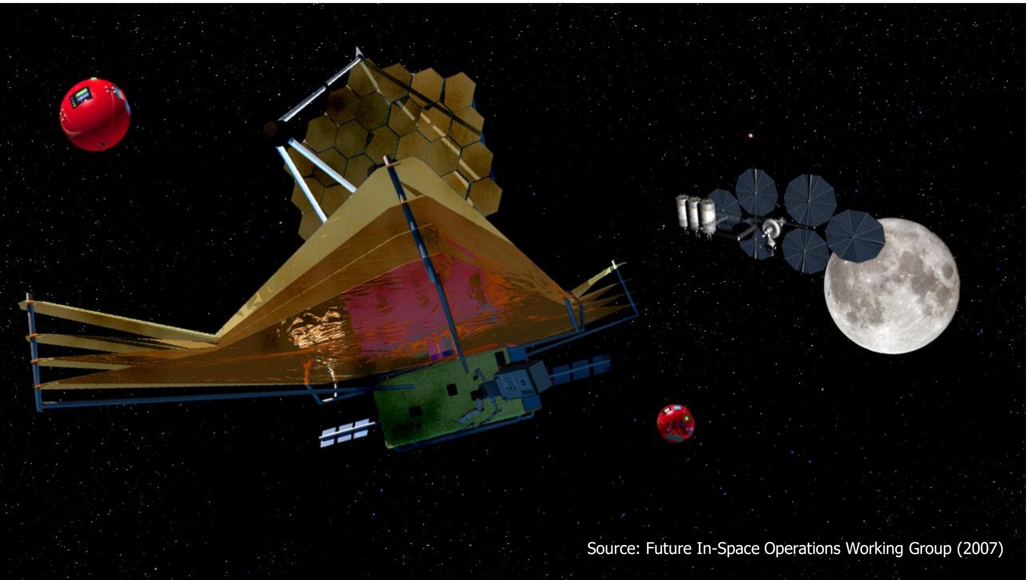
Science Systems PSST Technology

Polidan Science Systems & Technologies, LLC

In-Space Servicing and Assembly of Extremely Large Telescopes

Introduction and Overview

09 January 2018



Ronald S. Polidan, PhD

Polidan Science Systems & Technologies, LLC

for the iSSA Team

Overview and Concept Background

- Current studies have identified the largest UV/Vis/IR autonomously deployed telescope aperture that will fit within the largest envisioned launch vehicles (i.e. Space Launch System - SLS) at around 15 meters.
- The ground-based telescopes currently under construction will be much larger than 15 meters and it is certain that the science communities will eventually demand space telescopes larger than what can be launched and autonomously deployed by a single launch vehicle.
- The understanding that astrophysics needs will, at some point, exceed the capabilities of what can be launched by a single launch vehicle has been known for decades, but it was always seen as a distant problem.
- As studies are now showing, this "launch vehicle wall" is now not so distant – the community is currently designing missions that are at the full capacity of the largest launch vehicles envisioned.
- It is time to look seriously and <u>*quantitatively*</u> at how to assemble and service these extremely large space telescopes in space.

In Space Servicing and Assembly (iSSA)

- Early in 2017 we formed an ad hoc group to begin a coordinated (science, robotics, exploration) examination of in-Space Servicing and Assembly (iSSA) 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 goals, charter, 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).
  - In November 2017 we held a Technical Interchange Meeting (TIM) at GSFC that was 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).
  - In 2018 we expect to continue the TIMs, bringing together different stakeholders to coordinate resources and plans that will one day enable revolutionary exploration and science capabilities.

This presentation is a summary of the findings and observations developed during our group discussions and at the iSSA November TIM.

Interested in iSSA?

