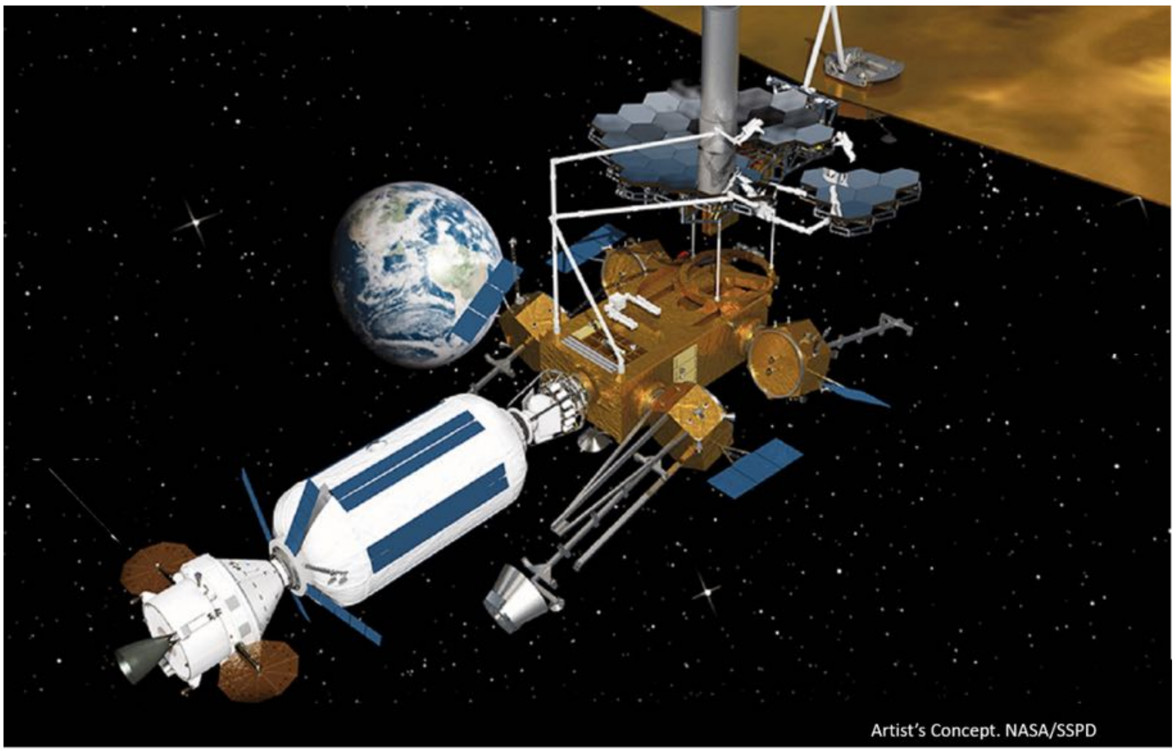
Servicing and Assembly: Enabling the Most Ambitious Future Space Observatories



