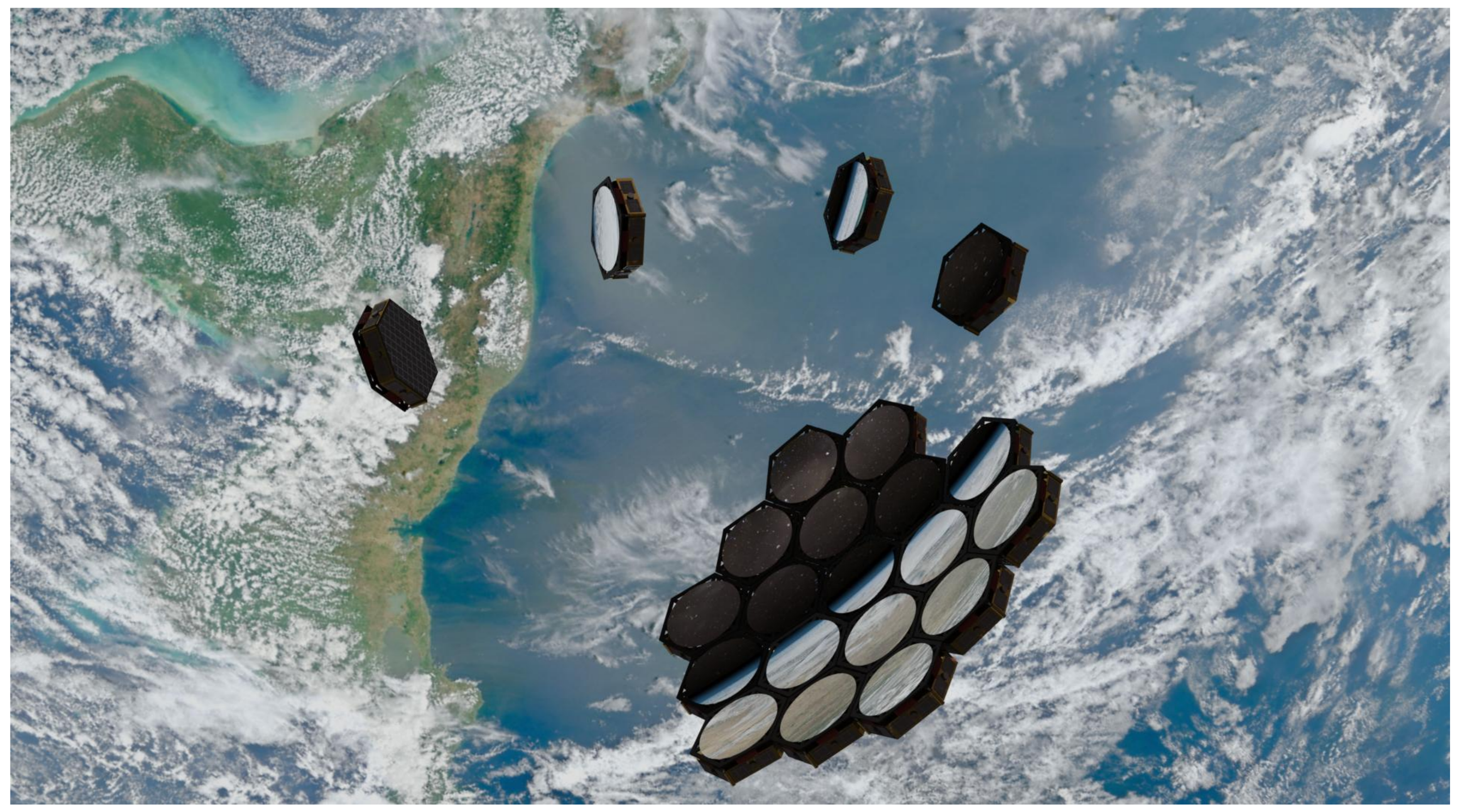
AAReST Technology Development

John Steeves, Keith Patterson, Namiko Yamamoto, Marin Kobilarov, Gwen Johnson, and Sergio Pellegrino