Points of Contact for future iSSA activities

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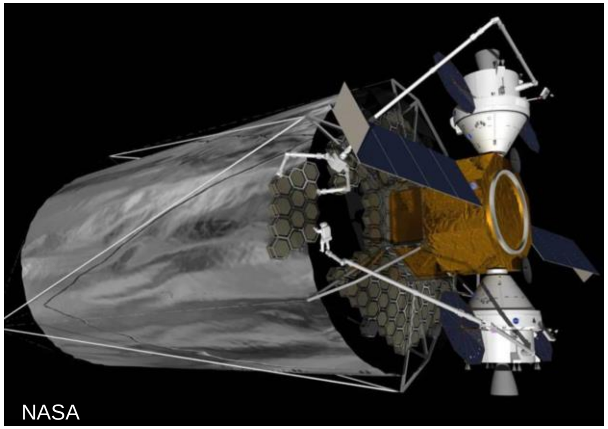
Anyone interested in iSSA concept development and future iSSA meetings, interactions, and technical exchanges should contact one of the individuals below (all are attending this AAS meeting)

- Ronald Polidan (PSST, LLC)
- Bradley Peterson (Ohio State U/STScI)
- Nicholas Siegler (NASA JPL)
- John Grunsfeld (NASA GSFC)
- Howard MacEwen (Reviresco, LLC)
- Matthew Greenhouse (NASA GSFC)

Community Technical Interchange Meeting on Future Capabilities in Space Servicing and Assembly Participants (Nov 2017 @ GSFC)

Why Look at iSSA now? (1 of 2)

- Concepts proposed for consideration by the coming Decadal Survey seem likely to be limited by the maximum capability of proposed future large launch vehicles.
- Significant advances taking place now and in the near future have the potential to enable high-priority astrophysics space missions:
  - There has been significant reduction in cost of medium-lift launch vehicles.
  - There are rapid advances in the TRL of robotics on the ground and programs such as DARPA's RSGS and NASA's Restore-L are embodiments of this for space applications.
  - Continued advances in robotic/telerobotic servicing and assembly capabilities have led to the development of free-flying GEO-based robotic servicing platforms that are expected to begin operations in the mid-2020s.
  - The deployment in cis-lunar space of an intermittently-occupied Deep Space Gateway facility (planned to be operational in the mid- to late-2020s) will significantly advance in-space assembly.
  - Advances in scientific instrument technologies are occurring at a rapid pace.
  - Congressional language for future space assets requires them to be serviceable.

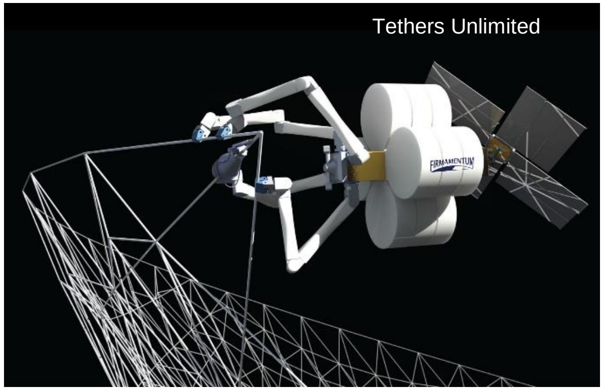


Why Look at iSSA now? (2 of 2)

- Architectures, technologies, and techniques for assembly must be developed long before the capability is required.
  - Development times will be many years to a decade, not months.
  - The International Space Station (a likely test/validation site) is scheduled to be decommissioned in the mid-2020s.

- There is a near-term opportunity to inform the 2020 Decadal Survey about the potential benefits of iSSA as a potential implementation approach.

- NASA and other national and international organizations are beginning studies of space-based servicing and assembly facilities for the 2020s and beyond. Understanding the requirements for an astronomical telescope/instrument servicing/assembly site and influencing the design of these facilities will greatly smooth integration and reduce the cost of having an astronomical capability included at the servicing/assembly site.
  - There is at present a window of opportunity through 2019 (*March-July 2018 is the optimal window)* to recommend augmentations to the NASA Deep Space Gateway team before their designs are frozen.



How does iSSA enable innovative telescope and instrument designs?

