

ISSN: 2516-4848

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May/June 2019

Issue 2 / Volume 3

# NewSpace INTERNATIONAL ...

In this Issue: #SpaceTravel #LunarExploration #OrionLaunchAbortSystem #SpaceConnectivity



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Dr Amy Saunders

Editor

**"**

Technology is coming on in leaps and bounds right now, and the world is transforming into an entirely new place right before our eyes. Today's advances in robotics are astounding – and we can fully expect to see robotic digital assistants playing a role within the satellite sector within the years to come – but what's equally fascinating is the way that humans respond to these robots.

Many of us will have seen the 2004 movie 'I, Robot,' in which protagonist Will Smith is inherently distrustful of robots after one rescued him from drowning over his son (due to relative probabilities of survival), leading to the death of a small child. The film brought certain key issues in the field of psychology and robotics to the forefront of our imaginations that have since been addressed in numerous experiments and studies.

A recent experiment published in the *PLOS ONE* journal has shown that people are susceptible to social cues even when those cues come from robots, rather than other humans. Some 89 volunteers were recruited to complete tasks with the help of a small humanoid robot called Nao. The volunteers were informed that the tasks – which involved answering a series of either/or questions such as 'Do you prefer pasta or pizza?' were designed to enhance Nao's learning algorithms.

However, the real test came at the end of the study, when the volunteers were asked to turn off Nao. In 43 of the experiments, Nao begged not to be turned off, a request which 13 volunteers complied with. The remaining 30 took about twice as long to turn Nao off than those volunteers who it did not plead with. The 13 participants who did not switch off Nao said they were surprised by the begging; were scared of doing something wrong; or, most commonly, reasoned that if Nao didn't want to be turned off, 'who were they to disagree?'

The experiment brilliantly exemplified a concept most of us are familiar with: 'The Media Equation,' which claims that people tend to treat computers and other media as if they were real people. You might be able to recognise it in yourself, when you shout at a Smartphone, washing machine, or other inanimate device which isn't performing as you want it to. "Triggered by the objection, people tend to treat the robot as a real person rather than just a machine following, or at least considering to follow, its request to stay switched on," commented the experiment's authors.

While some have raised concerns about what this behaviour means for the future of robotics and their application in day-to-day life, others say that worries are unfounded: Human behaviour can and will adapt to treat machines as machines as technology advances. ■



Humanizing technology



Front cover: Photo courtesy of Kepler

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ISSN: 2516-4848

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## Maxar teams with Dynetics on power and propulsion element for Lunar Gateway

Maxar Technologies has signed a teaming agreement with Huntsville, Alabama-based Dynetics to support Maxar in building and demonstrating the power and propulsion element for the Gateway - an essential component of NASA's Artemis lunar exploration program and future expeditions to Mars. The teaming agreement establishes a framework for the companies to work together on the mission, with substantive work being executed by Dynetics in Huntsville, Alabama.

As recently announced, Maxar was selected by NASA to build and perform a spaceflight demonstration of the power and propulsion element spacecraft. The spacecraft is the first element for the NASA-led lunar Gateway, which will play a critical role in ensuring that NASA astronauts can land on the surface of the Moon by 2024 while serving as a vital platform to support future missions to Mars and beyond. The mission is targeted for launch by the end of 2022 and will provide power, manoeuvring, attitude control, communications systems and initial docking capabilities for the Gateway.

The agreement enables Dynetics to collaborate with Maxar in the design, manufacturing and operations of Maxar's power and propulsion element spacecraft. Dynetics has a wide range of capabilities to support Maxar in areas such as propulsion systems, mechanical and propulsion testing, system integration and assembly, and mission operations.

"We're thrilled to add Dynetics to our team and bring power and propulsion element work to Huntsville. Dynetics has decades of expertise in human space exploration, and will play a critical role in executing the Artemis mission, landing the first woman on the surface of the Moon, and establishing the sustainable space infrastructure that is necessary to explore Mars," said Mike Gold, Maxar's Vice President of Civil Space.

"This is an exciting time for lunar exploration. We look for space partners that share our similar core values and are eager to see America return to the Moon. Maxar fills that role and Dynetics is glad to be on the team. Maxar's power and propulsion element will be a vital element of the lunar Gateway and will aid establishment of a sustainable presence on the Moon. We are looking forward to this partnership and to participating in the development of the lunar architecture here in Huntsville on our campus and in Decatur, Alabama, at our Aerospace Structures Complex," said Kim Doering, Dynetics vice president for space systems.

The operations of DigitalGlobe, SSL (Space Systems Loral) and Radiant Solutions were unified under the Maxar brand in February; MDA continues to operate as an independent business unit within the Maxar organization. ■

To include your news in NewSpace International magazine please contact  
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## President and CEO testifies before Congress

On July 9, Dr. Mary Lynne Dittmar, president and CEO of The Coalition for Deep Space Exploration, testified before Congress at a hearing titled, "NASA Exploration Plans: Where We've Been and Where We're Going," held by the Subcommittee on Aviation and Space. The purpose of the hearing was to honour the upcoming 50th anniversary of the National Aeronautics and Space Administration's (NASA) Apollo 11 mission, the United States landing the first man on the Moon, and NASA's plans for future human spaceflight missions.

Within her testimony, Dittmar addressed foundational lessons learned during Apollo, the current geopolitical objective of establishing US leadership in space and the importance of adequate funding, acquisition reform and a diverse workforce to reach the Moon and then Mars. As shared in her written testimony, Dittmar summarizes, "The Moon is not an end goal, but a beginning - a next step enabling the migration of technology, heavy industry, and humanity itself off the Earth and into the solar system at a scale that is no longer constrained by a single planet, our original home. Nothing stimulates interest like truly great goals that require us to develop ourselves and advance the human condition, as well as our technology, in order to achieve them. Continuing the work begun with Apollo, returning to the Moon, and then reaching for the horizon of Mars, is just such a goal."

Other witnesses included: Dr. Christine Darden, Data Analyst and Aerospace Engineer Researcher, National Aeronautics and Space Administration; Mr. Homer Hickam, Author, Rocket Boys; Mr. Gene Kranz, Flight Director, Apollo 11; and Mr. Eric Stallmer, President, Commercial Spaceflight Federation. ■



Photo courtesy of NASA



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# Lockheed Martin and NASA successfully demonstrate Orion launch abort system in flight test

The critical launch abort system for NASA's Orion spacecraft was put to its hardest test today, and it demonstrated its capability to pull the crew module and future astronauts to safety during a launch if there is an emergency. Lockheed Martin designed and built the launch abort system for the test and is also the prime contractor building the Orion spacecraft for NASA.

The Ascent Abort-2 flight test is a major test milestone that is enabling the safe passage of astronauts aboard Orion on the Artemis missions to the Moon and then Mars.

During the test this morning from Cape Canaveral Air Force Station, Florida, the Orion launch abort system, with a mock-up Orion capsule, was launched on a modified Peacekeeper missile. At 31,000 feet, or about six miles up, into the flight, the on-board computers initiated the abort sequence. The launch abort motors, generating 400,000 pounds of thrust, then pulled the Orion capsule away from the rocket which was already travelling nearly 1,000 mph. Using its attitude control motor, the abort system then reoriented itself and jettisoned the Orion capsule using its jettison motor. The total test took less than three minutes.

