Sun & fresh water

Taking the help of sunlight, new research has put forth two techniques to produce pure water and keep distillation plants clean

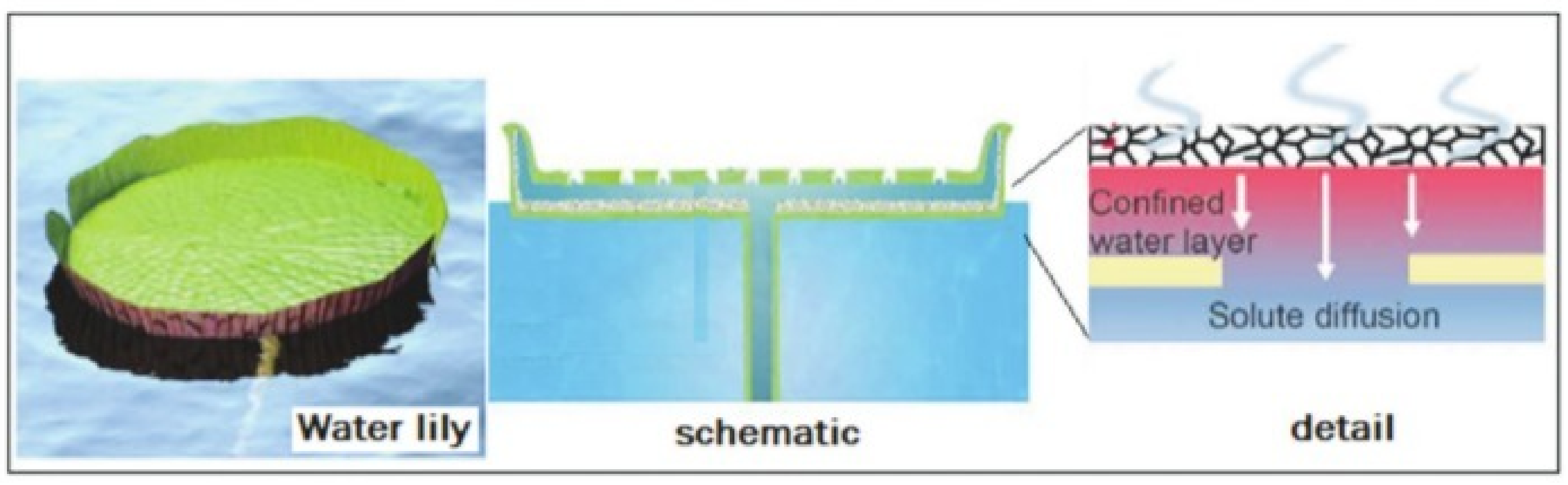
S ANANTHANARAYANAN

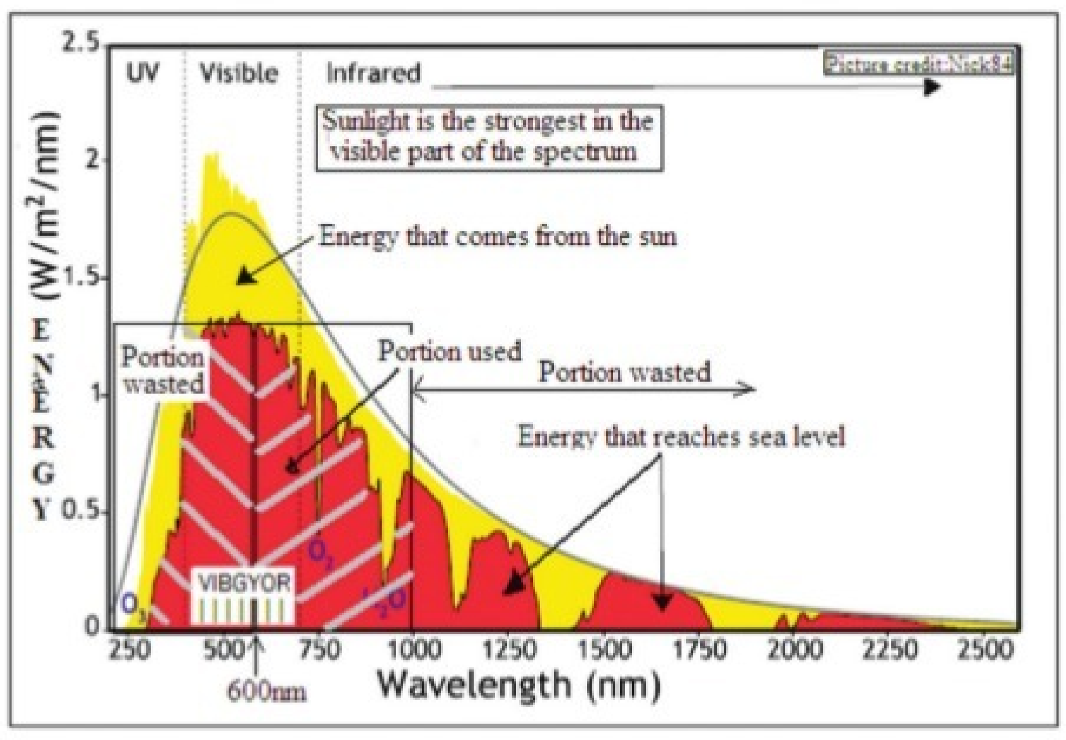
While global warming and the need for green energy are staring us in the face, so is growing scarcity of potable water in many parts of the world. Could the solar cell, a non-polluting source of electricity, be harnessed to evaporate and purify water? How about a nature-inspired way to keep that evaporating surface clean?

Wenbin Wang, Yusuf Shi, Chenlin Zhang, Seunghyun Hong, Le Shi, Jian Chang, Renyuan Li, Yong Jin, Chisiang Ong, Sifei Zhuo and Peng Wang, from King Abdullah University of Science and Technology, Saudi Arabia, write in the journal, *Nature Communications*, about a multi-stage, membrane distillation arrangement that works with photovoltaic devices to produce fresh water even as the devices create electricity. And in the same month, the journal, *Science Advances*, carries an account by Ning Xu, Jinlei Li, Yang Wang, Chang Fang, Xiuqiang Li, Yuxi Wang, Lin Zhou, Bin Zhu, Zhen Wu, Shining Zhu, Jia Zhu, from Nanjing University, China, of an adaptation of the water lily, to help distillation plants stay clean of the residue that impure water leaves behind.

While electricity generation accounts for nearly half of all the water that the world uses, there are places where distillation is the only way to recover fresh water, grom seawaufs ps gro n wastewater, and this consumes electricity. The King Abdullah University group has thus worked on getting the photovoltaic cell, while it generates electricity, to double as a distillation plant.

