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Building the Future: In-Space Assembled Telescopes

Future Assembly & Servicing Space Telescopes (FASST) Status Report

Harley Thronson (NASA GSFC), Nicholas Siegler (JPL/Caltech),
Rudranarayan Mukherjeee (JPL/Caltech), Lynn Bowman (NASA LaRC),
Matthew Greenhouse (NASA GSFC), John Grunsfeld (NASA GSFC *emeritus*),
Howard MacEwen (Reverisco LLC),
Bradley Peterson (Ohio State Univ/STScI),
& Ronald Polidan (PSST, LLC)

What’s this about?

- NASA’s highest-priority science goals require UVOIR space telescope apertures substantially larger than JWST, but at a manageable cost.
- Key capabilities are being developed by multiple sources that may make in-space assembly (iSA) feasible, where aperture is not constrained by launch vehicle.
- Our team, working with colleagues at GSFC, STScI, LaRC, and elsewhere just initiated its second year of engineering design work on a 20-meter UVOIR space observatory intended to be assembled in space.
- Near-term goal in spring 2019 is report on a proof of concept in to Astro2010, the National Academies’ Decadal Survey

Science enabled by iSA and iSA panel discussions on technology, multi-agency coordination, other studies, etc. on Wednesday morning, 1000-1230 in Bayhill 17/18.

This work supported in FY18 & FY19 by NASA HQ SMD Astrophysics Division.

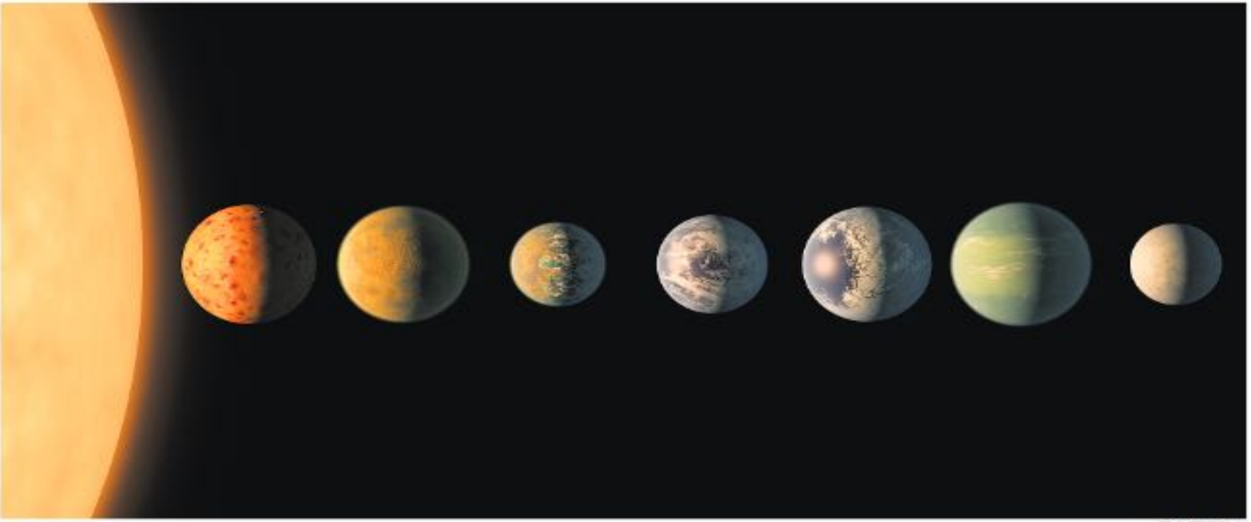
"All the News That's Fit to Print"

The New York Times

Late Edition

Today, patchy morning fog, partly sunny, warm, high 64. Tonight, mostly cloudy, mild, low 52. Tomorrow, clouds and sunshine, showers, high 66. Weather map is on Page B9.

VOL. CLXVI ... No. 57,517 © 2017 The New York Times Company NEW YORK, THURSDAY, FEBRUARY 23, 2017 $2.50



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.

TRUMP RESCINDS OBAMA DIRECTIVE ON BATHROOM USE

ENTERING CULTURE WARS

Question of Transgender Rights Splits DeVos and Sessions

This article is by Jeremy W. Peters, Jo Becker and Julie Hirschfeld Davis.

WASHINGTON — President Trump on Wednesday rescinded protections for transgender students that had allowed them to use bathrooms corresponding with their gender identity, overruling his own education secretary and placing his administration firmly in the middle of the culture wars that many Republicans have tried to leave behind.

In a joint letter, the top civil rights officials from the Justice Department and the Education Department rejected the Obama administration's position that nondiscrimination laws require schools to allow transgender students to use the bathrooms of their choice.

That directive, they said, was improperly and arbitrarily devised, "without due regard for the primary role of the states and lo-

Circling a Star Not Far Away, 7 Shots at Life

By KENNETH CHANG

Uber's Culture Of Gutsiness Under Review

By MIKE ISAAC

Migrants Hide, Fearing Capture on 'Any Corner'

By VIVIAN YEE

No going to church, no going to the store. No doctor's appointments for some, no school for others. No driving, period — not

IMMIGRATION A police department worries a crackdown will harm work to fight gangs. PAGE A14

MEXICO The secretary of state pays a visit at a time of rising

duras.

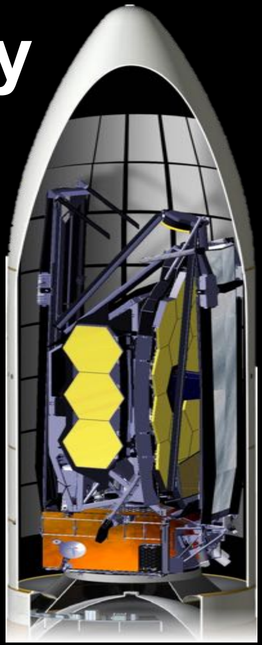
If deportation has always been a threat on paper for the 11 million people living in the country illegally, it rarely imperiled those who did not commit serious crimes. But with the Trump ad-

In the Search for Life on Distant Planets
Bigger is Better

- Improved sensitivity to faint objects
- Improved angular resolution
- Higher spectral resolution for a fixed observing time
- Enables time-resolved images to characterize individual regions of an exoplanet
- Increased exoplanet yield