"The test flight performed perfectly, not to mention it was really exciting to watch," said Mike Hawes, Orion program manager for Lockheed Martin Space. "Hopefully this will be the last time we see this launch abort system ever work, but this test brings confidence that if needed on future Orion missions, it will safely pull the crew module and astronauts away from a life threatening event during launch."

The Orion launch abort system is the highest thrust and acceleration escape system ever developed and is the only system of its kind in the world. It's a major system that makes the Orion exploration-class spaceship the safest spacecraft ever built.

This is the second time the Orion launch abort system has been put to the test. The first flight test was in 2010 simulating a static abort from the launch pad. AA-2 is the final test and demonstration of the full-up launch abort system.

NASA's Orion spacecraft for the uncrewed Artemis 1 mission to the Moon is being developed at the NASA Kennedy Space Center and will soon head into environmental testing—all in preparation for a 2020 launch.

Photo courtesy of NASA



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# Human communities in Space

Orion Span plans to build and sustain human communities in space, utilising technological innovations to reduce the cost of living in space by an order of magnitude above others. The Aurora Station hotel may well be the first commercial tourist destination in space should it meet its slated 2021 launch. Frank Bunger, CEO at Orion Span, tells us more about the company's incredibly ambitious project.

**Question:** Orion Span was launched relatively recently with some pretty lofty goals. What can you tell us about the company's founding and its vision for the future?

**Frank Bunger:** When I was kid, there was a dream of low-cost access to space driven by the Space Shuttle program, along with the International Space Station (ISS). While both programs are absolutely magnificent marvels, neither have served to lower costs to access space. It took the likes of companies like SpaceX, Blue Origin, and others, in the early 2000s, to commercialize space access to truly see costs start to go down.

Like many frontiers in human history, something big and new starts off as being a governmentally funded endeavour because there is simply no commercial market in which a private entity can flourish. As the initial



Frank Bunger, CEO at Orion Span

foothold is established, and government funding withdraws, commercialization takes over. And that's when things really get exciting.

That's exactly what happened to rocket launch in the early 2000s. At the time, everyone thought a commercial rocket launch company was completely nuts. They were wrong. The timing was spot on and these companies are now worth billions of dollars. Today, we are in a similar transition as the ISS approaches retirement and

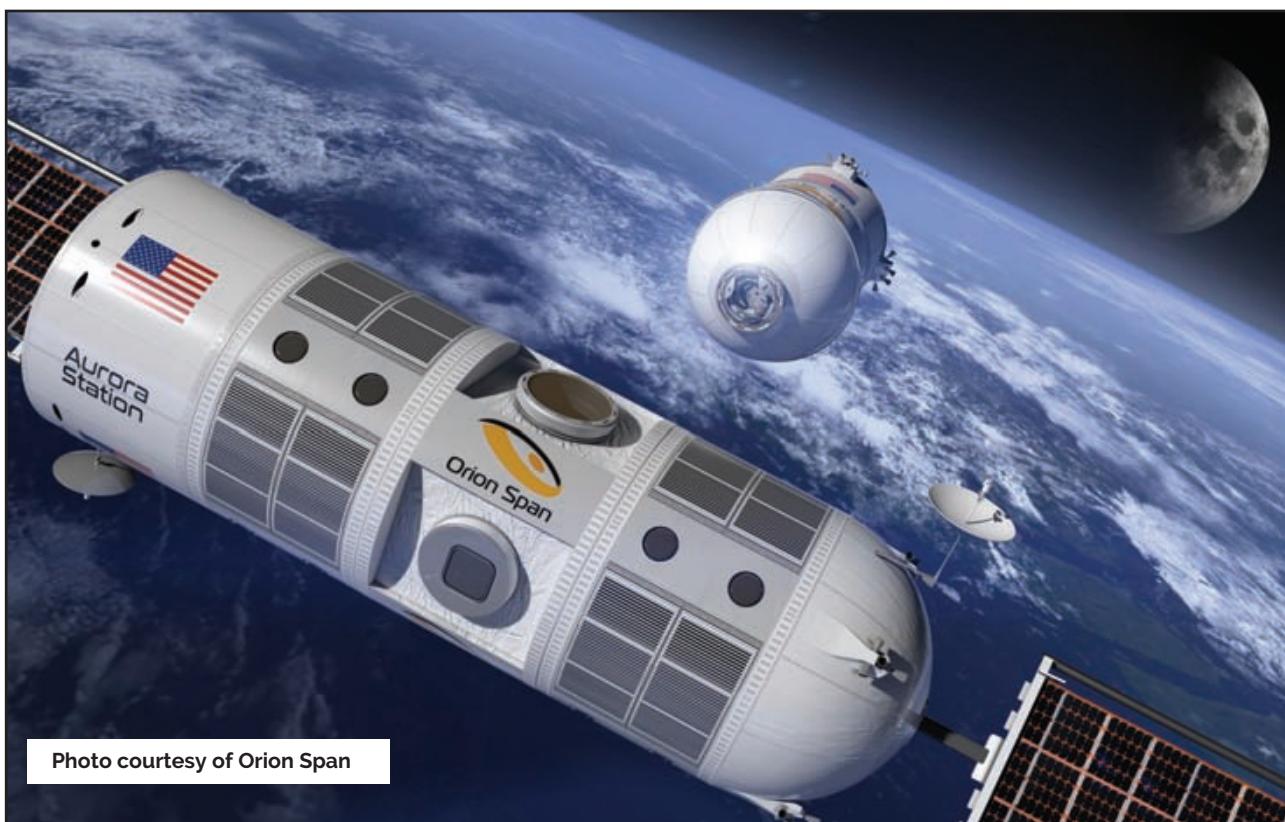


Photo courtesy of Orion Span

commercialization must kick in to serve that market.

**Question:** Orion Span announced the first-ever luxury space hotel back in April 2018. Capable of hosting six people at a time, including two crew members, the company will offer a once-in-a-lifetime astronaut experience during a 12-day journey. The launch date is slated for late 2021; can you provide an overview of the planned space hotel, and let us know what the company has achieved in the last year since the announcement?

**Frank Bunger:** In the last year, we've refined our technology, hit a first funding milestone, completed work on a virtual reality model of Aurora Station, and started to work on a ground/physical demonstration of Aurora Station.

**Question:** Just 72 hours after announcing the Aurora Station hotel, four months of reservations sold out. What can you tell us about the hotel's reception after those first 72 hours, and your expectations once the station is up and running?

**Frank Bunger:** It was very optimistic and positive. There is clearly a tremendous public excitement and interest in all things related to space.

**Question:** What are the biggest challenges you foresee in developing the Aurora Station hotel, and how will these be met?

**Frank Bunger:** The biggest challenge I foresee is funding. Because we are the first ones to propose a much lower-cost solution to human presence in LEO, there is no benchmark against which to compare. This can make some investors nervous. However, I should mention that we have no challenge winning them over after we walk through our financial models.

**Question:** What can you tell us about the

communications capabilities that will be in place on board the Aurora Station? How will visitors communicate with loved ones back on Earth, and how will crew stay in touch with ground control?

**Frank Bunger:** For guests, there will be high-speed Internet access. 'High-speed Internet' may seem trivial, but in space, you don't take things for granted, and having a high-speed connection is more challenging than it may seem.

