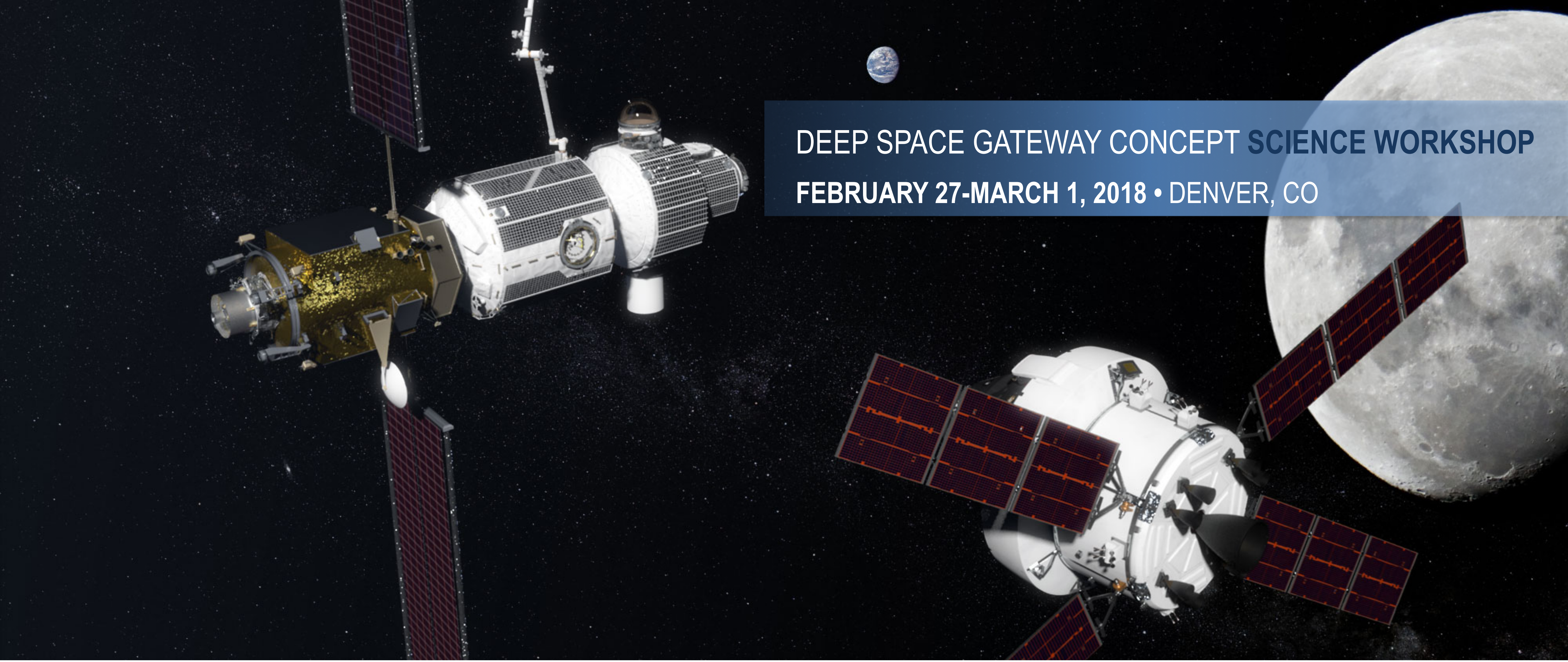


DEEP SPACE GATEWAY CONCEPT **SCIENCE WORKSHOP**

FEBRUARY 27-MARCH 1, 2018 • DENVER, CO

In-Space Assembly of Large Telescopes for Exoplanet Imaging and Characterization

February 28, 2018

CL#18-1114

Nick Siegler, NASA Exoplanet Exploration Program, Jet Propulsion Laboratory, California Institute of Technology

Enormous Public Interest in Exoplanets


"All the News That's Fit to Print"

The New York Times

VOL. CLXVI . . . No. 57,517 © 2017 The New York Times Company NEW YORK, THURSDAY, FEBRUARY 23, 2017

JPL-CALTECH/NASA

A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

Circling a Star Not Far Away,

Uber's Culture Of Gutsiness

Migrants Hide, Fearing Capture on 'Any Corner'

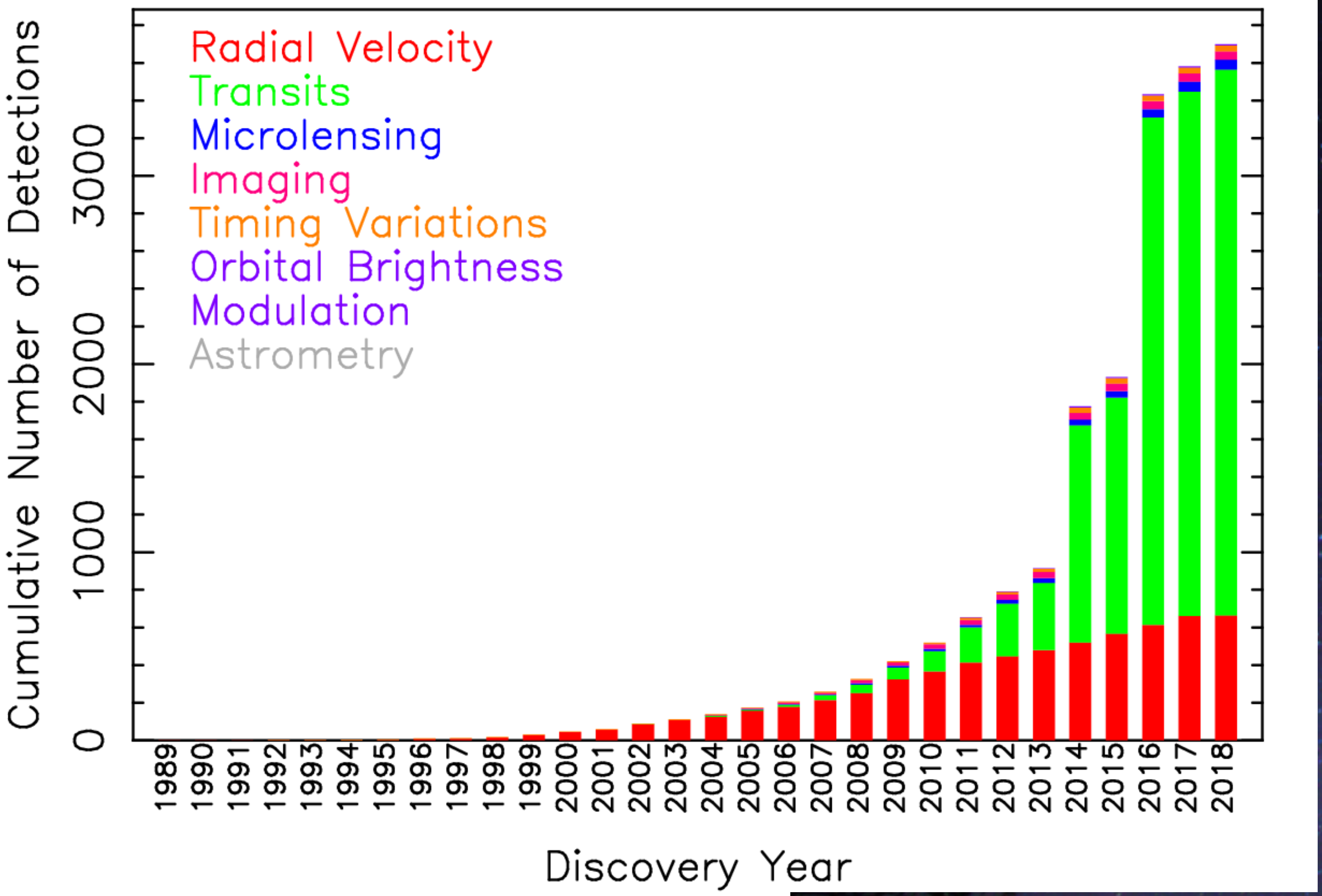
By VIVIAN YEE

IMMIGRATION A police depart-

duras.

