Space Agency (ESA) are looking to fund private firms to ship scientific instruments to the lunar surface, in the hope that the agencies will eventually be among many customers using the service.

NASA, which turned its sights back to the Moon after a 2017 US presidential directive, aims to provide a training ground for Mars missions and to study lunar resources that could sustain a human presence on the Moon, for example by mining oxygen and hydrogen for fuel, as well as purely scientific studies.

To help reach these goals, the agency launched the $2.6-billion, 10-year Commercial Lunar Payload Services (CLPS) programme in 2018. Last November, NASA picked nine consortia that it deems eligible to fly its payloads to the Moon. Each is led by a US firm and includes multiple partners to cover launch, lander and operations capabilities. Scientists are currently submitting proposals to NASA for instruments or technologies that could make up the payloads to be shipped commercially.

The programme is intended to "jump-start" a private Moon-lander industry, says Richards, and mirrors NASA's effort more than a decade ago to encourage development of commercial space-flight firms such as SpaceX. The agency is now among many clients that use these commercial services to send cargo to space.

RAILWAY TO THE MOON

Böhme says that NASA is likely to pick dozens of payloads as part of the CLPS programme, giving several firms a shot at the Moon, probably from 2020. "We're creating the railroad, a DHL delivery service to the Moon," says John Thornton, chief executive of Astrobotic, based in Pittsburgh, Pennsylvania, another firm hoping to land the first commercial lunar craft.

ESA is planning a single lander mission that would launch in 2025, aimed at demonstrating the feasibility of harvesting water or oxygen from soil at the lunar poles. Last month, the agency contracted PTScientists (which was created in direct response to the XPRIZE), rocket-makers ArianeGroup of Paris and aerospace firm Space Application Services of Brussels to explore the viability of such a mission. Böhme says that the agency hopes to secure the roughly €250 million (US$283 million) it would need from member states in November. Unlike in the CLPS programme, for which commercial partners will cover launch costs, ESA would pay for the mission's launch and operations, as well as for room on the lander, says Böhme.

Today, Richards estimates, a mission to the Moon's surface could cost about $50 million, half of what it cost a decade ago. Economies of scale for subsequent missions could bring the price of individual payloads down to just hundreds of thousands of dollars, he says. ■

BIOTECHNOLOGY

Life's genetic alphabet doubled

Synthetic, eight-letter DNA behaves like the real thing.

BY MATTHEW WARREN

The DNA of life on Earth stores information in just four key chemicals — guanine, cytosine, adenine and thymine, commonly referred to as G, C, A and T, respectively. Now scientists have doubled the number of life's building blocks, creating for the first time a synthetic, eight-letter genetic language that seems to store and transcribe information just like natural DNA.

In a study published on 22 February in *Science*, researchers led by Steven Benner, who established the Foundation for Applied Molecular Evolution in Alachua, Florida, suggest that an expanded genetic alphabet could, in theory, support life (S. Hoshika *et al. Science* **363**, 884–887; 2019). "It's a real landmark," says Floyd Romesberg, a chemical biologist at the Scripps Research Institute in La Jolla, California. The study implies that there is nothing particularly 'magic' or special about those four chemicals that evolved on Earth, says Romesberg. "That's a conceptual breakthrough," he adds.

Normally, as a pair of DNA strands twist around each other into a double helix, the chemicals on each strand pair up: C bonds with G, and A bonds with T. For a long time, scientists have tried to add new pairs of such chemicals, also known as bases, to the genetic alphabet. For example, Benner first created 'unnatural' bases in the 1980s, and Romesberg's laboratory inserted a pair of unnatural bases into a living cell in 2014. But the latest study is the first to systematically demonstrate that the complementary unnatural bases recognize and bind to each other, and that the double helix they form holds its structure and information.

"There is nothing particularly 'magic' or special about those four chemicals that evolved on Earth."

Benner's team created the synthetic letters by tweaking the molecular structure of the regular bases, which pair up by forming hydrogen bonds. Each contains hydrogen atoms, which are attracted to nitrogen or oxygen atoms in their partner. Benner says that it's a bit like Lego bricks that snap together when the holes and prongs line up.

By adjusting these holes and prongs, the team has come up with several new pairs of bases, including a pair named S and B, and another called P and Z, all of which are similar to the natural four (M. M. Georgiadis *et al. J. Am Chem. Soc.* **137**, 6947–6955; 2015). In the *Science* paper, the researchers describe how they combine these four synthetic bases with the natural ones.

The team then conducted a series of experiments to show that its synthetic sequences share properties with natural DNA that are essential for supporting life. The researchers created hundreds of molecules of the synthetic DNA, and found that the letters bound to their partners predictably, which is important for the reliable storage of information. They then showed that the structure of the double helices remained stable, no matter what order the synthetic bases were in, which is important for evolution because DNA sequences need to be able to vary without the structure falling apart. This is a substantial advance, says Philipp Holliger, a synthetic biologist at the MRC Laboratory of Molecular Biology in Cambridge, UK, because other methods of expanding the genetic alphabet are not as structurally sound.

Finally, the team showed that the synthetic DNA could be faithfully transcribed into RNA — a key step for translating genetic information into proteins. "The ability to store information is not very interesting for evolution," says Benner. "You have to be able to transfer that information into a molecule that does something." To demonstrate transcription, Benner's team created synthetic DNA that codes for an aptamer, an RNA sequence that binds and activates specific molecules rather than serving as a protein template. The transcribed RNA was able to bind and activate a fluorescent molecule.

Benner's team has also developed further pairs of new bases, opening up the possibility of creating DNA structures with 10 or even 12 letters. But the fact that the researchers have already expanded the genetic alphabet to eight is in itself remarkable, notes Romesberg. "It's already doubling what nature has."

Holliger says that the work is an exciting starting point, but that there is still a substantial distance to go before a true eight-letter genetic system is reached. One key question, for example, will be whether the synthetic DNA can be replicated by polymerases, the enzymes responsible for synthesizing DNA inside organisms during cell division. ■