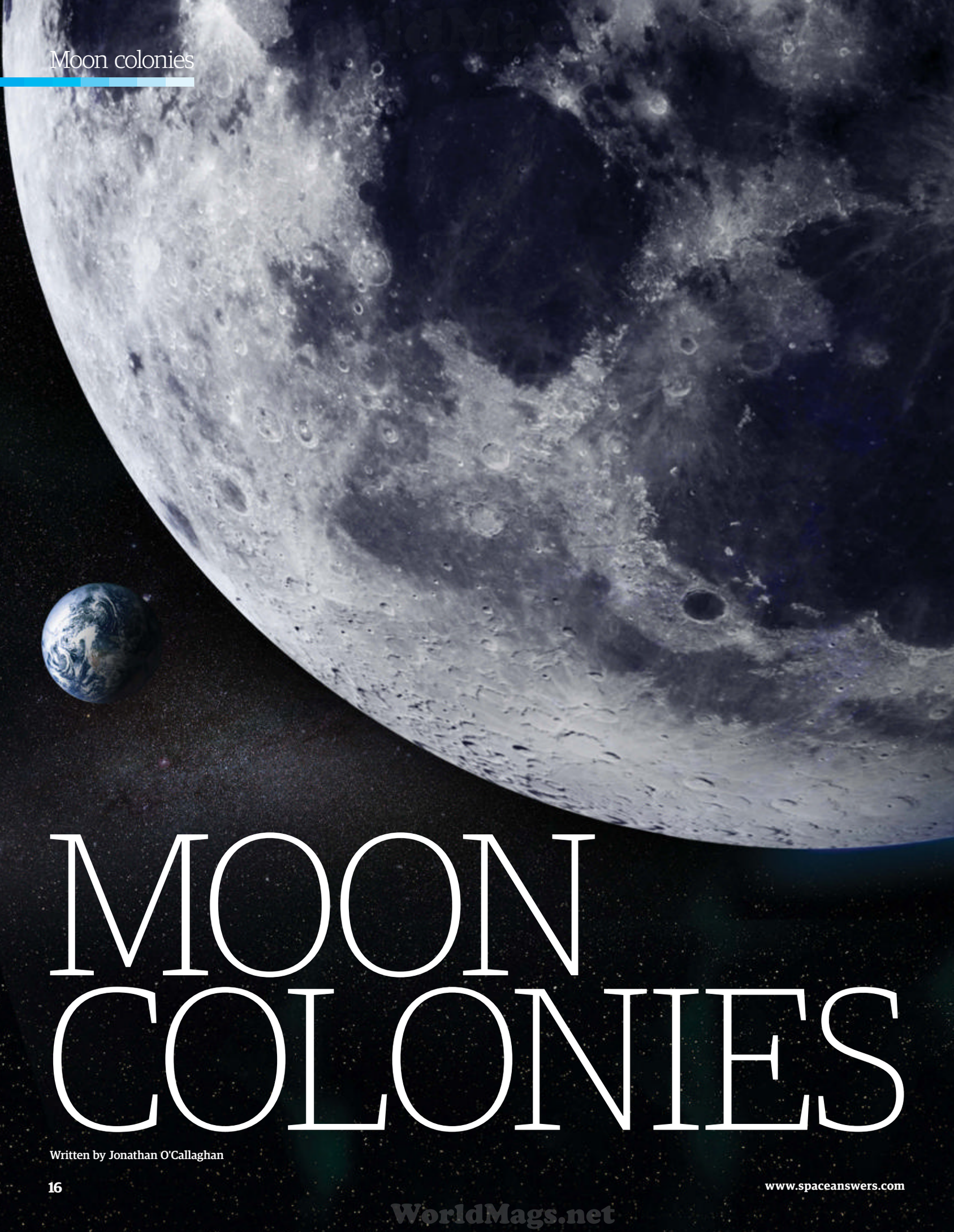

MOON COLONIES

Written by Jonathan O'Callaghan

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Moon colonies

As the fortieth anniversary of the last manned Moon mission passes, **All About Space** investigates the progress being made towards establishing a permanent lunar base on the surface of our satellite

"America's challenge of today has forged man's destiny of tomorrow," said Apollo 17 astronaut Gene Cernan as he stepped back into the Lunar Module with fellow astronaut Jack Schmitt on 14 December 1972. The Apollo missions were expected to kickstart an age of human space exploration including lunar colonies, manned Mars missions and possibly ventures beyond. But four decades later, and the pipe dreams of 20th Century visionaries seem further away than that fateful first step in 1969.

