Self Assembling Space Telescope

by John Johnson
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The long list of discoveries made by the Hubble Space Telescope has proved the value of putting instruments in space, where the images are not blurred, or obliterated, by Earth's atmosphere. X-ray astronomy and much of infra-red astronomy can only be done from space, where orbiting telescopes have the additional advantage of being able to survey the entire sky.

Studies have indicated, however, that launching a telescope much larger than the upcoming, 6.5-meter James Webb telescope would require more powerful rockets than are readily available today.

To find an alternative to the single-mirror telescope design, scientists at the California Institute of Technology and the Jet Propulsion Laboratory are studying the feasibility of a self-assembling space telescope. Individual mirror segments, mounted on separate satellites called MirrorSats, would be carried into space aboard multiple rockets. Once in orbit, the segments would maneuver in cooperation with each other to link up and produce a mosaic telescope mirror perhaps even larger than the James Webb telescope.

To prove the validity of the approach, the team headed by Sergio Pellegrino, the Joyce and Kent Kresa Professor of Aeronautics at Caltech, plans to launch a 1-meter proof of concept version of the self-assembling telescope by 2015.

"We started out to do a general theoretical study of the concept," said Pellegrino, who also serves as a senior research scientist at JPL. "Gradually, we began focusing on showing how it would work."

This is not the first time anyone has proposed building a space telescope out of segments launched one at a time. Scientists in Europe and the United States have looked into self-assembling telescopes as a way out of the gravity box that limits the size of payloads launched from the Earth's surface[1]. This time researchers are rigorously tackling the daunting engineering problems that must be overcome before such an instrument can be successfully placed in space.

The program – Self Assembling Space Telescope -- has four goals:

1. Finding the right architecture for the telescope;
2. Designing lightweight mirrors that can maintain their shape and yet are flexible enough to change their configuration to resolve a range of viewing targets;
3. Writing guidance, navigation and control (GNC) algorithms that will enable the individual MirrorSats to dock with each other without colliding; and
4. Validating the design and in-space assembly of the telescope through computer simulations.

According to Greg Davis, Chief Technologist for the Mechanical Systems Division at JPL, a great advantage of projects such as this one is the hands-on experience it can give students.

In one lab, Caltech grad student Keith Patterson spreads a liquid polymer resin on a small silicon wafer before spinning it at high speed on a small turntable-like wheel. When finished, the resin has coated the wafer to a depth of just a few microns. This is one of several ultra-thin layers of plastic and electronics that will make up the mirror on each of the satellites.

The layer cake design is bounded by Kapton[2], a commercial insulating plastic. Other layers contain electrodes that will provide an electric charge on actuators made of another plastic, polyvinylidene fluoride (PVDF)[3].

In other telescopes, the actuators that focus the mirrors and adjust for the effects of atmospheric blurring are located outside the mirror structure. In this design the actuators are built into it[4]. The electric charge causes the PVDF layers to bend, deforming the reflective surface, which will be made of silver or aluminum. In this way, the mirror segments can be focused, or adjusted to compensate for shudders and vibrations of the entire mosaic mirror, without bulky external machinery.

"Our inspiration for this actuation scheme was the LCDs (Liquid Crystal Display) used in computer screens," Pellegrino said. "The charge to each pixel is distributed across the surface, the same way the charge will be distributed across the surface of each PVDF layer."

Even with all these layers, the structure should be flexible enough to be folded into the fairing of a rocket, which would allow large MirrorSats to be placed in space.

In a second lab, a Keck Institute Postdoctoral Fellow named Marin Kobilarov is using a computer to send a small robotic device skimming over the surface of what resembles an air hockey table.

"We're focusing on developing novel algorithms to figure out how to control the individual MirrorSats," Kobilarov explained[5,6].

Tests like this one will help the team learn how to program the best routes for the individual MirrorSats to choose as they assemble themselves into the mosaic mirror. To simplify the docking procedure, magnets will be used to safely draw the mirror segments into the correct alignment[7]. The study is expected to be complete in late 2012.

A demonstration version of the self-assembling telescope is being developed as part of the Autonomous Assembly of a Reconfigurable Space Telescope (AAReST) mission being developed for launch in 2015. It will consist of six tiny MirrorSats, each 10 centimeters in diameter, grouped around a larger central mirror, like the petals of a flower. Once in space, four of the mirror segments will detach. Using a small amount of fuel each MirrorSat will carry on board, they will then maneuver, something like square dancers shuffling to a new position, to re-attach in a linear configuration about 1 meter long.

The seven spacecraft will be built at Great Britain's University of Surrey, which has a lot of experience in making small satellites[8]. Caltech and JPL will provide the mirrors, controllers and focal plane sensors. To save launch costs, designers hope to hitch a ride on a rocket carrying another payload.

Pellegrino believes future telescope construction must apply the cheaper is better approach, given budget constraints facing NASA and other space agencies around the world.

According to Yunjin Kim, a project manager at JPL, such an approach should favor failure tolerant designs consisting of identical parts that can easily be replaced if there is a malfunction[9]. Where possible, commercial-off-the-shelf materials should be employed to lower the mission cost.

"Space missions traditionally cost a lot of money," Kim said. "This approach is a stepping stone to the future."

The demonstration telescope will not aim to deliver new science, yet researchers don't want to send it into orbit with nothing to do. In collaboration with Sterl Phinney, professor of Theoretical Astrophysics at Caltech, they have identified several possible missions, including UV or optical photometry and interferometry. One possible job would be to focus exclusively on a particular part of the Earth's surface, waiting for an earthquake. Ground movement during an earthquake has never been observed from space, Pellegrino said.

Since the project will test a range of innovative structures and technologies, it's possible that some things could go wrong, Pellegrino said.

"This is not a NASA mission," he said, referring to the American space agency's rigorous, and costly, pre-launch testing regime aimed at preventing mission failures.

"Even if some element of our mission doesn't work, the investment will be worth it because of what we learn."

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Footnotes

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