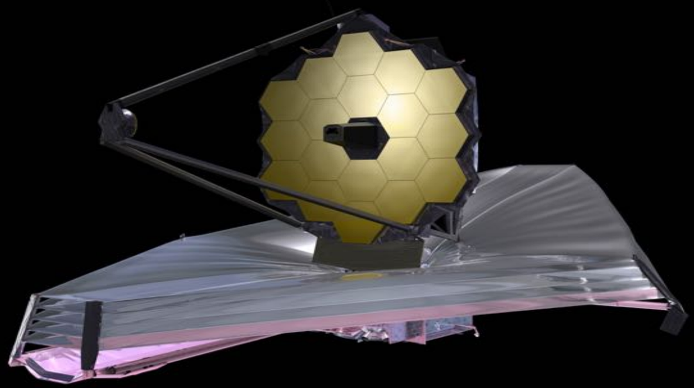
CREDIT: ATLAST Study Team (NASA) 2015

Telescope Size Currently Limited by Deployment Complexity, Fairing Size, and Lift Capacity



Ariane 5 (4.6 m fairing)

6.5 m JWST →



SLS Block Ib Cargo (8.4 m fairing) < 9 m telescope
SLS Block 2 Cargo (8.4/10 m fairing) ~ 12 -- 15 m telescopes
?? – > 15 m telescopes

- 40 deployable structures
- 178 release mechanisms (all of which must work for the deployment to be successful)

Challenges in the not-so-distant future

- Science will require increasingly larger telescopes for which no existing or planned launch vehicles can deploy autonomously *a la* JWST.
  - SLS versions are not guaranteed

- Expensive telescopes and spacecrafts will continue to have relatively short lifetimes (~10–20 years) unless upgraded.
  - JWST's lifetime is expect to be 5-10 years and is not planned to be serviced
  - HST is entering its 29th year of operation and still providing exceptional science
  - Ground-based telescopes can have ~ 50+ year lifetimes

- Deployment designs are getting more complicated (i.e. costlier) and riskier

We need a new paradigm that provides the capability to build larger telescopes for less money and with less risk.

We need to begin developing the capabilities and technologies to service and assemble future generations of large space telescopes and spacecraft in-space robotically now.

A New Vision for Large Space Telescopes

1) **Assembled in space**

2) **Serviced in space to extend their utility by:**
   - replacing the instrument payloads with newer more advanced ones
   - upgrading spacecraft subsystems as they wear and age
   - refueling to extend their lifetimes,
   - repairing when needed, and
   - incrementally enlarging the apertures over time

Why Now?

- **Inform the 2020 National Academies' Decadal Survey, which is starting in a few months, and NASA's Science Mission Directorate that space servicing, upgrade, and assembly offers:**
  - potential science enabling capabilities: large science telescopes, extended lifetimes
  - cost reduction possibilities
  - risk reduction opportunities
  - synergies with other NASA directorates, commercial, DoD
- **Technology development time**
  - The process of identifying, developing, and maturing the technologies to enable servicing, repair, and assembly will take time
  - We need to begin creating a technology roadmap and implementing early development efforts in the very near future, for example using ISS as a testbed prior to its termination
- **Opportunity to coordinate early**
  - Early involvement with industry and NASA Gateway teams offers opportunities to influence studies before designs are “frozen in”

Future Assembly & Servicing Study Team (FASST)

- **Early in 2017 we formed the FASST to begin a coordinated examination of in-Space Assembly (iSA) of future astrophysics assets.**
  - Telescopes, interferometers, starshades
  - Group members are drawn from interested members of the science and industry communities.
    - NASA GSFC, JPL, LaRC, aerospace consultants, an HST astronaut, and colleagues working on post-JWST/WFIRST mission concepts

- **In September 2017, NASA SMD Astrophysics Division gave the green light to hold a workshop on in-space assembly and servicing (iSSA)**
  - Purpose was to gauge the community of their interest and ideas

First In-Space Assembly and Servicing Workshop

70+ participants from government, industry, and academia

- 30 NASA Centers
- 29 Industry
- 7 NASA HQ
- 4 academia
- 4 STScI
- 1 DARPA

Planning team chair: Harley Thronson (NASA GSFC)
November 1-3, 2017
NASA GSFC

How *might* iSSA reduce cost?

- Eliminates engineering design work and testing required to (1) creatively fit large structures into existing fairings and (2) autonomously deploy
- Mass margins increased, reducing modeling and light-weighting costs
- Reduces “ruggedization” to survive launch environment
- Reduces need for new and unique ground test facilities for each mission
- Leverages existing and less-costly medium-lift launch vehicles
- New instruments can be swapped out without additional observatories
- Reduced standing army for I&T: no systems-level performance tests
- Moves architecture away from “every new telescope is a new point design” if standardization can be agreed upon
- By extending the lifetime of future observatories, fewer new observatories, lower total cost amortized over more years.

But iSSA may also increase cost…

- Would a full-scale, robotically-assembled telescope have to be demonstrated on the ground to mitigate concerns and risks? And then disassembled?

- Potential additional cost if any astronauts in the loop

- New robotic capabilities will be required as part of iSSA that is not required in the autonomous deployment approach.

- Sending multiple modules into space will require new containers and interfaces each having to undergo environmental testing.

- New Earth-based problems yet unknown in standardization and assembly, as well as new unknown problems created in space, will likely need to be solved.

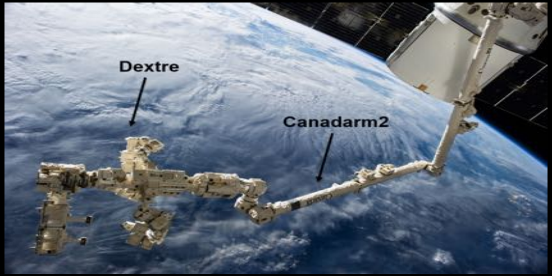
How does iSSA reduce risk?