14 June 2018

Ronald S. Polidan, PhD
Polidan Science Systems & Technologies, LLC

and

The Future Assembly/Servicing Study Team

Supported by the NASA HQ Science Mission Directorate, Astrophysics Division

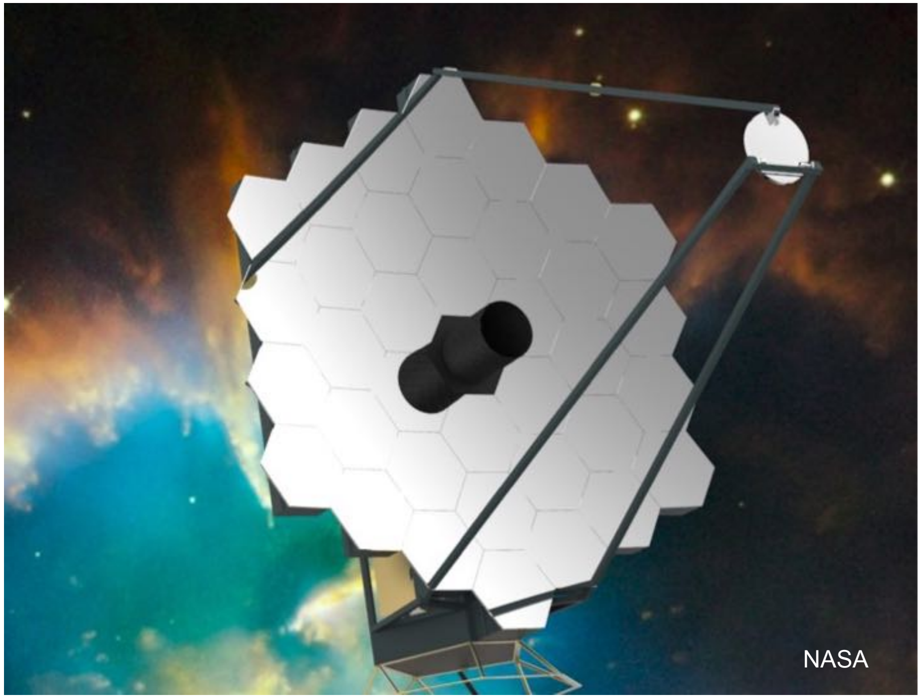
Presentation Overview

- At the morning plenary session yesterday (13 June) Harley Thronson presented an overview of our in-Space Assembly (iSA) concept and work the Future Assembly/Servicing Study Team (FASST) has been doing over the past year.

- In this talk I will give a brief summary of his overview to set the context and the rationale for iSA.

- The majority of the talk will be presenting interim results derived from two iSA workshops (Nov 2017 and June 2018) and numerous technical telecons that the team has held over the past year.

- The final part of the talk will discuss the current status and future plans for this group.



Acknowledgements

Science Systems PSST Technology
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The work presented here has been a collaborative effort

My co-authors are:

W. K. Belvin (NASA HQ), M. A. Greenhouse (NASA GSFC),
J. M. Grunsfeld (NASA GSFC), J. Guidi (NASA HQ),
H. A. MacEwen (Reviresco, LLC), R. M. Mukherjee (JPL-Caltech),
B. M. Peterson (OSU & STScI), B. B. Reed (NASA GSFC),
N. Siegler (JPL-Caltech), and H. A. Thronson (NASA GSFC)

Information on FASST/iSA (past work, current status, future plans) can be found at:

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

iSA Overview and Rationale

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- Current studies have identified the largest UV/Vis/IR telescopes that could be autonomously deployed from current launch vehicles have a maximum aperture of ~9 meters, and for the largest envisioned launch vehicles (i.e. Space Launch System - SLS) this would grow to around 15 meters aperture.
- Ground-based telescopes currently under construction will be much larger than 15 meters and it is certain that the science community will eventually demand space telescopes larger than what can be launched and autonomously deployed by a single launch vehicle.
- ***Astrophysics needs large telescopes***: these needs will, at some point, exceed the capabilities of what can be launched by a single launch vehicle has been known for decades. Numerous papers have been published on approaches and architectures for building telescopes in space. But this was always seen as a distant problem.
- As studies are now showing, this "launch vehicle barrier" is now not so distant – the community is currently designing missions that are at the limit of the largest launch vehicles envisioned.

The Future Assembly/Servicing Study Team (FASST)

- **Early in 2017 we formed a group, the Future Assembly/Servicing Study Team (FASST) to begin a coordinated (science, robotics, exploration) examination of in-Space Assembly (iSA) of future astrophysics assets, specifically very large (>20 meter) filled aperture and interferometric space telescopes and starshades.**
  - Group members are drawn from interested members of the science and industry communities.
  - In July 2017 we presented our charter, goals, and near-term plans to a joint meeting of the NASA Advisory Council’s Human Exploration and Operations (HEO) and Science Committees (to positive responses and recommendations).

iSA enables innovative telescope and instrument designs for the benefit of science (1 of 2)

- **iSA enables space telescope designs that are much less constrained by launch vehicle fairing size and mass limitations.**
  - > 20 m aperture telescopes, long-baseline interferometers, large starshades, and other architectures not permitted by deployment
- **iSA enables telescope architectures that can grow in aperture size over time and, hence, enhance science through greater resolution and signal-to-noise.**
  - "Evolvable observatories", "Pay as you go"
- **iSA enhances our capability to more rapidly respond to new science questions through the replacement and upgrade of payload instruments**
  - HST is ~200 times more powerful today than when it first launched
  - Instrument technology is ~10-15 years old by launch (technology lag)
- **iSA extends the lifetime of observatories.**
  - Potentially enabling a Great Observatories paradigm of concurrently operating observatories with access to the whole EM spectrum.
  - Spacecraft could be refueled, subsystems could be replaced or upgraded
  - Mirrors could be recoated and decontaminated
  - Starshade membrane and edges could be repaired after micrometeoroid damage

iSA enables innovative telescope and instrument designs for the benefit of science (2 of 2)

