Infrastructure for a Permanent LUVOIR Observatory in Space

FOUNDATION FOR CONTINUING ASTRONOMY IN SPACE

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  - Unless Specifically Noted Otherwise
A COMPLETE OBSERVATORY……

ON THE MOUNTAINTOP

REQUIRES………

A COMPLETE INFRASTRUCTURE……

ON THE MOUNTAIN

LARGE……

W. M. Keck Observatory

SMALL……
In-Space Astrophysics
Requires an Evolving Science Fleet

• Determine What Ground Observations Do Not Do Well (Or At All)

• New Flagship Class Capabilities Every Decade or So
  – Vital for critical high resolution observations
  – And for general astronomy / astrophysics observations

• Supplement With Smaller Systems: Probes and Explorers
  – More rapid programmatic response to newly identified questions
  – And less expensive
  – May want to service, replenish, and switch instruments on all space platforms

• Indicates need for an In-space Astrophysics Infrastructure
  – To support all sizes of Space Telescopes and Instruments
  – And science spacecraft designed and built for upgrades, major and minor
Embryonic Space Observatory

• Starts small but with a full scale Observatory in the future
  – Lifetime approaching a century
    • Constant growth, modification, and upgrading
    • And removal of obsolescent elements
    • Provide the same science as a sequence of Flagships
  – Support smaller auxiliary telescopes in a complete infrastructure framework
    • Added wavelength coverage (complete spectrum)
    • Perhaps in same SEL2 Halo Orbit, but separated
  – Similar to Mt. Wilson – 100" telescope opened in 1917
    • Approximately same aperture as Hubble

• The Evolvable Space Telescope (EST) Provides an Initial Concept
  – Perhaps the Embryonic Observatory itself
  – And a core capability for long-term growth
Evolution

• The Beginnings:
  – The Evolvable Space Telescope (EST)
  – In-Space Assembly and Servicing Infrastructure
    • Large scale to small scale to touchup
    • Significant dependence upon developments outside SMD

• Conduct Upgrades and Servicing Missions
  – Expedite Selected Upgrades, Repair Malfunctions
  – Possibly Enable Earlier Launches with “Incomplete” Technology/Subsystems
  – And Provide Operational Demonstrations of Servicing as Confidence Builders

• The Goal: a semi-permanent LUVOIR Observatory at SEL2
Two Telescopes – An Observation

- Hubble Space Telescope (HST) began life with an in-space support infrastructure
  - The Space Shuttle
  - Lifetime has reached 25 years
  - And continues………..

- James Webb Space Telescope (JWST) will begin life with no in-space support infrastructure
  - Expected lifetime of 10 years
  - And………..
Evolvable Space Telescope

Three Phases

Note: aperture sizes scale with segment size.
Assembly and Service Infrastructure

• MacroPlatforms: Crewable; e.g., ISS, Deep Space Habitat (DSH)
  – Capable of complete servicing missions, manned or unmanned

• MiniPlatforms: Generally not equipped for crew
  – Too small or inappropriate for life support (mission length, etc.)
  – But can carry out “significant” servicing (to be defined)

• MicroPlatforms: e.g., SPHEREs
  – Limited roles, but potentially important, such as:
    • Evaluating servicing in volumes too small or hazardous for other systems
    • Inserting small components into such areas
    • Rehearsing orbit maneuver

An Effective Long Term Infrastructure Must Include A Mix of All Three
But Attention Has Focused on Macro and Micro – With Little Exception
Hence, A Need to Consider Mini

Deep Space Habitat (DSH) and Human/Robotic Telescope Servicer (HRTS)*
Assembling a Large Space Telescope

MicroPlatforms

SPHERES

Demonstrate Telerobotic/Autonomous Guidance, Navigation, Rendezvous, and Docking Under Microgravity Conditions

NASA CubeSat

CUBESATS
MiniPlatforms

Principal Area of Interest

• Systems have been studied, but not built and deployed
  – Functions performed by subsystems on the parent mission spacecraft
  – Robot arms on the Space Shuttle, ISS
  – And EVA by Astronauts

• Representative studies
  – Goddard GEO Servicer*
  – Single Person Spacecraft (SPS)

• Following discussion - MiniServ

Representative Studies

Single Person Spacecraft (SPS)

• By Definition, A Manned Vehicle
  – Provides Scale for MiniPlatforms
  – Specific Functions, Notably to Replace Space Suits

• Limited by Crew Needs to Neighborhood of Large Manned Systems:
  – International Space Station
  – Deep Space Habitat (DSH)/Transport (DST)