It's no exaggeration to say that, in the year 2012, many had predicted space to be teeming with human life. The fact that it's not, save for a handful of astronauts aboard an orbiting space station, is a disappointment to many a space enthusiast. But is it really all doom and gloom? Are we truly destined to remain constrained to our Blue Planet, left to observe the Moon from afar rather than setting foot, and living, where only a dozen men have done so before?

"If something can be done, it ultimately will be done," says Dr Paul Spudis, talking to **All About Space** about the possibility of a future Moon settlement. "If at some point it makes sense for the Moon to be permanently inhabited, then it will happen."

Dr Spudis is somewhat of an expert when it comes to lunar exploration. He is currently a senior staff scientist at the Lunar and Planetary Institute in Houston, Texas, and has worked on both the Indian Chandrayaan Moon programme and NASA's Lunar Reconnaissance Orbiter. He also served on a White House panel to analyse a return to the Moon and the establishment of a lunar base.

From the outside looking in a possible Moon colony might seem improbable, if not impossible, but it's an idea that has been suggested by scientists since the dawn of the space age, including Dr Spudis himself.

"I advocate a return to the Moon to use it for the creation of a new space-faring capability," says Dr Spudis. "That essentially means that we hope to extract the material and energy resources of the Moon to build a permanent, space-faring capability. In practical terms that means, initially, the extraction of water from the deposits near the lunar poles and its use for a variety of purposes, mostly rocket propellant but also human life support and power storage. Eventually, we can build structures from lunar materials, but water is the easiest and most useful substance to get at first."

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The reference of water on the Moon is an important one, and is one of the primary reasons that lunar exploration has become such an intriguing talking point once again. The discovery of water on the lunar surface was formally announced by NASA on 24 September 2009. Found by the Chandrayaan-1 orbiter and impact probe, it was a huge announcement with far-reaching ramifications.

As Dr Spudis mentions, water is a vital ingredient for any form of manned space exploration. It's essential for life, and its constituents (hydrogen and oxygen) also happen to be the primary components of rocket fuel. Previous visions of a lunar base envisioned a colony constantly resupplied by missions from Earth, a costly and timely endeavour that a multinational mission would struggle to accomplish, let alone one nation going it alone. The discovery of water on the Moon, hiding as ice in the shadowed and cold reaches of the deepest lunar craters, raised the very real possibility of a lunar colony being self-sustaining, rather than reliant on resupplies from Earth.

"Water on the Moon is the most important discovery for spaceflight since the rocket equation," explains Dr Spudis. "It means that we can learn how to 'live off the land' on the Moon, an essential skill for any space-faring species."

It's not quite as easy as landing on the Moon and scooping up bucketfuls of water, however. While water ice exists, its quantities are up for debate. The lowest estimates place it at making up just 0.00001 per cent of a portion of lunar soil, sparser than the driest deserts on Earth. Upper estimates suggest a quantity of 8.5 per cent, a much more useful amount if correct. In March 2010, Chandrayaan-1 again made an important discovery, this time finding 40 permanently darkened craters near the Moon's poles with a potential 600 million metric tons (1.3 trillion pounds) of water ice if the upper estimate holds true.

Dr Spudis highlights the need to quantify how much water ice is available to ensure the success of a lunar colony: "Although we know that water exists on the Moon, we have many questions about its physical state and how it varies in concentration. We need to prospect and map ice deposits, extract some water to determine how difficult it may be, and use it in space to completely demonstrate the use of lunar water from an end-to-end systems engineering basis."

