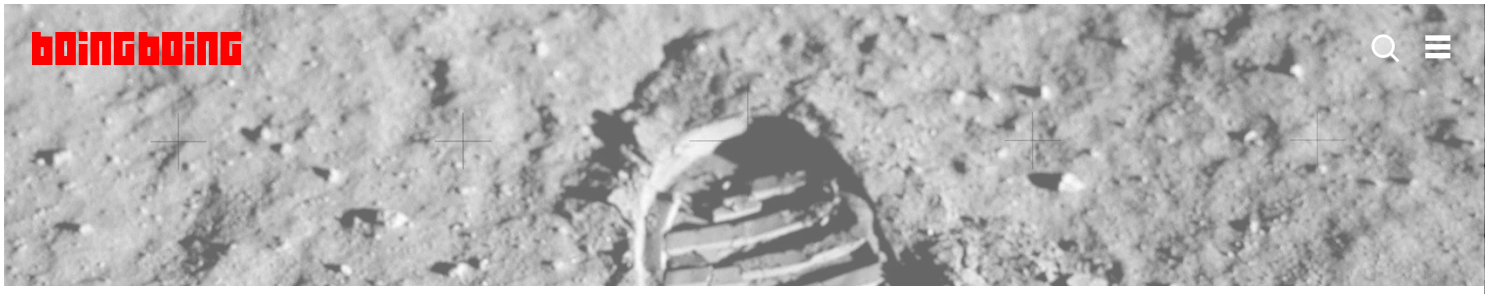
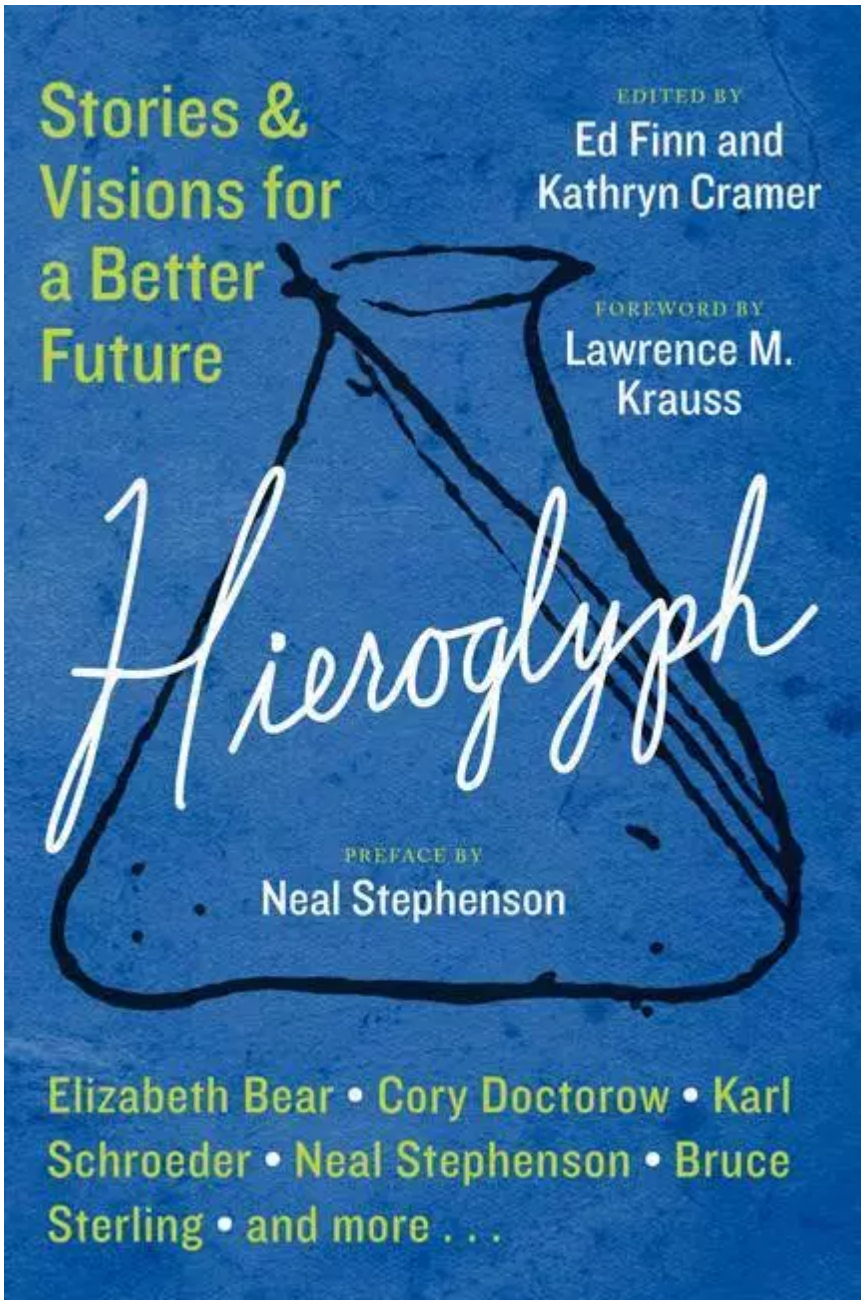