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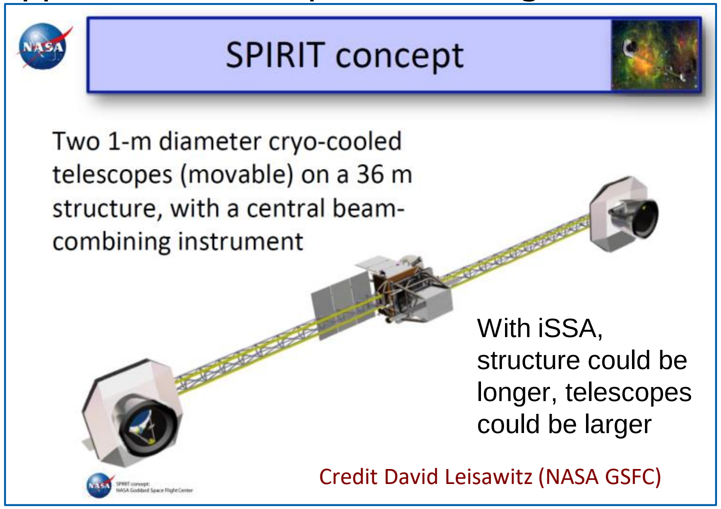
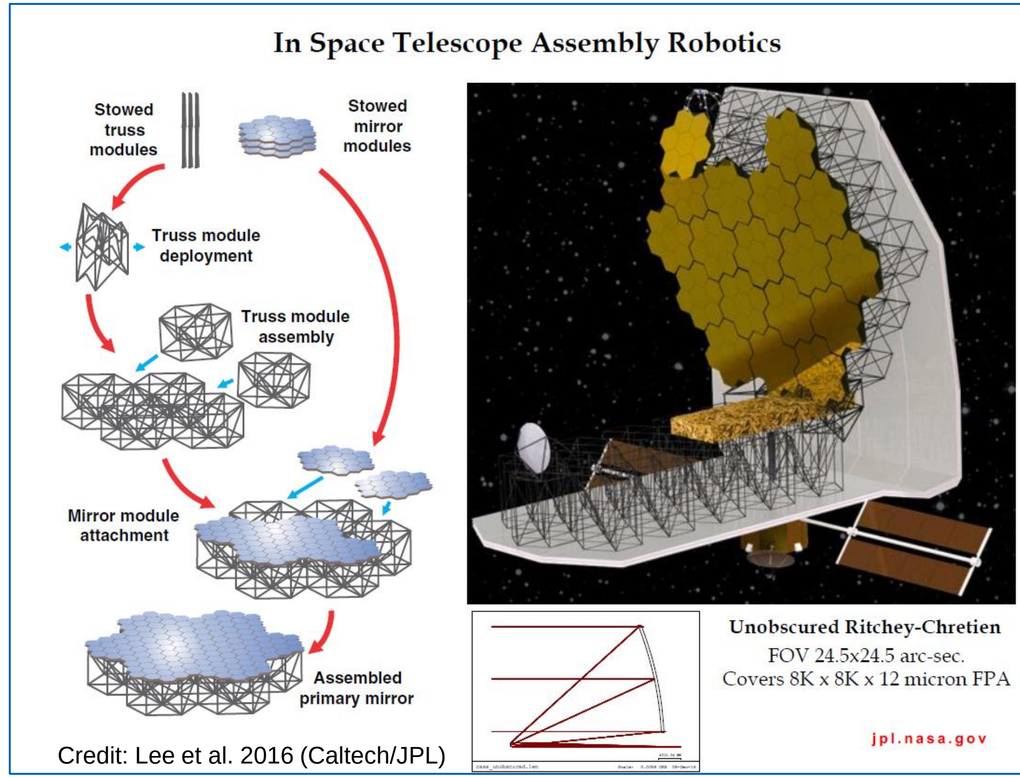
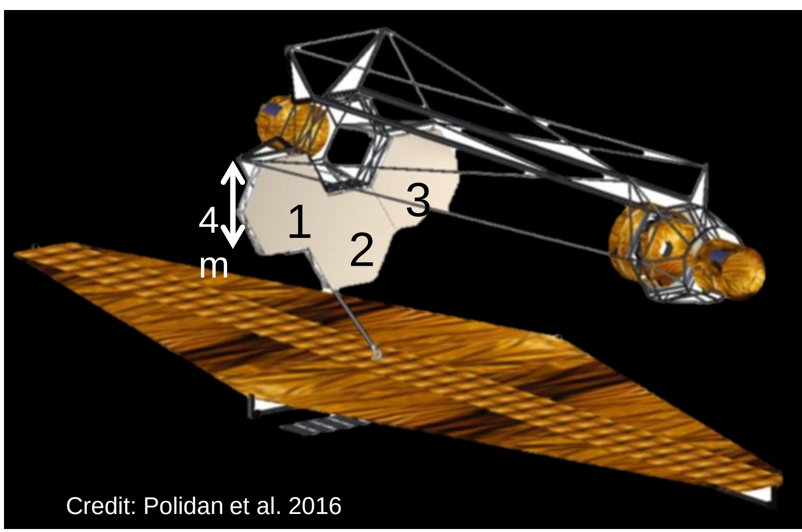
- iSSA enables space telescope designs that are much less constrained by launch vehicle fairing size and mass limitations.
  - > 20 m aperture telescopes, long-baseline interferometers, and large starshades
- iSSA enables telescope architectures that can grow in aperture size over time and, hence, enhance science through greater resolution and signal-to-noise.
  - “evolvable observatories”, “Pay as you go”
- iSSA extends the lifetime of observatories.
  - Potentially enabling a Great Observatories paradigm (persistent assets)
  - 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
- iSSA enhances our capability to more rapidly respond to new science questions through the replacement and upgrade of payload instruments
  - “HST is a better observatory today than when it first launched”
  - Instrument technology is ~10-15 years old by launch (technology lag)
- iSSA enables the use of new materials in space, for example ultra-low weight optics, that cannot be adequately tested at 1 g or safely survive launch environment in an integrated state.
- iSSA enables a much lighter overall structure due to the elimination of launch loads at the full assembly level.

