ASSEMBLY AND SERVICING OF SPACE TELESCOPES

NASA MIRROR TECH DAYS 2017

HAWTHORNE, CALIFORNIA

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REVIRESCO LLC

howard.macewen@hmacewen.com

The Astrophysics Advisory Council (APAC) also recognizes that we are now "hitting a wall" in terms of the ability to build the missions we are considering, and thus novel methods may be needed, such as on-orbit assembly.

Scott Gaudi

Ohio State University

NASA APAC Chair

FORESEEABLE FUTURE

- Current candidate mission concepts for the 2020 Decadal Survey will be designed for autonomous deployment using launch vehicles available in the early 2030s (e.g., SLS, Falcon series)
- Beyond that period (e.g., late 2030s – 2040s) some science priorities are certain to require much larger apertures (and/or interferometers/sparse apertures)
  - Many more exo-planet candidate targets at greater distances
  - Higher-resolution observations of galactic evolution in the early universe
  - And inevitable, unforeseeable discoveries from breakthrough capabilities
- Major scientific goals after the first third of the 21st Century will require launch systems far surpassing the most inventive autonomous deployment concepts
  - A larger launch vehicle is an unlikely prospect due to risk and cost
- Therefore, it is time to begin developing new capabilities and technologies, specifically for assembly
  - A program that can be built on a servicing and upgrading technology foundation

THE ASSEMBLY SOLUTION

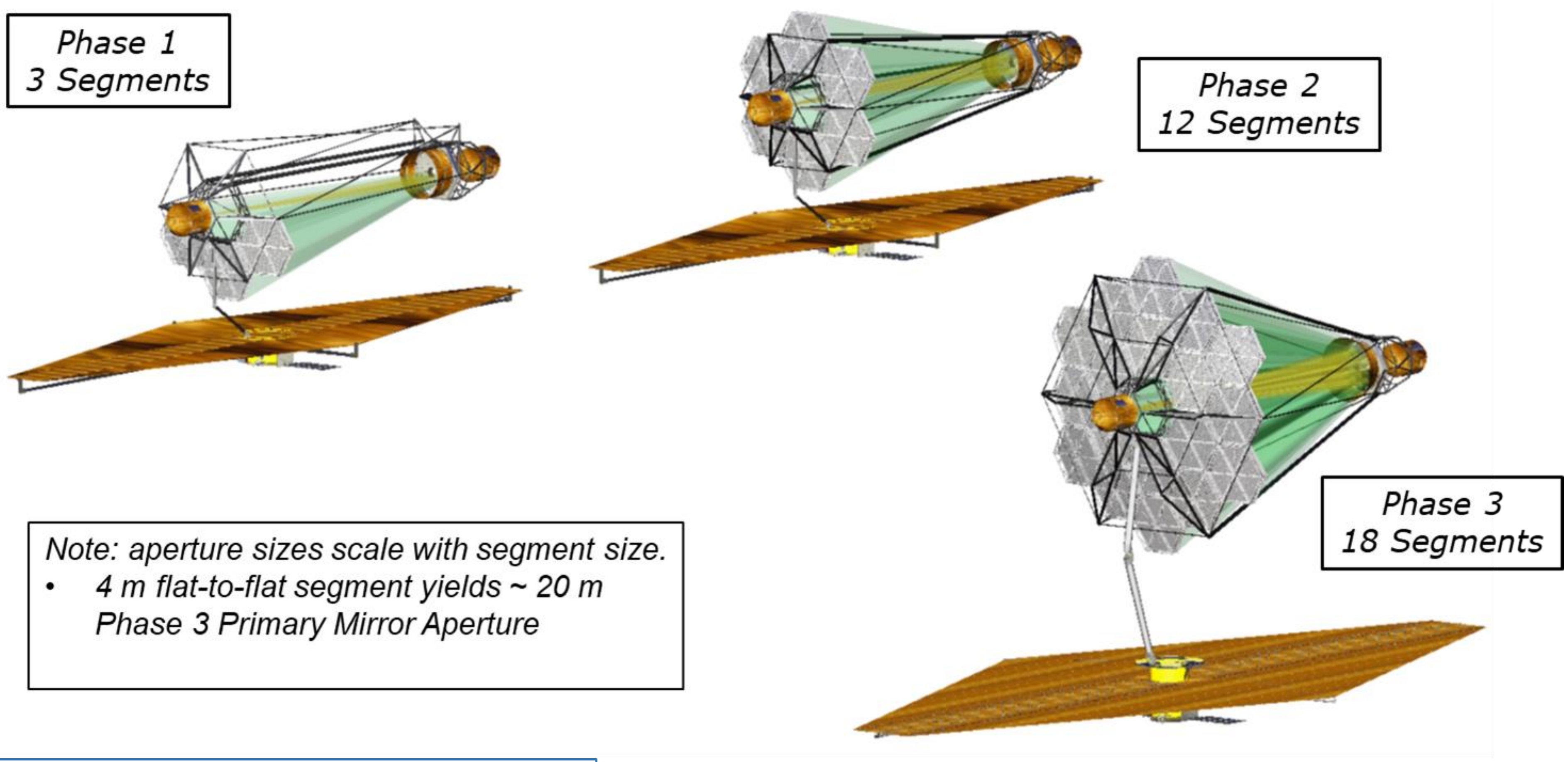
IN-SPACE ASSEMBLY AND SERVICING (ISA)