If deportation has always been

More than 3700 Exoplanets Discovered to Date



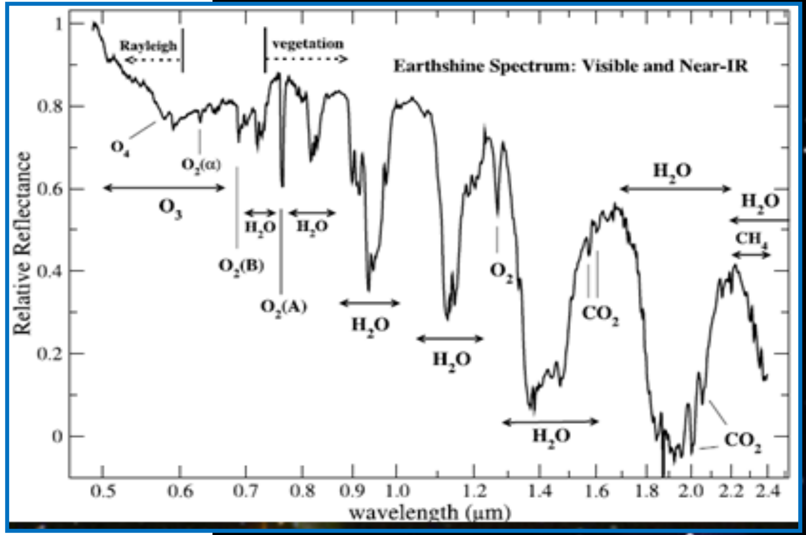
https://exoplanetarchive.ipac.caltech.edu/

There is on average at least one planet for each of the stars in our Galaxy…

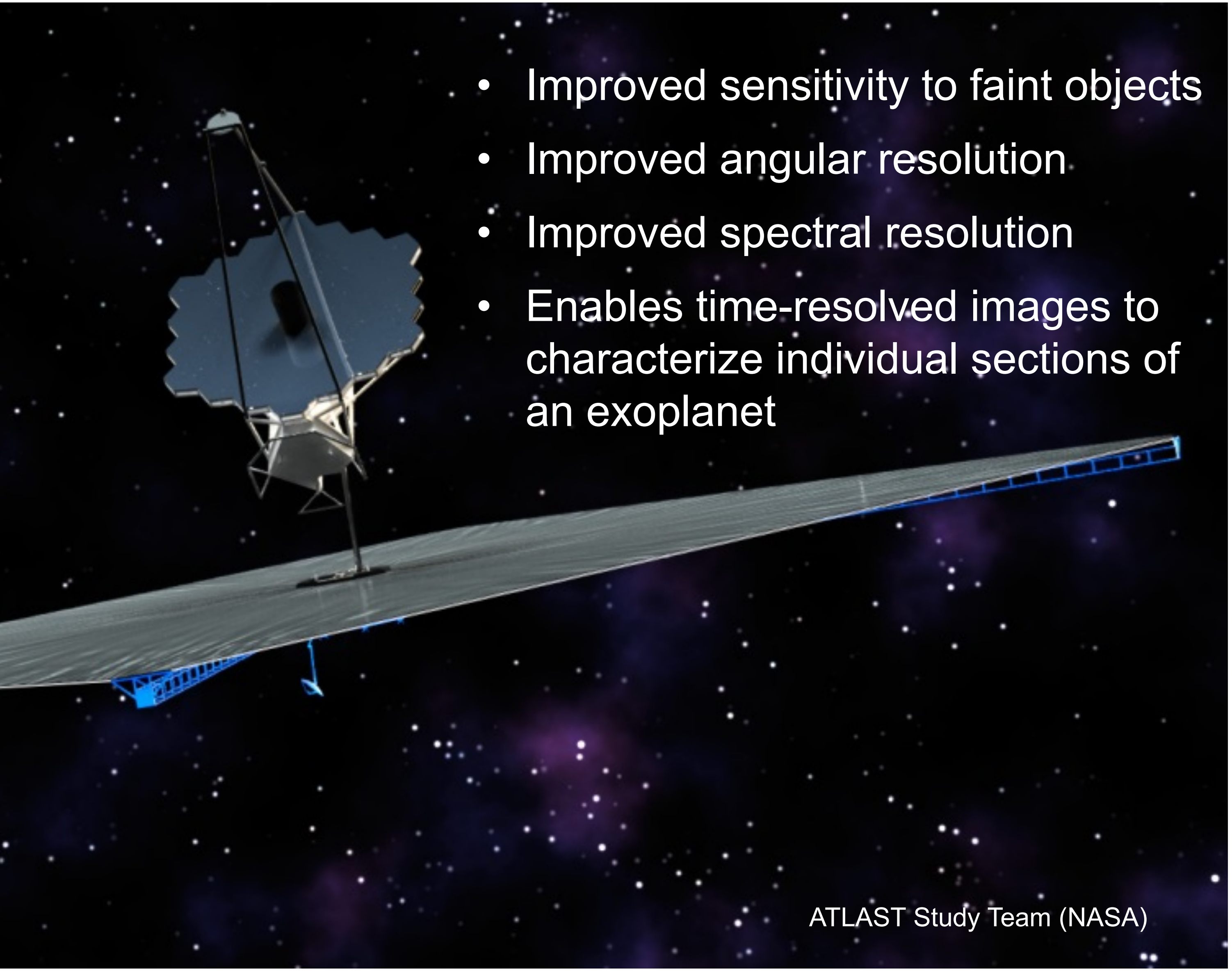
… and most likely a planetary system.

But do any harbor life?

