

# Robotic Infrastructure for Lagrange-Point Observatories

Henry C. Ferguson

Space Telescope Science Institute

3700 San Martin Drive, Baltimore MD 21218

NASA's strategic roadmaps contain two focus areas that will generally require large deployable space telescopes:

- Conduct advanced telescope searches for Earth-like planets and habitable environments around neighboring stars; and
- Explore our Universe to understand its origin, structure, evolution and destiny.

A common feature of the next generation of space observatories is that they exceed the size of fairings of our launch vehicles. Thus, observatory designs require clever packaging into a small shroud, with active deployment on orbit. The size of rocket fairings limits the size of our observatories, and the need for accurate and highly reliable deployment drives designs in ways that have little to do with the science goals of the missions.

Another common feature among proposed missions is the desire to locate the observatory at the second Earth-Sun Lagrange point (EL2). Halo orbits around EL2 are favorable for energetic reasons (little fuel is required for station keeping) and thermal reasons (the Sun and the Earth are nearly in line, as seen from the observatory). For these reasons and others, WMAP was placed in an EL2 halo orbit, and JWST will go there. This a natural location for future missions as well.

In the light of the Columbia tragedy, NASA has embarked on serious study of robotic servicing for Hubble. Demonstrations of most of the servicing activities have been carried out with flight hardware and mockups. While the schedule is very challenging, the technical capabilities appear extremely promising.

*This white paper highlights the potential benefits of a telerobotic deployment and servicing facility for observatories at the Earth-Moon or Earth-Sun Lagrange points.* These ideas have been around for a number of years, and even encapsulated in previous NASA strategic plans. What has changed is the greater demand for large telescopes beyond low earth orbit, recent advances in telerobotics that now make this possible, and the fact that sustained human exploration of the Moon and Mars will almost certainly require similar capabilities.

## *The Hubble experience*

The *Hubble Space Telescope* provides many examples of the benefits of on-orbit servicing. The telescope was launched with optics that had passed ground testing, and nevertheless had serious spherical aberration. Thermally induced vibration of the solar panels significantly affected *Hubble's* ability to stay locked on to faint targets. By fixing both these problems, the first HST servicing mission essentially rescued the mission. Subsequent missions provided an infrared camera, a two-dimensional spectrograph, and a greatly improved optical/UV camera. Together these have produced the best constraints on black hole masses in the centers of galaxies, the first detection of the atmosphere of an extra solar planet, spectacular views of planetary systems in formation, and strong evidence that the universe is accelerating. Servicing made *Hubble* the most scientifically productive mission ever flown.

Hubble servicing was conceived in an era when the cost of human space flight was expected to decrease dramatically with an increasing rate of shuttle flights. This has not proven to be the case, and it is largely the costs associated with human space flight that made Hubble servicing expensive. The costs of instruments and replacement equipment have generally been comparable to similar equipment flying on new missions and only a few percent of the initial cost of Hubble.

## *Deployment and servicing of future space observatories*

There are two fundamental reasons why large-aperture space telescopes are required and inevitable. First, the intrinsic diffraction limit of a telescope is inversely proportional to the diameter (or separation of elements in a sparse aperture). Second, the number of photons collected from a source increases as the square of the diameter of the telescope primary mirror. Basic physics drives us toward the largest apertures that can be assembled and flown. We see the size issue as not solvable without a basic paradigm shift involving multiple launches and assembly in orbit.

Observatory deployment mechanisms represent a critical point of failure and thus add significantly to overall mission complexity. They must be designed and tested to survive launch loads, while at the same time affording the performance needed in a different dynamical and thermal environment once the observatory is deployed. Design and testing of these *use-once mechanisms* drives the overall mission design and costs in ways that have little to do with the science goals. Offloading the deployment tasks to a general-purpose robotic facility offers significant advantages:

- Construction of the satellite could involve modular assembly of several components, perhaps launched separately.
- Spacecraft components can be packaged in the launch shroud in a wider variety of ways, allowing larger telescopes in the same volume, improving contamination control, and/or decreasing launch stresses.
- Missions will need fewer “use once” mechanisms for deployment.
- The observatory could be tuned during deployment, without the need for motors and actuators built into the observatory. Examples include collimation, focus, and mirror figure.

A robotic facility could also provide upgrades and servicing for these major facilities, including:

- Installing science instruments to take advantage of new technology or explore new scientific frontiers.
- Replacing essential subsystems such as gyroscopes, reaction wheels, fine guidance sensors, power systems, or computers (all of which were replaced on Hubble).
- Replacing or refueling propulsion systems.

To accomplish these tasks for a large observatory, we conceive of a satellite with multiple long arms (booms) and manipulators, not a small anthropomorphic robot.

While EL2 is the desired location for many future space-astronomy missions, it is not necessary that the telerobotic facility be located there. Low-energy transfers are possible from EL2 to other Lagrange points (Lo & Ross 1997). A particularly attractive location for a telerobotic facility is Earth-Moon L1 (LL1). The one-second light-travel time from Earth to LL1 is short enough to allow control with reasonable feedback from the ground. LL1 is also an energetically favorable location for servicing or staging lunar or Mars missions. An LL1 manned gateway was a centerpiece of NASA’s NExT initiative, as a steppingstone to human exploration of the Moon and Mars. A telerobotic facility at LL1 could thus serve the joint needs of the manned spaceflight program and the space science program.

A multi-purpose orbiting telerobot is a compelling alternative to current mission concepts, essentially allowing multiple missions to share deployment and maintenance costs. Such a facility serving the Lagrange Points of the Earth-Moon-Sun system may well be an essential strategic capability for reaching NASA’s goals in manned and unmanned space exploration.