- Fabricate subassemblies using existing ground facilities and workforce
  - Launch using lower-cost medium-lift vehicles (Falcon, Delta, Vulcan, or …)
  - Complete manufacture in orbit – possibly with Gateway assistance
    - Astronaut habitation and operations site in cis-lunar space
    - Robotic and/or crewed
    - Transfer to observation sites via low-energy orbits
  - Finished spacecraft and telescope assembly readily enables servicing and upgrading
- Benefits include:
  - Fundamental: enable space telescopes too big for known launch vehicles and budgets
  - Less stress during launch, hence weaker, lighter, less expensive structures possible
    - And burden on ground integration and testing eased, reducing costs
  - Greater launch vehicle availability – no single path to failure
  - Design philosophy forces system serviceability
  - Distributed acquisition cost, lower annual (and total) cost
  - Broader competitive base for launch as well as for space telescope itself

BREAKING THE COST MODEL WITH ISA

- Costs of commercial medium-lift launch vehicles will continue to decrease with competition and enhanced technology
- More benign launch environment simplifies design while simultaneously enhancing survivability
- Leverage increasing capabilities of space robotics and perhaps astronauts on site (e.g., the Gateway)
- Mission life extendible with repairs, upgrades, propellant re-supply
- Minimize need for hardware redundancies
- Buy by the yard: increase aperture as funding is available
  - And instrument resolution, sensitivities, etc.

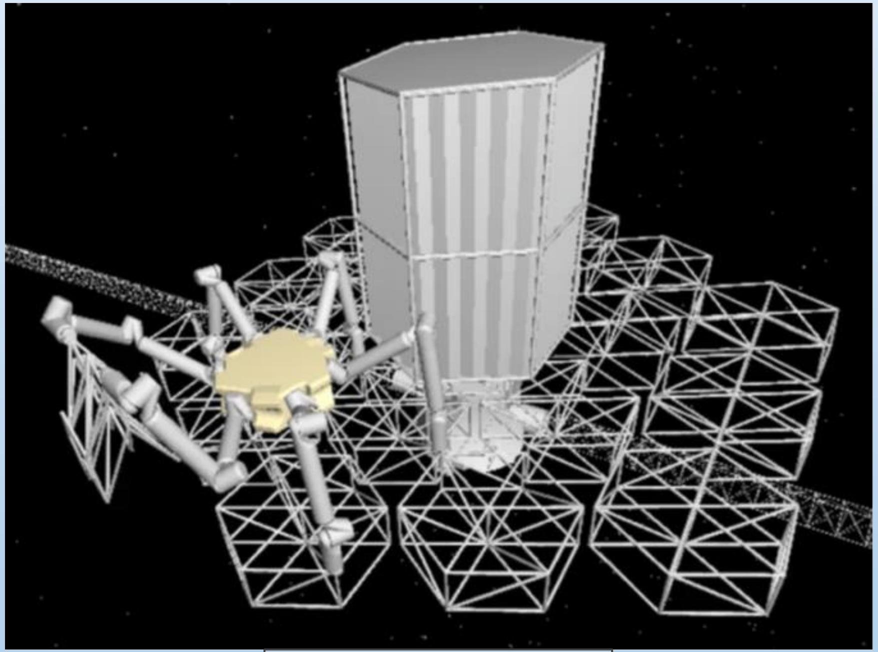
Evolvable Space Telescope (EST) Northrop Grumman Concept