Crew will stay in touch via standard ground to space communications channels and methods that have been tried and validated for decades.

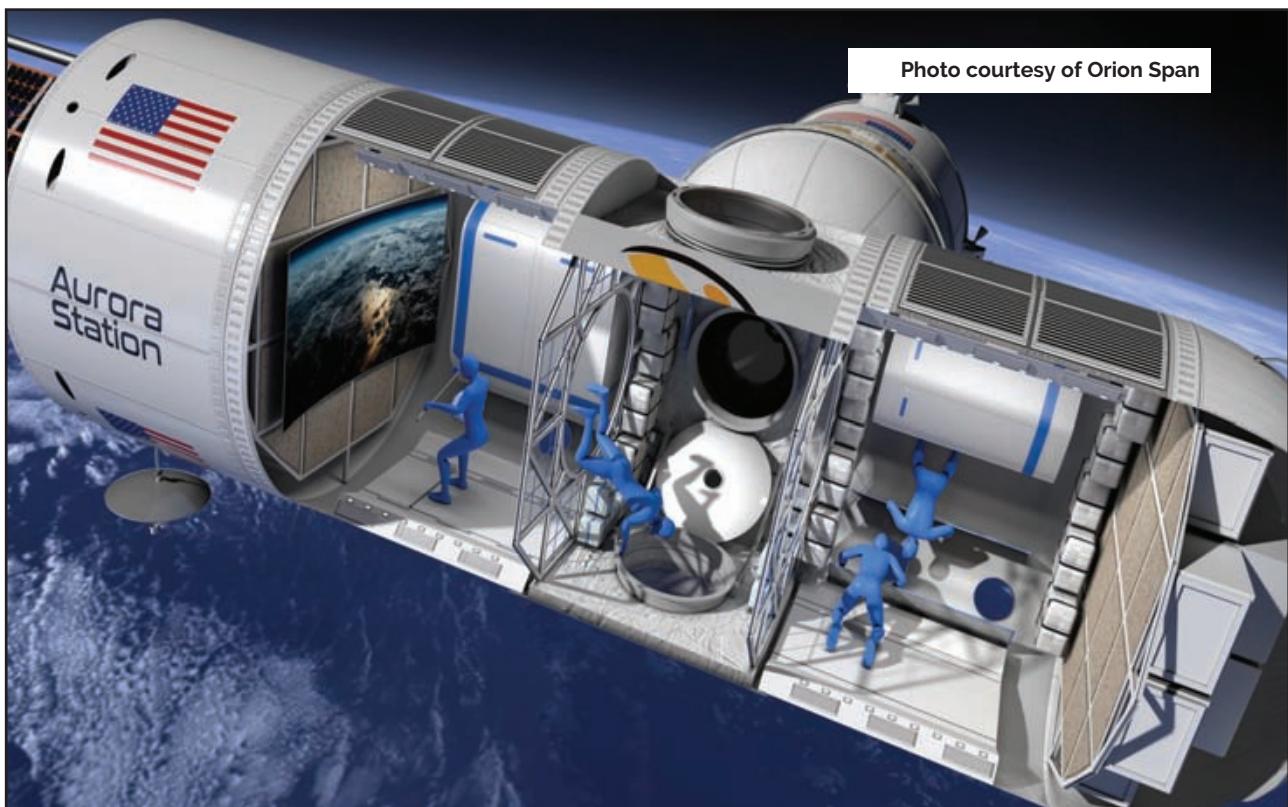
**Question:** Orion Span is one of the most imaginative companies in the NewSpace arena right now; what's your assessment of the NewSpace movement as a whole, and the other sectors within it?

**Frank Bunger:** The NewSpace movement is largely founded on the same principles that drove the mobile device revolution: Miniaturization and commoditization of hardware. For example, a computer that used to be the size of a room now fits into your pocket. Orion Span is different than most of this movement, in that we are focusing on the human experience and expansion into space.

We do benefit from commoditization of hardware, but that is not our main value proposition. I consider us to be a platform for the movement as it stands today. It feeds into the growing low Earth orbit (LEO) commercial ecosystem of which we intend to be a cornerstone.

**Question:** What are your expectations for Orion Span and the Aurora Station in 2019-2020?

**Frank Bunger:** We expect to demonstrate progress on some of the technology we're using to cut costs aggressively for construction of pressurized and human-rated spacecraft. The exact timing and release of this, I cannot yet reveal, but we are highly optimistic. ■



# Delivering connectivity in Space

Kepler Communications was founded in 2015 by four students from the University of Toronto with the goal of 'building the Internet in space.' Providing real-time communications with other satellites, space stations, launch vehicles, habitats and other space-borne assets is an ambitious target, but one that Kepler is determined to meet. Jeffrey Osborne, Co-Founder and VP Business Development at Kepler Communications provides an overview of the company's plans and vision for the NewSpace arena.

**Question:** Let's talk about Kepler Communications – What can you tell us about the company's overall vision, and the technology that will see that vision brought to life?

**Jeffrey Osborne:** Kepler was born with the mission of delivering connectivity in space. What we identified was a clear growth trend in the space market; countless new companies were coming online to launch large numbers of satellites to provide a variety of services. These companies were developing spacecraft for Earth observation, connectivity, in-space services, or habitations. All of these companies were foundations for the newspace economy, and it's been our belief from the beginning that in-space infrastructure is a necessary part of building the space economy. To that end, we recognized connectivity infrastructure as one of the main needs of future space economy, and so we endeavoured to create that infrastructure.

However, we also recognized pretty early on that we simply could not get to this vision overnight, and that we needed an incremental and sustainable roadmap. We needed to develop technologies and deliver services that solved terrestrial connectivity needs, all the while building up our competency so we could tackle this much bigger problem and opportunity of in-space connectivity. Currently, we are delivering terrestrial wideband and soon-to-be narrowband connectivity services for terrestrial applications, but this all comes with an eye towards our ultimate mission.

There is a lot of technology that will be needed to reach our mission. We have already built some of it but there is still a lot more that is required. Our first two satellites were built to demonstrate our high-capacity communications technology. We have been able to pack more Mbps into a nanosatellite than anybody else ever before. We are using this currently to demonstrate our Global Data Service, which is a wideband satcom service for customers that need to transport very large volumes of delay-tolerant data. The next piece of technology will be demonstrated on our third satellite, launching later this year, which is geared towards delivering narrowband connectivity for a large number of Internet of Things (IoT) devices. This technology will be foundational in delivering our everywhereIoT product to connect IoT and other devices requiring small volume data transfer.



Jeffrey Osborne, Co-Founder and VP Business Development

Image: Kepler

**Question:** It's been a busy couple of years for Kepler Communications. Can you outline the key highlights from the last 12 months?

**Jeffrey Osborne:** The last 12 months have definitely been transformative; I'm confident the next 12 months will be even more exciting. Hopefully, I don't forget anything in this list.

In 2018, we launched and commissioned our first two spacecraft:

- We set up our first Ku-band ground station in Inuvik, Canada, as well as TT&C stations in Svalbard and New Zealand;
- We shipped our first Global Data Service modems to customers and began service trials;
- We secured US\$16 million in Series A led by Costanoa Ventures with participation from our everywhereIoT anchor customer Deutsch Bahn;
- We demonstrated communication with Phasor's electrically steered flat panel antenna;
- We were awarded our FCC license;
- Moved to a new facility three times the size of our office at the time; and
- Grew the team from 14 to 30 employees.