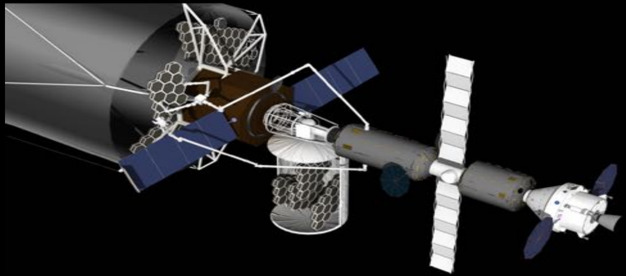
- **Note: Reducing risk becomes increasingly more important as mission costs increase.**
- **Future larger observatories are likely to require more complex deployment schemes. iSSA can mitigate risk of failure by:**
  - Modularizing the design enabling repair and replacement of faulty sections
  - Designing servicing capabilities (robotic and/or human) into the architecture
  - Eliminate mission-ending single-point failures
- **In-space assembly (iSA) does not require next-generation launch vehicles**
  - Several future mission concepts under study rely on the SLS Block 1 or 2, a potential programmatic uncertainty
- **Launch failure need not be equivalent to mission failure**

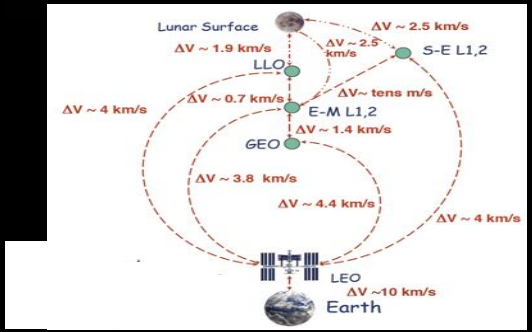
Assembling and Infrastructure for the ISAT

Activity 1b

Select a reference in-space assembly and infrastructure concept for the "assemble-able" space telescope architecture, defining robotics, assembly platform, orbit, and launch vehicle.







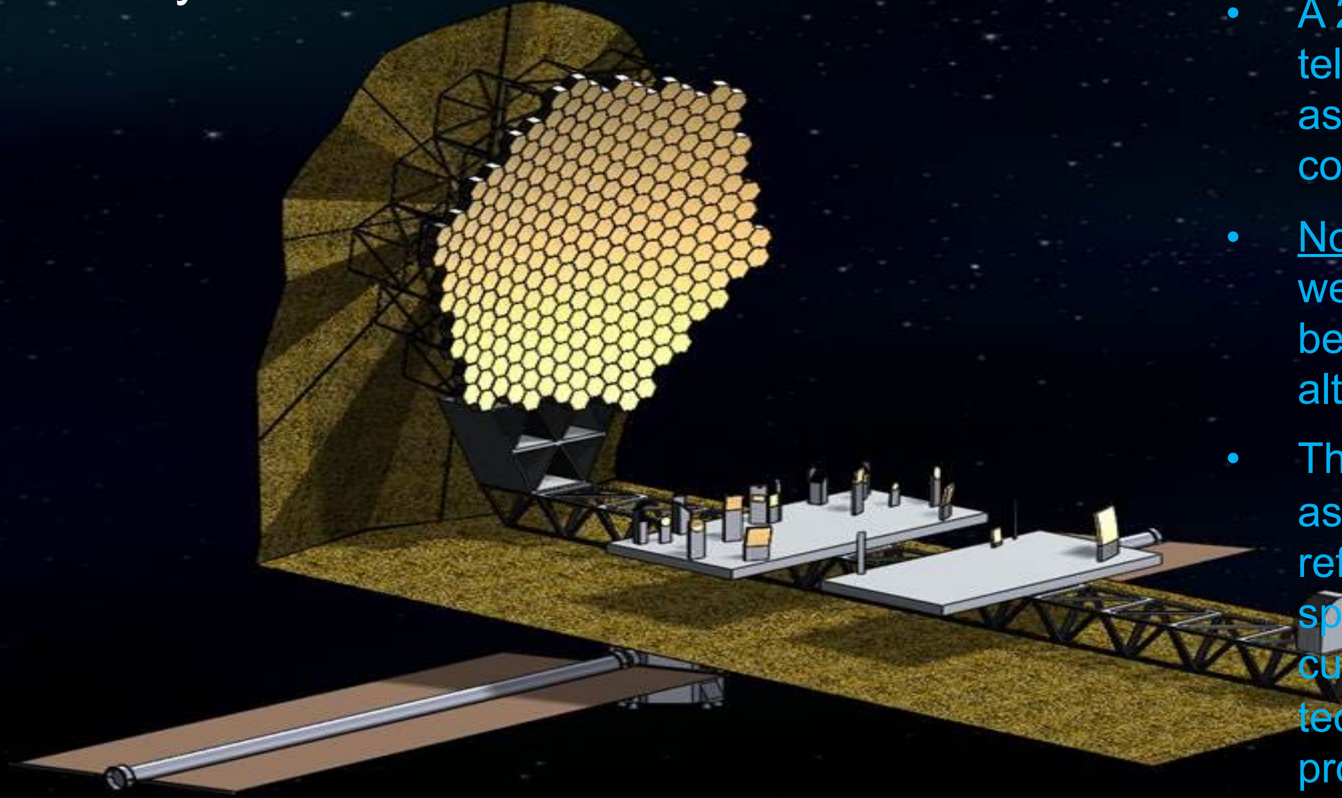
Telescope Modularization Workshop

Caltech, June 5-7

47 invited participants from government, industry, and academia spanning the fields of astrophysics, engineering, and robotics organized by Nicholas Siegler.

