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The world goes to Mars

How to reach another planet when a pandemic hobbles yours.

On 15 July 1965, humanity got its first close-up look at Mars when NASA's Mariner 4 spacecraft flew past the red planet, recording grainy images of a barren, cratered surface. They were the first glimpse of another planet as seen from space.

Almost exactly 55 years later, 3 long-awaited Mars missions are due to launch (see page 184). Amid a coronavirus pandemic and raging geopolitical tensions, the missions, from the United States, China and the United Arab Emirates (UAE), are a powerful symbol of how nations can transcend their Earthly woes as they seek to explore and understand other worlds.

In the decades since Mariner 4, NASA has sent 19 missions to Mars, 4 of which failed. Today, the agency has three active missions orbiting the planet and two robots that are carrying out experiments on its surface. The latest US mission, Perseverance, which lifts off on 30 July at the earliest, is meant to push this exploration to the next level. It will roll around an ancient river delta in the Jezero Crater, searching for signs of past life. More importantly, it will drill into Martian rocks and collect rock and dirt samples as it travels. The ambition is for a future mission to land at Jezero, retrieve these rock samples and return them to Earth. If this happens, it would be the first-ever sample return from Mars — something researchers can't wait to analyse.

China's plan is just as ambitious. Later this month, the China National Space Administration intends to launch an orbiter, lander and rover combination called Tianwen-1, or 'quest for heavenly truth'. Many details have not yet been revealed, possibly because of the risk of failure — China tried unsuccessfully to send an orbiter to Mars in 2011. But it has pulled off several recent impressive accomplishments in space, including a series of Moon missions that culminated last year in the first mission to the lunar far side. The time may be right for Beijing to succeed in reaching Mars.

And then there is Hope, a Mars orbiter to be launched by the six-year-old UAE Space Agency (see page 190) no earlier than 15 July. It is the first interplanetary attempt by any Arab nation. Much of the spacecraft technology has been developed in collaboration with former NASA mission engineers hired by the UAE Space Agency. But the science is being primarily driven by Emirati researchers: a young and vibrant team of explorers. Hope aims to build the biggest, most-detailed map of Martian weather produced so far.

All three missions, which are due to arrive at Mars next February, need to launch in the next few weeks while Earth and Mars are in the best positions in their orbits for a spacecraft to travel between them — an event that happens only once every 26 months. It's remarkable that the coronavirus pandemic did not derail their plans. There was to have been a fourth Mars mission this summer, but the European Space Agency postponed its launch to 2022, in part because of the pandemic. NASA had to deploy some of its own planes to fly engineers between California and Perseverance's launch site in Florida because commercial flights were grounded. Meanwhile, China and the UAE both scrambled to finish their missions as COVID-19 raged.

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Equally remarkable is that the three missions are not competing with each other, even though some commentators are calling the present state of US–China relations a new cold war. Whereas the original cold war between the Soviet Union and the United States dominated both nations' space ambitions in earlier decades, today's space agencies have relatively more-cooperative relationships.

That said, although NASA and the UAE Space Agency plan to make data from their missions publicly available, China's data policy remains unclear. China has been rolling out tranches of data from its Moon missions — the third batch from its lunar far-side mission was released last month. It should join the others, and pledge to share data from its Mars mission too.

Whereas intergovernmental relationships on Earth look ever more fraught, researchers must keep trying to transcend geopolitical squabbles. That includes ensuring that international collaboration on these missions continues, and that data are quickly made publicly accessible.

If these three emissaries launch successfully in the coming weeks, then we wait. We wait for them to traverse hundreds of millions of kilometres through the frigid vacuum of space, piloting themselves by the occasional command relayed from Earth. Red Mars will appear bigger as blue Earth grows smaller. They will arrive early next year at an alien, yet strangely familiar, planet. So, too, will we.

Pulling carbon from the sky is necessary, but not sufficient

Carbon dioxide removal is becoming a serious proposition — but it is not a substitute for aggressive action to cut emissions.

Could spreading basalt dust on farmers' fields help to remove atmospheric carbon? A large multidisciplinary team of scientists is confident it could, and that doing so could boost crop yields and soil health at the same time.

In this issue, David Beerling, a biogeochemist at the

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University of Sheffield, UK, and his colleagues explore a strategy to enhance rock weathering (D. J. Beerling *et al. Nature* **583**, 242–248; 2020).