California Institute of Technology

Motivation

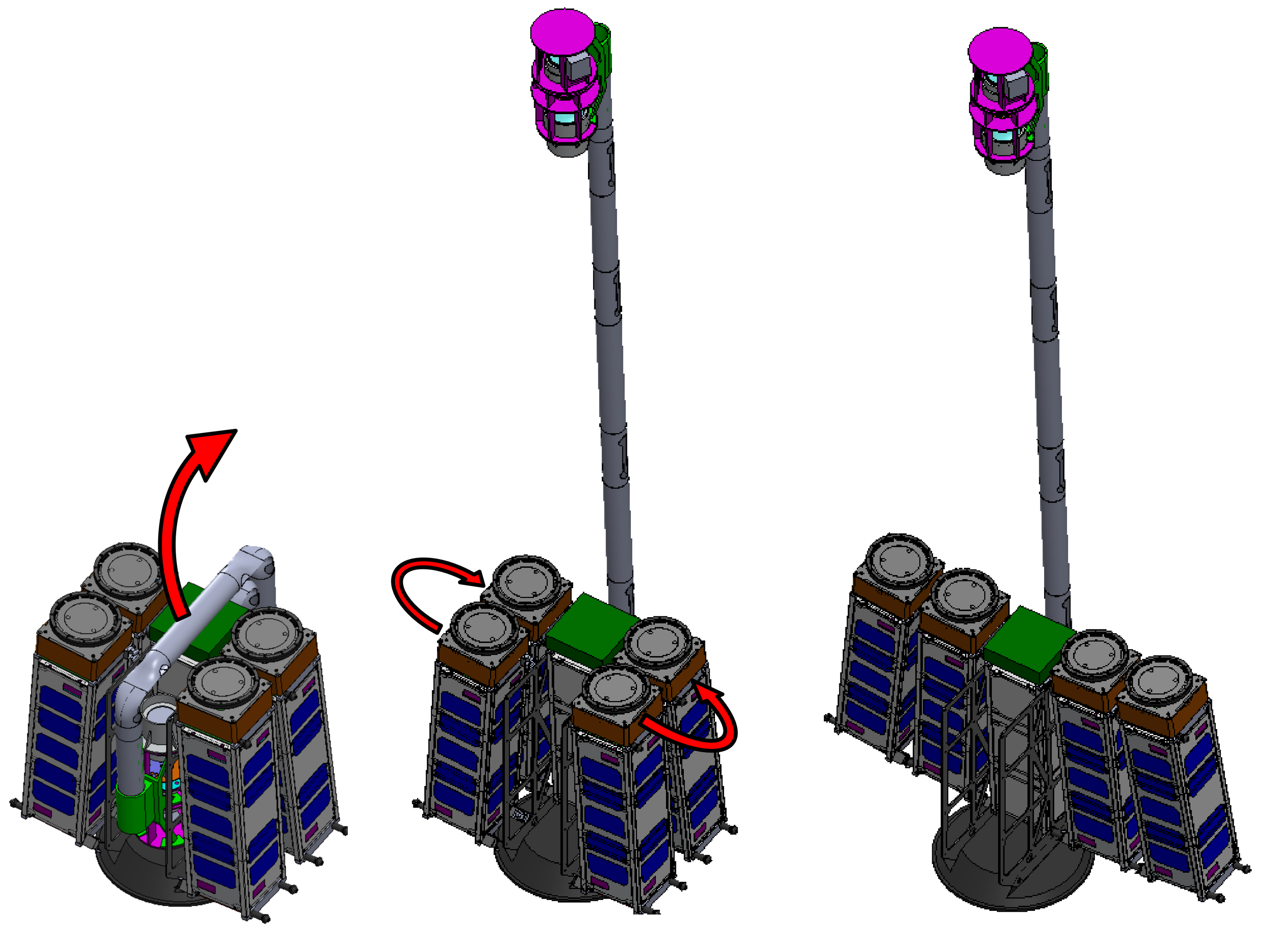
In recent years there has been a desire to develop space-based optical telescopes with large primary apertures (over 10 m in diameter). Currently the largest primary aperture under development is that of the James Webb Space Telescope with a diameter of 6.5 m. However, its size is still limited by the diameter of the launch vehicle; a limitation for all current space-borne telescopes. One method to overcome this obstacle is to autonomously assemble small independent spacecraft, each with their own deformable mirror, while in orbit. In doing so, a telescope with a large, segmented primary mirror can be constructed. Furthermore, if each of these mirrors is manufactured to have an identical initial shape, and then adjusted upon assembly, a substantial reduction in manufacturing costs can be realized.



Depiction of a large aperture telescope being assembled in space using smaller, modular mirror segments. Each segment can be made identical to one another due to the active capability of the deformable mirrors.

Telescope Overview

In order to demonstrate the concept of a self-assembling telescope the "Autonomous Assembly of a Reconfigurable Space Telescope" (AAReST) mission has been developed. The AAReST spacecraft is a prime focus, sparse aperture telescope (1.2m focal length, 1.0° field-of-view) consisting of four 10cm diameter circular mirrors, two of which are highly deformable. These mirror segments are attached to a cluster of Cubesats. The Cubesat structures housing the deformable mirrors can be detached from the primary cluster in order to perform the desired reconfiguration maneuvers. A deployable carbon-fiber boom is utilized in order to position the optical instrumentation package at the focus of the telescope.

