Why Hacking DNA Is the Secret of Deep-Space Travel

Genetic engineering will revolutionize the way we send humans to other worlds.

By William Herkewitz Dec 11, 2015 Space

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Scientists worldwide are rapidly increasing their ability to genetically re-engineer plants, animals, and microbes. Amor Menezes, an aerospace engineer and synthetic biology researcher at the University of California, Berkeley, argues that augmented organisms could transform long-term human space missions. Menezes and his research team just published an outline in the *Journal of the Royal Society Interface* on the six most promising applications for such engineered organisms. Here's how genetic engineering will revolutionize space travel.

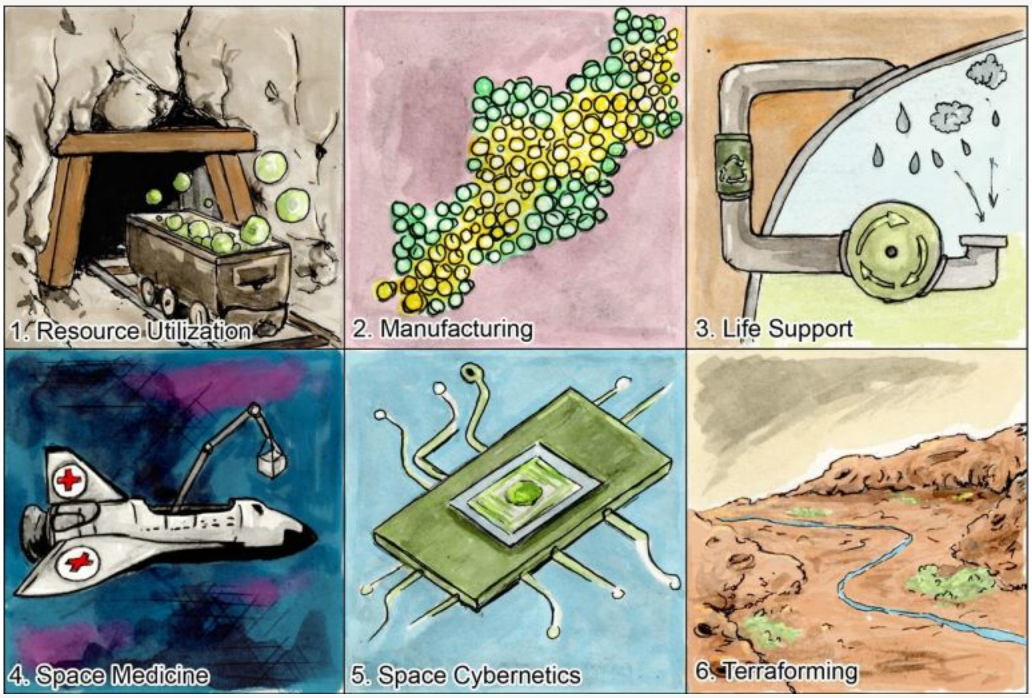
PM: What is synthetic biology, and why does it matter for space missions?

AM: Very broadly speaking, synthetic biology refers to any organism that's been genetically tweaked to do something differently or totally new. This could be anything from a bacteria that's been manipulated to produce some new chemical to a plant that's more adept at dealing with radiation.

"ONE OF THE MOST BEAUTIFUL THINGS ABOUT BIOLOGICAL ORGANISMS IS THEIR ABILITY TO SELF-REPAIR."

So, what's in it for space missions? Well, to take a step back: our research team conducted a study last year looking at how much payload mass you could save on a space mission if you simply incorporated biological organisms to perform various tasks—for example, creating fuel and food, or crafting spare parts mid-mission. To our surprise, we found that *right now* you could cut down between 26 and 85 percent of your mass for these applications. This would be done by, say, supplementing diets with nutritious bacteria-grown biomass, or manufacturing bio-polymers that could be run through 3D printers to create spare parts.

