DARPA Wants to ‘Grow’ Enormous Living Structures in Space

Living materials could self-assemble into antennas, nets to capture debris, or even space station parts.

By Shelly Fan

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Space stations break down. Satellites get damaged. Repairing them requires launching replacement components on rockets.

The US Defense Advanced Research Projects Agency (DARPA) is now exploring an alternative: growing these parts directly in space. The concept would skirt delivery headaches. Without a rocket’s size and weight constraints, engineers could also design and construct large structures—over 1,640 feet or 500 meters long—that can't be shipped from Earth.

The technology could be especially useful as we inch towards missions to Mars and beyond.

The agency has previously explored space manufacturing that would rely on robotic construction or self-assembling materials. The new proposal adds synthetic biology to the mix. Compared to traditional rigid materials, alternatives that incorporate living microbes could be more flexible. Embedded in a biocompatible matrix that provides structure, they could form a living material that withstands the unforgiving environment of space.

It sounds like science fiction, and it still is. But in late February, DARPA called for ideas to make the vision a reality.

Space Factory

Building large objects directly in space has multiple perks. Instead of folding up structures to fit into rockets—like the James Webb Space Telescope, which engineers folded origami-like for its ride to space—ferrying lightweight raw materials from Earth could be more energy- and cost-efficient. The materials could then be made into much larger objects in orbit. Microgravity also allows engineers to design structures that would sag under their own weight on Earth. Space offers an opportunity to build objects that are wildly different than any on the ground.

Space manufacturing is already in the works. In 2022, DARPA launched the Novel Orbital Moon Manufacturing, Materials, and Mass-Efficient Design (NOM4D) program to test the idea.

"Current space systems are all designed, built, and tested on Earth before being launched into a stable orbit and deployed to their final operational configuration," NOM4D program manager Bill Carter said in a 2022 press release. "These constraints are particularly acute for large structures such as solar arrays, antennas, and optical systems, where size is critical to performance."

Three years later, the program is almost ready to launch its first raw materials into space to test assembly. One of these, designed by the California Institute of Technology and Momentus, will hitch a ride on a SpaceX Falcon 9 mission in early 2026. In orbit, a robotic device will transform the material into a circular "skeleton" mimicking the diameter of an antenna.

"If the assembly technology is successful, this would be the first step toward scaling up to eventually building very large space-based structures in the future," program manager Andrew Detor said in a press release.

Another team from the University of Illinois Urbana-Champaign is partnering with Voyager Space to test their own material and manufacturing process on the International Space Station. Made up of flat carbon-fiber sleeves, similar to finger-trap toys, their material uses a novel chemical process that hardens liquid components into solid structures. Heating up one side of the sleeve stiffens the entire structure. Their test is also scheduled for 2026.

A Dose of Biology

But DARPA is ready to get even more ambitious.

Thanks to synthetic biology and materials science, we've seen an explosion of biomaterials compatible with living cells. These have been used to deliver drugs deep into the body, form tough structures to support prosthetics, or 3D bioprint organs and tissues for transplant.

Meanwhile, scientists have also discovered a growing number of extremophiles—microbes that can withstand extremely high pressures and temperatures or survive acidic environments. Bacteria dotting the outside of the International Space Station can survive extreme ultraviolet radiation. Sequencing extremophile genomes is revealing genetic adaptations to these harsh environments, paving the way for scientist to engineer bacteria that survive and thrive in space.

The stage is set, then, for hybrid living materials that grow into predefined structures in space.

DARPA's new vision is to rapidly engineer biological objects "of unprecedented size" in microgravity, with lengths reaching over half a kilometer, or more than 1,640 feet.

One idea is to weave biomaterials, extremophiles, and non-organic fibers into materials with different stiffnesses and strengths. This would be a bit like manufacturing a tent. Some materials could be used as tent poles supporting the overall structure. Others—such as bacteria—can grow the tent's walls, floor, and roof, with the ability to stretch or shrink. Balancing the amount of each component would be critical for the material to work in multiple scenarios.

But space is an incredibly hostile environment. A crucial challenge will be figuring out how to keep the bacteria alive. Another will be directing their growth to form the desired final shape.

The setup will likely need biomaterial scaffolds to store and provide nutrients to the critters. These could be supplied to so-called leading edges, where rapidly dividing bacteria expand the material. Adding specific chemical signals—which many microbes already use for navigation—could nudge them toward designated locations as they form the final structure.

Some biomaterial building blocks sound rather exotic. For inspiration, DARPA suggested fungal filaments, protein-based fibers from hagfish slime, and graphene aerogels that are already being explored for drug delivery, wound healing, and bone and nerve regeneration.

The type of microbe used would likely also impact designs. Those that require oxygen are harder to keep alive in space, even when they can survive radiation-contaminated areas, Antarctic permafrost, or extreme dehydration. Bacteria that don't require oxygen are likely easier to keep alive. But additional hardware would be needed to tinker with pressure, temperature, and humidity so they can thrive in space.

If all goes well, designers may also embed electronics inside the finished structures to transmit radio frequencies or infrared signals for communication.

DARPA is currently calling for proposals and planning a workshop in April to debate the idea with experts. Eventually, they hope the work leads to objects that can be “biologically manufactured and assembled, but that may be infeasible to produce traditionally.”