The way the photocell works is that it converts the energy in sunlight, in a specific frequency band, to electricity. But, as the energy in sunlight is distributed over a wider range, a large part of it is not used by the photocell. As the picture of how the energy of sunlight is distributed would show, a portion, between the wavelengths of 600 and 1000 nm is useful, but sizeable energy at shorter and longer wavelength is wasted.





Given this wasted energy, as well as the efficiency of conversion, solar cells do not practically work at more than 15 per cent efficiency; most of them are at 10 to 12 per cent. But what is worse is that this wasted energy is not just lost, it warms up the photocell, which leads to a drop in the conversion efficiency. Research effort is hence directed both at converting the wasted parts of the spectrum to useful wavelengths as well as finding ways of drawing away the heat.

The King Abdullah University group does one better — it makes use of the heat that the photocell radiates to distil seawater. Not that using sunlight to get fresh water from seawater is something new — but existing processes waste much of the heat that comes from the sun and cannot do better than half a litre, from a square metre, over a whole day. The Kaust group has found a way to get a lot more fresh water from the heat that the photocell gives off, without affecting the efficiency of the photocell itself.

The approach of making use of "waste heat" is also not new. In typical electricity generators, turbines are driven by steam at a high temperature. The steam cools down when it loses energy to the turbines, but is still pretty hot when it is released. Many industries that need steam for their processes now tap this waste steam from the power facility. The hot exhaust gas from engines in locomotives and machinery has also been put to use with benefit.