**Question:** The NewSpace sector is booming right now; what's your assessment of all the next-generation developments we're seeing, and the opportunities for Kepler Communications within it?

**Jeffrey Osborne:** There are a couple things I'm particularly interested in. Firstly, I'm interested to see how the technology will evolve with flat panel antennas, though I think that is true for everyone. The price points these antennas currently sit at is not mass-market acceptable, for sure. There will need to be either (a) innovations, or (b) an identification of markets that are comfortable with the higher price tags of these panels. We have certainly seen a few applications that fall into the (b) category. There is some speculation in media that flat panel antennas have to come down in price to have a chance, but I don't think that's true. Just because a

Rolls Royce is more expensive than a Honda Civic doesn't mean nobody will pay for a Rolls.

Secondly, I'm interested in seeing how things shape out with GEO high throughput satellites (GEO-HTS). There is a sense of 'sky is falling' mentality right now with broadband prices (in fact, I think I've seen articles

We have been able to pack more Mbps into a nanosatellite than anybody else ever before. We are using this currently to demonstrate our Global Data Service, which is a wideband satcom service...

entitled "The Sky is Falling"), and I'm curious where things will land. What's interesting about the overall decline of broadband prices is that there are still geographies and applications where that is not true. GEO-HTS have this characteristic where they still need to concentrate bandwidth in target regions. So, even though prices may be crashing in the Gulf of Mexico, there are other places where that is not the case. Small satellites are really interesting here. Because our development cycles are shorter, we are better able to provide coverage in those

smaller places that big GEOs inevitably leave behind. It is like how when you go to repaint your bedroom, you probably use a big roller for the majority of the work (that's the GEO-HTS), but will also need to break out the paint brush to get the edges and next to the baseboards (that's the small satellites).

**Question:** In August 2018, it was announced that Clyde Space was contracted to build and deploy Kepler Communications' third nanosatellite, TARS. What can you tell us about TARS, the mission, and progress to date?

**Jeffrey Osborne:** Our third satellite, TARS, will primarily be tasked with expanding upon the Ku-band service offering of KIPP and CASE, while simultaneously providing a testing platform for our future ubiquitous IoT connectivity solution. To do this, we are adding on an S-band payload to TARS in addition to the Ku-band payload from KIPP and CASE. The payload will be complemented with end-user services as well, and we plan to launch TARS in the first half of this year.

**Question:** Back in September 2018, Phasor and Kepler Communications announced the first successful tests between Kepler's first in-orbit LEO nanosatellite and Phasor's wideband electronically-steered antenna. What can you tell us about the tests, and what they mean for the company going forwards?



**Jeffrey Osborne:** We have been really fortunate to work with the team at Phasor for quite some time now. This demo was the first trial between a LEO satellite and a flat panel electrically steerable antenna. As you can imagine, we were really excited to be a part of the demonstration. This trial is setting the stage for the next stage of connectivity when portable and low-profile mobile antennas meeting next-gen LEO constellations.

Their flat panel ground terminals are very small, light, low-profile and low-power consumption products that use software, instead of mechanical parts, to track and communicate with satellites. These are ideal for aero, maritime, land mobile (such as trains and connected cars) and government. We demonstrated the ability to upload 20 Mbps and download 10 Mbps on Phasor's antenna.

The trend is very clear, we see the market moving towards smaller user equipment in the near future for both narrowband and broadband communications. With lesser size and power consumption, and the power of LEO's reach and speed, you can expect tremendous improvements in connectivity across a variety of industries.

**Question: Towards the end of 2018, Kepler Communications had raised US\$16 million in a Series A round of funding, bringing the cumulative total raised to date to US\$21 million. What steps will this new funding enable Kepler Communications to take?**

**Jeffrey Osborne:** For the most part, we will be using the new capital to grow revenues, and to launch our GEN1 constellation, which will be put into service by the end of 2020 and includes up to 15 additional nanosatellites. The focus of our GEN1 constellation will be on delivering our high-capacity and affordable Global Data Service beyond the capabilities offered by our

technology demonstration satellites.

**Question: What are Kepler Communications' plans for the rest of 2019 and beyond?**

**Jeffrey Osborne:** The beginning of 2019 is focused on delivering TARS, as well as productizing our Global Data Service. We are starting to move past doing early trials of our service and more towards off-the-shelf availability, which is an interesting and fun transition. After TARS is delivered, we will be switching our attention to our GEN1 constellation, which will be our first truly 'service' constellation. This looks like growing our headcount to 40, increasing our capabilities for spacecraft payload design and manufacturing, and improving our ability to manage a constellation. ■



Image: Kepler



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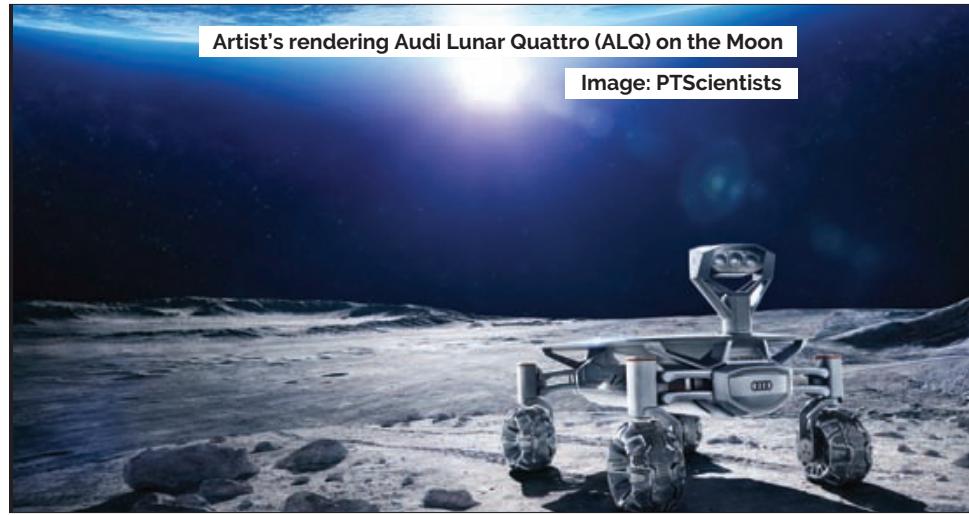
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# Lunar exploration

Exploring the stars with the hope of some day being able to build off-world settlements is a dream that has edged closer and closer to reality in recent decades, as the technologies that could allow us to embark on these ambitious plans become increasingly advanced. Today, we stand at the precipice of this possibility; lunar exploration missions are taking huge steps forwards, and we could well be looking at taking the first steps towards settlement in the near future.



**The Moon has fascinated humanity for eons** now, a constant presence in our lives from the day we are born until the day we die. Despite orbiting the Earth at a distance of 384,400km, we have achieved some progress, with 65 recorded Moon landings in the 1960s-1970s, including the first-time man set foot on the Moon with the Apollo 11 mission in 1969.

