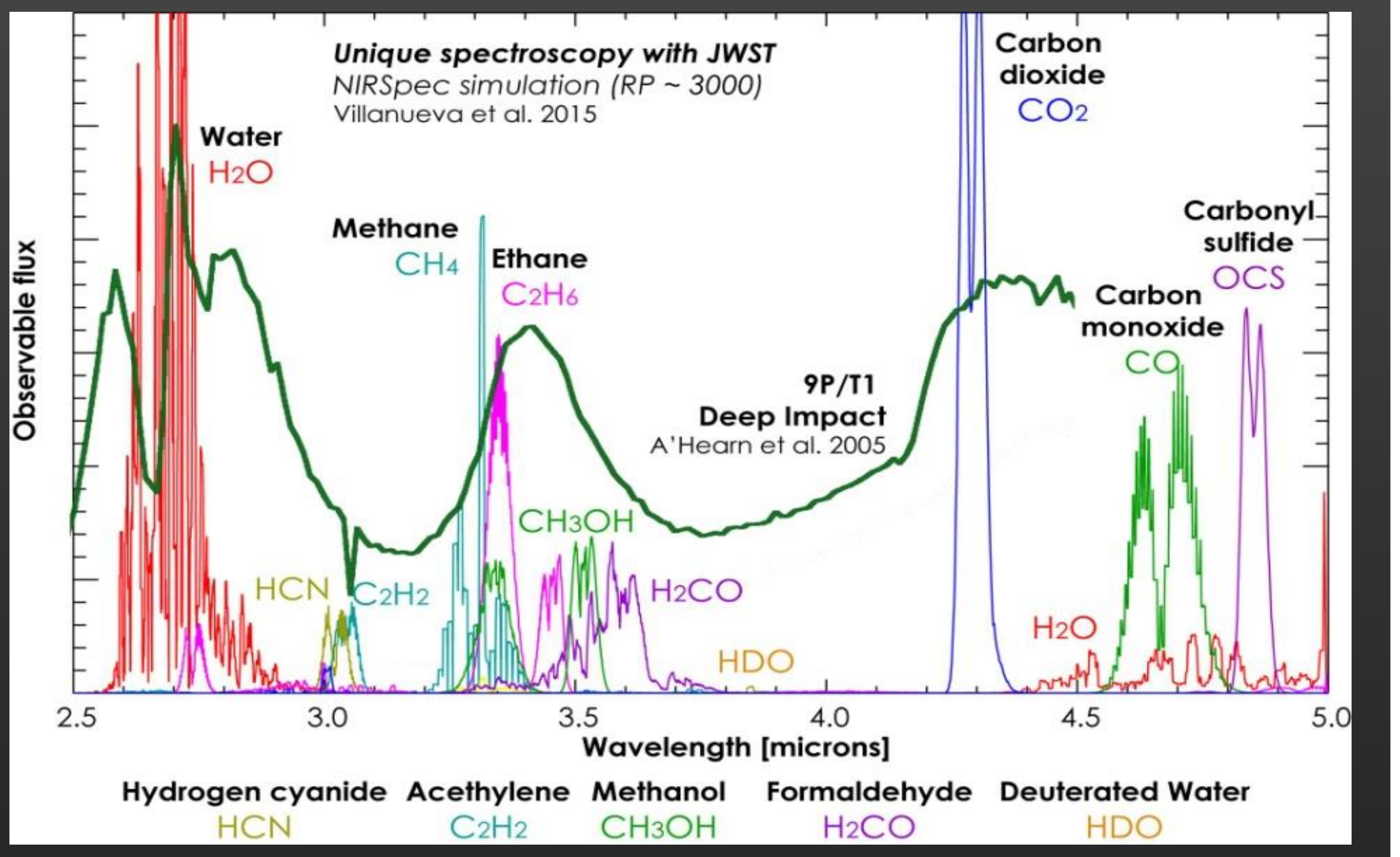

Figure 2. Simulated spectra of JWST at R~3000 with NIRSpec compared to Deep Impact spectra acquired from Comet 9P/Temple 1. From Milam et al. 2016.