What will it take to get us back to the Moon?

By Jekan Thanga

It took 40 years for us to get back to the surface of the Moon. The adventures of China's late Jade Rabbit rover ended an absence that would have been unthinkable to families clustered around their TV sets in the 1960s, watching the incredible achievements of the Apollo Program. Where did we get off track? **Jekan Thanga** from ASU's School of Earth and Space Exploration, explains the science and politics behind Cory Doctorow's new novella, "The Man Who Sold the Moon."

One answer is that we stopped imagining what we could do on the Lunar surface, at least in a way that captured public interest and government funding. This is exactly the problem that the anthology Hieroglyph: Stories and Visions for a Better Future, which will be released on September 9, tackles: how can we reignite our ambitions to do Big Stuff? "The Man Who Sold the Moon," Cory Doctorow's contribution to the book, is not just an inspiring narrative but also timely and relevant for Lunar and space exploration.



One of Cory's observations is that the political landscape is shifting. There are notable private efforts being propelled by the Google Lunar XPRIZE to land crowdfunded landers and rovers that will beam HD images and surface video. In addition, several commercial entities such as Planetary Resources and Deep Space Industries plan to mine resources in space, with a particular focus on asteroids.

Our mindset about how to achieve a lunar mission has also evolved. We no longer expect to bring everything we might need for a mission with us on an expensive ride through the Earth's atmosphere -- there have been significant ongoing efforts to utilize Lunar resources to build a permanent human habitat. "The Man Who Sold the Moon" centers on the idea of using robots and 3D printing techniques to create structures from moondust... which is not as science fictional as you might imagine.

NASA's Marshall Space Flight Center has conducted research on metal 3D printers and sintering of titanium since the late 1990s. Their efforts have produced titanium based fixtures and tools that could one day be created from Lunar ilmenite. In 2008, Lockheed Martin demonstrated the extraction of oxygen from samples comparable in quality and composition to the ilmenite found on the Moon (more technical documentation available here and here). These breakthroughs will be the basis for big things to come. Such work would fill critical needs to make a permanent human habitat a reality, enabling human explorers and scientists to build tools and widgets in situ without having to travel back to Earth. Beyond just building products, tools, and replacement parts, Doctorow's story hints at a vision of the Moon as a service center and a manufacturing depot for NASA's "Massless Space Architectures." These architectures shoot for reduced mass or minimal launch mass of feedstock from Earth that would kick-start production processes utilizing resources in space or on the Moon to create

buildings, entire spacecraft, and more. As "The Man Who Sold the Moon" highlights, such architectures would be truly revolutionary and have the potential to minimize the cost of building, assembling, and testing next generation off-world structures, and even spacecraft.

However, the low gravity conditions on the Moon and the microgravity conditions in space remain a daunting obstacle. These conditions pose major challenges to all of our known manufacturing techniques because of the need to efficiently dissipate heat, transport fluids and particles from one location to another, and produce such simple things as ingots into a set shape. This is extremely critical for metallurgy. Our technology has evolved over thousands of years, exploiting the Earth's gravity as a helpful and generative force. Thus one promising effort to apply our vast manufacturing knowledge to the off-world lunar environment is to produce artificial gravity.

Artificial gravity using a centrifuge (ironically, an idea that one of Cory's characters roundly rejects in the story) is a plausible solution to overcome the many difficulties posed by the Moon's low gravity. However, to date we have yet to test a large centrifuge in space. Efforts led by the Japanese Aerospace Exploration Agency (JAXA) and NASA's Johnson Space Center proposed developing a centrifuge big enough to perform life science experiments and human habitation experiments (in that order, naturally) on the space station. However, the rest of the space station was to remain stationary. It turns out that having one portion of the space station rotate while the rest remains stationary is quite a tricky technical problem. Such challenges substantially increased the cost of both admirable efforts into the billions and resulted in eventual project cancellations.