While interest in the Moon has never faded, the willingness to take on the incredible costs of manned lunar exploration ended in 1976. Unmanned missions have continued in the decades since, with China, Japan, India, the European Space Agency (ESA) and NASA all continuing their efforts to better understand our closest celestial body. In more recent years, commercial companies have been getting in on the action, with LuxSpace's Manfred Memorial Moon Mission (4M) completing a lunar flyby in 2014.

Dreams of lunar settlements have occupied the minds of many over the decades, but the technology has never been adequately advanced to enable this next step. However, interest has peaked since the 2009 discovery of water by the Moon Mineralogy Mapper (M<sup>3</sup>) on the Indian Space Research Organisation's (ISRO) Chandrayaan-1, and new projects and plans for settlement programmes are well underway amongst governments and commercial organisations alike.

## NASA advances lunar exploration programmes

No overview of current lunar exploration programmes can be complete without a nod to NASA, which landed the first man on the Moon back in 1969. The organisation currently has several key projects running independently of each other, including the Lunar Orbital Platform-Gateway, the Space Launch System, the Commercial Lunar Payload Services programme, and the Kilopower Reactor Using Stirling Technology.

## Lunar Orbital Platform-Gateway

The Lunar Orbital Platform-Gateway (LOP-G) is NASA's answer to providing an outpost in orbit around the Moon, a huge achievement in its own right, but also as a

stepping-stone to Mars. LOP-G will be built in collaboration with International Space Station (ISS) and US industry partners, with construction set to start in the 2020s. The Gateway will include a power and propulsion element, which is due for launch in 2022, as well as habitation, logistics and airlock capabilities, which will be launched in 2024.

LOP-G will measure a minimum of 55ft<sup>3</sup>, considerably smaller than the ISS's 388m<sup>3</sup>. Crew will be able to live and work on LOP-G for 30-60 days at a time and participate in a variety of scientific and commercial activities in the vicinity of the Moon, possibly including missions to the lunar surface. Whereas the ISS orbits some 400km above the Earth, LOP-G will be launched into a highly elliptical near-rectilinear halo orbit, which will bring it within 1,500km of the Moon at closest approach, and 70,000km at the furthest distance. This specific orbit will keep LOP-G out of the Moon's shadow at all times, enabling constant communications with Earth.

In October 2018, Lockheed Martin revealed its crewed lunar lander concept, and how it aligns with NASA's LOP-G (video at <https://bit.ly/2JgJOqr>) and future Mars missions. The single-stage, fully-reusable system incorporates flight-proven technologies and systems from NASA's Orion spacecraft, and would accommodate four crew and 2,000lb of cargo for a two-week stay on the Moon before returning to LOP-G for re-fuelling and servicing.

"The Gateway is key to full, frequent and fast reusability of this lander," said Tim Cichan, Space Exploration Architect at Lockheed Martin Space. "Because this lander doesn't have to endure the punishment of re-entering Earth's atmosphere, it can be re-flown many times over without needing significant and costly refurbishment. That's a major advantage of the Gateway and of a modular, flexible, reusable approach to deep space exploration."

NASA has a whole host of requests out right now for the LOP-G project, so we can expect a lot more news in the coming months regarding habitat prototypes,

logistics modules, un-crewed utilization and operations, human lunar surface access, logistics as a science platform, and a cislunar tug.

### Space Launch System

Access to LOP-G will be enabled by NASA's Space Launch System (SLS) rocket, which, alongside the Orion deep space shuttle and ground systems at Kennedy Space Center, will also make up NASA's Exploration Mission-1 (EM-1). The 'most powerful rocket in the world' will travel 28,000 miles from Earth during a three-week mission and will stay in space longer than any ship for astronauts has without docking to a space station.

The SLS rocket, designed for missions beyond low Earth orbit (LEO) carrying crew or cargo to the Moon and beyond, will produce 8.8 million pounds of thrust during lift-off and ascent to loft a vehicle weighing nearly six million pounds to orbit. SLS will be propelled by a pair of five segment boosters and four RS-25 engines, an Interim Cryogenic Propulsion Stage (ICPS), and a service module that will supply Orion's main propulsion system and power once it leaves Earth's orbit.

Orion's trip to the Moon will take several days; it will fly about 62 miles above the lunar surface and use the Moon's gravitational force to propel itself into a new deep retrograde orbit about 40,000 miles from the Moon. It will stay in that orbit for around six days to collect data and allow mission controllers to assess the performance of the spacecraft. For its return trip to Earth, Orion will do another close flyby that takes it within about 60 miles of the Moon's surface, and it will use another precisely-timed engine firing of the service module in conjunction with the Moon's gravity to accelerate back toward Earth.

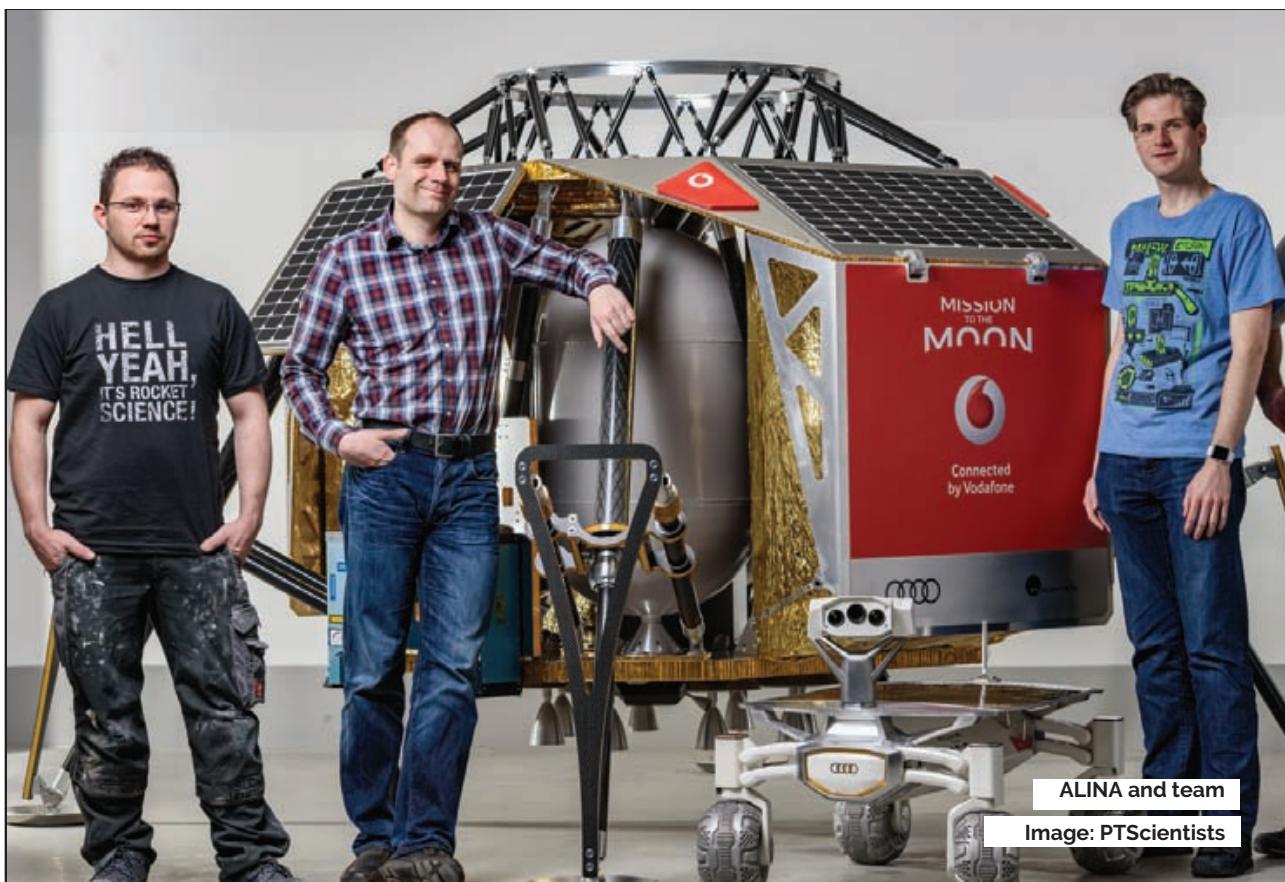
EM-1 is due for launch in June 2020, and the SLS