Whatever the true quantity of water on the Moon, the possibility of colonising the Moon is not only exciting but also incredibly useful. From a purely financial perspective, the prospects might seem bleak. Estimates suggest a lunar colony would cost upwards of tens of billions of dollars, an amount of money simply not available to any space agency in the world. But the potential returns are huge, in the form of job creation, new inventions and better technologies. For every dollar invested in the Apollo mission, it is said that around 20 dollars were returned to the American economy. The prospect of a permanent residence on the Moon would only increase the potential return. And this is before we even consider the existence of helium-3 on the lunar surface, an isotope blasted across the Moon by solar wind that could be the key ingredient to creating fusion reactors, and therefore huge sources of power, on Earth.

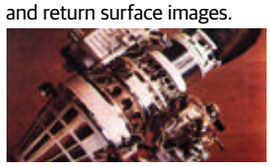
Humanity is not just a species driven by money, though, despite what some would have you believe. We are inquisitive, curious, and we constantly strive to further understand the natural world around us and the universe as a whole. Confining ourselves to our world and failing to invest in manned space exploration would be akin to giving up on our natural habits, to learn, and would relegate us back to an age where humans merely looked upon the stars with fondness, rather than the thought that they could be explored.

"Technically, we're not far away from returning man to the Moon and creating a Moon base"

Dr Paul Spudis, senior staff scientist, Lunar and Planetary Institute

History of Moon exploration

3 Feb 1966
Luna 9
This Soviet 'craft was the first probe to land on the Moon and return surface images.



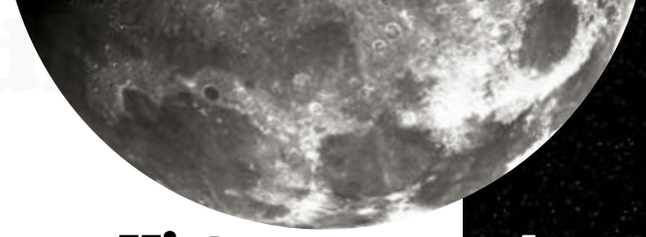
30 May 1966
Surveyor 1
The first successful unmanned American Moon landing returned 11,000 pictures.

20 July 1969
Apollo 11
Neil Armstrong and Buzz Aldrin were the first humans to set foot on the Moon.

11 Dec 1972
Apollo 17
While the last humans on the surface were Americans Gene Cernan and Jack Schmitt.

22 Aug 1976
Luna 24
This was the last spacecraft to date to land on the Moon and return lunar samples to Earth.

8 Nov 2008
Chandrayaan-1
This Indian probe found water on the Moon, and released an impactor to the surface.



A small step – developing lunar bases

While NASA has long had a vision to create a manned station on the Moon, other agencies have also announced plans to return humans to the Moon for a prolonged period of time.

China

The biggest emerging nation in space exploration, China has made no secret of its desire to land humans on the Moon. It launched its first two unmanned probes in 2007 and 2010, with the third set to follow in 2013.

It has also carried out extensive manned operations in Earth orbit, with a manned space station to follow in the coming years. All of this is building towards a manned lunar landing and, possibly, a permanent residence on the Moon.

Russia

Roscosmos, the Russian space agency, has a number of unmanned landers planned to touch down on the lunar surface by the end of the decade, but work is also underway on a manned mission that will take Russians to the Moon for the first time. Four automated probes will land on the Moon by 2020, followed by a larger station in 2023. This station could be the first part of a manned lunar base in a polar region to follow at an unspecified date.

India

The Indian Space Research Organisation (ISRO) has announced rather lofty goals for space exploration, including a manned landing by 2020. While this looks unlikely for now, its intentions to return man to the Moon at some point are clear.

Japan

The Japanese Aerospace Exploration Agency (JAXA) has suggested that it wants to build a robotic base on the Moon by 2020. This would be a precursor to a manned lunar base in 2030.