Examples of iSSA enabled telescopes

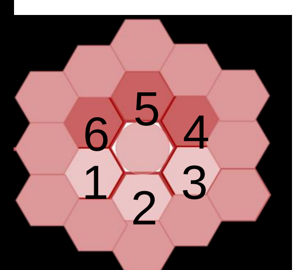
Interferometry space telescopes can be an application for in-space servicing and assembly.







Telescopes that incrementally evolve



What astronomical goals are enabled by iSSA

- iSSA enables future > 20 meter aperture space telescopes, long baseline interferometers, and starshades that will provide unprecedented spatial and spectral resolution and signal to noise in the UV, V, NIR, and MIR.
- iSSA enables multiple generations of instrumentation for future observatories to be added to an existing observatory, opening new science capabilities and facilitating longer lifetimes for observatories.
- Examples of greater capabilities include
  - Searching for Life Elsewhere
    - Increased yield of characterized Earth-like planets in the HZ of Sun-like stars
    - Increased spectral resolution of spectral signatures, some of which may be of biological origin, in the UV through MIR
    - Observations of daily and seasonal light spectral variations due to changes in surface features as the planet rotates and orbits
    - High-resolution, multi-wavelength remote sensing capabilities for Solar System objects that can enhance and extend planetary science missions
  - Discovering the Secrets of the Universe
    - Constrain the nature of dark matter and map its distribution through ultra-precise astrometry
    - Observing stars at all masses as individual objects beyond the Local Group to understand their formation and evolution in all environments
    - Observing galaxies at star cluster scales (< 50 pc) across all cosmic time
    - Observe atomic history across the full range of temperature and density, and track the rise of the periodic table
    - Observe gravitational wave precursors (binaries) just prior to collision
- By extending mission lifetimes and providing regular upgrades iSSA enables a Great Observatory-like system of concurrently operating observatories with access to the whole EM spectrum.

How will iSSA impact telescope development and performance?

- ❑ With iSSA, observatory lifetimes would be extended and performance enhanced (think HST), resulting in a lower total cost amortized over more years.
  - New and more advanced instruments can be swapped out without additional observatories
  - Spacecraft subsystems can be upgraded as they wear and age
  - Consumables can be replenished to extend their lifetimes
  - Repairing, when needed, can be conducted
  - Incrementally enlarging the apertures over time is now possible
- ❑ Telescope architecture moves away from "every new telescope is a new point design".
  - Modularizing the design would enable repair and replacement of faulty sections
  - Greater commonality with previous systems would reduce development costs
  - The need for "ruggedization" to survive launch environment is reduced
  - The need for new and unique ground test facilities is reduced
- ❑ It leverages existing and less-costly medium-lift launch vehicles and does not require next-generation launch vehicles.
  - By going with multiple launches, a launch failure need not be equivalent to mission failure