Appeared in "Innovative telescope architectures for future large space observatories," *J. Astron. Telesc. Instrum. Syst.*, **2**(4), doi: 10.1117

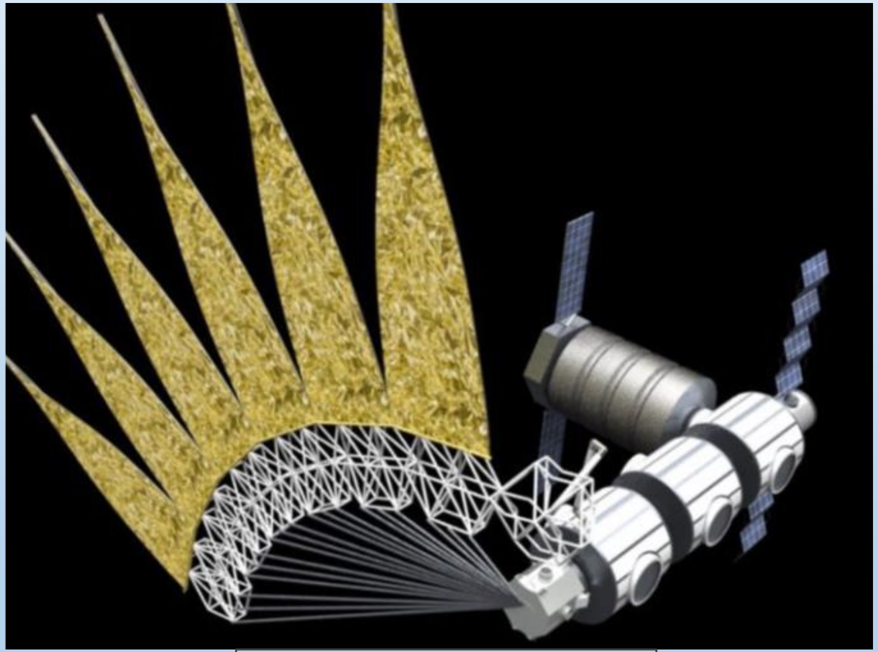
OTHER CONCEPTS

HEX BUILT – ROBOTIC TELESCOPE



Lee et al – JATIS

GATEWAY BUILT – TELEROBOTIC STARSHADE



Siegler et al - FASST

CURRENT STATUS OF ISA TECHNOLOGY

- Primarily (exclusively?) a LEO-demonstrated capability – but:
  - Rendezvous and docking accomplished in near-lunar orbit
  - Relevant technology is generally useable at any altitude
- Experience has validated ISA feasibility
  - Servicing and upgrading – Hubble Space Telescope (HST)
  - Assembly – International Space Station (ISS)
  - Crew EVA – Multiple missions from multiple platforms, planned/unplanned
  - Robotic operations – Mars landers and rovers (i.e., both high and low cadence)
- Infrastructure for Crewed Missions Under Development
  - ISS for experimental validation and data collection
  - Gateway design studies
  - Increasing launch system providers and launch sites

In General, all needed technologies are ramping up

SERVICE VEHICLE STATUS

- Service vehicles spend complete lifetimes in space
  - Human-occupied habitat: Gateway
    - Competitive studies for NASA/HEOMD
    - Operational in the mid- to late-2020s
    - Can be made available to support telescope servicing
    - Depending upon competition for scheduling
    - Program success will depend upon success of US human spaceflight program
  - Telerobotics: Restore-L (NASA), RSGS (DARPA), or combination; Commercial

    - In hardware development by government agencies
    - Successful development will lead to operational deployment
    - Supports possible servicing site in GEO

Multiple servers expected in operation by mid- to late-2020s

Courtesy: NASA

PARTICIPANTS AND STAKEHOLDERS

- In-Space Servicing, Repair, Upgrading, Manufacturing, Assembly of Large Space Telescopes have all been demonstrated in REAL programs
- NASA, DARPA, Commercial, International Efforts
  - Government programs are development programs
  - That encompass transitions to operational systems
- But: Programs all pursue either continuing markets for multiple servicers or critical geopolitical missions
  - And will require significant development to enable servicing of large space telescopes in deep space
  - And/or modifications to design or operations of servicing systems (Gateway)