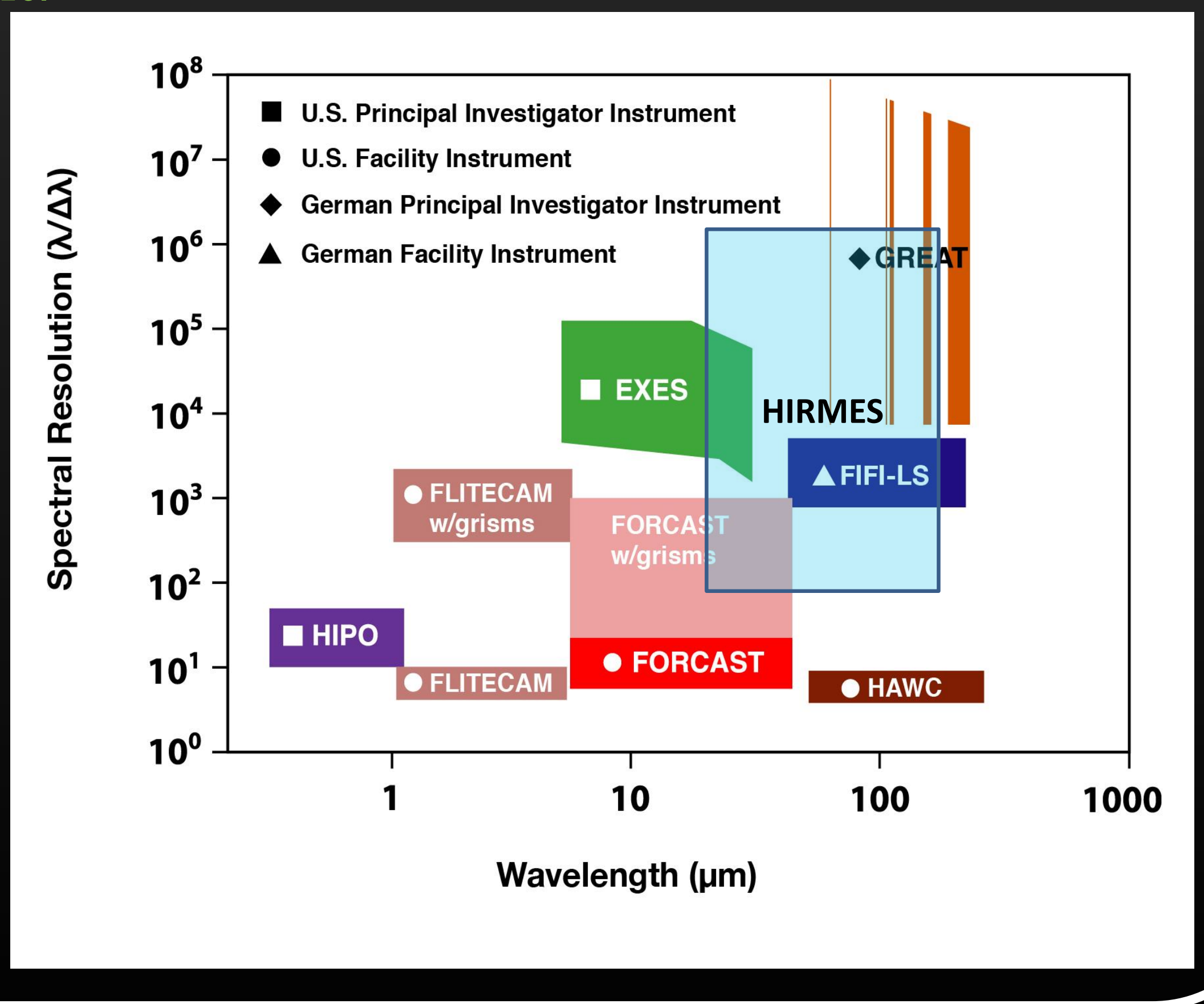

Figure 3. SOFIA's instruments showing spectral range and resolution.

Wide Field Infrared Telescope

NASA's Wide Field Infrared Survey Telescope (WFIRST) is NASA's next flagship mission after JWST. WFIRST is on track for a 2025 launch with a 6 year primary mission, see figure 4. This mission has two primary instruments: the Wide Field Instrument (WFI) with a 0.25 deg2 FOV and the Coronagraph Instrument (CGI) which is designed to take images and spectra of super-Earths. Between the two instruments, WFIRST will be capable of imaging and grism spectroscopy over the wavelength range 0.7-2 micron as well as R~100 spectroscopy with an IFU [4]. WFIRST will therefore be able to facilitate an array of small body science spanning surface mineralogy of asteroids and spectroscopic studies of comets to wide area surveys encompassing the more distant bodies in the solar system, including TNO populations.

