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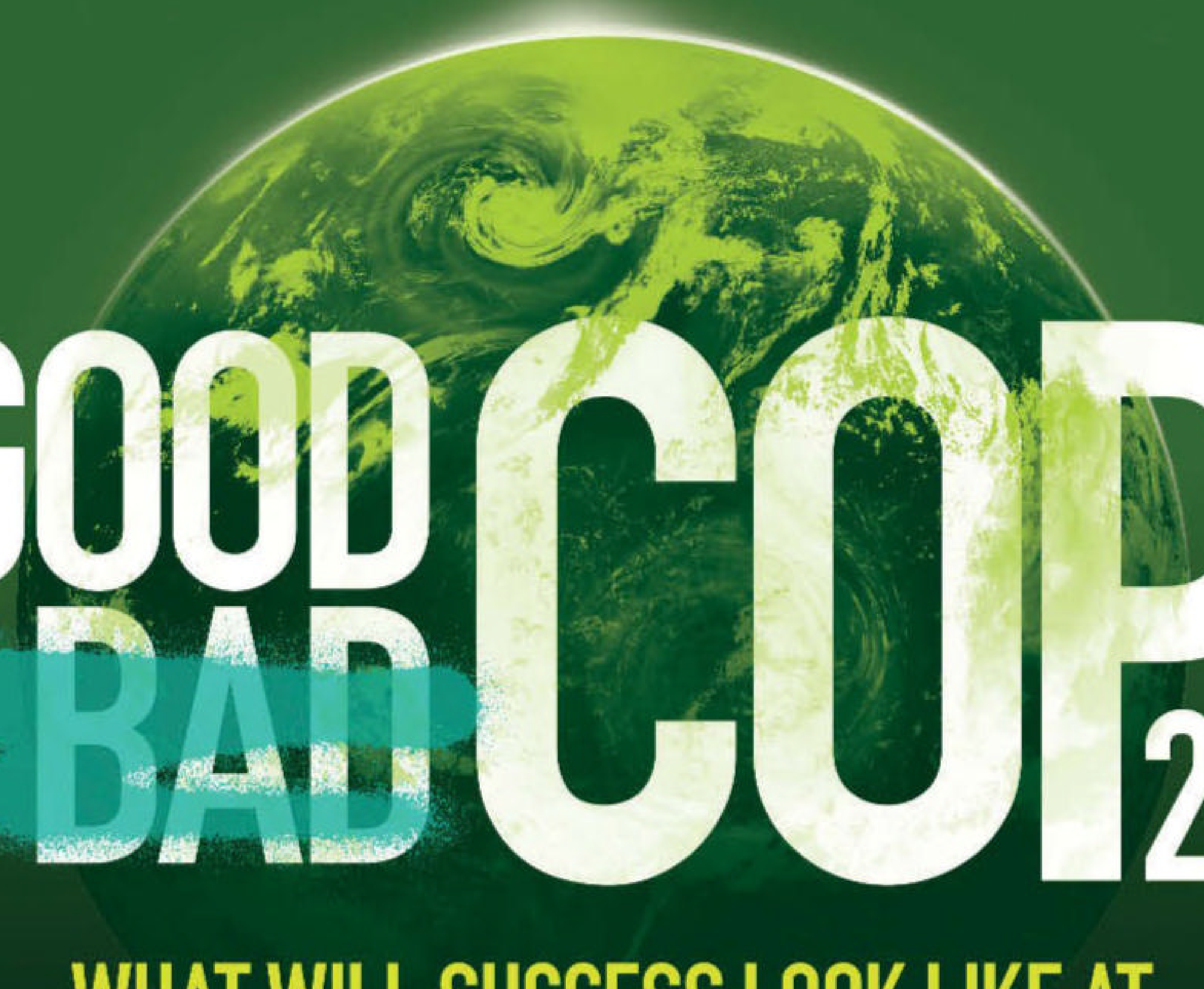

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JENNIE EDWARDS

'What we want to do is search intelligently'

We rely on space probes to explore the furthest reaches of our solar system and beyond. To succeed, we need to make them more curious, NASA's **Steve Chien** tells Neil Briscoe

HUMANS aren't well suited to long-duration space flight. We are too delicate, too heavy and we require far too many resources to keep us alive. When it comes to exploring our solar system and the worlds beyond that, it makes more sense to send machines.