The arrangement of the Kaust team is to make use of the comparatively modest warmth of the photocell, some 60°C, to generate vapour in three stages. In conventional solar distillation, an absorber generates vapour, at its own temperature, but the heat is lost when the vapour is drawn off and condensed. In the Kaust arrangement, the heat in the first lot of vapour is captured, to create a second lot of vapour, before it is drawn away. In the same way, there is again a third lot of vapour, till the temperature is down to less than 40°C, leading to a lot more fresh water from the same heat used up.

The vapour arises from water in a wet-friendly membrane, which is in touch with the warm surface. The next membrane, which repels water, draws away the vapour and passes it to a metal condensation surface, which also absorbs the heat. A three-stage Membrane Device, the Kaust paper says, can generate as much as 2.69 litres of fresh water, for every square metre, every hour.

Fouling the surface

This process of evaporating salty or wastewater, to tap the uncontaminated vapour, would naturally leave behind the solute or other residue. This material blocks passages of water and vapour, or light from reaching the absorber, which fouls the evaporation medium. Fouling has been the bane of solar evaporation plants, which have been widely in use long before the current work of the Kaust team.

The group from Nanjing, writing in *Science Advances*, addresses the problem by borrowing a method from the natural world. Many animals and plants need to keep their skin or surface dry and clean. In the case of plants, this is to shrug off the weight of water that collects, to allow maximum sunlight to reach the plant, for moisture harvesting and moisture retention or discharge or making insects stick or slip, and many more.

The Nanjing group created an arrangement that mimics the structure of the water lily, which, as their paper says, "has an elegant system" to separate the heat-absorbing surface from the surface where the water evaporates. The surface of the water lily, as shown in the picture (*left*), consists of an outer layer that absorbs heat, and has pores that allow water vapour to pass. As water does not stick to this surface, it efficiently washes away any solids and the surface stays clean. And then, the lily stays afloat, with passages for water from below to rise to the surface and evenly spread out.

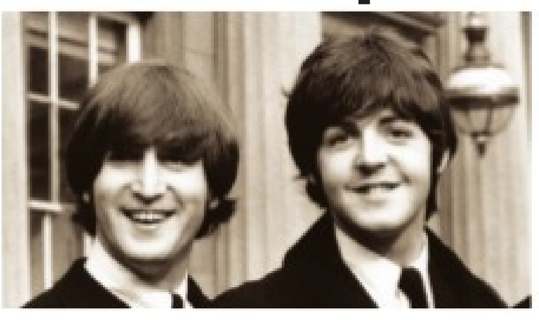
The device the Nanjing group has made has an upper, water-repelling surface, with pores to permit the passage of vapour, mounted on a bottom surface, which is in contact with briny water. The water does not rise to the upper surface, but is confined to a narrow space between the two surfaces. There is hence no fouling of the upper surface, which stays efficient for absorbing and passing heat directly to the space below. While the concentrated water in the narrow space continuously evaporates, the solute is washed downwards, through narrow channels.

In the usual methods of separating water from the solute the process slows down as the solution gets concentrated. In this new device, this does not happen even with high concentration, as the surfaces for absorbing heat and evaporation stay clean, like the water lily.

The writer can be contacted at
response@simplescience.in

PLUS POINTS

AI solves dispute



The contested origins of The Beatles' hits penned under the writing partnership of Paul McCartney and John Lennon could be put to bed by artificial intelligence software, which can identify each artist's musical influence.

Researchers from Harvard University trained a machine learning algorithm on hundreds of the Fab Four's hits to build a "musical fingerprint" for each songwriter. It was then asked to assess eight iconic songs, or musical fragments, recorded between 1962 and 1966, where debate rages over who was the major influence. This includes tracks like "A Hard Day's Night" and "In My Life" which are credited to the "Lennon-McCartney partnership", but are widely believed to be entirely written by one or the other of the pair.

The findings, published in *Harvard Data Science Review*, allow for each artist's influences on the song to be assessed, and predicts the probability that either McCartney or Lennon were chiefly responsible.