Figure 4. The 2.4m optics of WFIRST that were obtained from the US National Reconnaissance office.

Beyond…

NASA's Astrophysics division has re-quested four new mission concept studies to be provided for the next Astrophysics Decadal survey to follow JWST and WFIRST. These include: the Far Infrared Surveyor (now the Origins Space Telescope or OST), see Figure 6 [5], the Large UV-Optical-IR telescope (LUVOIR), see Figure 5 [6], the X-ray Surveyor, and an Exoplanet mission (HabEx). These studies are currently underway and will be completed by early 2018. Two of these studies are strongly considering planetary science cases in con-straining the design and instrumentation – OST and LUVOIR.

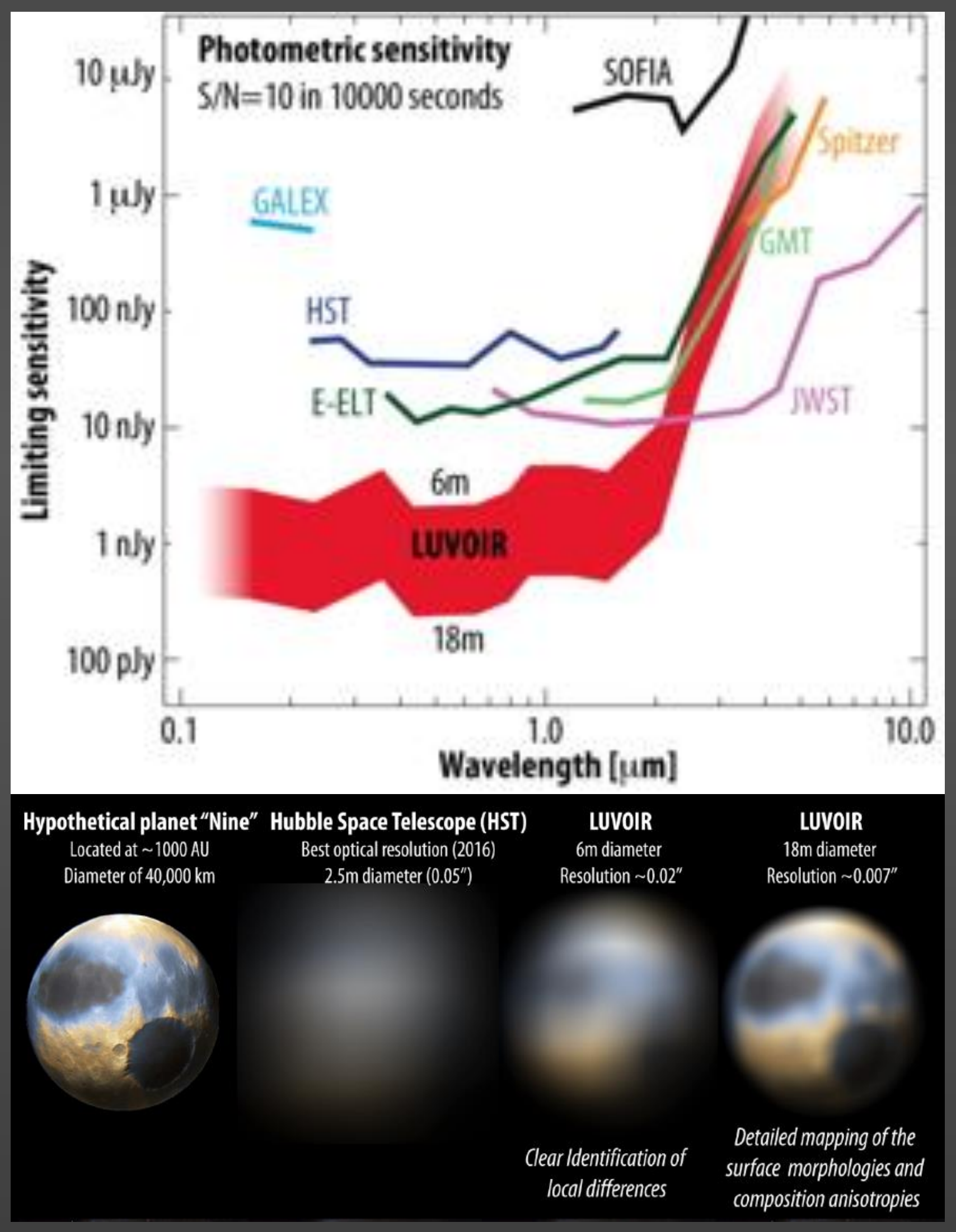

Figure 5. Upper: The LUVOIR proposed wavelength and sensitivity compared to other facilities. Lower: Simulation of LUVOIR imaging for a proposed Planet 9.