In the Search for Life Bigger is Better



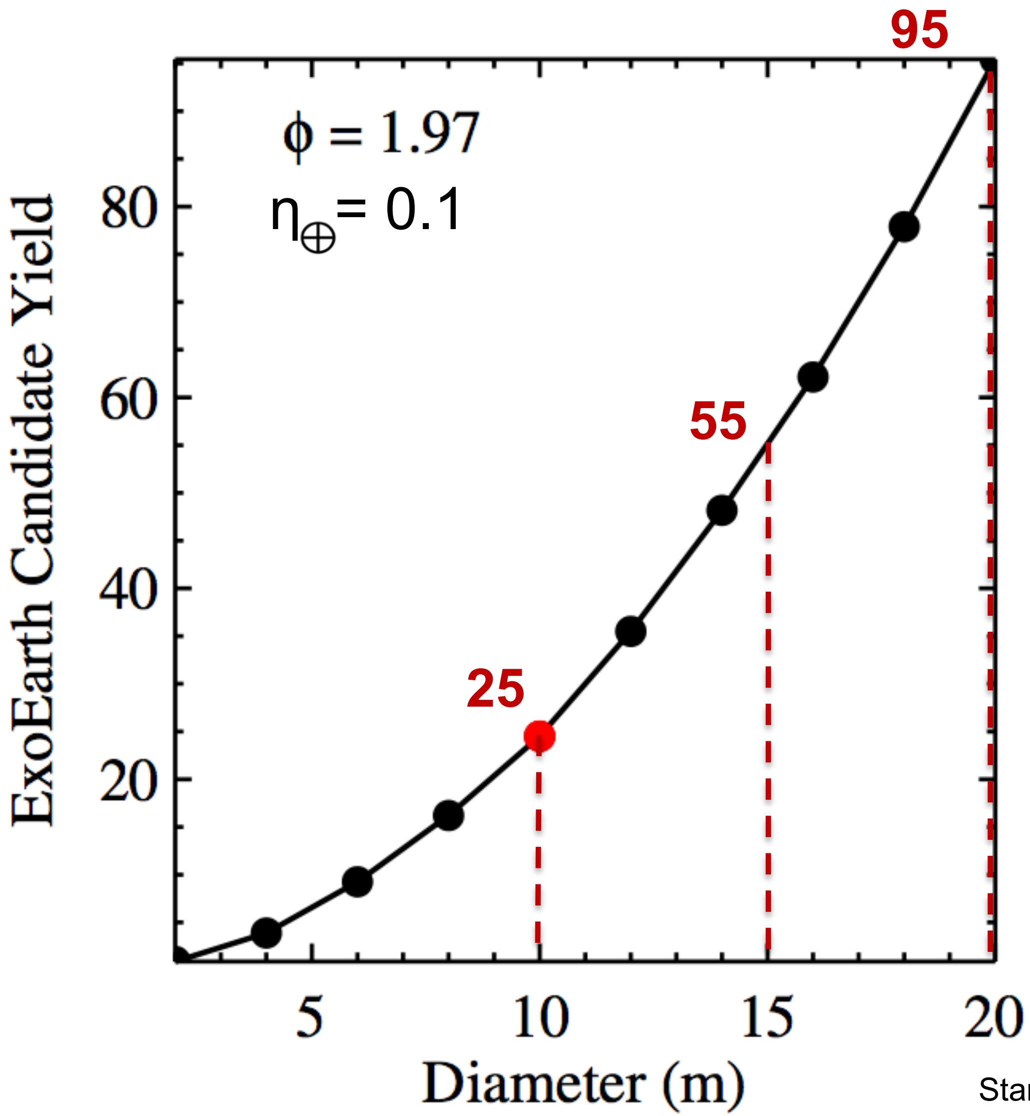
Turnbull et al 2006



- Improved sensitivity to faint objects
- Improved angular resolution
- Improved spectral resolution
- Enables time-resolved images to characterize individual sections of an exoplanet

ATLAST Study Team (NASA)

Number of Candidate ExoEarths Increases with Aperture



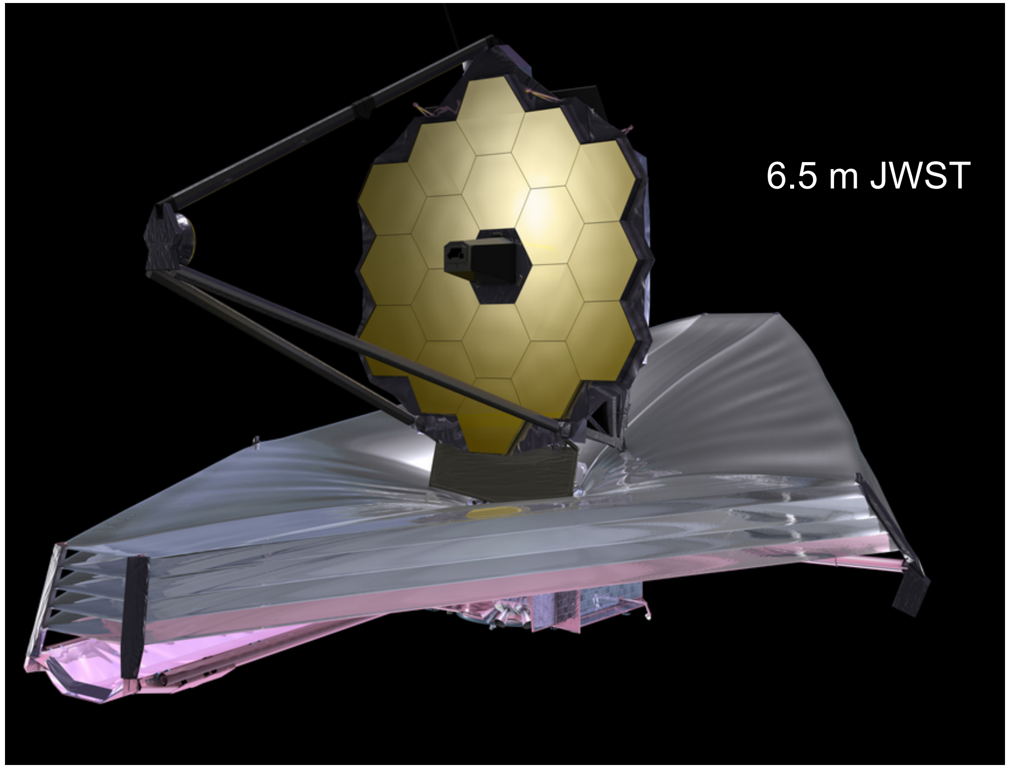
Stark et al. 2015

Other advancements in astrophysics with large aperture telescopes:

- **Constraining the nature of dark matter**
- **Understanding the formation of the earliest galaxies**
- **Observing gravitational wave precursors (binaries) just prior to collision**

Current Paradigm: Telescope Size Currently Limited by LV

Ariane 5 (4.6 m fairing)