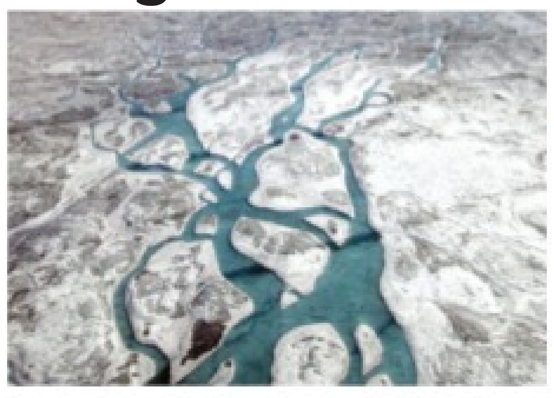
Most of the eight songs of contested authorship were predicted to be predominantly in Lennon's style, including tracks like "Ask Me Why" and the bridge to "A Hard Day's Night" which McCartney sang and has suggested in previous interviews he had a role in. "In My Life", which Rolling Stone magazine ranked, in 2011, the 23rd greatest song of all time has "garnered the greatest amount of speculation about its true author", the researchers said.

Lennon wrote the song's lyrics, but McCartney has claimed he wrote all the music — something Lennon's account disputed. The algorithm determined with 81.1 per cent certainty that Lennon wrote the verse, but McCartney's influence in the song's bridge was given with 43.5 per cent certainty.

This would corroborate Lennon's account that McCartney contributed to the song's middle-eight melody.

The independent

Sub-glacial lakes



Researchers have discovered 56 previously uncharted sub-glacial lakes beneath the Greenland Ice Sheet, bringing the total known number of lakes to 60. Although these lakes are typically smaller than similar lakes in Antarctica, their discovery demonstrates that lakes beneath the Greenland Ice Sheet are much more common than previously thought.

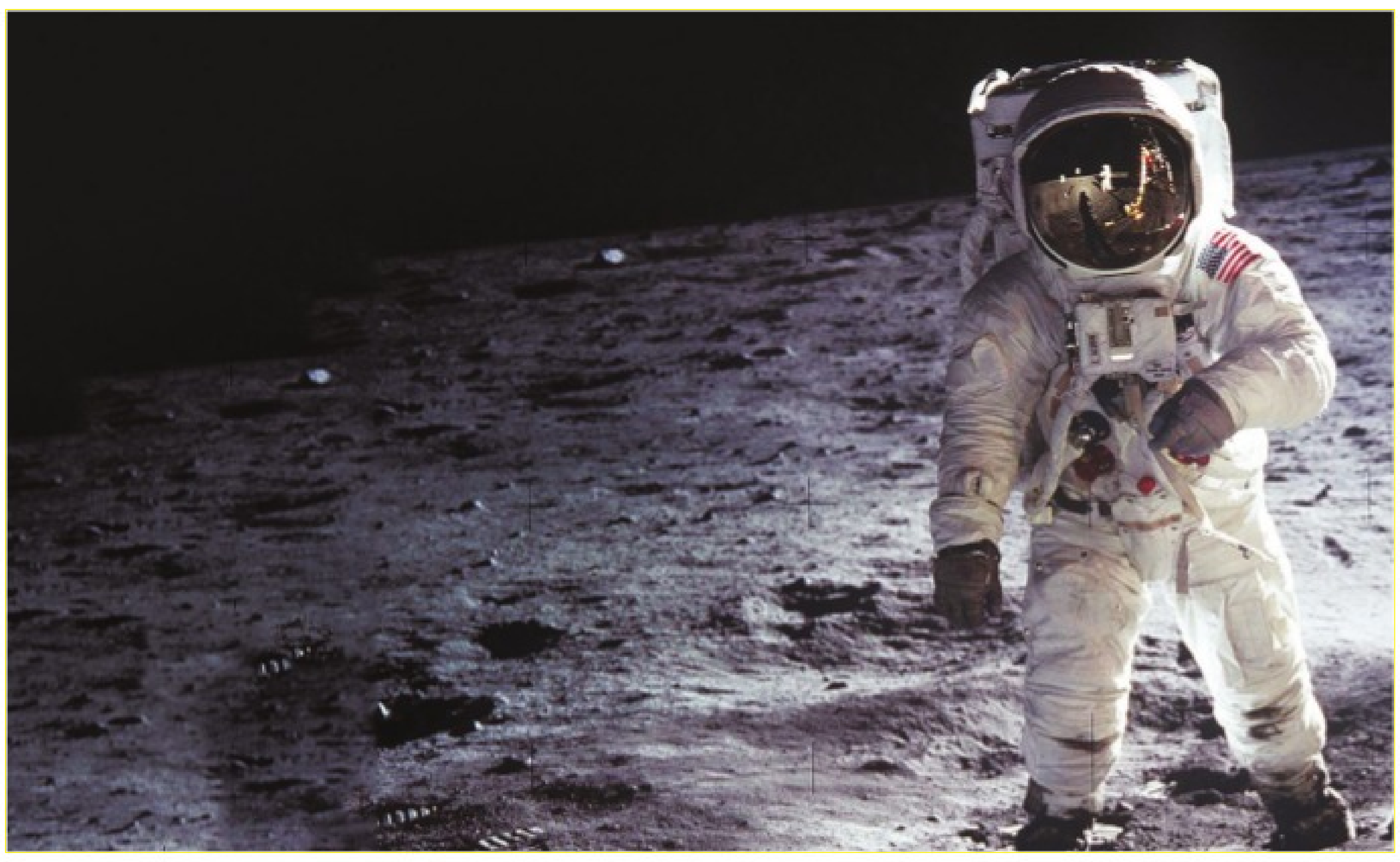
The Greenland Ice Sheet covers an area approximately seven times the size of the UK, is in places more than three kilometres thick and currently plays an important role in rising global sea levels. Sub-glacial lakes are bodies of water that form beneath ice masses. Meltwater is derived from the pressure of the thick overlying ice, heat generated by the flow of the ice, geothermal heat retained in the Earth, or water on the surface of the ice that drains to the bed. This water can become trapped in depressions or due to variations in ice thickness.