At Arizona State University, we have been exploring low-cost approaches to tackling this problem of producing artificial gravity in space. One of our proposed concepts under

development is the Asteroid Origins Satellite (AOSAT), a spinning 3U (30 cm x 10 cm x 10 cm) cubesat that will produce the required centripetal forces to produce artificial gravity as low as 0.01G or 0.001G. The AOSAT will simulate asteroid surface conditions by spinning while carrying crushed meteorite dust. This will be a low cost alternative alternative to sending a spacecraft to an actual asteroid, and will help to refine asteroid landing and mobility technologies. Landing on asteroid composed of rubble piles is considered one of the major challenges in space robotics. AOSAT will also be performing experiments on dust accretion to physically determine how star dust "collects" to form rocks and asteroids.

Our next step is to build a large 6U cubesat that would achieve to 0.5 to 1 G for life science experiments. The concept utilizes off the shelf space components that are relatively low cost and flight proven.

Manufacturing without gravity, although more challenging, is within sight for certain materials such as plastic. Plans are underway to deliver a 3D printer that would produce parts on the International Space Station, particularly simple fittings for hoses, tools, and racks that would in theory reduce the amount of finished products that would need to be delivered from Earth. Efforts by small businesses such as Made In Space, which have been flown on "Vomit Comet" parabolic flights to simulate microgravity, have shown promising results, with eventual deployment on the space station planned.

But for all these technical achievements, the most exciting development in space exploration for me is that it is becoming a more democratized, inclusive endeavor. Hackers and makers, crowdfunders and citizen scientists, a vast array of private companies and startups, and even groups of artists like the Mexican Space Collective are trying new things and viewing space as a place for experimentation and play, not just an arena for economic development and geopolitical jostling. It's

perfectly plausible that the next big thing we send to the Moon comes out of Kickstarter, rather than a national space agency. Ad astra!

-Jekan Thanga

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How the Apollo 11 rocket was projected onto the Washington Monument

Earlier this month, I was in Washington DC during the Smithsonian's festivities around the 50th anniversary of Apollo 11 and the first human moon landing. As you likely saw, UK-based creative studio 59 Productions and the Smithsonian National Air and Space Museum collaborated on an astonishing audiovisual experience centered around a lifesize Saturn V rocket […]

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NASA fed moonrocks to cockroaches and injected moon dust into mice

When the Apollo 11 crew brought home a big stash of moon rocks in 1969, NASA scientists immediately kicked off a series of carefully-planned tests to ensure that even tiny amounts of lunar dust wouldn't be bad news for Earth's biosphere. "We had to prove that we weren't going to contaminate not only human beings, […]

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Check out this massive dinosaur femur just found in France

This week, French paleontologists unearthed a two-meter long dinosaur femur in southwestern France. From Reuters: The... femur at the Angeac-Charente site is thought to have belonged to a sauropod, herbivorous dinosaurs with long necks and tails which were widespread in the late Jurassic era, over 140 million years ago. “This is a major discovery,” Ronan [...]

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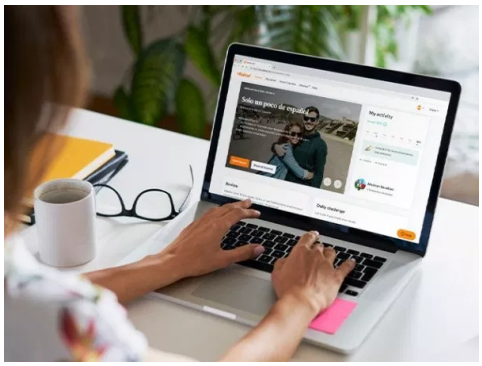

When it comes to language lessons, there’s no shortage of virtual teachers out there. But even with all that interactive technology out there, it’s tough to make the process of learning a new tongue seem as fun as actually getting out there and speaking it. There are some standouts, though. There’s a reason why Babbel [...]

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It's kind of a wild west age for drones these days. Most anybody can fly one (at least recreationally), and the technology that powers them is getting more impressive every day. Here are six of our current favorite drones, flyers that show how fun and innovative (not to mention affordable) these gadgets can be. Ryze […]

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