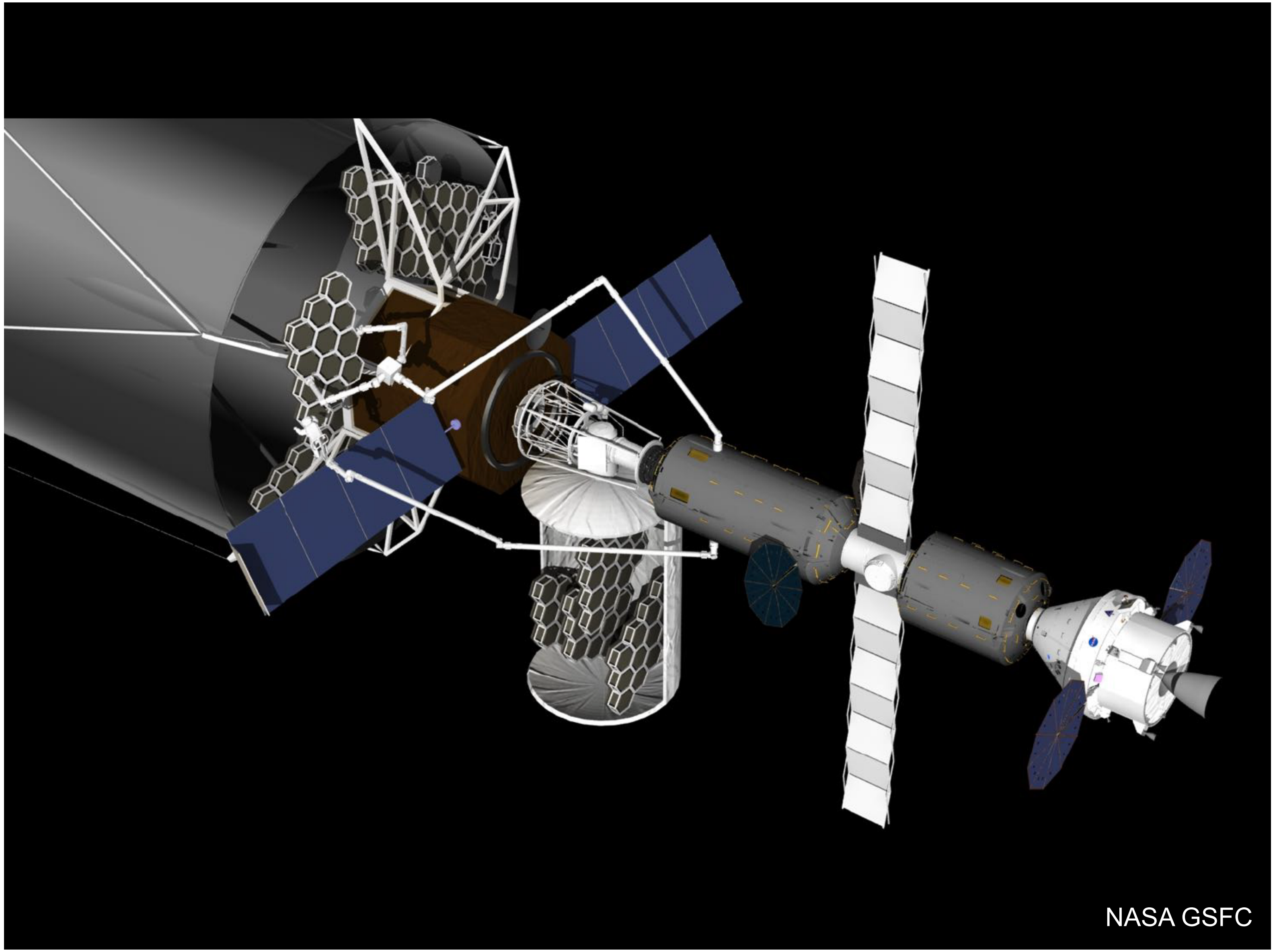


Falcon Heavy (5.2 m fairing) – 9 m telescope
SLS Block I (8 m fairing) – 12 m telescope
SLS Block II (10 m fairing) – 15 m telescope
? – ≥ 20 m telescope

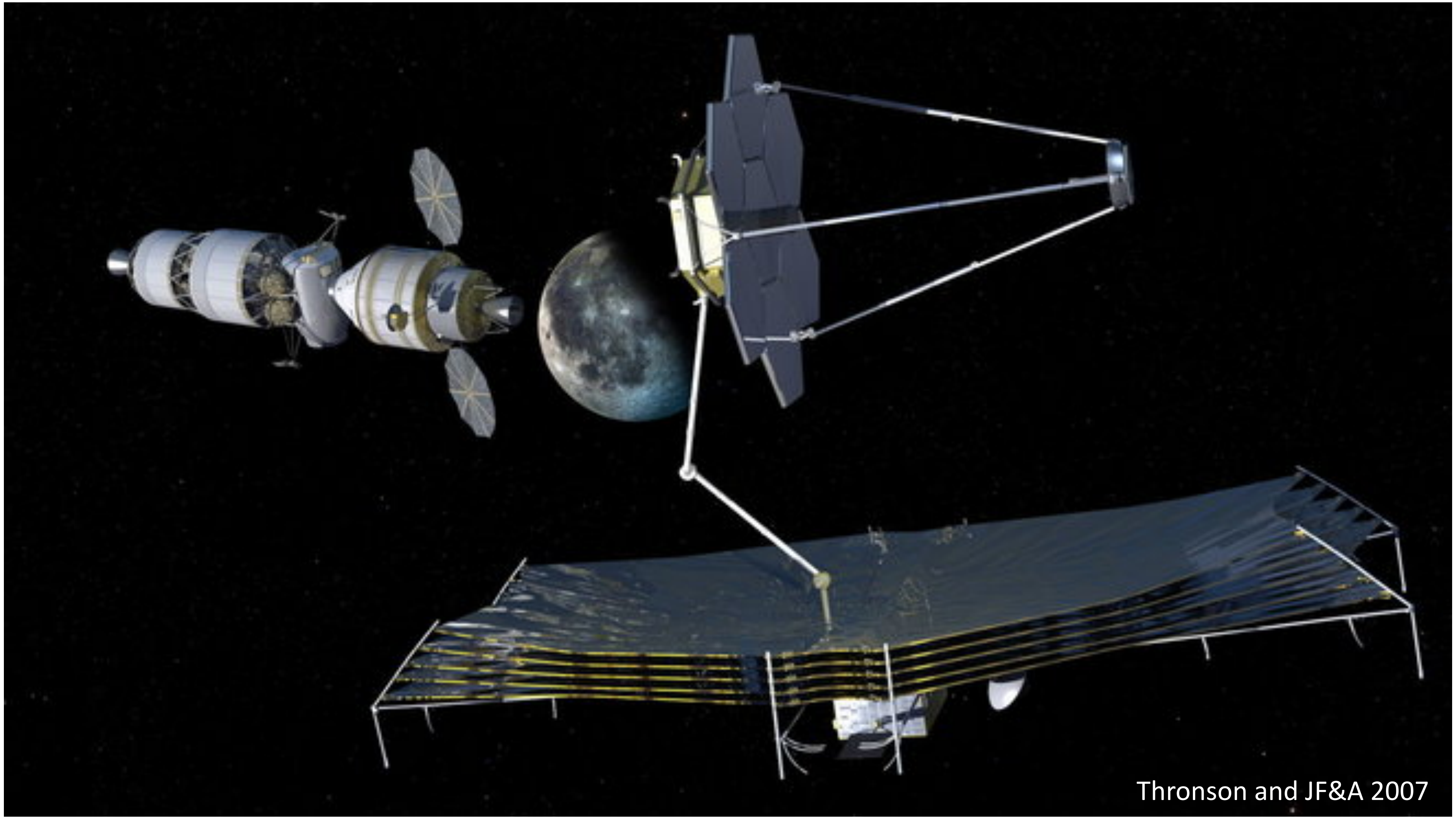
Deep Space Gateway: in-Space Assembly of Large Spacecraft

Potential Benefits of in-Space Assembly

- Enabling for structures that even folded do not fit in LV fairing
- Lower cost than autonomous deployment? (and breaking the cost curve)
- Lower risk than autonomous deployment?



Deep Space Gateway: in-Space Servicing of Large Spacecraft



Telescope returns from SEL2 for servicing at EML1

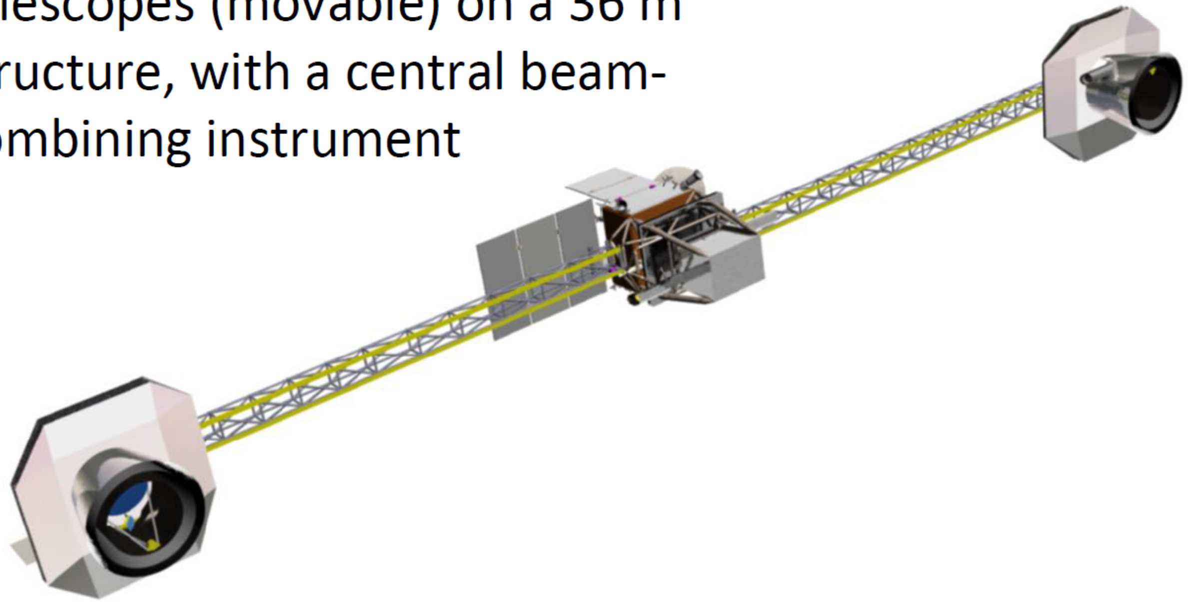
Benefits of in-Space Servicing

- Upgrade instrument payloads
- Upgrade spacecraft subsystems
- Refuel spacecraft to extend lifetime
- Repair when needed
- Incrementally enlarge aperture size with additional mirrors