Telescope Modularization Initial Results

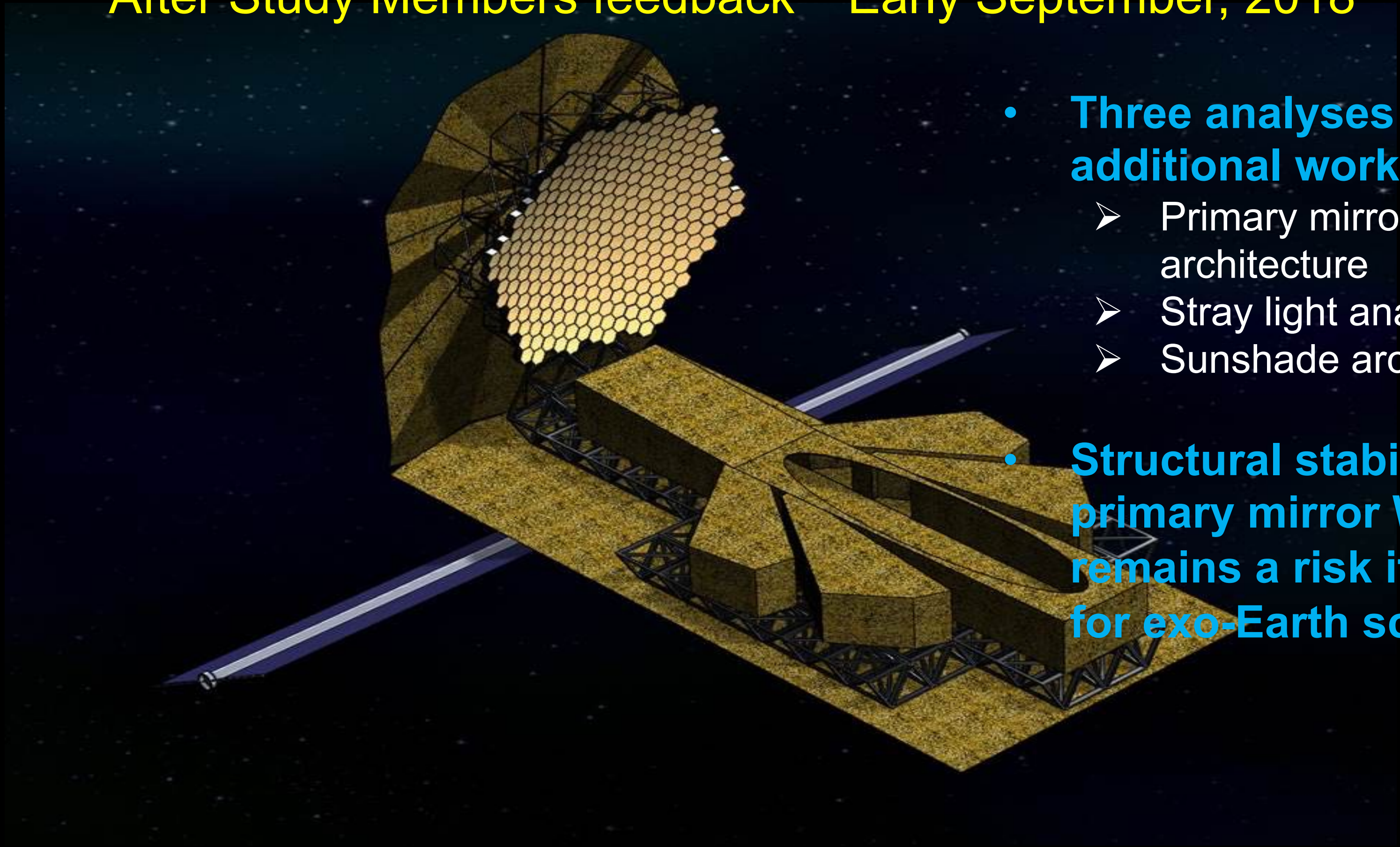
Activity 1a June 2018



- A 20-meter off-axis f/2 telescope would serve as a good proof of concept
- No major show stoppers were found and no better compelling alternatives.
- The consensus was that assembling the reference telescope in space was feasible with current and anticipated technology and processes.

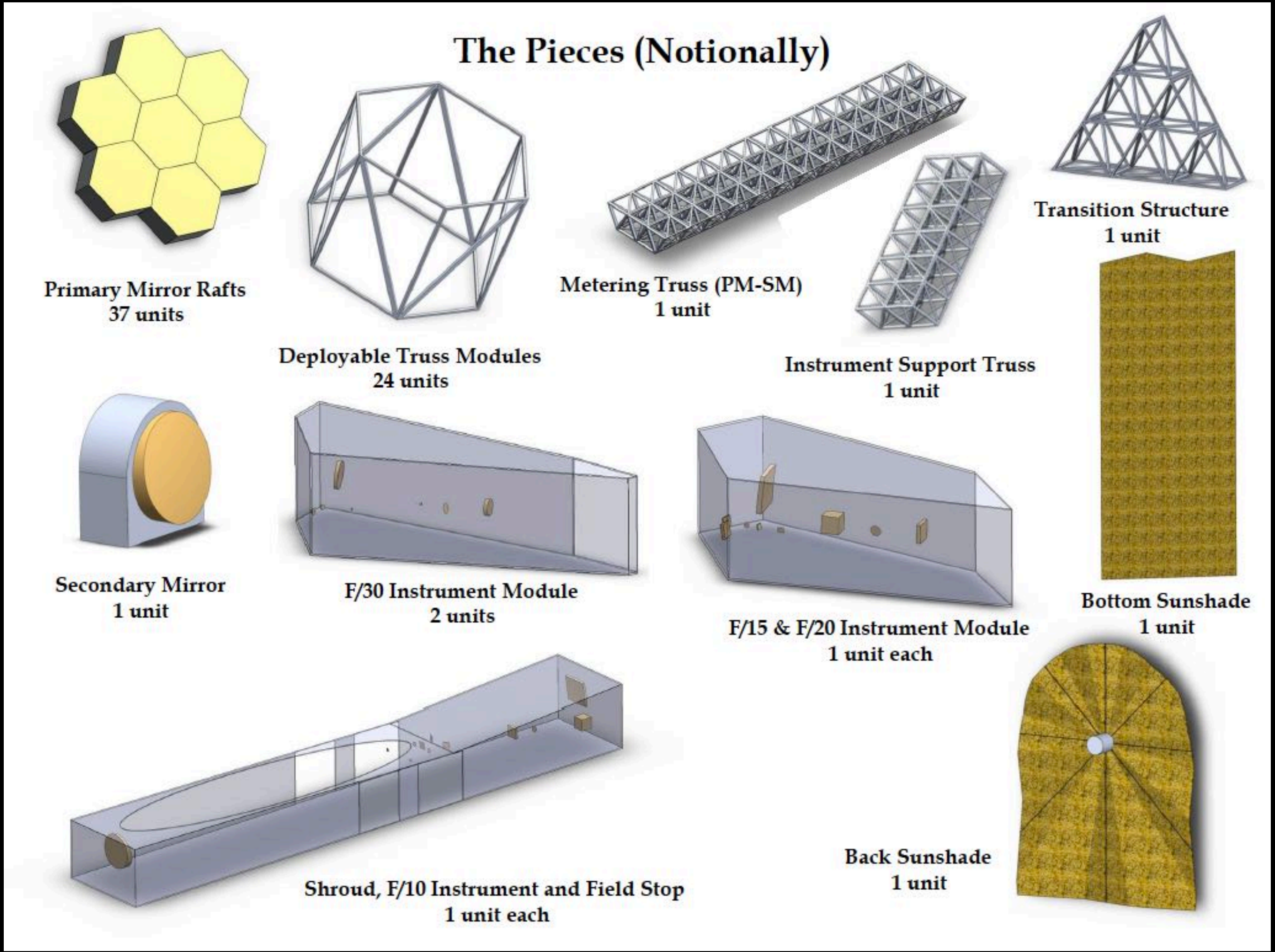
Design Concept for Modularized Telescope