Unfortunately, machines don't share our innate curiosity. A spacecraft designed to take pictures of the surface of a planet wouldn't be surprised if an alien suddenly scurried across the screen and switch its focus, it would just continue to take pictures of rocks. Steve Chien and his colleagues are trying to change that.

Chien heads up the department that looks after artificial intelligence during mission planning at NASA's Jet Propulsion Laboratory (JPL) – the birthplace of missions such as Voyager, which ventured to the edge of the solar system, and New Horizons, which flew by Pluto. In his day job, he creates software and systems that will allow deep space probes and planetary rovers – the likes of the Rosetta mission to a comet and Perseverance to ›

Mars – to better emulate the way humans think and act. He wants to turn spacecraft into true explorers, rather than just collections of cameras and sensors powered by a rocket motor.

When not working on space missions, Chien grapples with AI on Earth. He was recently a co-author on a US government report on the future of AI. The report found the US needs to reposition itself to become a leader in the field or experience the potential consequences of AI-based cyberattacks in the future.

Neil Briscoe: What is it like to work at the Jet Propulsion Laboratory?

Steve Chien: I am unusual at JPL in that I haven't dreamed of working there since I was a child. However, I've had the tremendous opportunity to work on a number of incredible missions, including the European Space Agency's Rosetta and currently the Mars 2020 Perseverance rover, and that's what has kept me so very interested in working at JPL. I've been honoured to work with such amazing scientists and engineers.

Do you have a favourite mission you have worked on?

It's hard to pick out a favourite. Certainly, Rosetta was incredible, for so many reasons. First and foremost, the people on the teams – the science team, the operations team – were incredible. It was amazing to see scientists from all of Europe, all of the world, coming together with this common goal of operating this spacecraft, of discovering the inner workings of comets and indeed our solar system. It was quite a rush to see the entire world become so engaged in the science.

What kind of intelligence does the Perseverance rover, currently exploring Mars, have? Is it a smart rover?

Well, smartness is a relative term. Perseverance can do much more than prior rovers, but it is still way behind what a human science and engineering team could do on Mars. For example, the rover can now, for certain instruments, "hunt for targets" given certain criteria such as colour, shape, distance from the rover. It will acquire wide field of view imagery, find targets within that which best match the criteria and then fire a laser to take a more detailed measurement.

Perseverance has more powerful navigation systems that allow it to drive faster and further, independently. But the progress is incremental and there's a long way to go. We are also working on software that will allow the Perseverance rover to adjust the plan sent from the ground [on Earth] in the event that activities are shorter or longer than anticipated, shuffling activities and adding and dropping activities to fit.

You have described your work as making space probes more curious. What do you mean by that?

The smarts we've been able to put on spacecraft and rovers thus far have been to recognise things we understand. To target specific types of rocks with a laser or to search for dust devils in a sequence of images, for example.

In the future, when we travel to the complete unknown, we will need to go beyond this. We'll need to look for patterns in data. For example, on Earth, we might look at overhead imagery and cluster it based on colour, texture, ruggedness and linear features. Based on these features, we might naturally discriminate between lakes, rivers, mountains, forests. But on another planet or moon, these might correspond to different types of sand dunes, oceans, vegetation and so on.

"The robots have to be smart enough to look on their own"

Why not send humans to investigate other planets and moons?

Humans are very sensitive, very fragile. Sending humans to low Earth orbit requires an amazing endeavour, to the moon required an enormous endeavour and sending them to Mars is even more challenging. And those are all places where we're certain there isn't life.

If you look within the solar system, there are several places where we believe there could be life. Basically, the strategy is to look for liquid water. One of the most promising places is Europa, a moon of Jupiter. You can't really send people there because the Jupiter radiation is very harsh, plus you need a very long mission to go there. So, we have to send robots to look for life. But because of the distances involved, the communication is very difficult. The robots have to be smart enough to look on their own.