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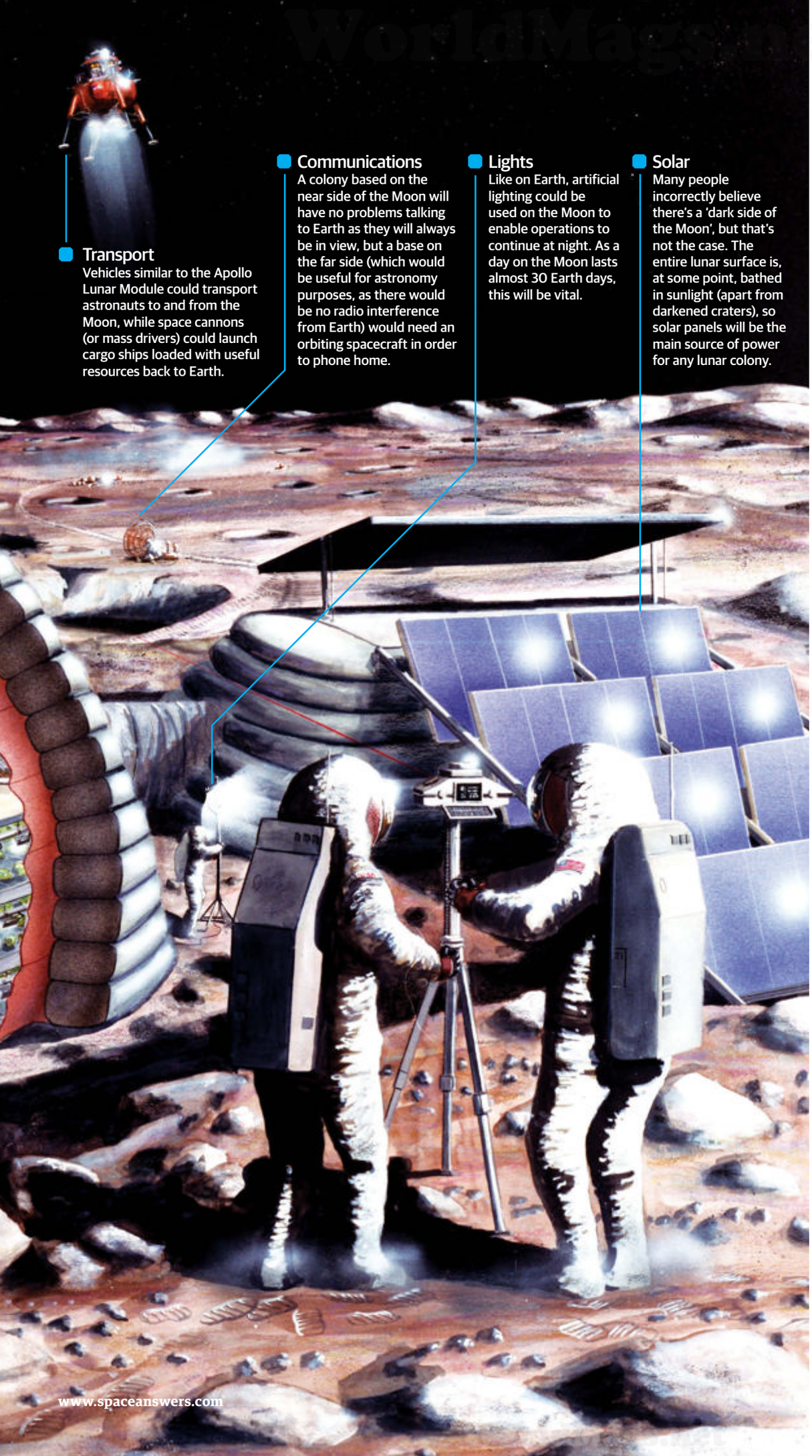


Transport
Vehicles similar to the Apollo Lunar Module could transport astronauts to and from the Moon, while space cannons (or mass drivers) could launch cargo ships loaded with useful resources back to Earth.

Communications
A colony based on the near side of the Moon will have no problems talking to Earth as they will always be in view, but a base on the far side (which would be useful for astronomy purposes, as there would be no radio interference from Earth) would need an orbiting spacecraft in order to phone home.

Lights
Like on Earth, artificial lighting could be used on the Moon to enable operations to continue at night. As a day on the Moon lasts almost 30 Earth days, this will be vital.