After Study Members feedback – Early September, 2018



- **Three analyses required additional work**
  - Primary mirror truss height and architecture
  - Stray light analysis
  - Sunshade architectural concept

- **Structural stability to enable primary mirror WFE stability remains a risk if the coronagraph for exo-Earth science is adopted**


The Pieces (Notionally)
Primary Mirror Rafts
37 units
Deployable Truss Modules
24 units
Metering Truss (PM-SM)
1 unit
Instrument Support Truss
1 unit
Transition Structure
1 unit
Secondary Mirror
1 unit
F/30 Instrument Module
2 units
F/15 & F/20 Instrument Module
1 unit each
Bottom Sunshade
1 unit
Shroud, F/10 Instrument and Field Stop
1 unit each
Back Sunshade
1 unit

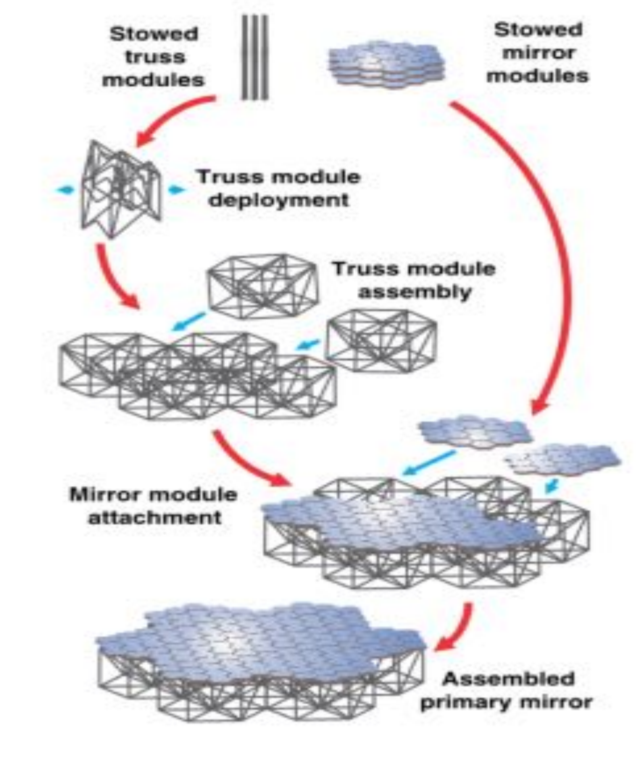
Activity 1b
(started first week in September)

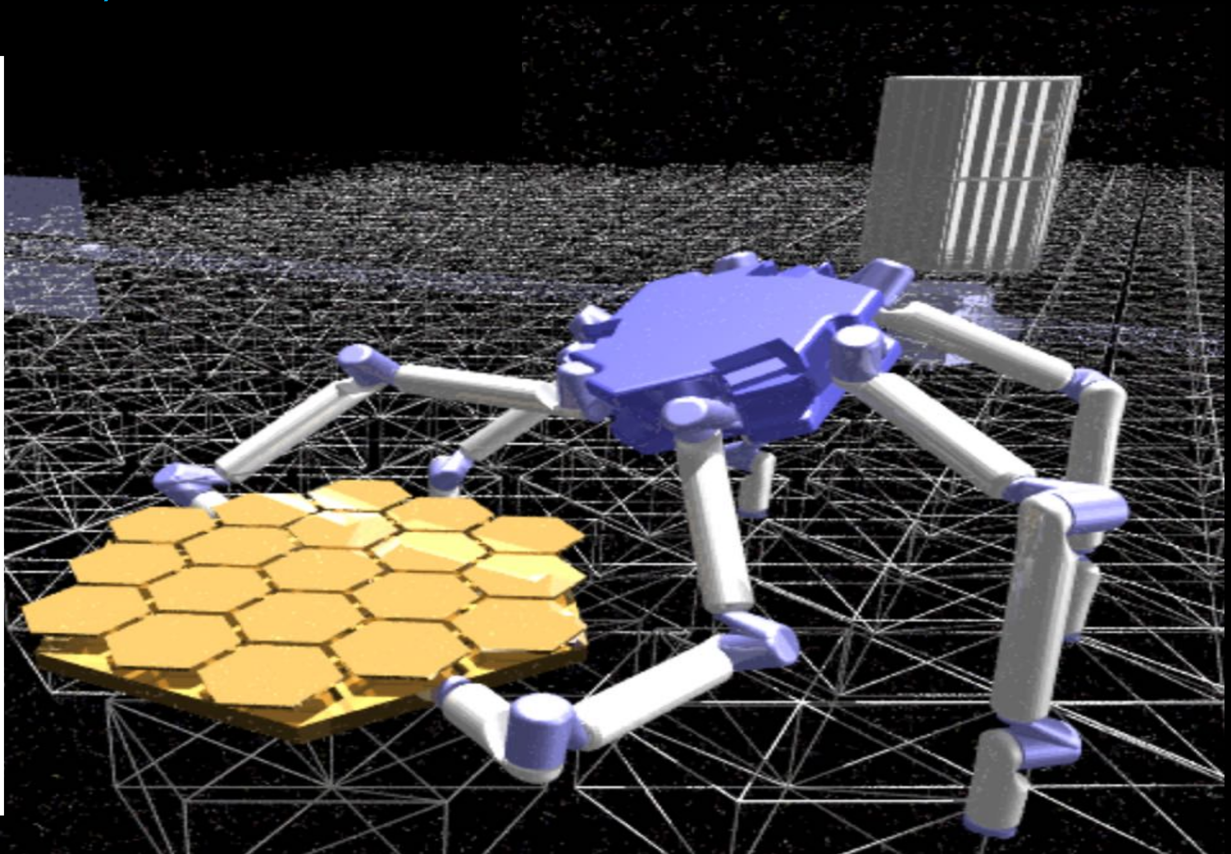
- Robot Candidates
- Assembly Platform Candidates
- Available Launch Vehicles
- Operations Site (SE L2)

Example Robot Candidates

Multi-Limbed Robot

Caltech/JPL; Lee et al. (2016)