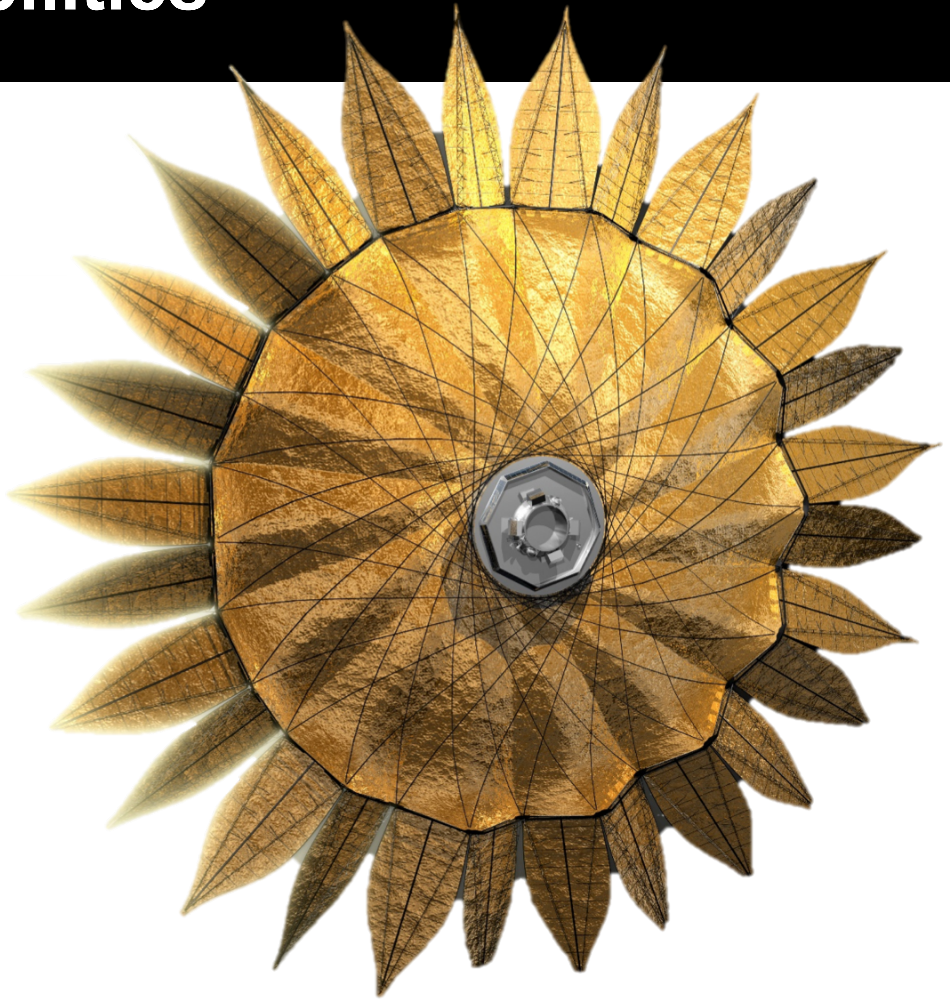
Other Spacecraft Assembly Possibilities

Interferometers

Two 1-m diameter cryo-cooled telescopes (movable) on a 36 m structure, with a central beam-combining instrument



SPIRIT, David Leisawitz (NASA GSFC)



Starshades

Starshade deployed to block light from central star, allowing orbiting exoplanet to be observed.

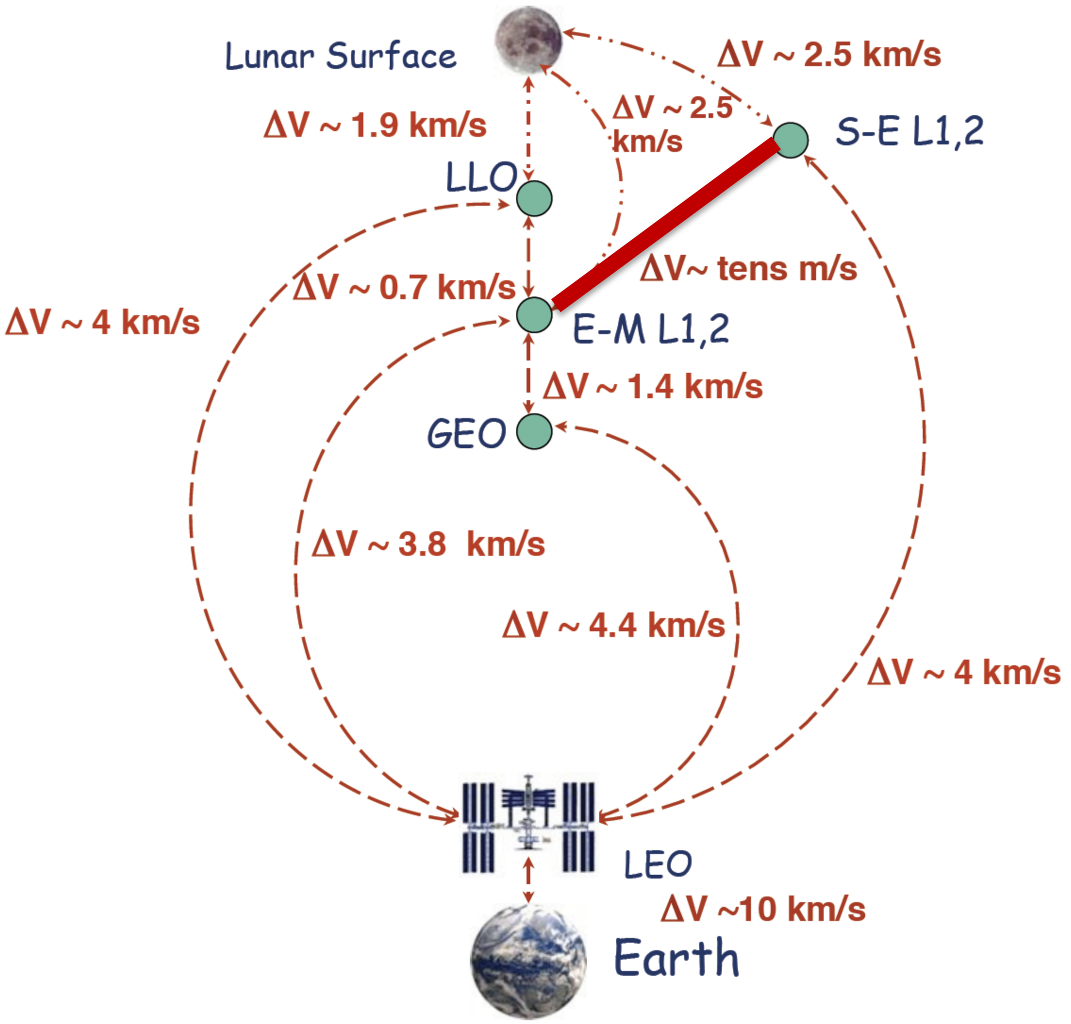
NASA/JPL/Caltech

Why the Deep Space Gateway?