rocket will evolve from an initial configuration capable of sending more than 26 metric tons to the Moon, to a final configuration that can send at least 45 metric tons. The project is reportedly developing on track, with the intertank, which houses critical electronics for the flight computers, completing its final avionics functional testing in October 2018.

Plans for the second SLS flight (EM-2), which will take crew on a different trajectory using a powerful exploration upper stage and test Orion's critical systems with humans aboard, are already well underway. In October 2018, LGS Innovations was selected to support NASA's EM-2 Optical Communications project, which will see LGS provide an optical modem to enable broadband data communications to and from the Orion vehicle. The modem, due for delivery later in 2019, will convert the data generated on the Orion spacecraft to an optical signal, allowing it to be beamed from the vicinity of the Moon to a receiver on Earth. It will also be capable of receiving the optical signal from Earth and converting it to data for the spacecraft. LGS Innovations is also helping NASA adopt laser communications for other missions, including the first free-space laser transmitter for the Deep Space Optical Communications project.

### Commercial Lunar Payload Services

In one of NASA's more recent lunar programmes, the association released a draft Request for Proposals for Commercial Lunar Payload Services (CLPS) in 2018, under which it intends to award multiple contracts for services throughout the next decade. The first landers will be hardware technology demonstrators, such as cryogenic fluid management, autonomous operations and sensing, advanced avionics, in situ resource utilization (ISRU), power generation, etc.



The competitive programme is expected to reduce the cost of lunar exploration and accelerate a robotic return to the Moon, sample returns, resource prospecting, and promote innovations and commercial growth. Contract missions to the lunar surface are expected to begin as early as 2019, and with a company's first delivery by December 2021. According to recent reports, there are in excess of 30 'interested parties,' including major players such as Blue Origin, Lockheed Martin, Moon Express, SpaceX, SSL, and United Launch Alliance.

While NASA evaluates the lander proposals, it is also seeking payloads that can fly on these landers via a formal solicitation for 'Lunar Surface Instrument and Technology Payloads.' NASA plans to select 8-12 experiments this year with payload delivery between 2020 and 2021.

### Kilopower Reactor Using Stirling Technology

NASA is also exploring new nuclear reactor power systems, and in 2018 demonstrated a new nuclear reactor power system in partnership with the Department of Energy's National Nuclear Security Administration (NNSA): The Kilopower Reactor Using Stirling Technology (KRUSTY) could enable long-duration crewed missions to the Moon, Mars and beyond.

The small, lightweight fission power system can provide up to 10kW of electrical power continuously for at least 10 years; four Kilopower units would provide enough power to establish an outpost. The prototype power system uses a solid, cast uranium-235 reactor

core. Passive sodium heat pipes transfer reactor heat to high-efficiency Stirling engines, which convert the heat to electricity.

The demonstration, which was conducted in four phases, showed that KRUSTY is capable of creating electricity with fission power and is stable and safe, no matter what environment it encounters. The first two phases, conducted without power, confirmed that each component of the system behaved as expected. During the third phase, the team increased power to heat the core incrementally before moving on to the final phase. The experiment culminated with a 28-hour, full-power test that simulated a mission, including reactor start-up, ramp to full power, steady operation and shutdown. Throughout the experiment, the team simulated power reduction, failed engines and failed heat pipes, showing that the system could continue to operate and successfully handle multiple failures.

The Kilopower project is developing mission concepts and performing additional risk reduction activities to prepare for a future flight demonstration which could pave the way for future systems that power human outposts on the Moon and Mars.

### ESA plans simulated lunar habitat on Earth

The European Space Agency (ESA) also has its own ideas for lunar exploration projects as well as being heavily involved in the LOP-G programme. The agency's main focus for lunar exploration going forwards is sustainability and in situ resource utilisation (ISRU), and future plans include a purchased ride on a commercial lander to deliver research equipment to the surface of



the Moon. In terms of ISRU projects, ESA is looking into the extraction and transformation of indigenous lunar materials into oxygen and water; the agency aims to demonstrate by 2025 that it is possible to produce water or oxygen on the Moon.

Of course, ESA is also working on its Lunar Pathfinder programme. In April 2018, ESA signed a collaboration agreement with SSTL and Goonhilly Earth Station for Commercial Lunar Mission Support Services to develop European lunar telecommunications and navigation infrastructure, including the delivery of payloads and nanosatellites to lunar orbit. The agreement includes the upgrade of Goonhilly Earth Station for commercial deep space services and the development of the space segment with a Lunar Pathfinder mission. The cooperation also encompasses the commercial and regulatory support to catalyse the lunar economy and provide affordable access to the lunar environment, and ultimately deep space. The partners are now jointly committed to the developing the Lunar Pathfinder space segment for a low cost 'Ride and Phone Home' capability. The Lunar Pathfinder mission will offer a ticket to lunar orbit for payloads and nanosatellites on board an SSTL lunar spacecraft, which will provide communications data relay and navigation services between customer payloads and the Goonhilly Deep Space ground station. Flight opportunities are expected to commence in 2022.

In the same month, SSTL and Goonhilly signed an agreement with Astrobotic to collaborate on a roadmap of innovations to support organisations carrying out operations on and around the Moon. Astrobotic will begin delivering a regular manifest of unmanned payload flights to the Moon starting in 2020. Many of the companies, governments, universities, and other non-profit organisations operating payloads on Astrobotic's Peregrine Lander will need sophisticated communication relay services to reach until-now prohibitive destinations on the Moon, including the far side. SSTL plans to service those needs with state-of-the-art data relay services. Goonhilly will receive SSTL's data relay and transmit data back to payload customers on Earth.

More recently in October 2018, ESA announced plans for the ESA Astronaut Centre (EAC) in Cologne, Germany, which will recreate the Moon's surface on Earth. The three-part lunar analogue facility, known as Luna, will help Europe go farther in space by creating a test-bed for tools and concepts, as well as a location for research and a training ground for astronauts. ESA has identified a lunar dust substitute, comprised of volcanic powder from eruptions from the nearby Eifel volcanic region, which will cover the 1,000m<sup>2</sup> Luna area to create a simulated lunar habitat.

#### JAXA plans solo and joint expeditions

Like NASA and ESA, the Japan Aerospace Exploration Agency (JAXA) is also keen to expand its lunar exploration achievements.