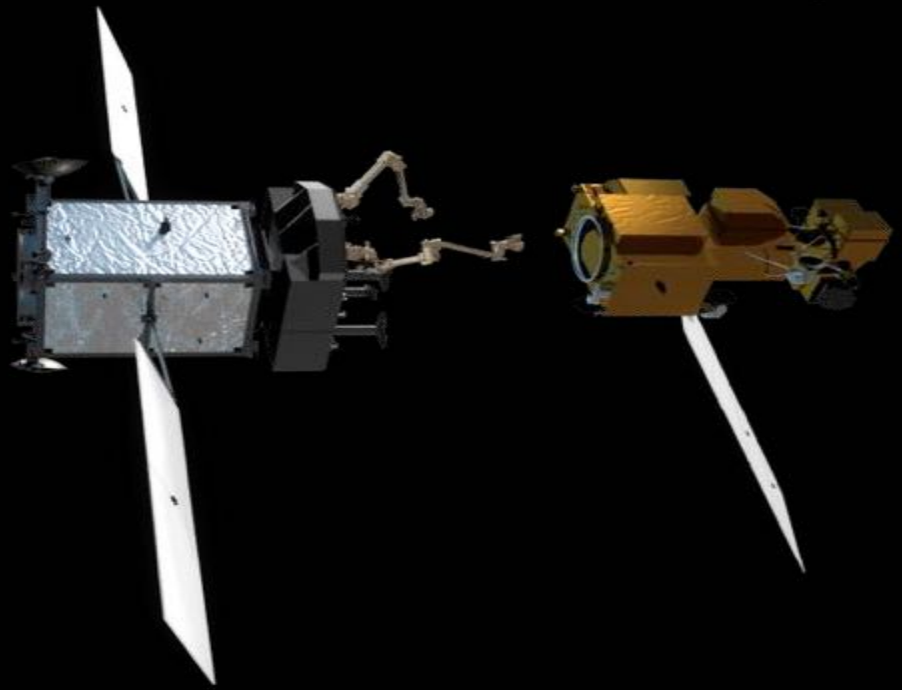


Caltech/JPL

Free-Flying Robots

NASA's Restore-L

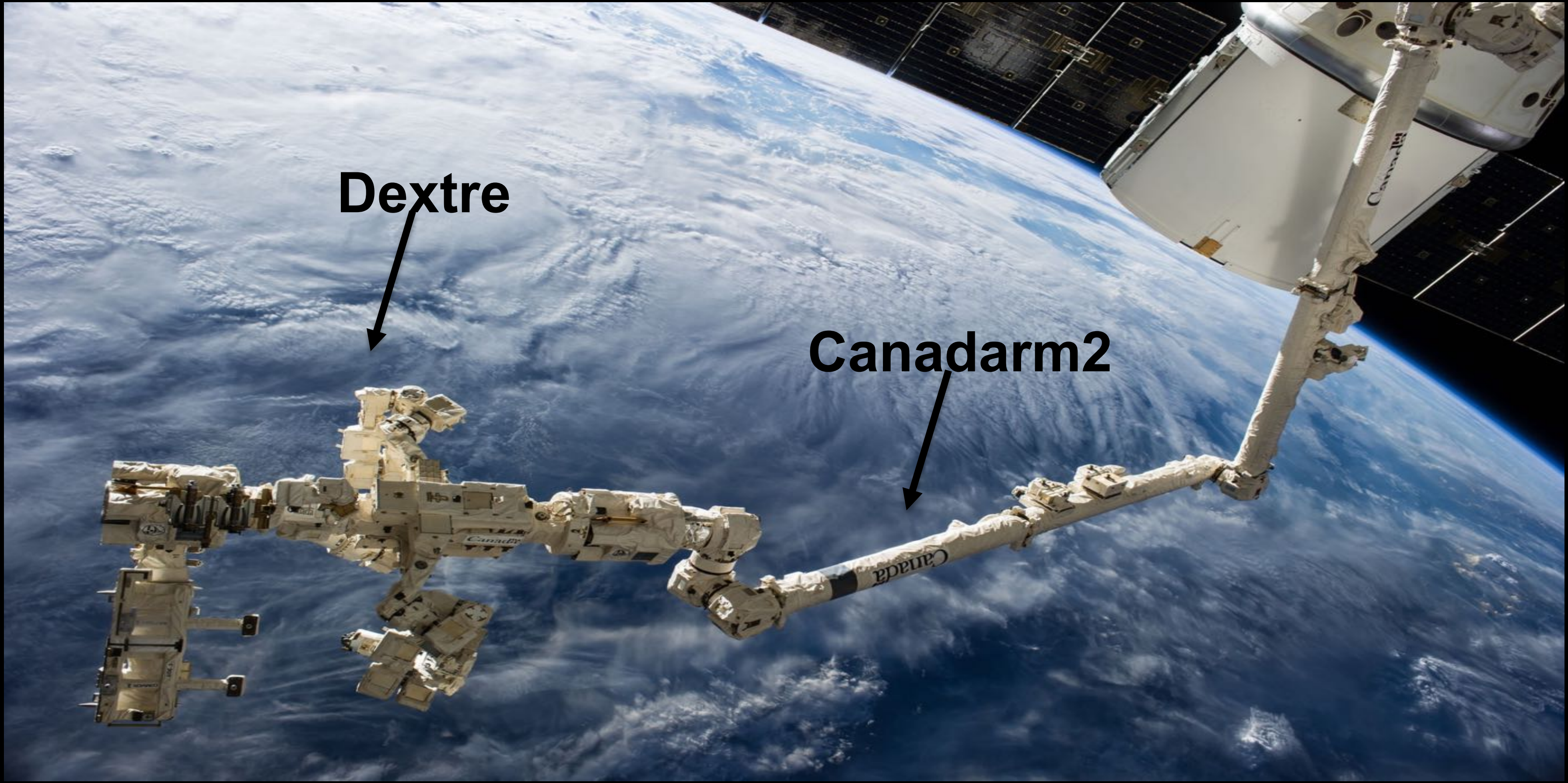
DARPA's Robotic Servicing of Geosynchronous Satellites – GEO Platform