- **Cis-lunar orbit is ideally accessible to Sun-Earth L2**
  - Δv ~ 10's of m/s
  - Low propulsion needs to go back and forth (EML1 <---> SEL2) for servicing

- **Expected to offer both astronaut and tele-robotics capabilities**

- **Expected to be equipped with important infrastructure**
  - High-data rate communication, versatile imaging systems, robotic arms, astronaut support

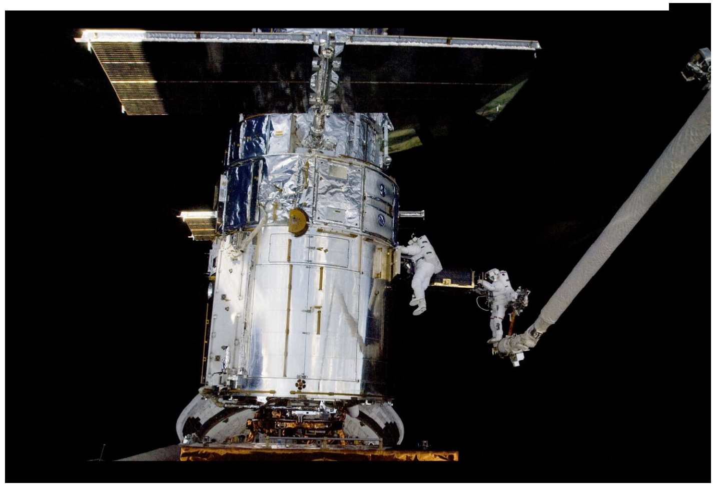


NASA's Decade Planning Team (2000)

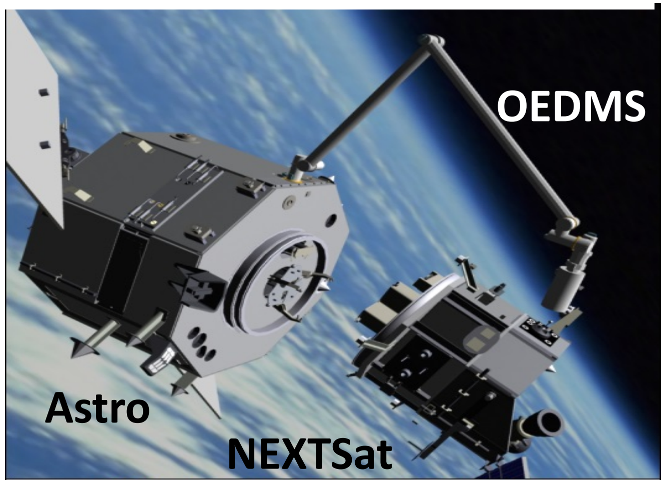
Status of Work in this Field: in-Space Servicing

Servicing activities are accelerating with government and commercial involvement.