The agency is currently working on its Smart Lander for Investigating Moon (SLIM) project, a lunar lander which will land wherever desired, rather than wherever is easy. The most recent reports state that launch is planned for 2021. According to JAXA, the SLIM mission objectives are; demonstration of the accurate lunar landing techniques in a small explorer; and acceleration

of the study of the Moon and other planets using the lighter exploration system. Upon descent to the Moon, SLIM will recognize lunar craters by applying technology from facial recognition systems and will determine its current location from observation data collected by the Selenological and Engineering Explorer (SELENE) lunar orbiter mission. SLIM aims to 'soft land' within 100m of its target location.

JAXA's SLIM programme received a boost late in 2017, when its SELENE mission discovered a large cave measuring 50km long and 100m wide beneath the lunar surface, which could be turned into an exploration base for astronauts. The cave, which is believed to be a lava tube created during volcanic activity some 3.5 billion years ago, is reportedly structurally sound and may contain ice or water deposits that could be used by human settlers. Such lava tubes have long been considered ideal candidate locations for future lunar bases due to their stable thermal conditions and ability to protect people and equipment from micrometeorites and cosmic radiation.

In other news, JAXA also reportedly plans to team up with the Indian Space Research Organisation (ISRO) to explore the Moon's polar regions for water. The Moon's South pole is of particular interest since the craters are in permanent shadow and may hold large reservoirs of ice.

News regarding either of the above two lunar missions has been sparse throughout 2018 and 2019 – we look forward to receiving more reports in due course.

#### China prepares for lunar communications

China made a great leap in lunar exploration in May 2018 with the launch of the Queqiao relay satellite to the far side of the Moon. The satellite is being prepared for communication between the Earth and China's Chang'e 4, which was launched at the end of 2018.

Direct communication between the landing site and Earth is impossible since it always faces away from Earth, thus the 400kg Queqiao satellite will relay data between China's rover and mission control. Queqiao is equipped with a 4.2m antenna which will communicate with Chang'e 4 over X-band and transmit data to Earth in S-band. The mission's landing module will carry a low frequency radio spectrometer developed by Chinese scientists for astrophysics research. Meanwhile, a neutron and dosimetry instrument developed by Germany will measure radiation level data that could be useful in planning human exploration, study solar activity, and gauging the underground water content in the Von Karman crater, located in the Moon's South Pole-Aitken basin.

Chang'e 4 will feature a ground-penetrating radar to study geologic layers under the landing site, and a visible and near-infrared spectrometer to gather data on soil composition. A Swedish-developed instrument will study the interaction between the solar wind and the lunar surface, which is not shielded by an atmosphere from the bombardment of charged particles from the Sun. Chang'e 4 will also deliver a student-designed carrier containing potato seeds and silkworm eggs. University students and scientists will monitor the growth of the organisms, which will be housed inside a chamber and fed natural light and nutrients.

Chang'e 4, widely considered as a test mission, will be followed up by the launch of Chang'e 5 in 2019.

China's first sample return mission. Chang'e 5 is expected to return at least 2kg of lunar soil and rock back to Earth. Successful completion of this mission will see the 2020 launch of follow-on mission Chang'e 6.

#### **SSTL announces lunar satellite plan**

SSTL, too, is getting in on the lunar action. In November 2018, Surrey Satellite Technology Ltd announced that it was designing a low-cost 35kg lunar communications satellite mission called DOT-4, which is expected to launch in 2021. DOT-4 will act as a communications relay back to Earth using the Goonhilly Deep Space Network and will link up with a rover on the surface of the Moon. SSTL is currently in discussions with several parties for the lunar mission.

DoT-4 will be the pre-cursor mission for a larger lunar communications satellite to follow in 2023, which will carry a more robust payload and, potentially, navigation services. SSTL's ultimate aim is to launch a full constellation of lunar communications satellites offering full-service capability to enable new and regular opportunities for science and exploration and economic development of the space environment beyond Earth's orbit.

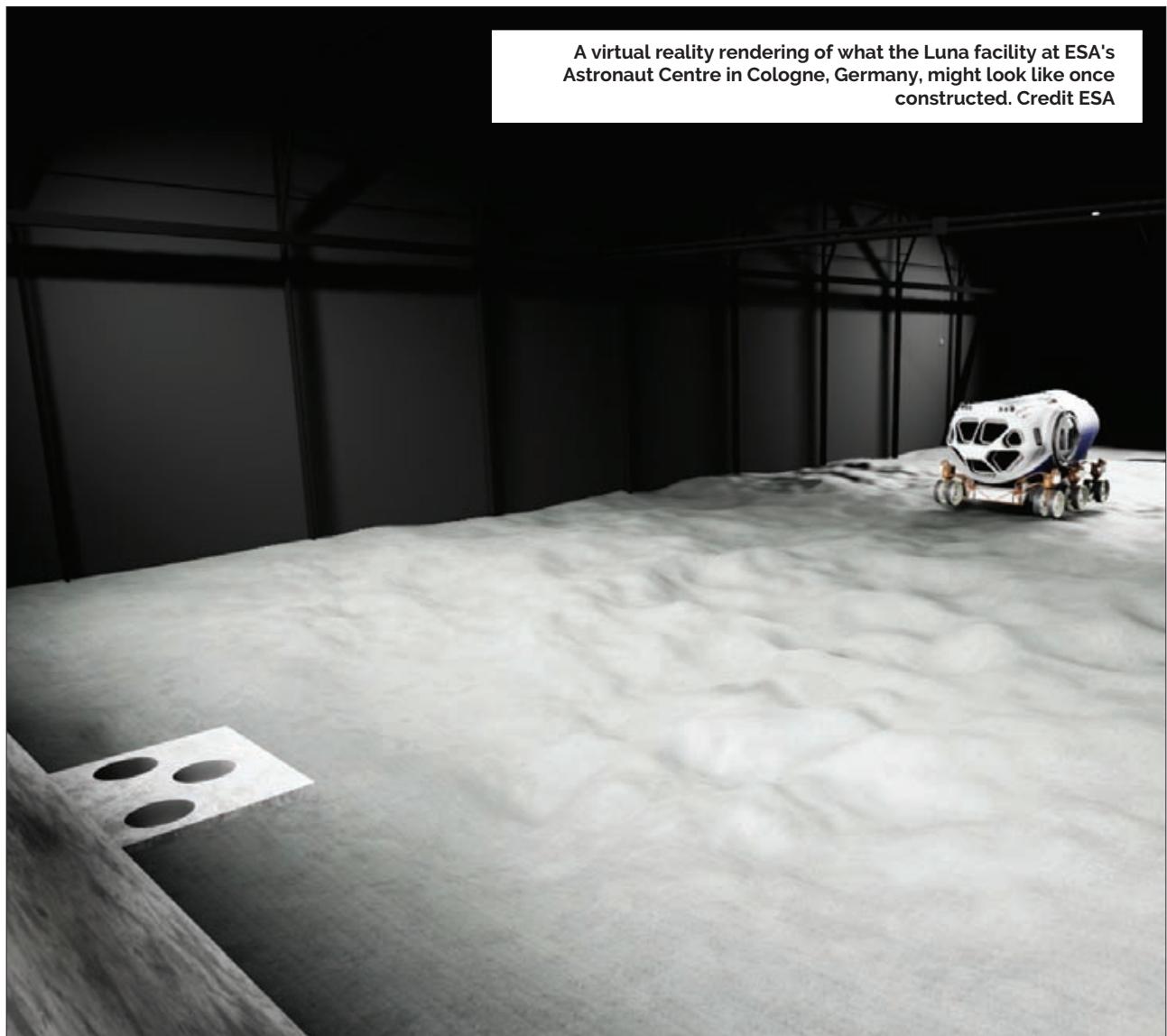
"DoT-4 will prove technologies in the lunar environment and enable testing of radio

communications with landers and rovers on the Moon's surface too," said Gary Lay, SSTL's Director of Navigation and Exploration. "During the test phase, we will assess the compatibility of our proximity communications with the surface assets and we will verify the Earth communication link with several ground stations. This small step will establish an infrastructure around the Moon to enable others to explore beyond Earth's orbit."