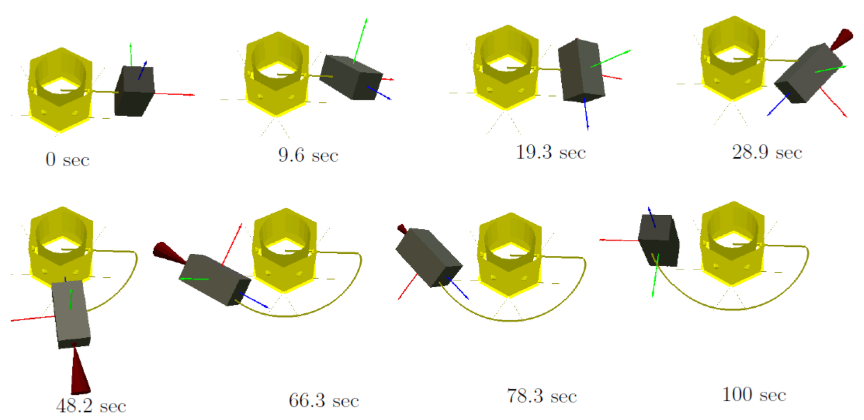


(a) (b) (c)

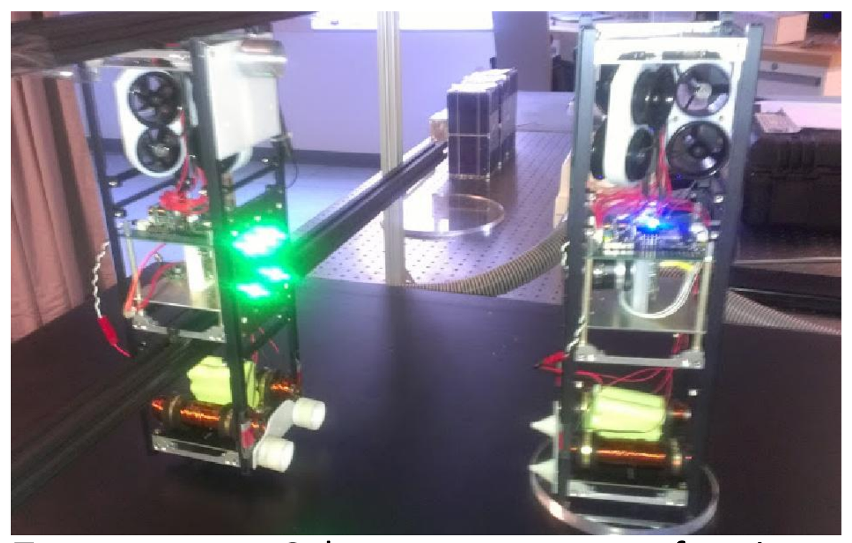
AAReST concept demonstrating a) initial launch configuration, b) initial imaging configuration and c) secondary imaging configuration subsequent to successful docking and reconfiguration maneuvers

Reconfiguration and Docking

Once the telescope has deployed and completed the initial set of imaging objectives in the "compact" configuration, two of the Cubesat structures will perform an autonomous reconfiguration maneuver. The Cubesat will detach and push away from the primary cluster, reorient itself using the internal reaction wheels, and then circle around the cluster to its new location. Once at this location, a computer vision system will precisely guide the spacecraft to its near-final docking position. Electromagnets will be used at the final stage to assist the Cubesat to its docking ports.



Outline of a proposed reconfiguration maneuver using a single cold-gas thruster.