Goddard GEO Servicer*

• Chemically Propelled System
  – ~3700 kg Wet Mass
  – Vicinity of Geostationary Orbit

• Mission To Move About 10 Non-functioning Satellites from GEO to Disposal Orbit (300 km Above)
  – Does Not Service, Replenish, or Upgrade

MiniServ

Unmanned, Long Endurance, Long Range Service Vehicle

- Limited to Deep Space
- Capitalize Upon Libration Point Dynamics
- Perform Limited Servicing Functions

Characteristics

- Modularity/Flying Framework
- Libration Points Exploitation
- Small Size
- Expendability
- Reusability
- Flexibility – Short and Long Term

Value and Utility

- Unplanned Service
- Assembly and Servicing Assistance
- Escort Duty for MacroPlatforms
- Enable Missions Prior To Large Scale Infrastructure
- Side Excursions in Deep Space
Application Examples (1)

Unplanned Telescope Service

• Base at DSH in Earth – Moon Libration Orbit for Minimal $\Delta V$ to SEL2

• Include Small Inventory of Repair Parts at Base
  – Consumables as Well

• Develop a Small Additive Manufacturing Capability for the Base
  – Requires Technology for All Materials Needed on Telescope
Application Examples (2)

Mirror Coating in Deep Space (SEL2)

- Bare Aluminum for UV (eliminate need for protective coating)
- Re-coating (gold, silver,…) for extended system duration – visible, IR
- Repair reflective solar/thermal shades
  - May affect trade between parasol and barrel
- Requires technology development for optical coating in deep space
  - Uniform coating in microgravity
  - Deposition controlled to mirror surfaces only
  - Investigation of Al reflectivity degradation in SEL2 orbits

ZeCoat Corp, D. Sheikh
Application Examples (3)

Reprovisioning Consumables for Deep Space Systems

• Reduce need for transits of large systems (Telescope, HRTS)
  – Minimize mission loads on DSHs required for human exploration missions
  – Enable more responsive telescope operations
  – Replenish additional spacecraft in same SEL2 Halo Orbit without incurring expense of HRTS operation

• Expand design space for cryogenic missions
  – May not need high capacity active cooling
  – With attendant weight/vibration

• Enable Addition of External Occulter Late in Program Life Cycle
  – See next chart for specific possibility
WFIRST/AFTA currently planned as next major space astrophysics initiative
  - Could serve as the collector for an external occulter system with relatively minor modifications (To Be Defined) AND IF deployed in SEL2
    • But currently planned for geostationary or Earth drift-away
  - No Starshade planned for deployment, primarily due to long repositioning times required and correspondingly low yield
  - Results enhanced with better propulsion on Starshade
    • And could be used late in WFIRST/AFTA mission to characterize identified exoplanets

Greater propellant load could be provided by refueling with an early MiniServ
  - Eliminate need to rotate Starshade through propellant depot (or launch anew)
  - Conceivably one of two that could rotate between refueling site and depot
  - Telescope and Starshade would operate in same SEL2 halo orbit

Concept details need to be fleshed out
  - Changes to WFIRST/AFTA required to enable concept
  - Potential exoplanet yield/characterization enhancement enabled
“A probe class starshade mission can rendezvous with and effectively leverage WFIRST-AFTA to capture early spectra from Earth-like exoplanets and critically inform the design of future exoplanet flagship missions.

Continuing dark energy observations in parallel with starshade observations minimizes the impact to primary mission objectives.

WFIRST-AFTA can be made starshade ready with minor modifications to the baseline coronagraph instrument and by adding a radio system for starshade communications and range measurement.”
OBSERVATIONS

• The Next Steps in Large Space Telescopes Will Depend Critically Upon:
  – The In-Space Infrastructure Available to the Program Office
  – Or – That Can Be Made Available at the Right Time

• Little to No Infrastructure Limits Development to A Single, Expensive Flagship
  – Essentially A Single Telescope with a Limited Lifetime (5 – 10 – 15 Years)
  – Which Could be Reused with a Very Expensive Service/Rebuild Program
  – Or To Smaller, Special Purpose Telescopes (Probes and Explorers)

• A Developing/Extensive Infrastructure Enables a True Observatory
  – Start Against the Current Most Pressing Science Issues Using Current Technology
  – Build Upon Current Capabilities and Systems
  – Maintain Vibrant Technology Programs for Both Science Missions and Infrastructure
  – And Evolve the Observatory as Technology Develops and Science Issues Deepen

• The Infrastructure Must be a Shared Enterprise
  – All Space-Oriented NASA Directorates
  – Other National/International Space Agencies and Organizations

Plan Space Telescope Technology and Concepts to Capitalize on Servicing
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