That lost mass is tremendously important, because when you ship something into space, your actual payload is only about one percent of what you send. Everything else is locked up in your rockets' fuel and structure.



I want to emphasize: When we did this first study we only looked at using organisms that hadn't been engineered. That made us think, well, what could we achieve *with* engineering?

For future deep-space missions, you outline six promising uses for synthetic biology.

We came upon our choice of these six by asking, what would we need to survive (and *thrive*)on space missions lasting more than 900 days? The first two uses for synthetic biology are resource utilization and manufacturing. They go hand-in-hand.

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For resource utilization, it's obvious that on a long-duration space mission you'll want to take advantage of every material at your disposal. We think that engineered organisms could certainly help us repurpose materials we're currently wasting, like the one kilogram of carbon dioxide that astronauts exhale each day. You can also imagine putting microbes to work pulling various fuels out of solid human waste, repurposing packaging materials and other trash, or even—if we're talking about on Mars or on an asteroid surface—leveraging the minerals and atmospheric gases. These are all tasks that engineered microbes could help us with.

As for manufacturing: We could use microbes in some sort of process to make solar cells or radiation-shielding materials. Or, for a Mars station, it would be supremely helpful to have organisms creating building materials by, say, producing adhesives from mussel foot protein, or using regolith [the Martian soil] to make bio-cement. And we've already talked about producing bio-polymers which would be run through 3D printers.

How could we use engineered organisms for the next two uses you mention, life support and space medicine?

Well, life support is pretty straightforward. Synthetic biology could recycle our wastewater and continually provide habitats with breathable oxygen—as opposed to requiring bulky machinery to manage these tasks. In some ways we're already doing this. On Earth, we already use microbes to help recycle solid human waste. Taking this life support goal a step further, you can also imagine creating a complex, closed-loop ecosystem aboard a spacecraft with self-sufficient food production, or even growing a secondary layer of living, self-healing radiation shielding.

As for medicine, we know that many pharmaceuticals expire faster due to space radiation. But, if those same pharmaceuticals could be produced by bacteria—which are easier to protect—you'd be solving many problems all at once. The truth is, pharmaceutical production is really just the low hanging fruit here. Right now, there are actually efforts under way to look towards synthetic biology to find ways to battle cancer tumors, a real risk for long-term deep-space missions.

You say synthetic biology could help even with cybernetic technologies and terraforming. How?

Well, by 'cybernetics' we're talking about the promise of biological organisms replacing things like sensors, circuitry, and actuators. The end goal here would be to create habitats that could construct themselves into a pre-programmed shape, or even self-monitor for radiation or toxins in the air, and adjust themselves accordingly. One of the most beautiful things about biological organisms is their ability to self-repair. By incorporating engineered organisms, it could be possible to have your habitat repair itself after being damaged by something like a meteoroid.

Regarding terraforming, we focused on just the much more manageable promise of *para*terraforming—or, transforming closed environments, like an enclosed base on Mars. Nonetheless, this is really the grandest challenge of all. We'd like to leverage the very qualities that microorganisms used to make *Earth* habitable, billions of years ago, for long-term space missions—transforming a harsh environment into one fit for human habitation by reducing carbon dioxide, producing oxygen, enriching soil, and so on. This won't take any one microbe. Paraterraforming would require a community of organisms and the culmination of all the knowledge we'll have learned from experimenting with all these other uses for synthetic biology.

So, how realistic is any of this?

Obviously it's impossible to forecast future scientific advancement with any presumed clarity. If you look at some of the genetic technologies we currently use to fabricate engineered organisms, like CRISPR/Cas9, well, that's a technique that became very powerful in a very short period of time, which nobody really saw coming. In all probability, there will be other, even more fruitful technologies that will crop up and improve our engineering capabilities in unexpected ways.

THAT MICROORGANISMS USED TO MAKE EARTH HABITABLE."

