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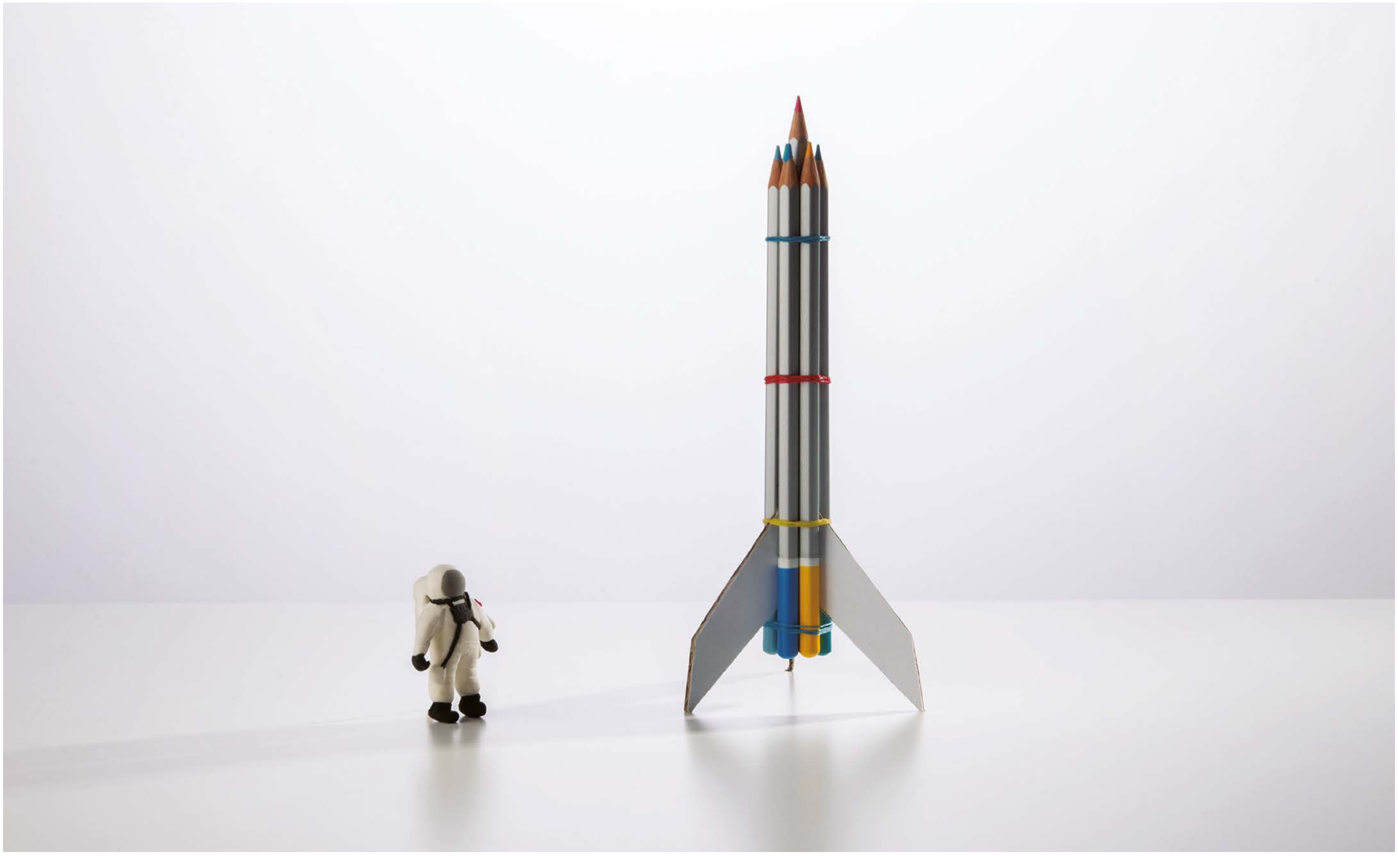

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TAKING RESEARCH FROM DESIGN TO LIFT-OFF

If you want an astronaut to run your experiment in outer space, you have to keep it simple. **By Brian Owens**

On 25 July, after years of planning, an experiment that Charles Cockell had spent years planning blasted into space. A SpaceX rocket launched from Florida, heading to the International Space Station (ISS). It carried 18 bioreactors, each the size of a deck of cards, that would be used to study whether bacteria could mine useful minerals on the Moon, Mars or asteroids.

Getting the experiment off the ground (literally) was "one of the most exciting things I've experienced", says Cockell, an astrobiologist at the University of Edinburgh, UK. But the process of getting from proposal to lift-off was long and involved: Cockell's biomining experiment was more than 11 years in the making.