Knowledge of these new lakes helps form a much fuller picture of where water occurs and how it drains under the ice sheet, which influences how the ice sheet will likely respond dynamically to rising temperatures. Published in *Nature Communications* recently, their paper, "Distribution and dynamics of Greenland sub-glacial lakes", provides the first ice sheet-wide inventory of sub-glacial lakes beneath the Greenland Ice Sheet.

By analysing more than 500,000km of airborne radio echo sounding data, which provide images of the bed of the Greenland Ice Sheet, researchers from the Universities of Sheffield, Lancaster and Stanford identified 54 sub-glacial lakes, as well as a further two using ice-surface elevation changes.

Stephen Livingstone, senior lecturer in physical geography at the University of Sheffield, said, "These lakes could provide important targets for direct exploration to look for evidence of extreme life and to sample the sediments deposited in the lake that preserve a record of environmental change."

Lead author Jade Bowling of the Lancaster Environment Centre, Lancaster University, said, "This study has for the first time allowed us to start to build up a picture of where lakes form under the Greenland Ice Sheet. This is important for determining their influence on the wider sub-glacial hydrological system and ice-flow dynamics, and improving our understanding of the ice sheet's basal thermal state."



Calculator	Year Released	ROM	Ram	Processing Speed

	TI 73	AGC	Compared to AGC

	TI 84	AGC	Compared to AGC

GRAHAM KENDALL

Many people who are old enough to have experienced the first moon landing will vividly remember what it was like watching Neil Armstrong utter his famous quote, "That's one small step for a man, one giant leap for mankind." Half a century later, the event is still one of the top achievements of humankind. Despite the rapid technological advances since then, astronauts haven't actually been back to the moon since 1972.

This seems surprising. After all, when we reflect on this historic event, it is often said that we now have more computing power in our pocket than the computer aboard Apollo 11 did. But is that true? And, if so, how much more powerful are our phones?