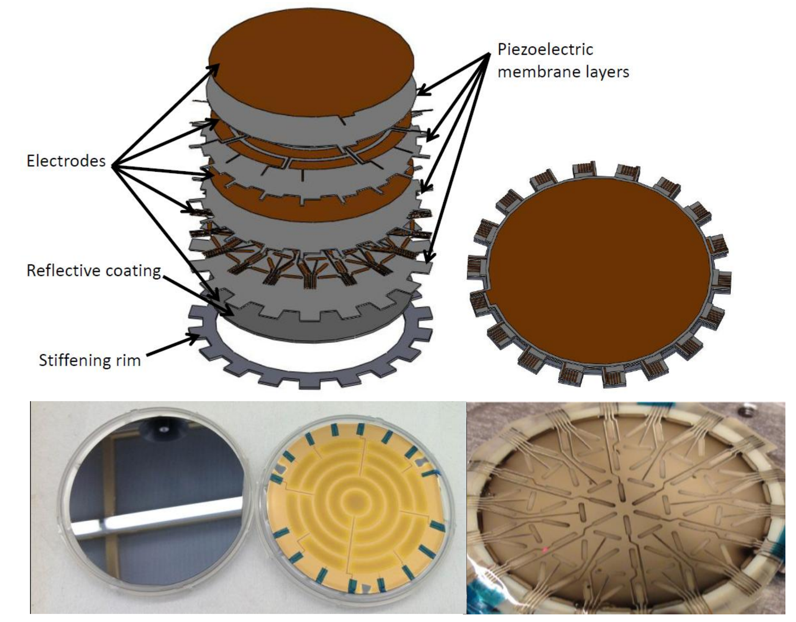


Two prototype Cubesat structures performing a docking maneuver on an air-table test bench. The prototypes are equipped with fans (mimicking thrusters), LEDs for a computer-vision system, as well as electromagnets and docking ports.

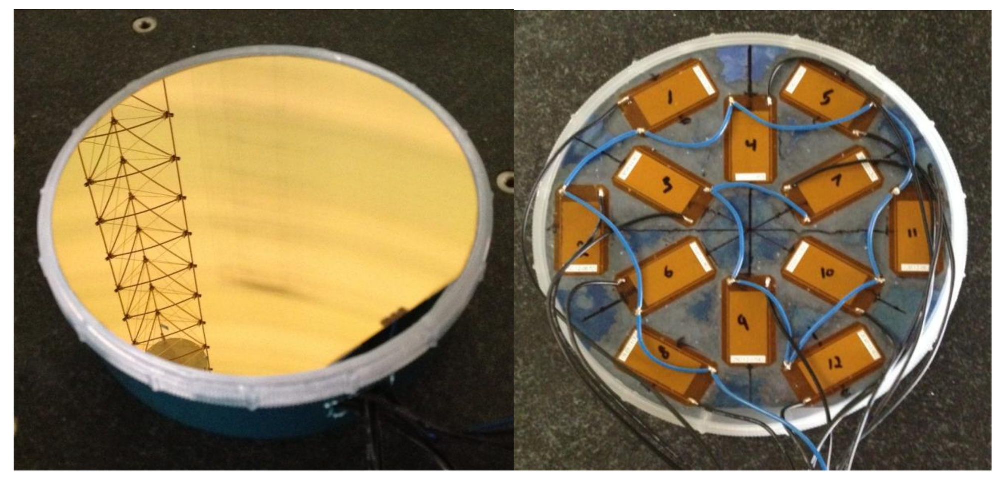
Deformable Mirrors

Currently, two approaches are being pursued in order to accomplish the task of manufacturing highly-deformable mirrors. The first method is to construct the mirror from a piezoelectric polymer, polyvinylidene difluoride (PVDF), using manufacturing processes developed in the microdevices industry. The mirror is built as a sequence of PVDF and metal electrode layers. Two sets of actuation patterns are contained within the stack-up in order to provide greater control over the mirror figure. A thin layer of aluminum is then added to the front surface in order to provide the reflective surface.

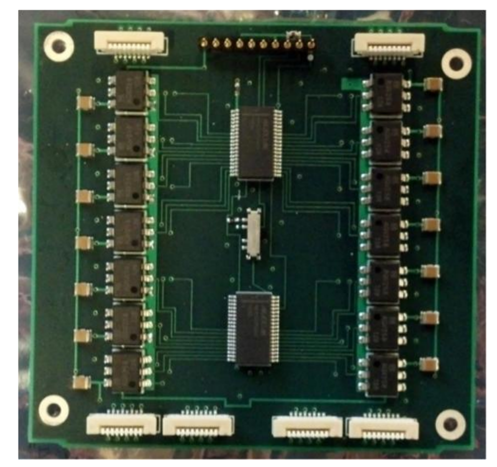
The second approach uses ultra-thin carbon fiber laminates as the substrate of the mirror. Patches of piezoelectric ceramics (PZT, PMN-PT) are then tessellated on the back surface of the mirror in order to provide the actuation capabilities. A smooth layer of epoxy coated in aluminum or an optical quality nanolaminate will act as the front reflective surface.



Schematic of an active polymer mirror stack-up as well as current prototypes depicting the reflective surface and patterned electrodes.



Front and back surface of a 150mm, 12-actuator, gold coated silicon substrate mirror.



High voltage (+/-500V) multiplexer board with 42 independently addressable channels capable of fitting within a standard Cubesat structure.

Conclusions and Acknowledgements

We have developed a number of key technologies as a step towards our goal of constructing future large-aperture space telescopes. All components have been designed to fit within the standard Cubesat platform demonstrating its efficacy in the area of technology development.

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