NASA - HST

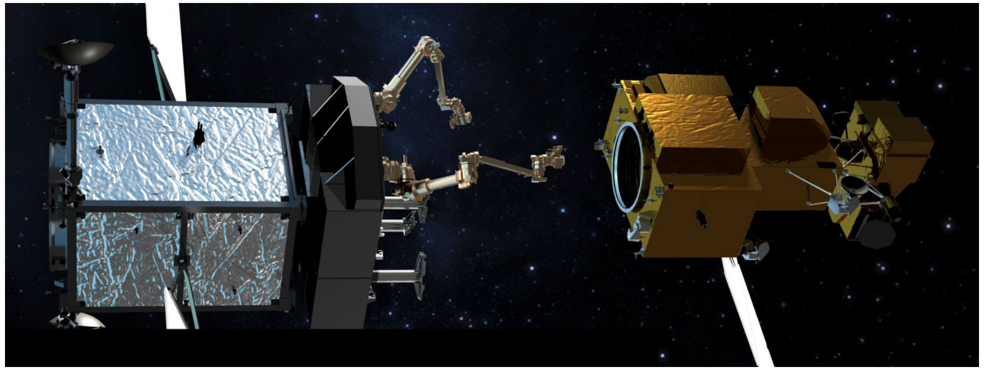


DARPA - Orbital Express

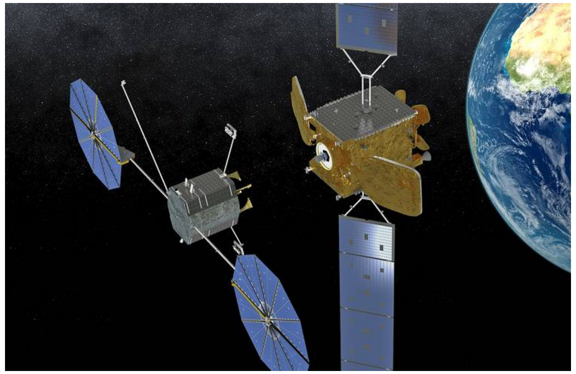


DARPA - Robotic Servicing of Geosynchronous Satellites

NASA - Restore-L

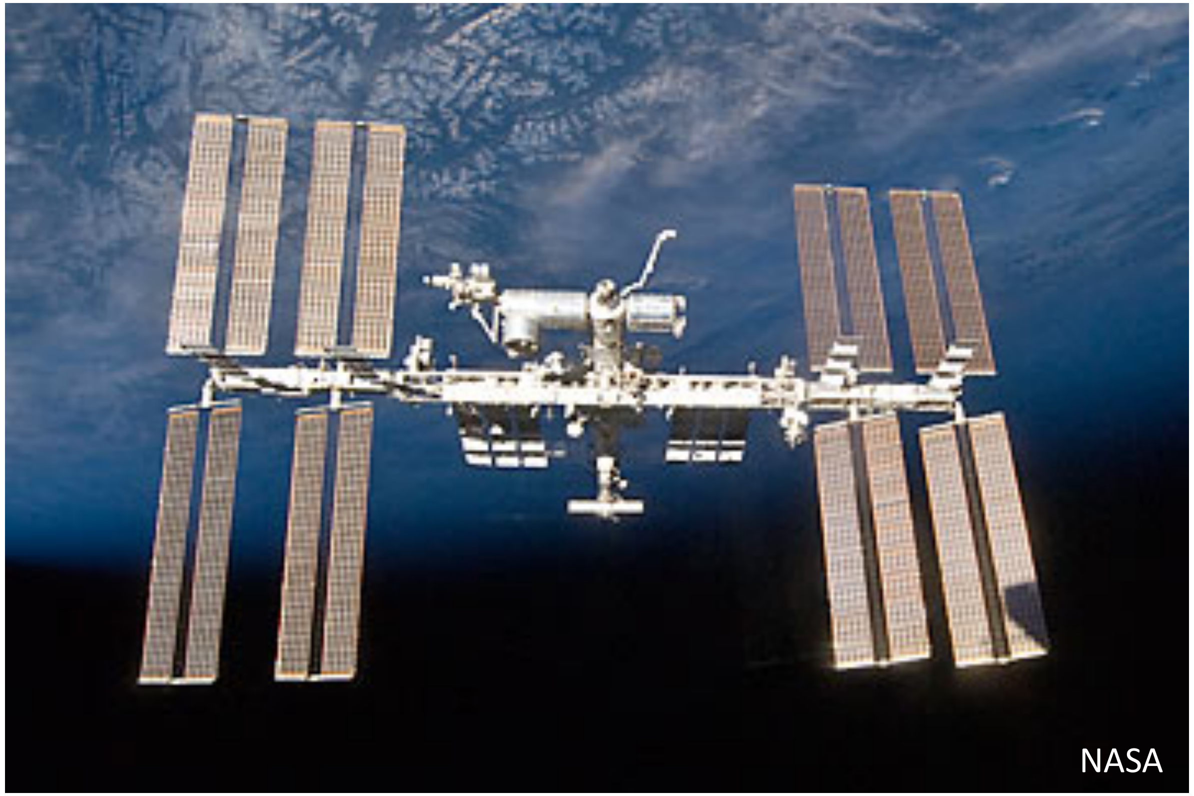


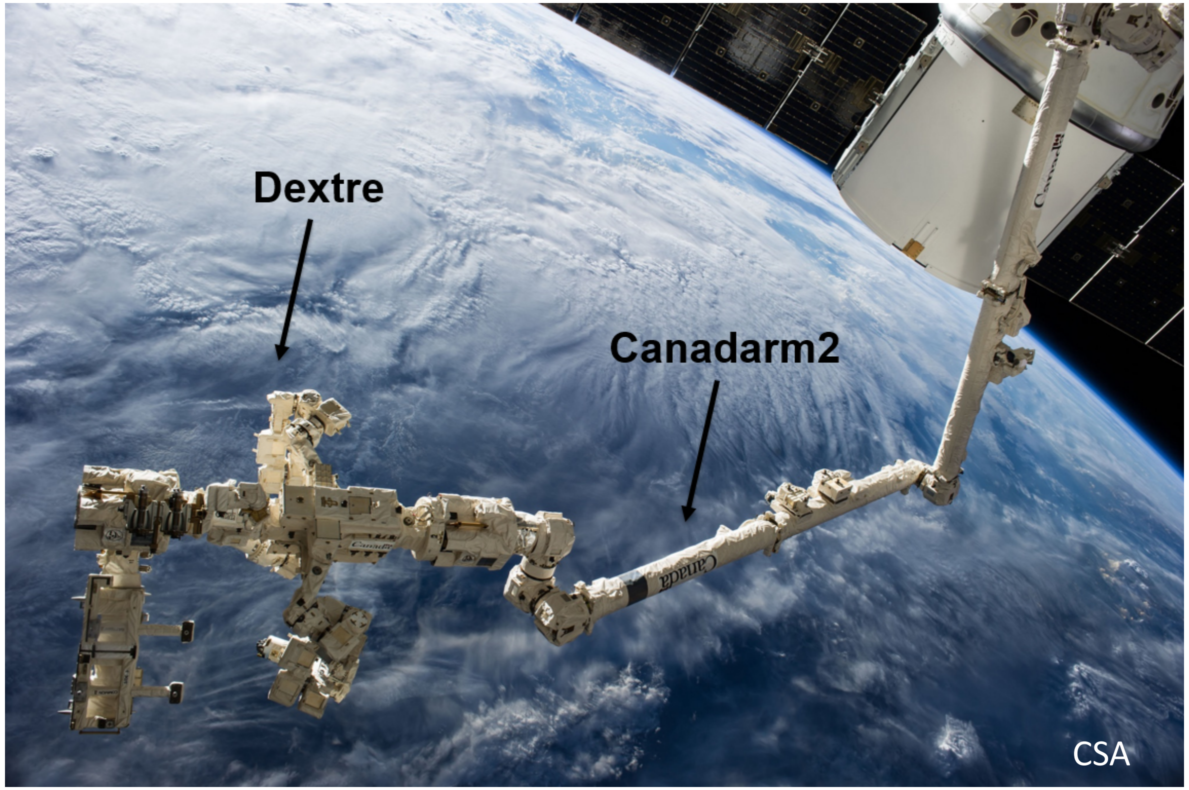
Orbital ATK - Mission Extension Vehicle



Status of Work in this Field: in-Space Assembly

ISS is the best example of large-scale assembly in space.





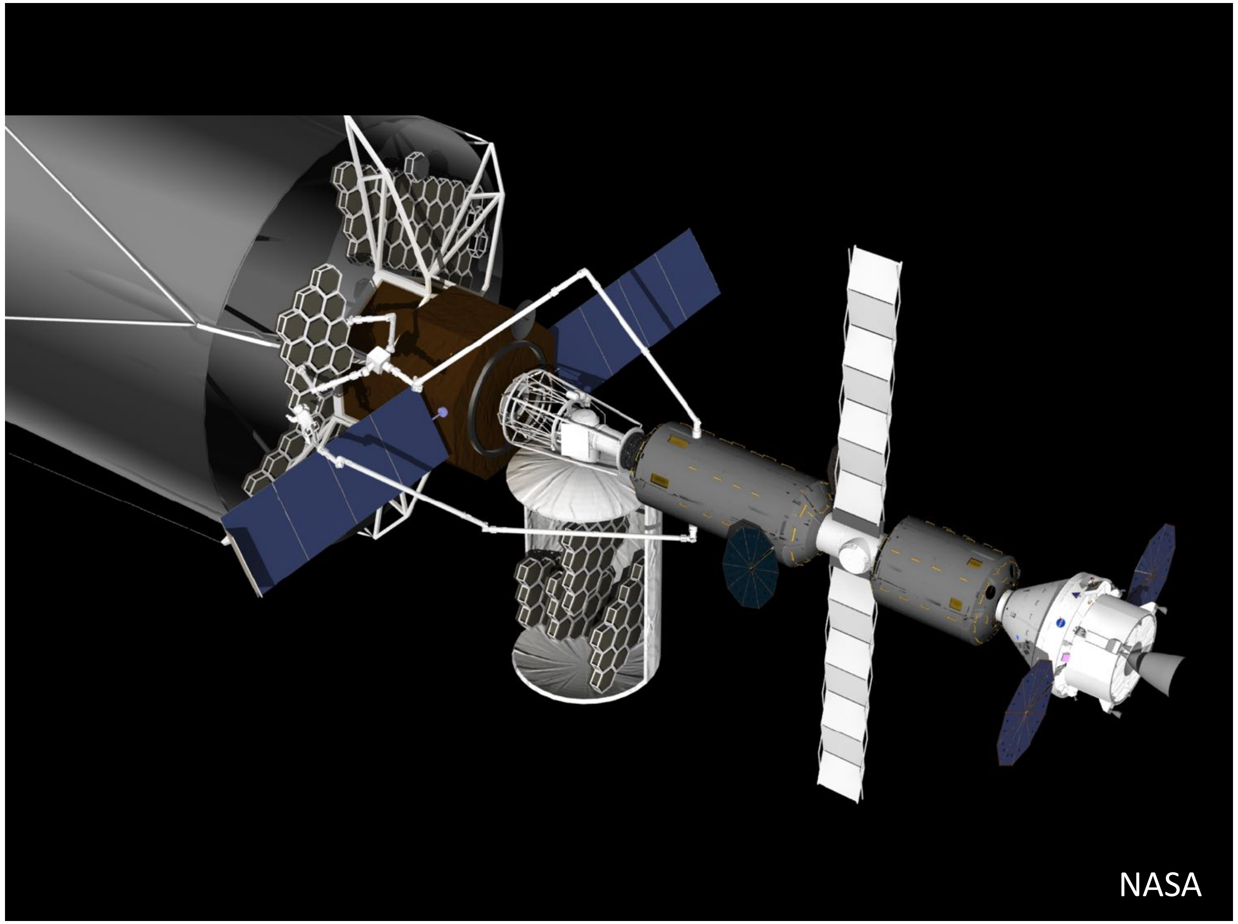
But no precision assembly activities currently planned.