iSSA suggested next steps from the November TIM

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- ❑ 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
  - Multi-disciplinary, multi-institutional
  - Initiate the study in time for initial results to be available to Gateway and robotics designers within 2018, but certainly before end 2019.
- ❑ The study would produce several iSSA prioritized concepts.
  - One or two implementation concepts would be selected for a deeper engineering study.
  - Capability needs, SOA, and technology gaps would be created and a list of technologies that could be demonstrated to close these gaps would be produced.
  - Assessments of opportunities for engineering demonstrations that may be deployed on the ISS within the next few years would be identified.
  - Determinations of the balance of human and robotic support would be investigated.
  - An early list of preliminary interface considerations to the NASA DSG would be created.
  - Cost estimations and understand scaling laws would be generated to compare costs/risks of an iSSA approach to that of an autonomously deployed telescope.
- ❑ Consider providing input to the 2020 Decadal Survey about iSSA as a potential implementation approach for future large apertures.

For copies of the full TIM finings, contact: Nicholas.Siegler@jpl.nasa.gov

Summary

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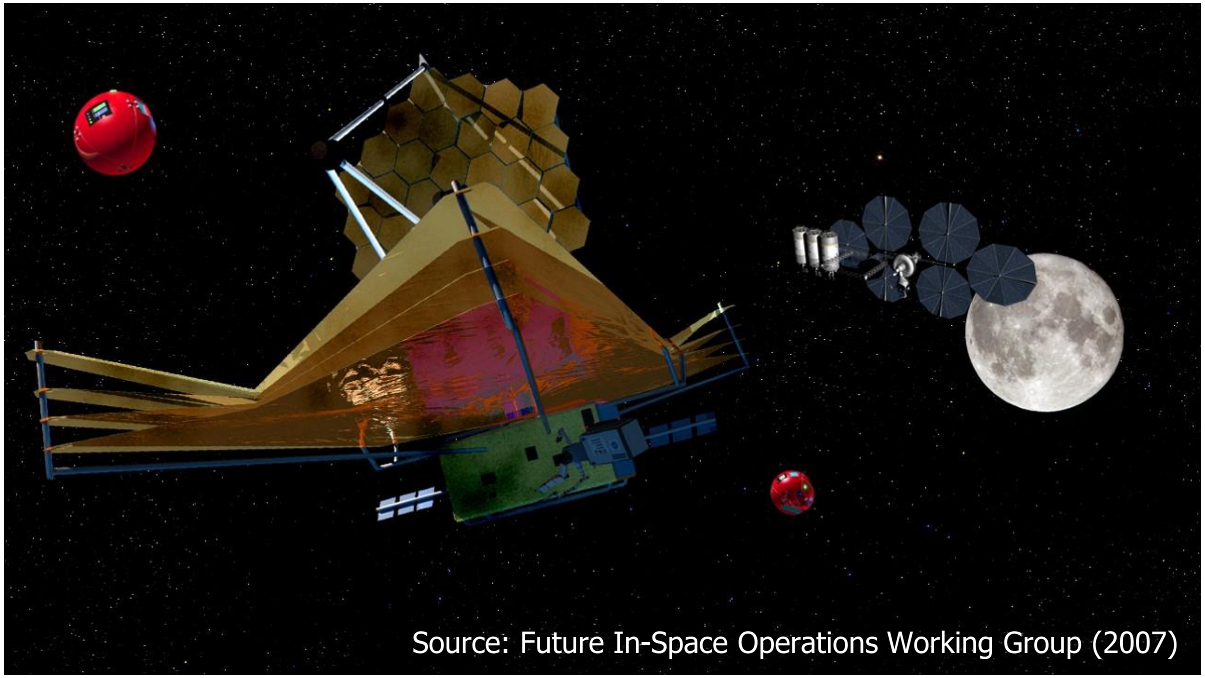
- The need for ever-increasing telescope apertures in space to answer the Universe's most challenging mysteries will continue, as will the desire to change the payload instruments that process that light.
- iSSA has the potential to be an important and enabling capability that has clear applications to near-term APD objectives – but its benefits require more detailed near-term assessment studies.


Source: Future In-Space Operations Working Group (2007)