There are various routes to the ISS, but most go through one of the five space agencies – those in Canada, Japan, Russia and the United States, and the 11-nation European Space Agency (ESA) – that support the space station. These agencies periodically release calls for research proposals that help to meet their space-science goals.

"Most of our research has an eye toward enabling exploration, but it can also have terrestrial benefits," says Craig Kundrot, director of NASA's Division of Space Life and Physical Sciences Research and Application. The US portion of the ISS has been designated a national laboratory, meaning that it's available for any research that would benefit from access to space, even if the project is not aimed at advancing space exploration.

Cockell's experiment is intended to study how future Moon or Mars missions could use bacteria to extract materials from rocks in space, including minerals and metals for construction, water for rocket fuel, and soil.

Around 600 experiments are conducted each year on the station, which has extremely limited space, power and time allocated to astronauts to work on experiments. The payload specialists for research on the ISS – those who plan what to spend and when – have to juggle all of these factors as they decide which experiments can go when, and how these will all fit together. "They're playing tetris on a daily basis," says Kundrot.

Getting chosen by a space agency is just the start of the process. Then comes the tricky business of designing an experiment that can be packed into a rocket, blasted to the

NASA/NICK HAGUE

NASA astronauts Christina Koch and Andrew Morgan stow biological research samples in a science freezer on the International Space Station.

station and conducted by an astronaut who has hundreds of other responsibilities each day. It must also survive re-entry into the atmosphere and recovery, sometimes from hard-to-reach places such as the middle of the Pacific Ocean. Luckily, there are teams of engineering contractors and payload specialists that take the lead on making each experiment function within the limits on mass, size and power consumption.

"As a scientist, you're not responsible for getting it to work. There's a whole team who support the technical aspects," says Monica Driscoll, a molecular biologist at Rutgers University in Piscataway, New Jersey. She was involved in a project running from December 2018 to January 2019 that used the nematode worm *Caenorhabditis elegans* to study the neurological effects of space flight.

Depending on the experiment, the engineering challenge can be relatively simple or fiendishly complicated. Physical-science endeavours tend to take longer to plan because they need bespoke equipment, whereas those in the biological sciences can often repurpose gear that worked in other projects. Driscoll had the benefit of drawing on the experience of previous work on *C. elegans* in space, but Cockell's bioreactors had to be designed from scratch – part of the reason for the long timeline.

On the experimental design side, the challenge is to keep the project as simple as possible while getting useful results. Something as basic as using a freezer, which wouldn't require a second thought in a lab on Earth, can add another layer of complexity. The freezer on the ISS, which is designed to operate in microgravity, has a smaller storage capacity than a freezer in a domestic refrigerator, limiting the number of experiments that can use it. It has a waiting list,

"If you want an astronaut to turn a knob, it has to be in their schedule."

says Kundrot. Plus, you have to work out how to keep the samples frozen during re-entry and recovery. That's why Cockell's team decided to forgo freezing its samples and instead opted to keep them in cooling packs for the return to Earth.

"Even simple things are complicated," says Cockell. "If you want an astronaut to turn a knob, it has to be in their schedule."

The experiment then undergoes several dry runs on Earth. One to verify that the science will work – for example, that Cockell's bacteria were able to grow in the bioreactors – and then another, more detailed run-through of the operation of the experiment as if it was actually on the station. Once it has passed those tests to the satisfaction of the researchers, the space agency and the engineering contractors, the experiment goes to a launch site, such as the Kennedy Space Center in Merritt Island, Florida, and is loaded onto a rocket. That, says Cockell, is when the excitement of what you are doing really hits home – as your work is readied to leave the planet.

"The station is not actually that far away – just 400 kilometres up, less than the distance from Edinburgh to London," says Cockell. "But it's the frontier of physical difficulty."

Cockell's experiment is now back on Earth, and he and his team are getting started on analysing the results. But they are already planning more work to send back to space. In two years, they will conduct another version of the experiment, this time bypassing the space agencies and using commercial contractors – Kayser Space in Didcot, UK, and its sister company Kayser Italia near Livorno, Italy. For £170,000 (US$207,000), the researchers have bought access to the ISS for their experiments, without having to rely on the ESA peer reviewers to approve their work. Cockell says that it's "just like buying a plane ticket to do research in another country". Opportunities like this are opening up space research in a way that would not have been conceivable just a few years ago, he says. "It's exciting for future generations. Within the next few years, this is something that a lot more people will be able to do."

Brian Owens is a freelance science journalist based in St. Stephen, New Brunswick, Canada.