NOT ALL MISSIONS ADDRESSED

- Servicing, assembly, etc. for large space telescopes in Deep Space are “side issues”
  - Generally one-of-a-kind missions
  - While similar in size to human exploration systems, differences are significant
  - And therefore market for expensive, specialized technologies is inadequate
    - Most servicing and assembly can be provided using generic approaches
    - But Life Cycle of large space telescopes needs to be even more thoroughly evaluated
    - Including modifications to generic approaches for special needs
- Options:
  - Trusted, lightweight servicers operating untended near delicate spacecraft
  - Crewed missions
  - All known options have the same basic problems
    - Unpredicted failure modes
    - Contamination issues: some of which will lend themselves to technological solutions
- In truth, we all know the conditions for acceptable solutions (mission design)
  - Affordable (considering all resources required)
  - Least compromise to mission/repairable
  - Easiest to monitor/short latency/close to servicing location

SPACE TELESCOPES ASSEMBLY STUDY

- Engage stakeholder communities to assess options for servicing and assembly
- Series of Technical Interchange Meetings (TIMs) on future priorities in astrophysics enabled by space servicing and assembly
- Participation by:
  - Astrophysicists
  - Spacecraft engineers
  - Industrial representatives
  - NASA Management
- First meeting held Nov 1 – 3 2017 at Goddard Space Flight Center
- Subsequent workshop(s) organized and hosted by JPL (2018)

CHARGE TO 1st MEETING

- Major developments in space exploration will take place in the coming decade that have the potential to significantly enhance cost effective science return from major space astrophysics missions
  - Significant reduction in cost of medium-lift launch vehicles
  - Continued advances in robotic/telerobotic capabilities: refueling, upgrading, assembly
  - Deployment in cis-lunar space of a long-duration human-occupied “Gateway” ops site
  - Advancements in relevant instrument technologies increases the payoff of servicing
- First in a series of 3-day Technical Interchange Meetings (TIMs) that will bring together ~70 professionals to assess current concepts and capabilities for a Gateway, as well as candidate augmentations that would enable major science missions not otherwise possible
- TIM organizing team consists of representation from four astrophysics “Decadal Survey” studies, NASA SMD, HEOMD, and STMD, industry “Gateway” concepts, DoD, SMEs from NASA Centers, and other experienced industry leaders.

CANDIDATE TIM DELIVERABLES

- Value to science of Gateway-based human operations and habitation facility: science-related activities in addition to astronomy: telerobotic ops of lunar rover, sample return, far-side meter-wave array, Solar System…….
- Precursors or demonstration activities: e.g., initial Orion rendezvous/docking scenarios with observatory, LEO demonstration, "pathfinder Gateway" able to service, assemble, upgrade science facilities, upgraded over time to full capabilities
- Coordinated/joint technology priorities, investment milestones, technology capability development plans and priorities, esp. near-term
- Coordinated/joint science and engineering design activities to enhance Gateway-type facilities: i.e., coordination with observatory and robotic designs
- Early identification of how – whether? – operations with a Gateway either decreases total science mission costs or significantly increases science return
- Does in-space assembly enable innovative mission design?
- Future coordination among scientists and Gateway designers: next steps

CONCLUSIONS TO DATE

- Large space telescopes in excess of ~15 meters will exceed all current and planned launch vehicles, thus requiring space assembly capability.
- There is currently no NASA capability to repair, upgrade, assemble, or extend the life of current and planned large telescopes requiring in-space servicing capabilities
- Space servicing is a potential risk mitigation approach to extend mission lifetime and repair failed systems
- A multi-institution Assembly and Servicing Study Team has been formed to assess and suggest options to NASA that will enable the largest, most challenging space astronomy missions (other science specialties to follow).
- Upgrading and space assembly is a capability that should be assessed as part of the next Decadal Survey.