Solar
Many people incorrectly believe there's a 'dark side of the Moon', but that's not the case. The entire lunar surface is, at some point, bathed in sunlight (apart from darkened craters), so solar panels will be the main source of power for any lunar colony.

Privatising the Moon

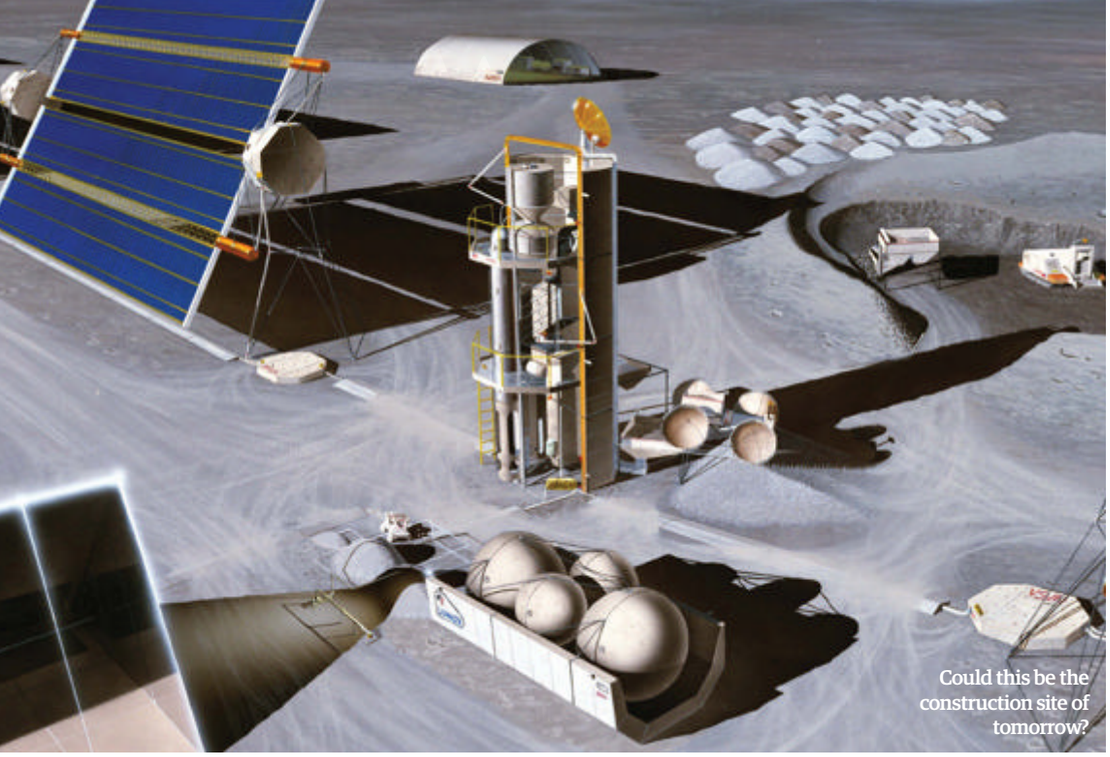
The best way to colonise the Moon might be to realise the commercial benefits of it, space settlement expert Al Globus told **All About Space**. Globus has previously worked on the ISS from Earth and, alongside being chairman of the National Space Society's Space Settlement Advocacy Committee, he is a big proponent of space settlement and has written many papers on the subject.

By the end of the 2010s, Globus said, governments around the world will have a number of landers and orbiters on and around the Moon. The big change in manned space exploration, however, will be the huge growth of the private sector. Sub-orbital tourism (with the likes of Virgin Galactic) will take-off, with over 1,000 people a year reaching space by 2020.

The next two decades will see lunar mining companies begin to spring up on the Moon, he continued, although they could struggle financially at first. The key for their success will be the growth of the space tourism industry; even though the ISS will be decommissioned in the early 2020s, space hotels will be launched into Earth orbit and expand the private space sector. Over the next 50 years the number of space tourists could grow to millions, not just thousands.