This is a continuously occurring natural phenomenon in which carbon dioxide and water react with silicate rocks on Earth's surface. In the process, atmospheric CO_2 is converted into stable bicarbonates that dissolve and then flow into rivers and oceans. The idea of scaling up this process to remove carbon has been considered for some three decades. The team's results provide the most detailed analysis yet of the technical and economic potential of this approach — and some of the probable challenges, including gaining public acceptance.

The researchers modelled what would happen to atmospheric carbon if basalt dust was added to agricultural lands in the world's biggest economies, including Brazil, China, the European Union, India, Indonesia and the United States. According to their calculations, doing so would remove between 0.5 billion and 2 billion tonnes of CO_2 from the air each year. The upper limit is more than 5 times the annual emissions of the United Kingdom, and akin to offsetting emissions from around 500 coal-fired power plants.

The team is also carrying out field trials in four countries — the only such trials yet. The authors have told *Nature* that preliminary results suggest the theory is holding up. The application of 20 tonnes of basalt dust to a half-hectare UK plot boosted CO_2 removal by 40% compared with that seen on an untreated plot, and by 15% in another trial, which spread dust over oil-palm plantations in Malaysia. The early results also indicate that adding basalt boosted yields in these and other crops.

These are encouraging developments at a time when governments around the world are struggling to meet their climate commitments. The approach, if successful, could enable high-emitting countries such as the United States and China to remove some of the carbon they have pumped into the atmosphere in recent decades. Moreover, the machines that are required to spread basalt dust on fields already exist: farmers use them to treat soils with limestone.

Costing the Earth

But, like many promising technological fixes, spreading basalt dust across the world's agricultural fields could prove more complicated than it first seems. Researchers must answer a host of pressing questions about the economic costs and environmental impacts. And there are potential questions for regulators, too.

Tinkering with the geochemical cycle will inevitably alter ecosystems in soils, rivers and even oceans. Some of this might be beneficial: rock dust of the right variety could bolster desirable plant communities, for example. And the alkaline content that runs off to the oceans could, in theory, counteract acidification, helping to protect corals and other creatures that are threatened by rising atmospheric CO_2 levels. But we need to be confident that there are no harmful consequences to land and sea, and any potential effects would need to be monitored carefully.

> "Like many promising technological fixes, it could prove more complicated than it first seems."

Moreover, mining rock on industrial scales, pulverizing it and spreading the dust on crop fields will not be cheap. The current price of carbon on the European Union's emissions trading system is less than €28 (US$31) per tonne. By contrast, Beerling and his colleagues estimate that enhanced rock weathering will cost between $80 and $180 per tonne of CO_2. That said, such costs are in line with competing technologies that could be used to pull CO_2 out of the atmosphere. And although rock will need to be mined, the Sheffield team is rightly calling for an inventory of free, suitable waste rock from existing mining operations. This will bring costs down, increase carbon uptake and make more efficient use of mined materials.

Citizen science

The project team also studied how members of the public would react to such technologies (E. Cox *et al. Nature Clim. Change* https://doi.org/10.1038/s41558-020-0823-z; 2020). From research carried out in the United Kingdom and the United States, it is clear that CO_2-removal strategies could face scepticism. Respondents who took part in surveys and workshop discussions feared that they might take too long to develop, and expressed concern that the basalt dust could affect ocean ecology. Many also opposed the idea of such technologies becoming a substitute for tackling the root causes of climate change.

Concerns surrounding the ecological impacts could be allayed with appropriate government oversight. But there is no intergovernmental process that is considering the full suite of issues — including safety and ethics — that will need to be addressed if carbon-removal technologies are to be applied at significant scales. The Carnegie Council for Ethics in International Affairs, a think tank in New York City, is working to build awareness among governments about the issues they are likely to face if these technologies are applied, through the Carnegie Climate Governance Initiative. Much of the group's work has been focused on how to regulate technologies associated with the 'geoengineering' label, such as lofting aerosols into the stratosphere to reflect solar radiation back into space. Carbon removal, although less controversial, is just as important.

Beerling and his colleagues also deserve credit on this front. The University of Sheffield's Leverhulme Centre for Climate Change Mitigation is 4 years into a 10-year, £10-million (US$12.5-million) research programme that includes modelling and field trials, as well as laboratory studies and public-engagement research. But the centre cannot be expected to shoulder such a heavy responsibility alone. Other groups and funders need to step up.

With the dangers of climate change becoming more apparent each year, countries must continue to pursue the aggressive action that will be required to meet the goals of the 2015 Paris climate agreement. Carbon-removal technologies cannot be a substitute for such action. But it is becoming clear that if humanity is to limit global warming to 1.5–2 °C above pre-industrial levels, it must pursue every promising idea.