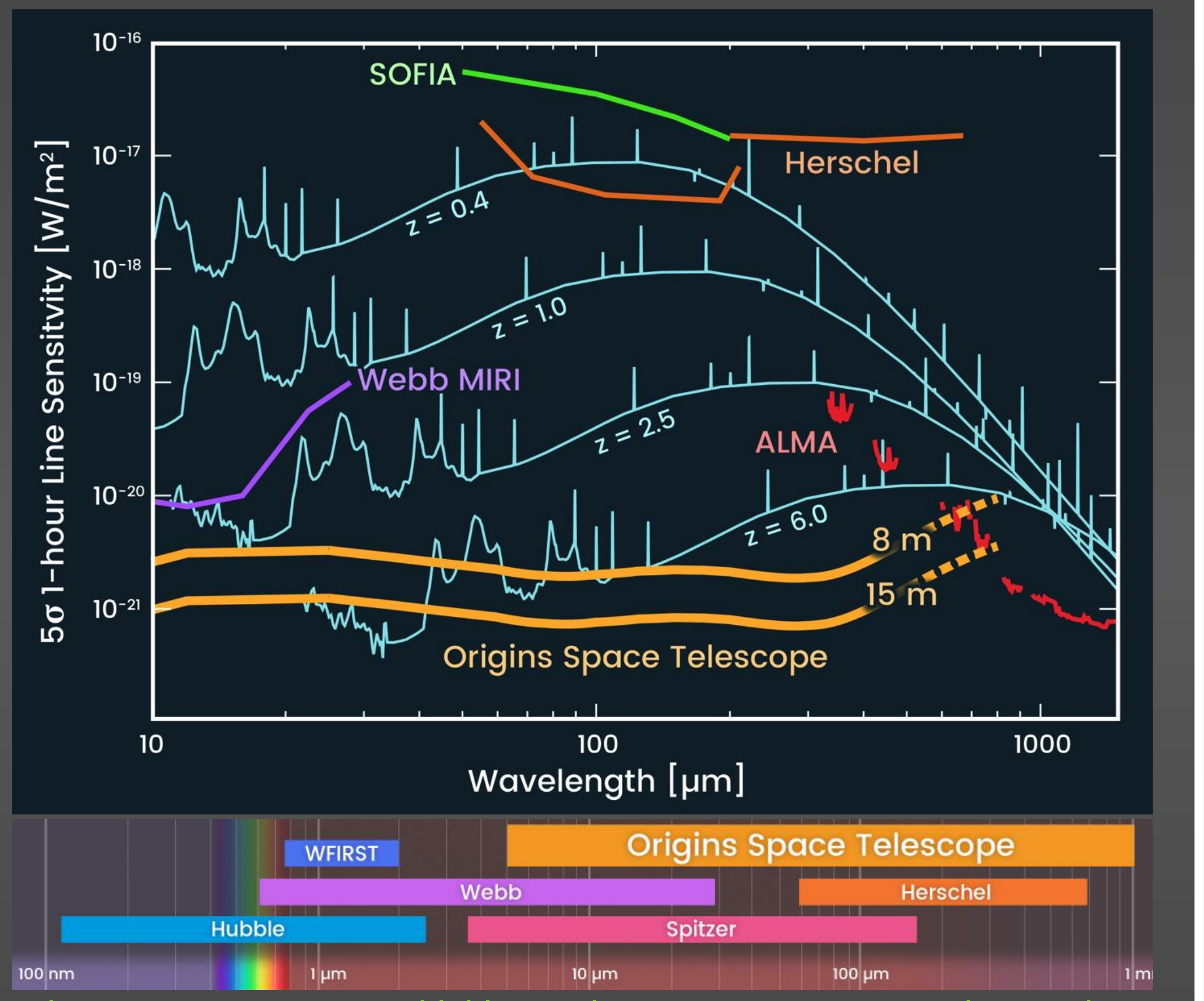

Figure 6. OST sensitivitiy and coverage compared to other facilities.

