

ISS-based Development of Elements and Operations for Robotic Assembly of A Space Solar Power Collector

Azita Valinia^{1,2}, Rud Moe¹, Bernard D. Seery¹, John C. Mankins³

Categories: Applications Benefiting Earth, Applications Enabling Exploration

1. Motivation

We present a concept for an ISS-based optical system assembly demonstration designed to advance technologies related to future large in-space optical facilities deployment, including space solar power collectors and large-aperture astronomy telescopes.

The large solar power collector problem is not unlike the large astronomical telescope problem, but at least conceptually it should be easier in principle, given the tolerances involved. We strive in this application to leverage heavily the work done on the NASA Optical Testbed Integration on ISS Experiment (OpTIIX)⁴ effort to erect a 1.5 m imaging telescope on the International Space Station (ISS). Specifically, we examine a robotic assembly sequence for constructing a large (meter diameter) slightly aspheric or spherical primary reflector, comprised of hexagonal mirror segments affixed to a lightweight rigidizing backplane structure.

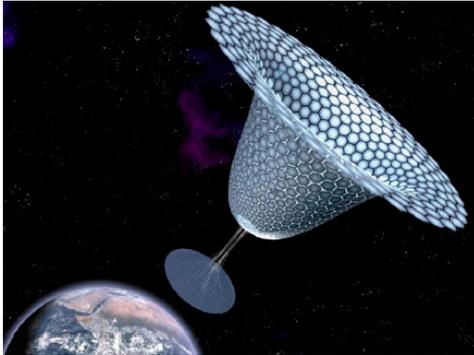
This approach, together with a structured robot assembler, will be shown to be scalable to the area and areal densities required for large-scale solar concentrator arrays.

2. Assembly Demonstration Concept

The assembled solar power collector will be scaled to about a meter diameter to fit ISS accommodations readily and practically as a FRAM-mounted payload on an exterior site (such as one of the existing ELC sites). The Assembly Demonstration will utilize ISS resources for electrical power, command and data, robotic transportation of the kit of elements from the launch vehicle dock location to the assembly demonstration site, and robotic manipulation of the several kit elements for assembly. Three-axis gimbal designs, based on prior hardware developments on the OpTIIX Project, offer a slightly redesigned Robonaut gimbal (which has already been space qualified) to take out ISS image rotation due to its gravity-gradient stabilized platform dynamics and allow us to two-axis point the collector to track the Sun.

The demonstration hardware will comprise six hexagonal-shaped reflector modules with pre-integrated articulation actuators, six modular backplane elements which provide utilities distribution, and the core module which serves as the structural and electrical interface to the ISS via FRAM and provides controls for operations. The ISS SPDM robotics will be used to unpack the kit and assemble the elements onto the core module to build up the solar power collector. Alternatively, a pair of simple assembly manipulators would be included in the kit. The manipulators would be commanded to autonomously assemble the other elements to build the collector.

After assembly is completed, the collector will demonstrate effective and efficient solar power collection and conversion. During these solar passes, the articulated reflectors will self-control to track the sun over their field of regard to reflect and direct its radiation onto the converter in the core with sufficient accuracy to realize the demonstration objective.



Solar Power Satellite Concept by means of Arbitrarily Large Phased Array (SPS-Alpha)⁵

3. Concept Applications to Multiple Disciplines

Progress toward robotic autonomy, e.g., blind-mating, of modular structural and utilities connections and structure crawling, would be needed to inform future studies for large in-space assembly projects. The structured assembly of large solar collector space structures using autonomous robots can be shown to be extensible to other scientific and technical disciplines, with examples being the large, diffraction-limited telescopes and large space structures associated with notional orbiting fuel depots configured to support in space refueling of propellants and oxidizers for transfer vehicles. The solar power collector concept, equipped with a power converter stage and a phased array microwave emitter antenna, can be applied to either the in-space power delivery problem, or the delivery of power from geosynchronous orbit locations through the planetary atmosphere to terrestrial receiver stations, as described in the body of this paper. One scenario is described in detail the 2012 NASA NIAC Report (SPS-Alpha)⁵.

4. Pathfinding Technologies

Segmented articulated reflector concept implementation will demonstrate sufficient actuation range, accuracy and stability for solar power collection. The core module will be instrumented to measure net collected power and/or conversion efficiency.

Robot-friendly design of module interfaces through use of self-aligning blind-mating/releasing structures and connectors, and assembly sequence operations with clear access corridors and use of targets and handling fixtures to facilitate local robotic sensing and manipulation will support the demonstration of robust autonomous controls and sufficiently accurate and stable assembly of optical elements.

5. Path Forward

A small-scale technology demonstration project that can achieve the various technologies involved will serve as a pathfinder for larger ISS-based telescopes. The optical system assembly demonstration has wide application to affordable large space telescopes for

astronomical purposes (such as search for Earth-like planets) as well as harnessing solar power for use on other space-based platforms (and one day possibly on Earth).

This revolutionary pathfinding approach can help advance the timescales for achieving such large-scale space telescopes by at least a decade, through demonstrating the needed technologies for proof of concept.

1 NASA Goddard Space Flight Center, Greenbelt, MD 20771

2 Corresponding Author Azita.Valinia@nasa.gov

3 Artemis Innovation Management Solutions LLC, P.O. Box 6660, Santa Maria, CA 93456

4 Burdick, G.; Callen, P.; Ess, K.; Liu, F.; Postman, M.; Sparks, W.; Seery, B.; Thronson, H, “The ISS as a Testbed for Future Large Astronomical Observatories: The OpTIIX Demonstration Program”, ISS Research and Development Conference, American Astronautical Society, June 26 – 28, 2012

5 SPS-Alpha: The first practical solar power satellite via arbitrarily large phased array (2011-2012 NASA NIAC Phase 1 Project Final Report, John Mankins, Principal Investigator)