- **iSA enables a much lighter overall structure due to the elimination of launch loads at the full assembly level.**
- **Telescope architecture moves away from "every new telescope is a new point design".**
  - Modularizing the design would enable repair and replacement of faulty or aging sections
  - Greater commonality with previous systems would reduce development costs
  - The need for "ruggedization" to survive launch environment is reduced
  - Telescope designs can use new materials, for example ultra-low weight optics, that cannot be adequately tested at 1 g or safely survive launch environment in an integrated state.
  - The need for new and unique ground test facilities is reduced
- **iSA can leverage existing and less-costly medium-lift launch vehicles and does not require next-generation launch vehicles.**
  - Relying on "standard" launch vehicles – analogous to standardized shipping containers – will reduce costs and help break the cost curve.
  - By going with multiple launches, a launch failure need not be equivalent to mission failure
- **iSA is a crosscutting capability applicable to other space-based remote sensing and exploration systems.**
  - The astrophysics community does not have to bear all of the development costs.

Examples of iSA enabled telescopes

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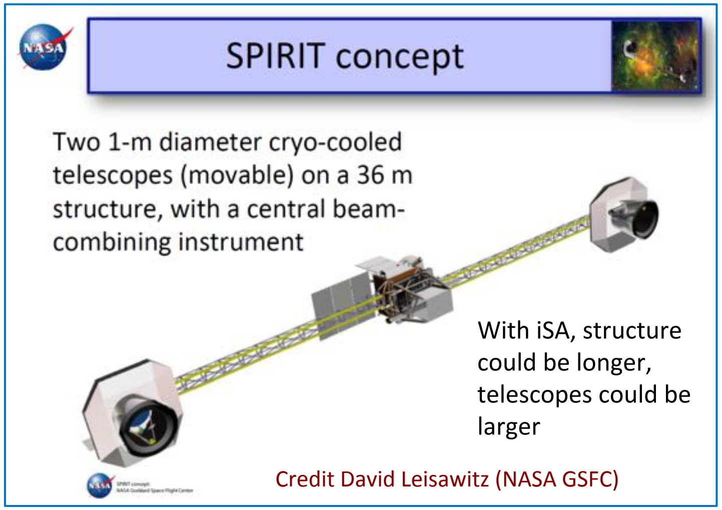
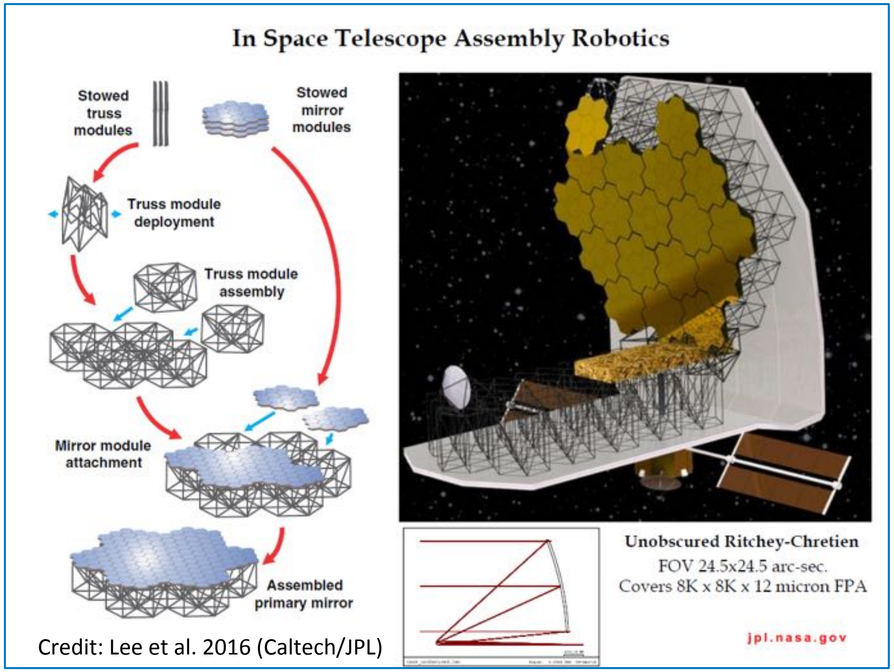
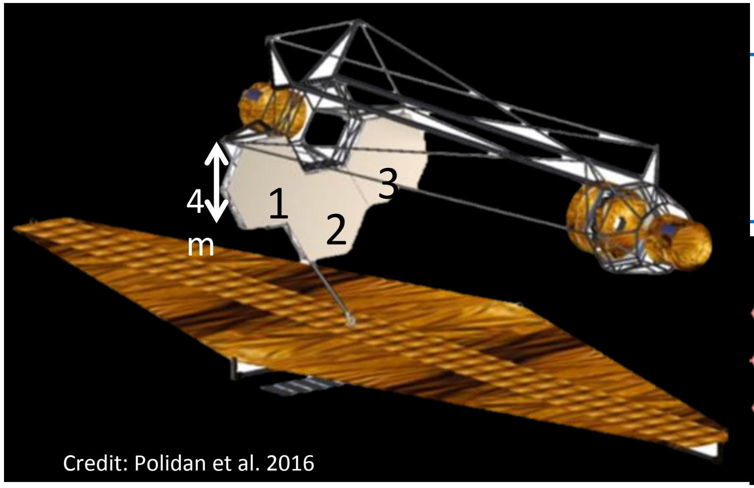
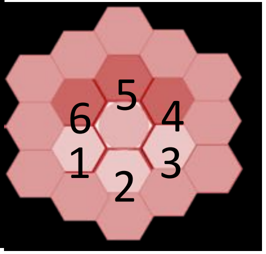
Interferometry space telescopes can be an application for in-space servicing and assembly.