On-Orbit Assembly of Large Telescopes

Looking forward to the next astrophysics generation beyond LUVOIR or OST is likely to include even larger space observatories, 25m class, that consider new innovations to assemble large mirrors and components remotely [7]. This concept builds off of heritage from JWST deployment, segments, and testing as well as servicing to Hubble and the International Space Station. Notionally, a large mirror would be segmented and modular, such that current test facilities could be used for each component. The scientific implications for 25m class space telescopes reach beyond our most imaginative expectations. With extreme sensitivity and resolution, detailed studies of habitable worlds could be readily achieved. Additionally, the capabilities within the so-lar system will include ground-truths of in situ measurements on much broader scales. For example, to date, the Rosetta spacecraft has identified a number of complex, prebiotic species through mass spectroscopy on comet 67P/Churyumov–Gerasimenko [8], that can-not be measured remotely due to low abundances and limitations in sensitivity from the ground. Large space observatories will help reveal trace species in comets, as well as other solar system bodies with unprecedented new sensitivities and capabilities. Additionally, this can be achieved for not one target, but numbers of tar-gets to probe the true nature and composition of primitive bodies in the solar system. 25m class facilities can also offer context for Mars and Jupiter in situ measurements and even probe the composition of ocean worlds as revealed through minor atmospheric constituents, geysers, or volcanos.