On board Apollo 11 was a computer called the Apollo Guidance Computer. It had 2048 *words* of memory, which could be used to store "temporary results" — data that is lost when there is no power. This type of memory is referred to as Random Access Memory. Each word comprised 16 binary digits (bits), with a bit being a zero or a one. This means that the Apollo computer had 32,768 bits of RAM memory. In addition, it had 72KB of Read Only Memory, which is equivalent to 589,824 bits. This memory is programmed and cannot be changed once it is finalised.

A single alphabetical character — say an "a" or a "b" — typically requires eight bits to be stored. That means the Apollo 11 computer would not be able to store this article in its 32,768 bits of RAM. Compare that to your mobile phone or an MP3 player and you can appreciate that they are able to store much more, often containing thousands of emails, songs and photographs.

Phone memory and processing

To put that into more concrete terms, the latest phones typically have 4GB of RAM. That is 34,359,738,368 bits. This is more than one million (1,048,576 to be exact) times more memory than the Apollo computer had in RAM. The iPhone also has up to 512GB of ROM memory. That is 4,398,046,511,104 bits, which is more seven million times more than that of the guidance computer.

But memory isn't the only thing that matters. The Apollo 11 computer had a processor — an electronic circuit that performs operations on external data sources -- which ran at 0.043 MHz. The latest iPhone's processor is estimated to run at about 2490 MHz. Apple do not advertise the processing speed, but others have calculated it. This means that the iPhone in your pocket has over 100,000 times the processing power of the computer that landed man on the moon 50 years ago.

The situation is even more stark when you consider that there will be other processing built into the iPhone, which looks after particular tasks, such as the display.

What about a calculator?

It's one thing comparing against a state-of-the-art phone, but how did the Apollo 11 computer compare against a classic calculator? Texas Instruments was one of the most famous manufacturers of calculators. In 1998, they released the TI-73, and in 2004, they released the TI-84.

The tables (*above right*) show the specification of these two calculators. If we compare the two calculators against the Apollo guidance computer we can note that the TI-73 has slightly less ROM, but eight times more RAM. By the time the TI-84 was released, amount of RAM had increased to 32 times more than the Apollo computer and the ROM was now more than 14,500 times more. With regard to processing speed, the TI-73 was 140 times faster than the Apollo computer and the TI-84 was almost 350 times faster!

It's mind-blowing to think about that a simple calculator, designed to help students decades ago pass their exams, was more powerful than the computer that landed man on the moon.

What if Apollo 11 had had a modern computer?

The Apollo computer was state-of-the-art in its time, but what would have been different if the moon landing had the state-of-the-art computers that are available today?

I suspect that the software development time would have been a lot faster, due to the software development tools that are available today. It would have been a lot quicker to write, debug and test the complex code required to deliver a man to the moon.

The user interface called Display Keyboard had a calculator-type interface where commands had to be input using numerical codes. Today's interface would be a lot easier to use -- which could matter in a stressful situation. It would almost certainly not have a keyboard, but would use swipe commands on a touch screen. If that were not possible, due to having to wear gloves, the interface might be through gestures, eye movement or some other intuitive interface.

Surprisingly, one thing that wouldn't be better today is the communication speed with Earth. The actual time it takes to communicate is the same today as it was in 1969 — that is, the speed of light, which means that it takes 1.26 seconds for a message to get from the moon to Earth. But with the larger files we now send — and from greater and greater distances — to get an image from a spacecraft to Earth today will take relatively longer than it did in 1969. That said, it would look much prettier thanks to advances in camera technology.

Perhaps the biggest change we would see is the computer being a lot more artificially intelligent. I am sure that the flying and landing of the space craft would not be put solely into the hands of the computer, but it would have much more information and intelligence, and would be able to make many more decisions than the Apollo 11 computer was able to do in 1969. This could be a huge relief for the astronauts. Armstrong did say that, on a worrying scale from one to ten, walking on the moon was about a one — whereas making the final descent to land was about a 13.

So let us end by acknowledging what it took to land people on the moon in 1969 with the limited computing power that was available at the time. It really was a remarkable achievement.

The writer is professor of computer science, University of Nottingham, UK. This article first appeared on www.theconversation.com