RESULTS FROM 1st TIM

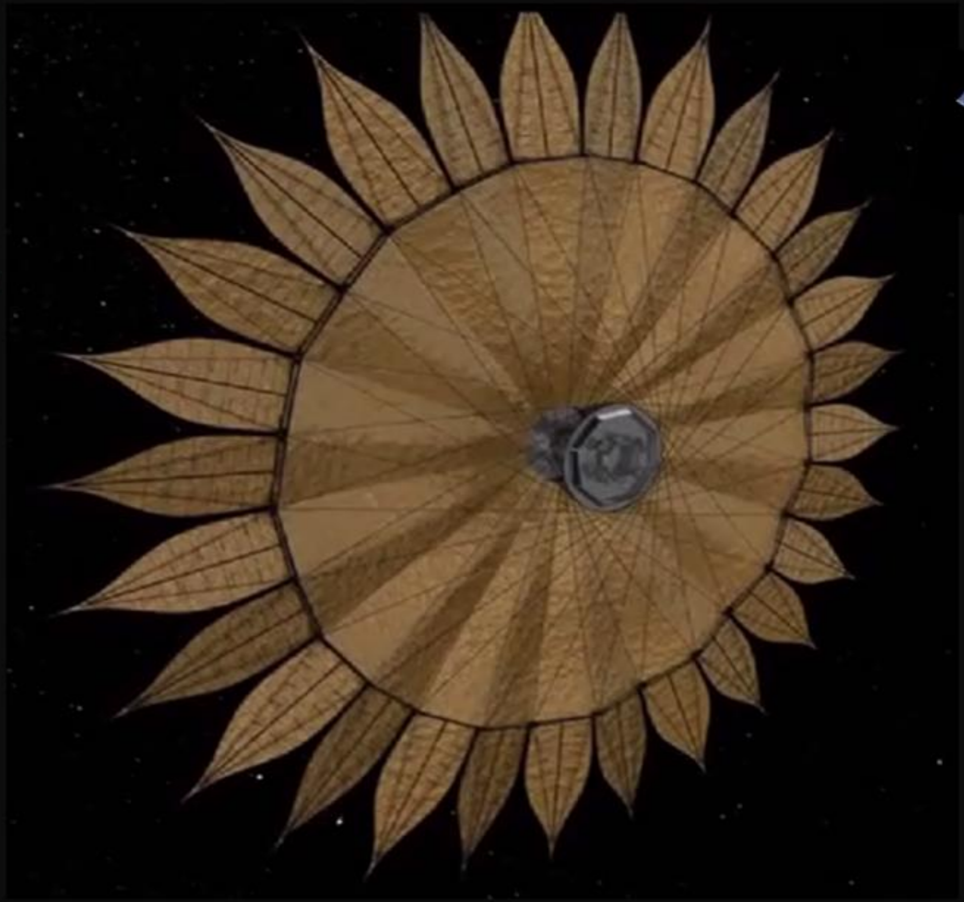
- Systems arising through Decadal 2020 will be serviceable, but there are no plans at this time for actual servicing
  - But this will help lay foundation for future servicing missions
  - And multiple applicable technologies and systems are in development
  - Basic capabilities have been established and validated
- The science return from serviced missions can be of major significance
  - As witness the mission expansion of HST, once it was an operational system
- Systems need to be designed for serviceability
  - But lack of this capability does not necessarily preclude servicing in all cases
- Servicing holds the promise of breaking the cost curve
- A detailed analysis of all aspects is essential data for the 2020 Decadal

WEBSITE

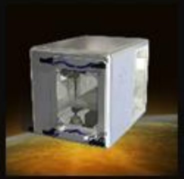
UNDER CONSTRUCTION

- Schedules
  - Internal and External Meetings and Conferences, e.g.:
    - Jan AAS
    - Jan AIAA
    - June SPIE
- Library of Past Briefings and Papers
- Membership and Contacts
- Future Technologies Watch List, e.g.:
  - 3D Printing of High-Strength Aluminum Alloys: Martin, et al; Nature, 21 Sep 2017
  - Gecko Gripper for rendezvous and temporary structures, mobility on large surfaces, etc.
  - Near perfect contamination control

Cis-lunar station



Assembly module docks to starshade bus



In-space manufacturing

Free-flying servicer

Mobile assembly robot

Fixed assembly robot

Astronaut support

VOLUNTEERS and SUGGESTIONS

- Next TIM 2018 at Jet Propulsion Laboratory
- Sign up with any member of the team
- Follow the website (once active)

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howard.macewen@hmacewen.com

BACKUPS

-- *Co-Authors* –
CORE TEAM

Harley Thronson (NASA GSFC) , *Principal Co-Author*

Matt Greenhouse (NASA GSFC)

John Grunsfeld (NASA GSFC)

Howard MacEwen (Reviresco, LLC)

Rudra Mukherjee (NASA JPL)

Brad Peterson (STScI and OSU *emeritus*)

Ron Polidan (Polidan Science Systems and Technologies, LLC)

Nick Siegler (NASA JPL and Exoplanet Exploration Program Office)