This, Globus said, is where privatising the Moon will be key. Mining resources from the lunar surface, such as water, could provide essential supplies for these hotels. It'll take a while for lunar mines to become profitable, but by the 2070s they could be supplying most of the materials necessary for space hotels.

Furthermore, if NASA or another agency constructs a lunar mass driver on the Moon, which would allow for cargo to be sent back to Earth, then Globus said the lunar mining business will become extremely profitable, allowing it to potentially dominate the metal markets on Earth. In the 2050s these mines would need a crew of just 20 people, but by the 2080s there could be thousands of people living on the Moon and operating them.



Could this be the construction site of tomorrow?

The Apollo missions returned a lot of useful lunar rock

The colonisation of the Moon is a vital stepping stone in our grander scheme of exploration.

That's not to mention the constant threat our planet is under from extinction. It's easy to forget that just 65 million years ago, a mere 1.4 per cent of our planet's 4.5 billion year existence, an asteroid wiped out almost every living thing on the surface. We know that there's no impending impact event, but one is likely to occur at some point. With no other-world colonies to inhabit, we are doomed to extinction.

"The Moon serves as our first 'off-shore coaling station' on the ocean of space," agrees Dr Spudis. "We can use its material to fuel a permanent transportation system, one that allows us to not only access the Moon and explore it in detail, but more importantly, to routinely access all of cislunar space [the zone between the Earth and the Moon], where all of our satellite assets reside. The Moon is also a major scientific resource because it records in detail a period of Solar System history that has been erased from the Earth."

So, if we were to decide to build a lunar colony, could it be done?

> "From a policy perspective, we are light years away, mainly because few people recognise the value of the Moon" **Dr Paul Spudis**

"Technically, we're not far away from returning man to the Moon and creating a Moon base at all," says Dr Spudis. "We have all the individual pieces and technology we would need to live and work on the Moon right now." Technology, however, is not the problem, explains Dr Spudis: "From a policy perspective, we are light years away, mainly because few people recognise the value of the Moon as I have described it here. I am trying to change those misperceptions."

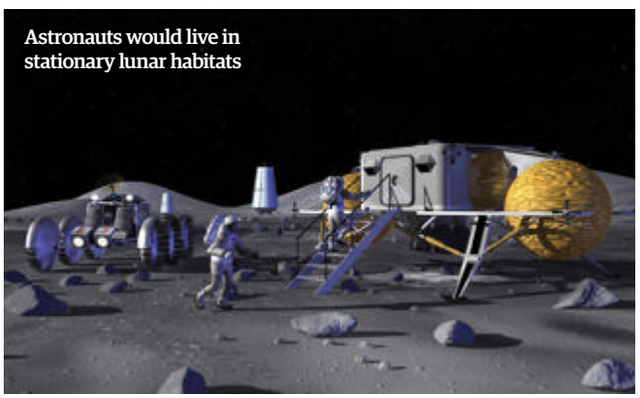
Many agencies have carried out studies into the feasibility of a lunar colony, reaching as far back as 1959 when the US Army first established a plan to build a fort on the Moon with two astronauts. Known as Project Horizon, it would have required about 150 separate rocket launches, making it unattractive from a cost perspective.

Various proposals have followed, and in the 21st Century numerous countries have at least announced their intentions to build a base on the Moon (see 'A small step' boxout on page 18), including Japan, Russia and the USA. It is NASA, however, that has carried out the most research in the area. For example, it has been testing its Lunar Electric Rover for several years now and, while it might be repurposed for use on an asteroid rather than the Moon, it could provide weeks of habitation for astronauts on the Moon if deployed.

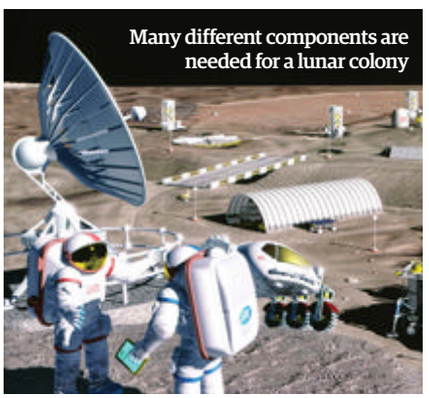
All forms of research, though, have focused on visits longer than the Apollo missions (so over three days) but not quite at a level of permanent habitation. As Dr Spudis explains, we still have problems to overcome if we are to colonise the Moon. "Although we understand how to extract and use lunar resources in theory, we have not done so in practice," he says. "The biggest need right now is experience: in accessing and surveying the ice deposits, in digging up the ice and processing it into water, in converting that water into its gaseous components, in cryogenically freezing the gases into liquids and, finally, using the product in a variety of applications. We understand how to do all these things in theory, we simply need to learn to do them to learn where the problems are."