That said, I think it's safe to say we're still talking a few decades out for a majority of these technologies. But that's about the time we might expect the 2nd or 3rd generation of long-duration space missions. I think it's very possible these sorts of organisms will be deployed then—even if only as a redundant technology. After all, when you can keep literally millions of individual pieces of backup equipment suspended in a small cooler... why wouldn't you?

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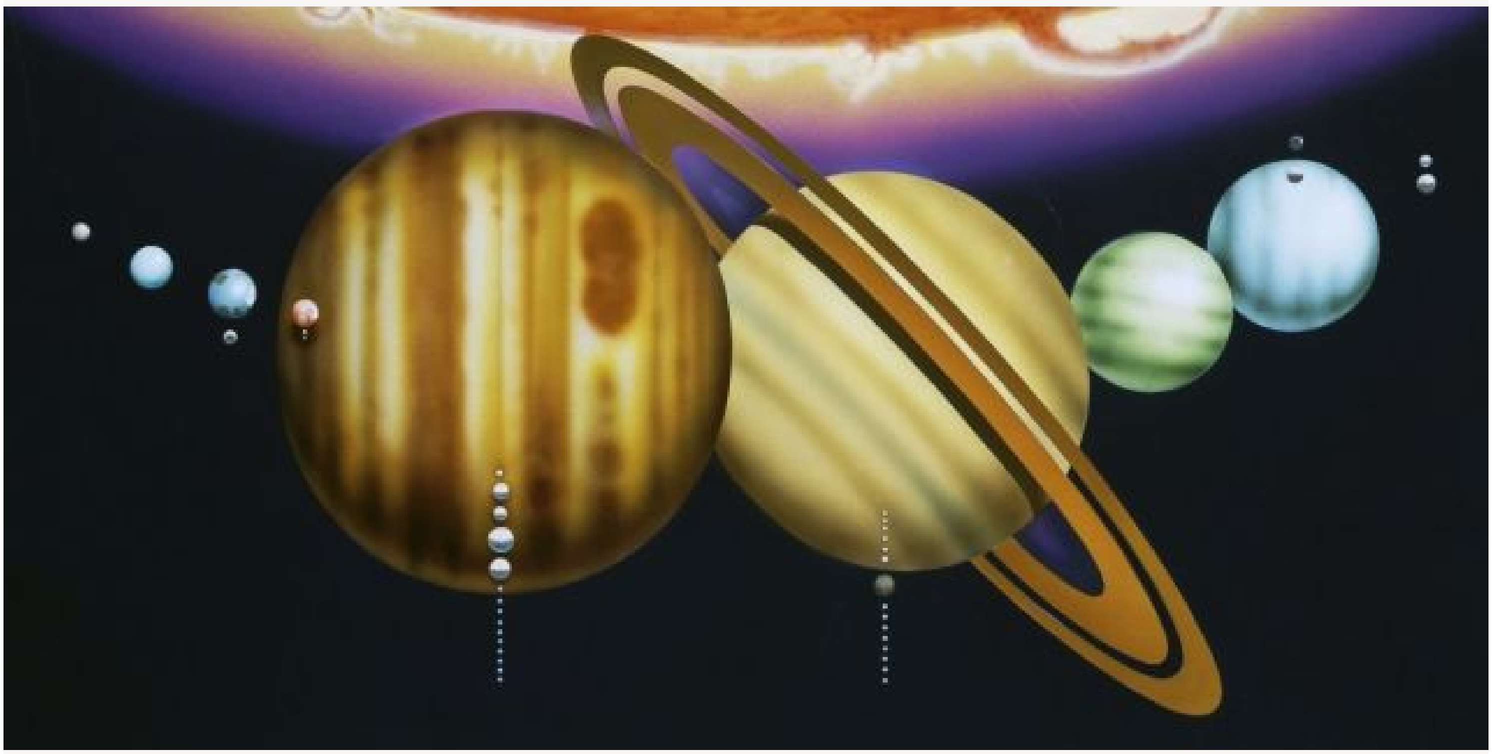