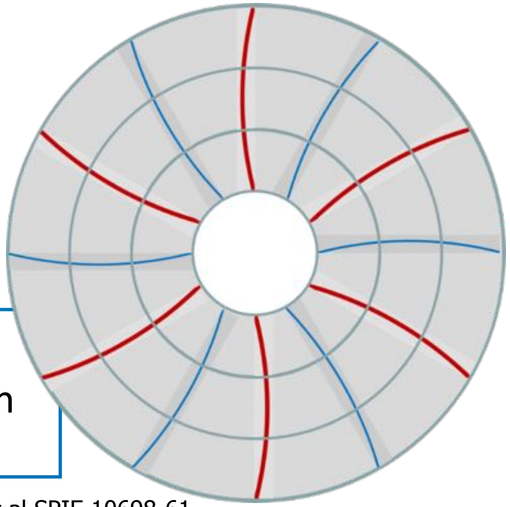




Telescopes that can incrementally evolve over time



Alternate segmentation approaches



Credit: Breckinridge et al SPIE 10698-61

First iSA Technical Interchange Meeting

November 1-3, 2017 at GSFC

- **Attended by 70+ professionals representing three major communities (astronomers, developers of future space robotics systems, and NASA- and industry-led designers of a cis-lunar habitat).**
- **A few findings from this first TIM, as reported to NASA HQ APD**
  - iSA is an important and enabling capability that has clear applications to near-term NASA Astrophysics Division objectives.
  - The current paradigm of telescope design (deployed or monolithic) does not contribute to the design of subsequent large-aperture space telescopes. Hence, the cost model for large telescopes is unlikely to change unless there is a paradigm shift.
  - There is a revolution in the TRL of robotics on the ground, and DARPA RSGS and NASA Restore-L are embodiments of this for space demonstrations.
  - The "serviceability" of future telescopes is ambiguous as there is recognition that there are no ready servicers. Consideration ought to be given on how to leverage existing servicer work (RSGS, Restore-L), including the opportunities enabled by a DSG.
  - Industry has very strong interest in iSA and can play an important role.
  - A completed NASA Gateway infrastructure potentially offers a unique facility in which SMD may be able to leverage the iSA of future large telescopes.

First iSA Technical Interchange Meeting
Some Recommendations to NASA (see the web site for a full list)

- **Commission a design study to understand how large-aperture telescopes could be assembled and serviced in space**
  - Suggest joint SMD/STMD/HEOMD study with industry and academia participation
  - Initiate the study in time for initial results to be available to Gateway and robotics designers within 2018, but certainly before end 2019.