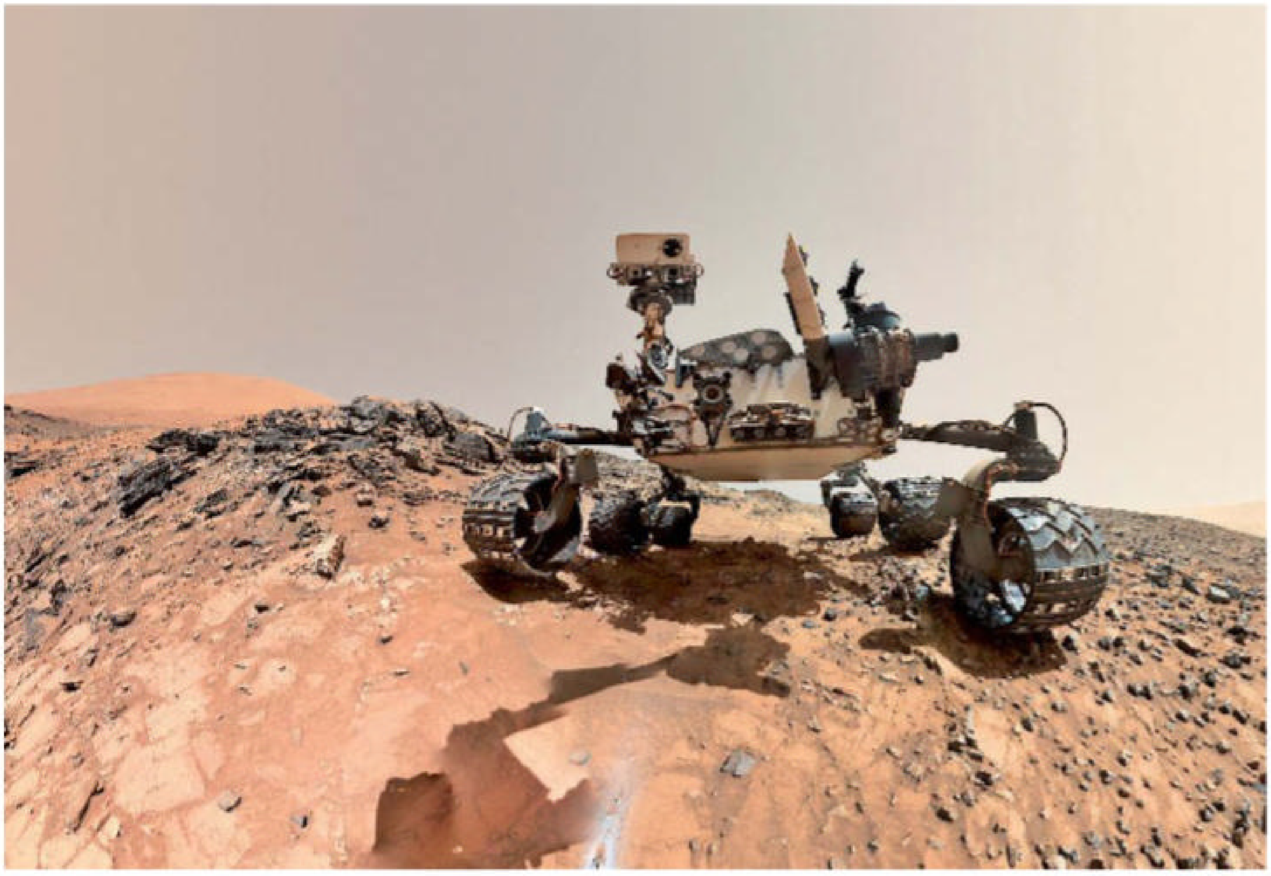
Can AI make probes and rovers recognise things in the same way a human does?