Credit: NASA GSFC

Robotic Arm

ISS’s Dextre and Canadarm2



Assembly Platform Candidates

International Space Station

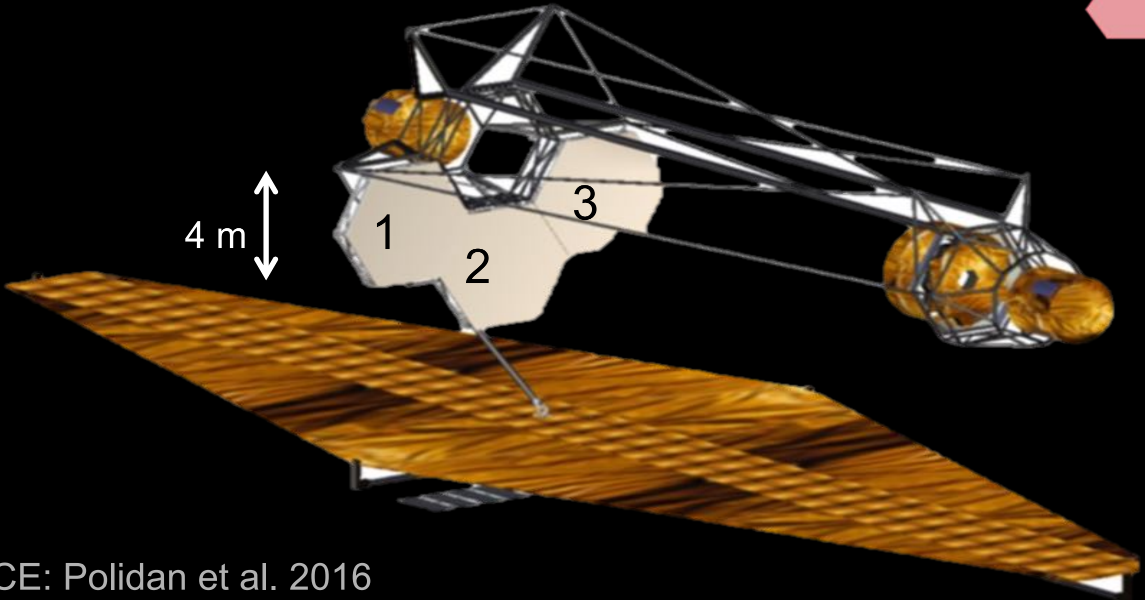
LEO

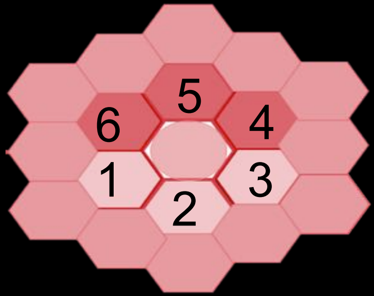
Gateway human operations and habitation facility