- **NASA may want to initiate an iSA coordination group between the three Mission Directorates and perhaps with international space agencies as well.**

- **Consider providing input to the 2020 Decadal Survey about iSA as a potential implementation approach for future large apertures.**

NASA accepted the 1st and 3rd recommendations and a funded iSA design study was initiated.

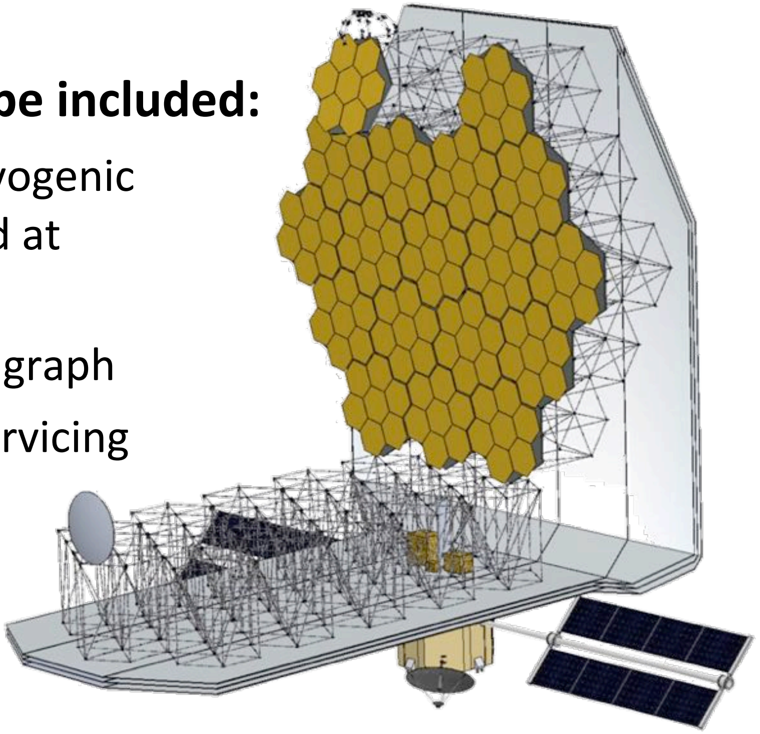
In-Space Assembled Telescope (iSAT) Study Workshop

- **The first face-to-face meeting for the iSA design study was held on June 5-7, 2018 at Caltech, hosted by the Exoplanet Exploration Office.**
  - 47 participants from government, industry, and academia spanning the fields of astrophysics, engineering, and robotics.

In-Space Assembled Telescope (iSAT) Study Workshop

- **The goals of the Workshop were to:**
  - Assess the feasibility of assembling a large telescope in space in the context of current and anticipated technologies.
  - Begin advancing concepts for modularizing the telescope for future assembly in space.

- **Initial conditions for the reference telescope included:**
  - A 20-meter, filled-aperture, off-axis, non-cryogenic telescope operating in the UV/V/NIR, located at Sun-Earth L2.
  - The instrument suite would include a coronagraph
  - Astronaut- and robotic-enabled assembly/servicing is available



iSA Study Telescope Reference Concept Topology

Polidan et al, 2018 SPIE AT+I 10698-75

iSAT Workshop

- **Three broad areas were addressed in technical breakout sessions.**
  - Modularizing the Primary Mirror and Backplane
  - Modularizing the Rest of the Telescope
  - Assembly, Integration, and Testing (on the ground and in space)

- **Extremely preliminary (it has only been a few days) results**
  - The 20 m off-axis f/2 telescope would serve as a good reference for the Study
  - No major show stoppers were found. The consensus was that assembling the reference telescope in space was feasible with current and anticipated technology and processes.
  - Follow-on science and engineering analyses, increasing in technical depth as the concept matures, are essential to truly assess the viability and value of the iSA approach
  - We will decide over the next few weeks which trades should be advanced
  - Structural stability to enable primary mirror WFE stability remains a risk if the coronagraph for exo-Earth science is adopted
  - Confidence there are cost savings and risk mitigations moving forward