Overcoming these problems and testing key technologies are imperative goals if we are to achieve the ultimate dream of building a settlement or colony on the Moon. There's little doubt, however, that positive progress is being made in many of the necessary areas by several nations around the world. Lunar colonies are not just the fancy of space visionaries any more; they will play a useful and important role in our continued exploration of the Solar System, and provide us with an off-world habitat the likes of which have never been seen before. "I believe that the Moon is a critical enabling step into the Solar System," says Dr Spudis. "It is a stepping stone to space capability."

Manned and unmanned vehicles could scour the Moon's surface



Astronauts would live in stationary lunar habitats



Many different components are needed for a lunar colony

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Road map to the Moon

NASA Johnson Space Center engineer John Connolly speculates on how he thinks lunar colonisation might develop.

2070-2079

The Moon becomes the stepping off point for human voyages to Mars and beyond. Due to its rich resources, and low gravity, the Moon becomes the choice for launching missions into deep space.

2060-2069

Colonisation begins to increase, with distinct communities occupying different parts of the Moon. Like the Antarctic of 100 years earlier, different countries have established permanent outposts for scientific purposes, but other areas are being developed for commercial resource purposes and for residential communities.

2050-2059

Lunar colonies begin to spring up at multiple locations around the lunar globe. 'Vacations' to the Moon, though still costly, become the top destination, with lunar 'hotels' beginning to emerge. The first child is born on another world.

2030-2039

The 2030s will see a continued buildup of an international science base near one of the lunar poles. 30-day missions with crews of four will mature to 180-day missions in which teams of pressurised rovers carry crews to more remote sites. Lunar resources will be in full use to provide the crews' oxygen, water, and the propellant for their return to Earth. The lunar surface will increasingly be used to test hardware that will be used for an upcoming human mission to Mars. In lunar orbit, or perhaps at an Earth-Moon libration point, the deep-space habitats and propulsion systems for the Mars mission will also be tested. The first lunar tourists will likely arrive in this decade.

2040-2049

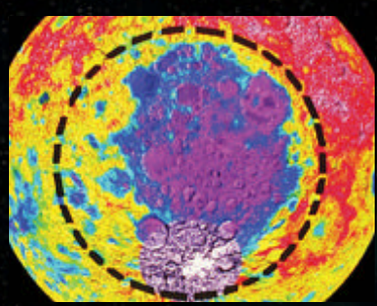
Scientific exploration of the Moon begins to combine with commercial visits. Interest in lunar metals and resources fuels commercial missions to produce not only fuels and consumables to support lunar operations, but to extract high-value materials for export to Earth. Helium-3 mining, which occurs as a by-product of other resource extraction processes, reignites the interest in nuclear fusion as a clean power source for Earth.

2020-2029

In the 2020s humans will return to the Moon. Lunar surface missions will become international partnerships, following on from the experience of the ISS, and multiple countries will raise their flags on the Moon. We will test in-situ resource utilisation at human-scales, producing water and propellants from lunar feedstock.

2010-2019

Leading up to the year 2020, the first private lunar lander will land on the Moon, likely to claim the Google Lunar X Prize. This may open up an entire new way of performing lunar science missions – with science agencies purchasing 'rides' for their instruments rather than funding the engineering of the spacecraft and purchase of launch vehicles. Lunar sample return missions will date the deepest known impact basin (South Pole-Aitken basin) and return samples of polar volatiles. Other robotic missions will probe the permanently shadowed craters of the lunar poles and test in-situ resource utilisation technologies.



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