Cis-Lunar orbit

Evolvable Space Telescope

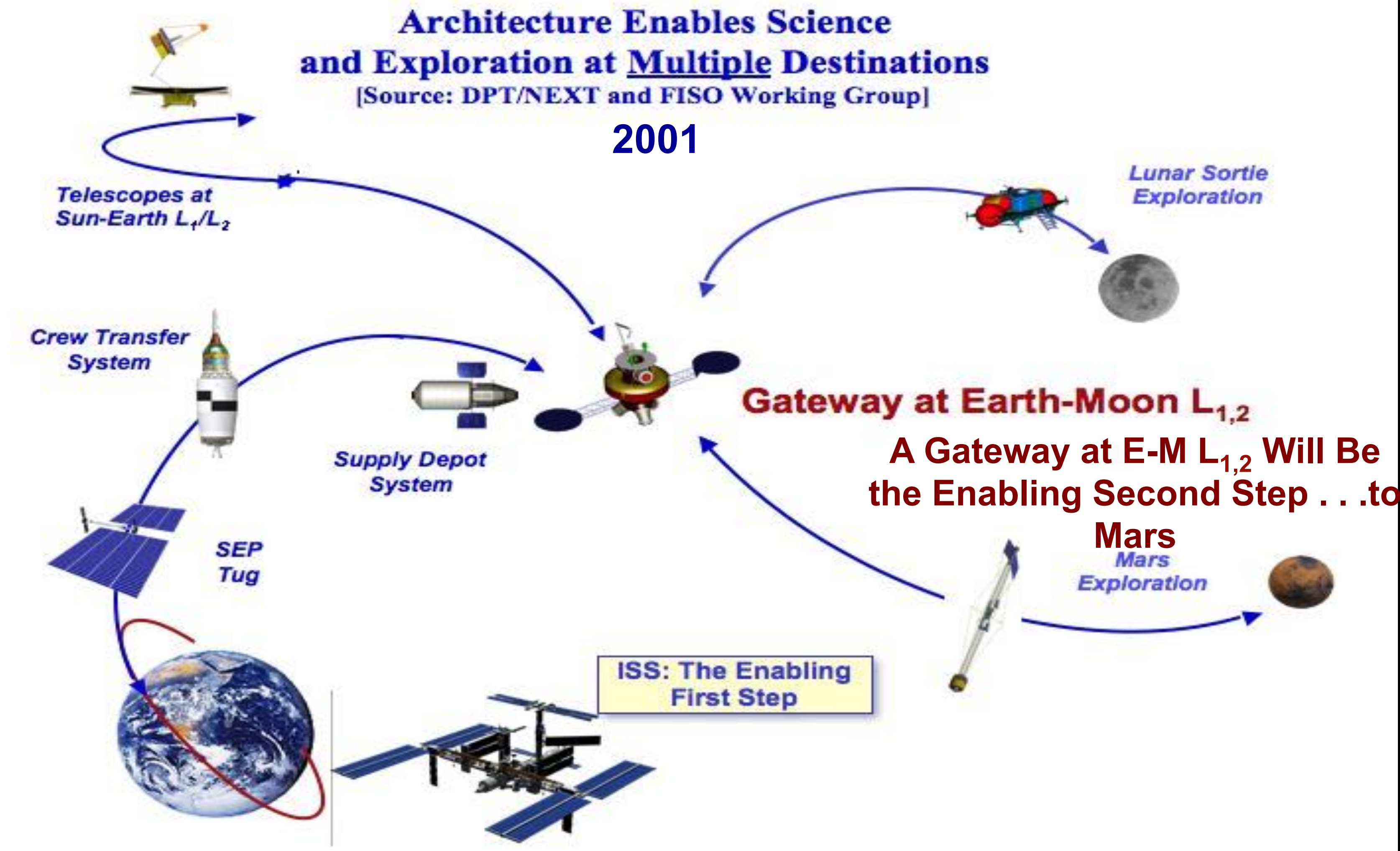
NGAS





SOURCE: Polidan et al. 2016

Orbit Candidates

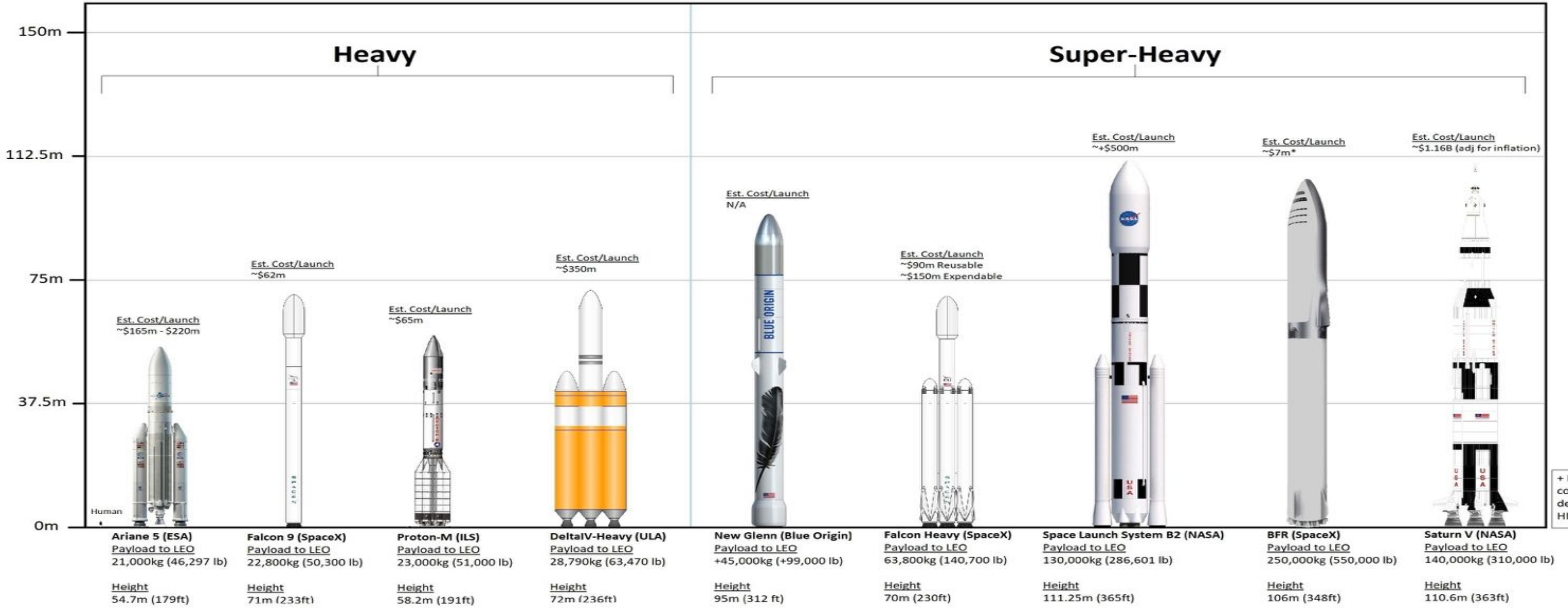


2001

A Gateway at E-M $L_{1,2}$ Will Be the Enabling Second Step . . .to Mars

Launch Vehicle Candidates

Candidate Launch Vehicles



Selected Priority Activities Through Mid-2019

Increasingly Detailed Engineering Design and Cost Estimate

Identify Priority Technology Investments

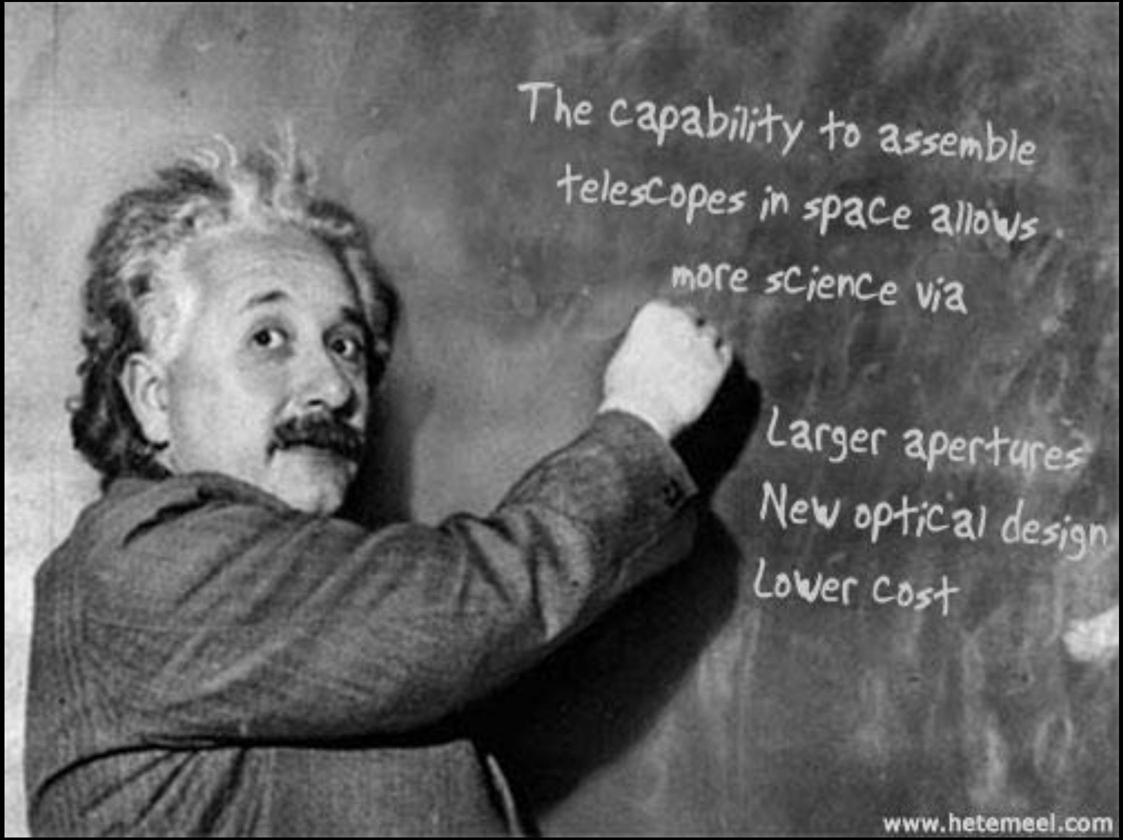
Augmented Science Program: e.g., Aperture Increases Over Time

Write and Deliver Report to SMD and Astro2020 Decadal Survey

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

Or search “JPL Exoplanet iSA”

QUESTIONS?


The capability to assemble
telescopes in space allows
more science via
Larger apertures
New optical design
Lower cost
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