Current Status – Future Plans

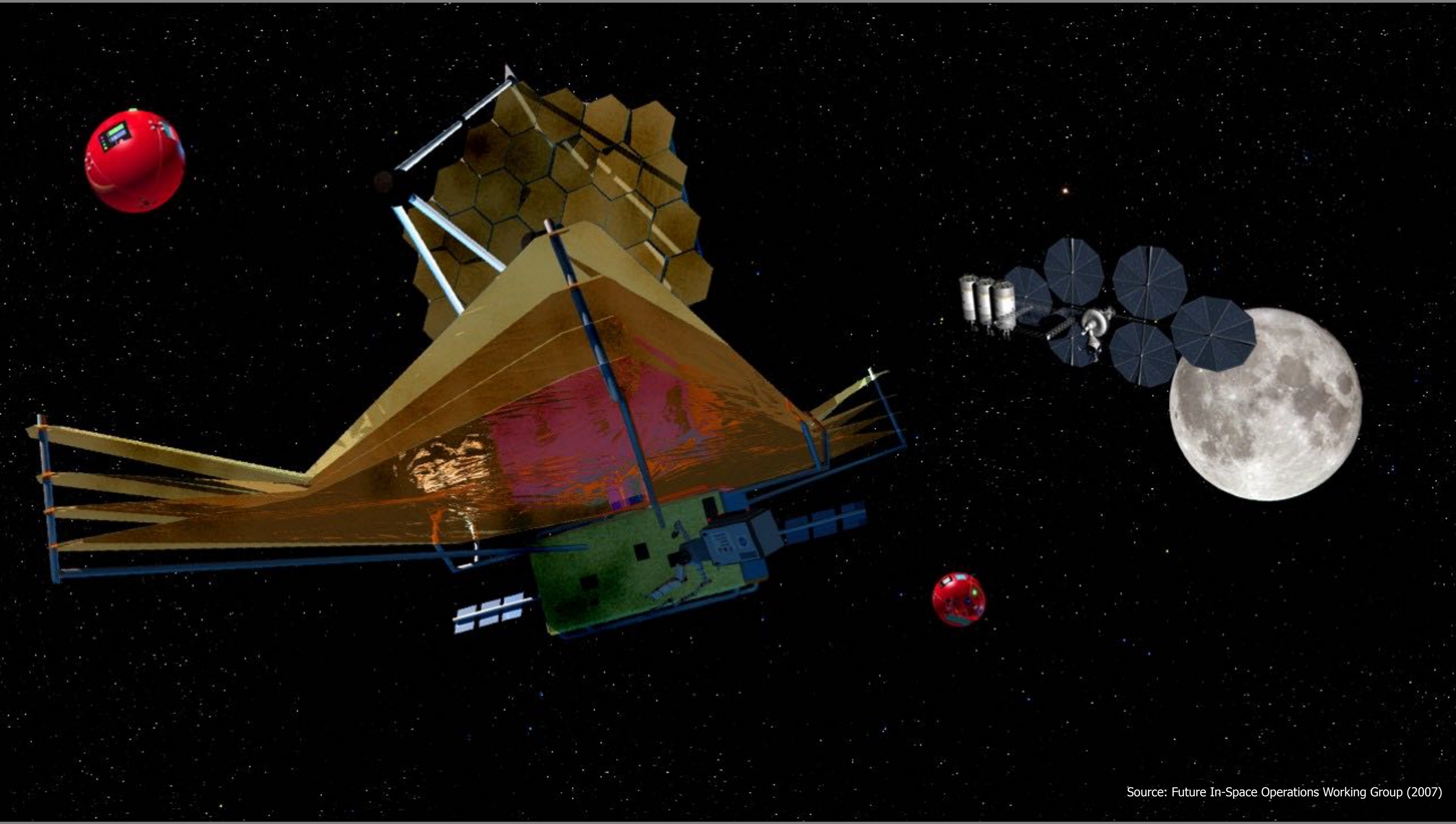
- **Virtually all of the participants were pleased with the products from the workshop and want to continue down the path of a more detailed assessment.**

- **A series of telecons are planned for the summer to advance the telescope modularization activity sufficiently to enter the assembly and testing phase.**
  - Topics will include: robotics, robotic platform, orbit selection (delta-v options to ESL2), and launch vehicles

- **A technical workshop will be held in Fall 2018 (site and time TBD) on the topic of assembling and testing the modularized reference telescope**

- **Assuming a few end-to-end concepts are produced with promise of reducing cost and mitigating risk, an in depth engineering study will commence in 2019 (pending funding).**

Thank you!



To keep up to date on iSA activities, please visit our web site:

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