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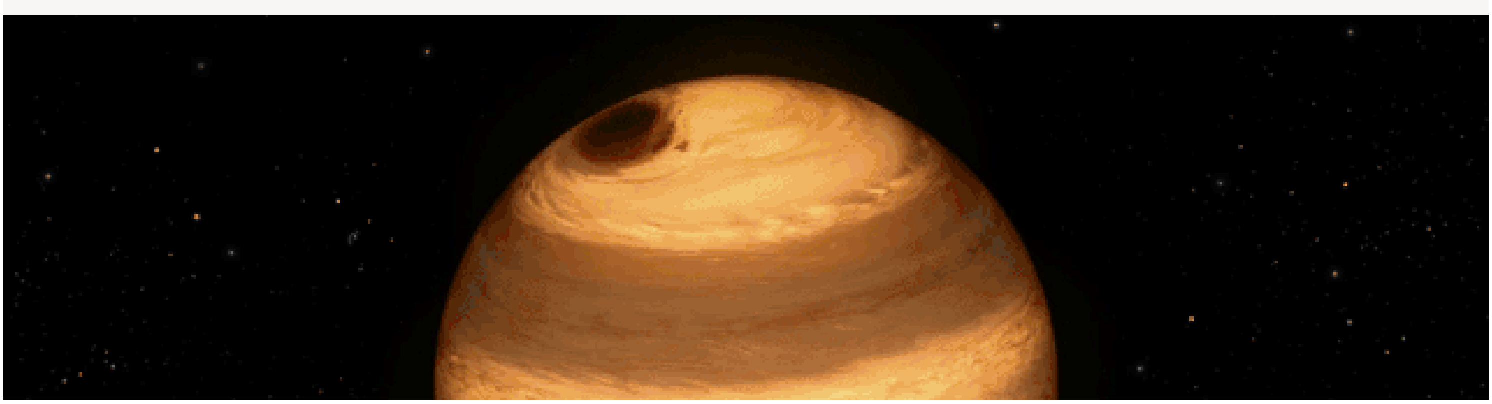

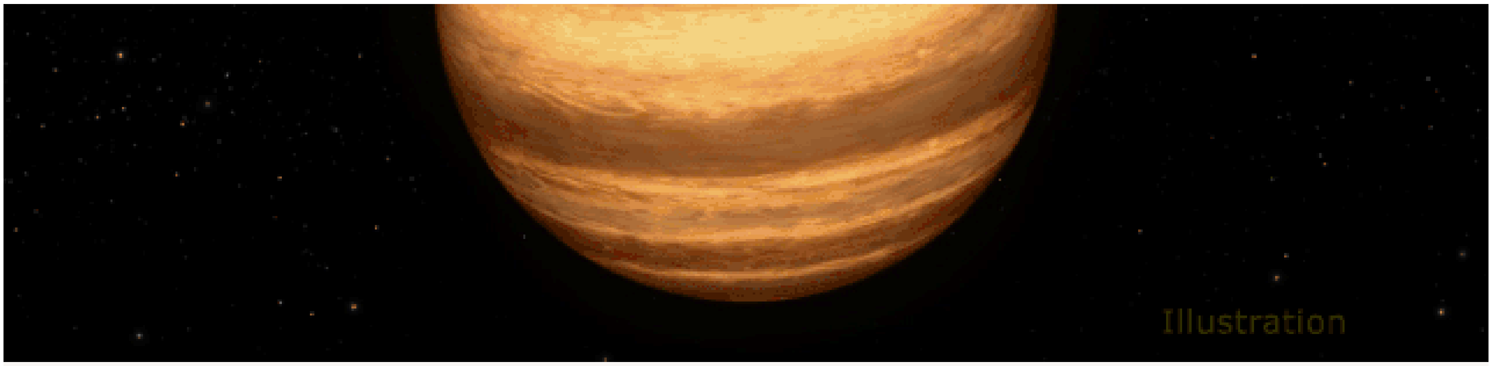

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