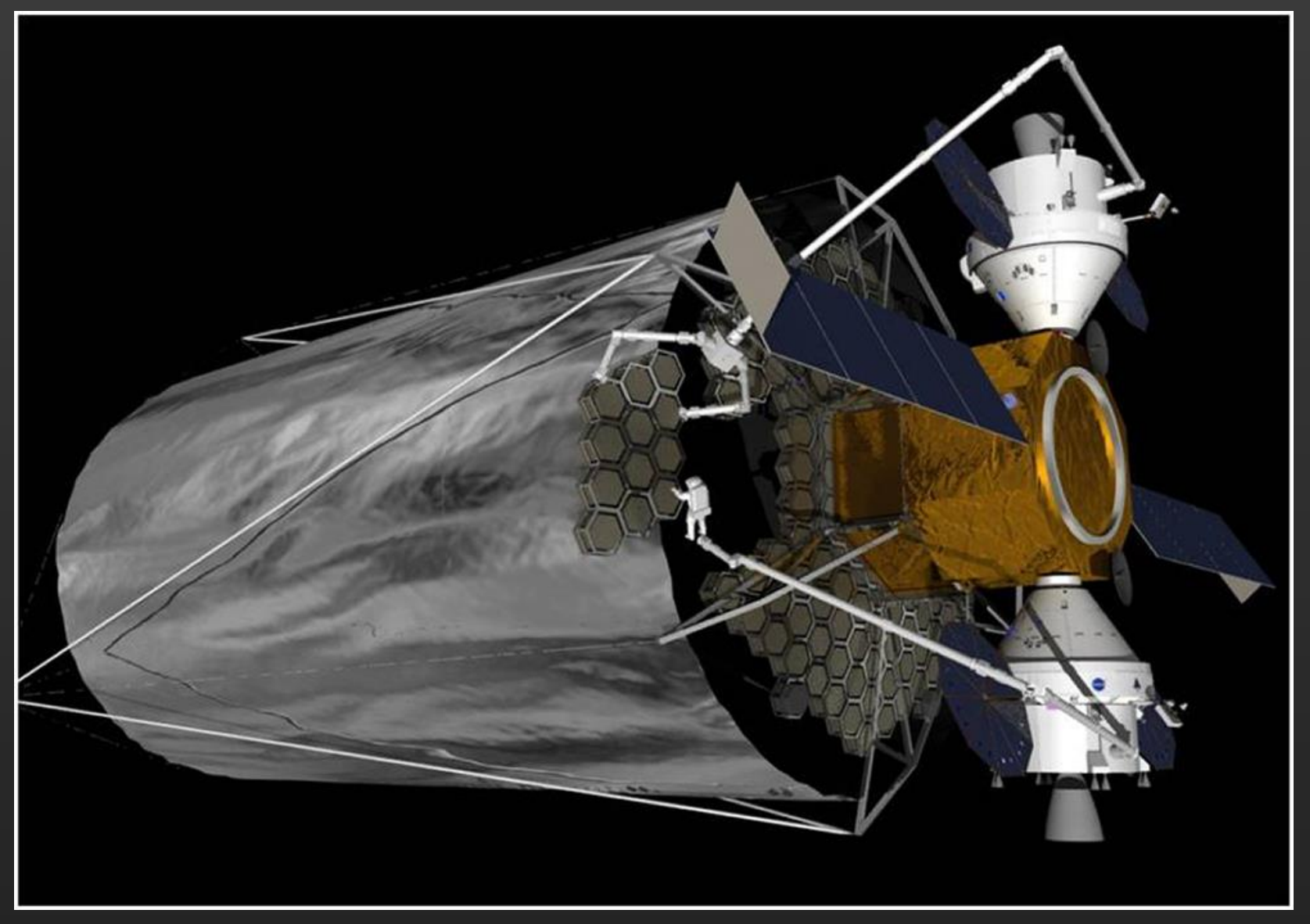

Figure 7. Notional 20-m telescope robot/astronaut installation of panels. From Feinberg et al. 2013.

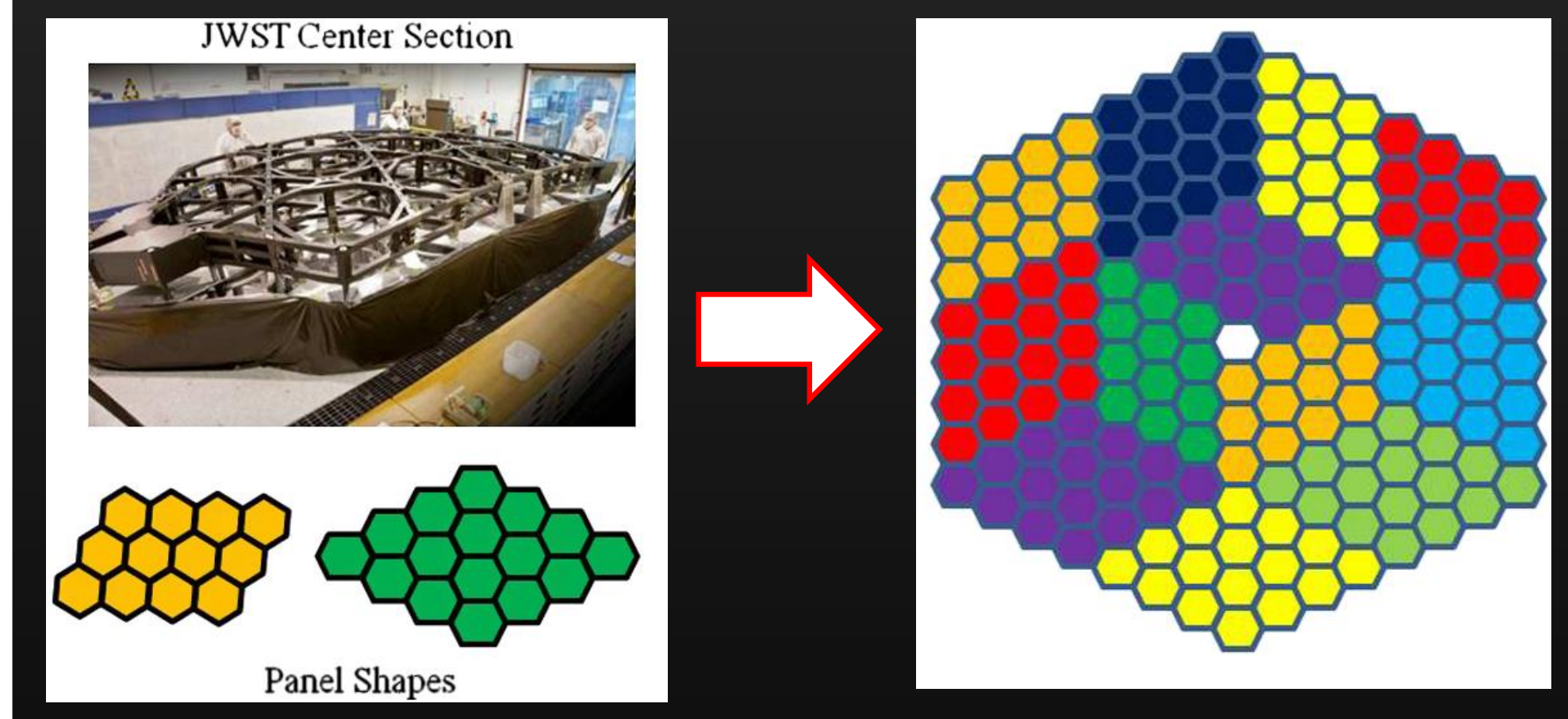

Figure 8. Primary mirror buildup from specific panel sizes. From Feinberg et al. 2013.

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