There's a central question of how smart machines need to be that's poking at the edges of artificial general intelligence. And that's what people talk about when they think of characters such as Data from *Star Trek* – something that could interact at a peer level with humans on a broad spread of topics, just like a human could.

We don't really need that in space. What we need is a specialised intelligence. A smart spacecraft doesn't need to know how to take a bus in Dublin, or how to book a flight. It needs to know very specific things, such as how its sensors work. It needs to know about the science that people want it to do.

So, AI is a way of stepping beyond just a probe sticking to a checklist?

Already the robotic missions are somewhat running themselves, autonomously, but we're just scratching the surface of the possible. A great example is that fantastic mission called New Horizons, which was run by a colleague of mine, Alan Stern. They did some amazing



NASA/JPL-CALTECH/MSSS

NASA's 2020 Mars Perseverance rover uses AI navigation

things – flew by Pluto, flew by the Kuiper belt object Arrokoth and did some incredible science. But they pre-planned how they would fly by those places.

What we'd like in the future is for the spacecraft to be smarter and look for certain things. It would look for satellites, for moons and moonlets and if it finds them, would take extra images of them. Plumes, little geysers, are a remarkable scientific phenomenon, so again the spacecraft would know to take more and more images of those.

How can we equip probes with these sorts of abilities?

It seems like this would be very easy, that you'd just tell the software to do that. But it turns out it's actually really complicated. You have to know how the spacecraft is moving, how and where to point, and most of all the spacecraft has to understand that "that's a plume".

These are all things that humans do very well. We walk around the world, and we say "that's a chair" or "that's rain falling". But making computers understand these things is not so easy. When you talk about curiosity, and you talk about wonder, the first steps to that are being able to spot what's unusual, what's different.

What we want to do is search intelligently, and we do that with things we call white lists and black lists. A white list contains specific things you're looking for. It might include sulphur, because sulphur is a sign of life, for example. A black list is where you're expecting to see certain things, but if we see something else, something we weren't expecting to see, that's interesting. You search, you see all of the things you expect, but – whoa! – you spot something you weren't ready for, like maybe a Martian runs past the lens. That is the big step towards intelligent curiosity – recognising that which is unusual and exciting.

How is your work with AI in space relevant down here on Earth?

I had the honour of supporting a congressional report on the role of AI in national security. In cyber, one can create hundreds or thousands of software agents far more easily than building physical tanks, airplanes, ships or missiles. By software agents I mean programs that allow hackers to take over computers and launch attacks from a myriad of hosts across the internet.

They are getting smarter and more complex every day. It is a global software arms race, with many advantages to the attacker. The defender needs to win all the time. The attacker only needs to win some of the time to succeed. The differentiating factor is speed and smarts derived from AI. Whoever has the smartest agents will win the cyberwar and whoever wins the AI competition will dominate cyberspace.

In today's world, everything is controlled by computers – power, water, communications, transportation – hence the importance of AI to nations. Cybersecurity is incredibly important to space missions too, as we use computers to plan out and operate these extremely complex missions. Any cyberthreat could jeopardise the entire mission.

My core expertise is AI as it relates to space, which is an important and large area. But AI, while certainly not the same across all applications, does share quite a bit of commonality. A lot of the report focuses on general issues, such as the challenges to AI research, deployment of AI, training workforces and global cooperation.

How far away are we from an artificially intelligent probe that can truly make discoveries in the same way that humans do?

This is a very tough question. Already, there are machine-enabled discoveries being made every day. In these cases, the AI is amplifying the human intelligence, enabling the combined team to consider more plans, to find better plans.

Humans have a better strategic view, and the computer can run down leads and search, taking high-level direction from humans. A machine making an independent discovery? This is far less common. But there are cases, typically where the human grasp of the problem is limited by huge amounts of data. Even in these cases, the human driven math and objective functions are a key part of the process.

As far as human-level competence in human-dominated fields, I do not see that in the near future, say in the next five or so years. But the pace of progress is astounding in some areas. I am unwilling to make any projections beyond five-to-10 years, which makes me sound like an economist! ∎

Neil Briscoe is a freelance writer based in Belfast, UK