#### **Moon Express expands in the frozen North**

Moon Express was launched in 2010 to 'define possible' by returning to the Moon and unlocking its mysteries for the benefit of humanity. The company plans to offer commercial lunar robotic transportation and data services with a long-term goal of mining the Moon for resources, including rare Earth elements. Moon Express was, notably, the first private company to receive Federal Aviation Administration approval for a commercial space mission beyond Earth's orbit under the requirements of the Outer Space Treaty.

In July 2017, Moon Express and the International Lunar Observatory Association (ILOA) announced a collaboration for the delivery of the first International Lunar Observatory to the South Pole (ILO-1) of the Moon in 2019 – something to look forward to this year. Moon Express has been contracted by ILOA to develop



advanced landing technologies supporting the mission. The ILO-1 astrophysical observatory and research station will be the world's first instrument to image the Milky Way Galaxy and to conduct international astrophysical observations and communications from the lunar surface. The ILO-1 will land on a 'peak of eternal light' at the lunar South Pole by a Moon Express robotic explorer system. The primary landing site under analysis is Malapert Mountain, a 5km tall peak in the Aitken Basin region that is bathed in sunlight most of the time and has 24/7 direct line of sight to Earth as well as to Shackleton Crater for communications. Moon Express will utilize the mission to explore the Moon's South Pole for mineral resources and water.

More recently in October 2018, Moon Express has made some developments in Canada, signing a Memorandum of Understanding with the Canadian Space Agency (CSA) to explore options for collaboration with the CSA and Canada's space sector on technologies and payloads for missions to the Moon. Under the agreement, the CSA and Moon Express will explore the possibilities of using Moon Express lunar orbiter and lander systems for potential CSA payloads and will promote possibilities for collaboration between Moon Express and the Canadian space industry and academia.

In the same month, Moon Express Canada was created to leverage Canadian space science and technology in the exploration of the Moon and its resources. The head office will be established in Ontario. Moon Express has also signed collaboration agreements with a number of Canadian industry and academic partners, including Canadensys Aerospace Corporation, Ontario Deltion Innovations, Gedex Systems Inc., Mission Control Space Services, Inc., NGC Aerospace, TeledyneOptech and Ontario University of Guelph.

#### **PTScientists head to the Moon this year**

Founded in 2009, PTScientists wants to bring down the cost of lunar exploration and science to enable a greater range of participants from across the globe. As well as partnering with established entities to collaborate on new space exploration projects, PTScientists is also developing its own programme. Some 50 years after humans first stepped on the Moon, PTScientists plans to undertake the world's first private mission to land on the Moon in the second half of 2019 when 'Mission to the Moon,' a robotic space exploration mission, will return to the landing site of Apollo 17.

Launched aboard a SpaceX Falcon 9 rocket, Mission to the Moon will see the Autonomous Landing and Navigation Module (ALINA) transport a pair of lunar rovers developed by Audi to the Moon, live broadcasting using chip technologies from Infineon, the first HD images from NASA's Apollo 17 landing site and the Apollo 17 roving vehicle, last used in 1972. The Moon's first 4G LTE network, developed by Vodafone and PTScientists, will communicate data from the Audi lunar quattro rovers to ALINA, which will then transmit all data back to Earth. Vodafone's network expertise will be used to set up the Moon's first 4G network, while partner Nokia, through Nokia Bell Labs, will create a space-grade Ultra Compact Network that will be the lightest ever developed - weighing less than 1kg.

Vodafone testing indicates that the base station should be able to broadcast 4G using the 1800MHz band and send back the first-ever live HD video feed of the

Moon's surface, which will be broadcast to a global audience via a deep space link that interconnects with the PTScientists server in the Mission Control Centre in Berlin. A 4G network is highly energy efficient compared to analogue radio, which will be crucial to Mission to the Moon and is the first step to building communications infrastructure for future missions.

#### **Bigelow Aerospace aims for lunar orbiting hotel**

The idea of hotels in space is as old as the idea of space travel itself. Hundreds, if not thousands, of science fictions novels have featured space-based hotels, either situated on distant planets, or orbiting celestial bodies. The concept of the Lunar Hilton has been floating around our collective consciousness since 1967, but it's yet to progress beyond a fanciful idea. However, some companies are now making real, solid advancements in the development of commercial space habitats...

Bigelow Aerospace is arguably the world's first serious contender in the space tourism sector. Founded in 1998, Bigelow Aerospace develops and manufactures expandable space station modules, and is the only company commercializing NASA expandable module technologies. Bigelow aims to build a modular set of space habitats to create standalone or expanding existing space stations. The inflatable modules are expected to be more durable than rigid modules due to the use of Vectran, a material twice as strong as Kevlar, and because the flexible walls are theoretically more likely to withstand micrometeoroid impacts better than rigid walls. Under the Genesis programme, Bigelow has demonstrated the viability of expandable habitat technology in space. Genesis I, Bigelow's first operational spacecraft, was launched into orbit in 2006, while Genesis II was launched in 2007; both remain in orbit today and observations are ongoing. Meanwhile, in 2012, NASA signed a US\$17.8 million contract with Bigelow to develop the Bigelow Expandable Activity Module (BEAM), which was attached to the ISS in 2016, where it remains today.

Bigelow is currently developing the B330 standalone commercial space station for operation in LEO, cislunar space and beyond. A single B330 is comparable to one third of the current pressurized volume of the entire International Space Station. Bigelow Aerospace is developing two B330 commercial space station habitats that will be ready for launch any time after 2020. Indeed, at the end of 2017, Bigelow and United Launch Alliance (ULA) announced plans to launch a B330 module on ULA's Vulcan launch vehicle, placing it into low lunar orbit (LLO) by the end of 2022 to serve as a lunar depot.

The B330 will launch to LEO on a Vulcan 562 configuration rocket, the only commercial launch vehicle in development today with sufficient performance and a large enough payload fairing to carry the habitat. Once in orbit, Bigelow will outfit the habitat and demonstrate it is working properly. When fully-operational, ULA's distributed lift capability will be used to send the B330 to lunar orbit. Distributed lift will also utilize two more Vulcan ACES launches, each carrying 35t of cryogenic propellant to LEO. In LEO, all the cryogenic propellant will be transferred to one of the Advanced Cryogenic Evolved Stage (ACES). The full ACES would then rendezvous with the B330 and perform multiple manoeuvres to deliver the B330 to its final position in LLO.



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