Potential Capability Needs of the Gateway

Proximity operations (docked during assembly; not docked during servicing)

Autonomous and dexterous external robotic arms capable of assembling and servicing

Berthing points for unpressurized cargo containers



Telerobotic operations from both Earth and Gateway

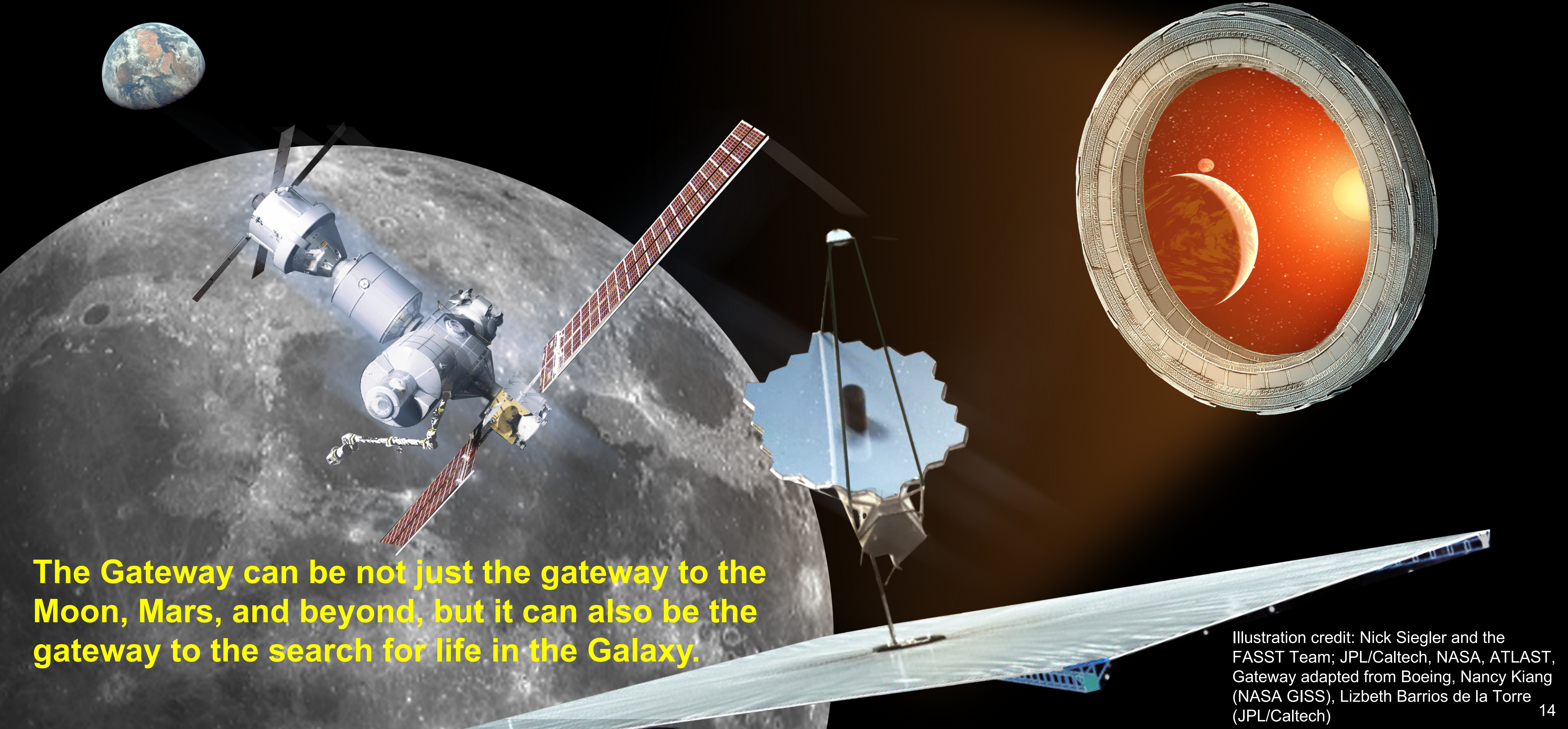
Astronaut EVAs

Defined power, propulsion, attitude control

Quiescent environment

Photogrammetry capabilities

GATEWAY TO DEEP SPACE
and
GATEWAY TO THE SEARCH FOR LIFE IN THE GALAXY



The Gateway can be not just the gateway to the Moon, Mars, and beyond, but it can also be the gateway to the search for life in the Galaxy.

Illustration credit: Nick Siegler and the FASST Team; JPL/Caltech, NASA, ATLAST, Gateway adapted from Boeing, Nancy Kiang (NASA GISS), Lizbeth Barrios de la Torre (JPL/Caltech)

Acknowledgment

Website: https://exoplanets.nasa.gov/exep/technology/in-space-assembly/

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- Brad Peterson (OSU/STScI)
- Howard MacEwen (Reverisco, LLC)
- John Grunsfeld (NASA retired)

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Backup/Additional Information

Instrument Function Statement and Gateway Usage

STATEMENT	INSTRUMENT/CONCEPT DETAILS
FUNCTION STATEMENT ***The Gateway offers a platform to assemble large space telescopes and other large structures in space, test them, and release them onto the low delta-v highway to multiple other locations in the Sun-Earth-Moon system.***	*The concept details are still TBD, however, we envision one of the Gateway modules equipped with 1-2 robotic arms to play the leading role in the spacecraft assembly. Supply vessels would dock with the Gateway, accessible to the arm. The spacecraft to be assembled (e.g. telescope) will have its bus docked and likely act as a central hub in the assembly. Commands will be sent by either astronauts aboard the Gateway or directly from the ground; robotics expected to have scripted assembly tasks once initiated.*
WHY IS THE GATEWAY THE OPTIMAL FACILITY FOR THIS INSTRUMENT/RESEARCH? ***The Gateway offers two unique features: (1) a facility that may be equipped with advanced telerobotics, astronaut tele-command, and EVA and (2) an orbit that permits low delta-v access to multiple venues in the Sun-Earth-Moon system.***	*The concept details are still TBD, however, thanks to the astronaut program, we expect the Gateway to be equipped with important infrastructure such as high-data rate communication, versatile imaging systems for inspection and photogrammetry, robotic arms, and astronaut EVA capabilities.*

Basic Instrument Parameters

PARAMETER	INSTRUMENT ESTIMATE & ANY COMMENTS
MASS (KG)	Order of magnitude tons
VOLUME (M)	Roughly 20 m cube (in case of 20 m aperture telescope); in the case of a starshade (70 m x 20 m x 20 m); in the case of an interferometer (40 m x 10 m x 10 m)
POWER (W)	TBD
THERMAL REQUIREMENTS	TBD
DAILY DATA VOLUME	Video streaming, telemetry
CURRENT TRL	2
WAG COST & BASIS	TBD (order of billions)
DURATION OF EXPERIMENT	Assembly and testing are expected to require order of months
OTHER PARAMETERS	Will need re-supply vehicles with components and sub-assemblies for robotic assembly

Instrument Gateway Usage

USAGE	INSTRUMENT REQUIREMENTS & COMMENTS
ORBIT CONSIDERATIONS	The cis-lunar orbit with the lowest delta-v to SEL2 is preferred; otherwise general cis-lunar orbit is fine.
FIELD OF VIEW REQUIREMENTS	Inspection of assembly; ideally view of berthing port from habitat
REQUIRES USE OF AIRLOCK	Potential astronaut EVAs for inspection, but not for assembly (open trade)
CREW INTERACTION REQUIRED?	Not nominally required, but may be required for anomaly resolution and contingencies. This may include EVAs for inspection.
WILL ASTRONAUT PRESENCE BE DISRUPTIVE?	Potentially during assembly testing and calibration.
DOES THE INSTRUMENT PRESENT A RISK TO THE CREW	No; assembly process and structure are external to the Gateway.
OTHER CONSUMABLES REQUIRED	Electrical power; if astronaut EVAs are required then additional consumables
SPECIAL SAMPLE HANDLING REQUIREMENTS	No
NEED FOR TELEROBOTICS?	Yes; we envision 1-2 robotic arms comparable to those on the ISS external to the Gateway. They will be used for robotic assembly (e.g. telescope module)

Instrument Gateway Usage

USAGE	INSTRUMENT REQUIREMENTS & COMMENTS
OTHER REQUIREMENTS OF THE GATEWAY?	At least two berthing ports, one of which will be dedicated for instrument/ spacecraft (e.g. telescope, starshade), rendezvous proximity operations, situational cameras external to the Gateway, quiescent environment (protection of optics), power and comm interfaces for robotic arm mobility (e.g. ISS), available large workspace external to Gateway for instrument assembly, robust ACS capabilities to handle large moments of inertia from external assembled payloads