KPMG

30 Voices on 2030

The future of space

Communal, commercial, contested

May 2020

KPMG.com/au/30voicesonspace

30 Voices on 2030

The future of space

Communal, commercial, contested

30 Voices on 2030: The Future of Space

Our 30 Voices on 2030 cover every facet of the global space industry and beyond – from space agencies and start-ups to VCs and media organisations. Taken together they create a valuable chorus of insight and expertise.

Many of the views expressed in this report may be personal and not necessarily represent those of the Voices' organisations or KPMG.

Visit **KPMG.com/au/30voicesonspace** to view the report online.

Share online #KPMG30Voices

Mike Kalms

KPMG

Space and Defence Industry Lead Partner,

KPMG Australia

Right now, nothing invigorates business more than space.

I'm serious. When the opportunity of space comes to the board, or another executive group in business, the first thing that happens is leaders smile. They smile because space reminds us all of something in our soul – that youthful quest for adventure, to explore and to grow.

What's amazing is we now live in a time when space isn't science fiction. When you read this *30 Voices on 2030: The Future of Space* paper, you'll quickly realise space is a today opportunity for business. To work in space, to grow food, to conduct medical research, to mine, to explore and expand – all this will happen in your lifetime. That's why you're smiling now.

But as your business starts to move from abstract consideration of space as a market to the mechanics of exactly what you might do, there are a number of considerations and insights you might take into account. Our 30 Voices offer perspectives.

The three that most resonated for me were: firstly, space will be made more accessible, making it likely that by 2030 you may well know someone who has been to space. Secondly, the use of space data will expand significantly and turn into a commodity, which will provide value across different industries – from emergency services to agriculture. And finally, the potential of medical research and manufacturing may well unlock breakthroughs many once thought impossible.

In your business, the insights you take from *30 Voices on 2030* will no doubt be different. I hope this paper and the informed, insightful predictions it offers, in some small way, influence you to either make or accelerate your first steps into the business of space.

If there is one thing we know about business, considered investment and active engagement with new markets trumps abstract consideration and PowerPoint slides. Now is the time to explore the business of space.

These 30 Voices will help you, and the industry as a whole, challenge thinking on what the future of space business holds.

Stand still and you will miss your launch window.

Jacob Hacker

KPMG

Space Industry Account Lead, KPMG Australia

If we look back ten years, the space industry was quite different to how we see it today. The Space Shuttle was still flying, adding the final modules to the International Space Station, Hayabusa was about to return to Earth with samples from Itokawa, and Space X were yet to launch their Falcon 9 rocket. The space sector was dominated by large government-led projects, with the idea of commercial space being little more than a theory.

When considering the space sector advancements of the past ten years, in particular the volume of commercial activity and investment we are seeing, the intersection of space with our daily lives and the well-funded global programs to go further with human exploration, while benefiting our lives on Earth, it is inspiring to imagine what we will list as achievements by 2030.

We have interviewed 30 people with an incredibly diverse range of perspectives on the space sector and explored how they see it changing in the coming ten years. The articles that follow look at the way barriers to entry will fall away, the evolution of involvement of a wider range of countries and the way new technology will drive new applications.

There are challenges we will face along the way, ensuring we can keep space clean of debris, avoiding conflict in space, and helping commercial ventures to be sustainable and thrive.

However, the environment that will result in 2030 is one where space has been democratised. Already many companies use space data every day - timing data for payments, positioning for logistics, communications for mining and imaging for agriculture. In 2030, all companies will benefit from the data, insights and services available from space, without necessarily owning and operating assets. We will know people who have been to space as tourists. People will be on the Moon developing an extended presence in deep space. And the benefits of space to our lives on Earth will be profound – whether through the development of medical transplants, unlocking the reasons for aging or the management of global warming.

None of this is beyond our reach and there is a role for all to play in the advancement of space – whether you are teachers, lawyers, doctors, trades people or public servants (to name a few), everyone can be involved.

Contents

30 Predictions for 2030

Humans will live, work and holiday in space

1. Space travel will be a collaborative multinational venture.

2. Living in space will be easier but not easy.

3. Zero gravity – new medical conditions and new treatments.

4. Many will experience space – but not all will go.

5. You will know an astronaut.

6. The human genome will change to support human deep space exploration.

Deep space exploration

7. We'll successfully mine the Moon for water by 2030.

8. We may finally discover evidence of life in space.

9. We'll operate assets remotely on the Moon like mines in the Pilbara.

10. Growing and eating food in space will be commonplace.

11. Virtual companions will assist with the mental health challenges of long space travel.

12. We will look back in time more than 4 billion years.

Space business models

13. Every business will be a space business.

14. The leading space businesses of 2030 are start-ups today.

15. Long-established terrestrial industries will build a presence in space.

16. Government will be a customer of civil space business.

17. Multinational co-operation, while challenging, will drive the peace dividend.

18. Manufacturing in space will be real and viable.

Space data comes back to Earth

19. Space data will become completely commoditised.

20. An international regulatory body for space data will be established.

21. AI will be commonplace in space.

22. Data will not be owned – rather shared.

23. Governments will conduct their census from space.

24. Personal privacy will be challenged.

Sustainability in space

25. Sustainability in space will benefit sustainability on Earth.

26. There will be a 'CFC moment' in space which will trigger a moratorium on space debris.

27. Space ecology will be imperative for our millennial generation.

28. Space will get its own legal jurisdiction.

29. Space will be forced to accelerate quickly as an operational domain for armed forces.

30. A Master's of Space Ecology will be offered at universities.

30 Predictions for 2030

How will new players, technological advancement and human curiosity shape the space industry by 2030?

While space has been the subject of human interest and a quest for discovery for a very long time, today we are at a pivotal point. Many national governments are launching ambitious space strategies. Private-sector players are making major breakthroughs to open the space sector to more people. And other industries – from agriculture to energy and natural resources – are looking at space to improve and transform their own businesses.

But, by the time the dust settles, what will the space industry look like?

At KPMG Australia, we believe that space will be communal, commercial and contested. Deliberately, three principles that cannot sit easily together. As the industry opens up and more developments are made, the industry will grow and generate opportunity and risk for all players.

Estimates suggest the global space industry could be worth US$600bn by 2030[1]. The fastest area of growth, with a predicted 55 percent compound annual growth rate from 2021 – 2030, will likely be second order impacts. This covers 'second wave' or 'unanticipated growth' in tangential areas – for example, increased space traffic could create new markets, like congestion planning or debris clean-up.

It's clear that the next ten years offer significant opportunities for those in the space industry – and beyond.

To bring to life what our presence in space in 2030 may look like, we spoke to 30 industry leaders – heads of agency, lawyers, surgeons, investors, entrepreneurs, academics and politicians – who painted a very vivid, exciting and challenging vision of what we can expect.

Their predictions for the industry align to the five pillars where KPMG Australia envisages significant change in the next ten years:

- Humans will live, work and holiday in space;
- Deep space exploration;
- Space business models;
- Space data comes back to Earth; and
- Sustainability in space.

This paper highlights that the potential of space to open up to new businesses and customers, create new products and services, and speak to our sense of curiosity and desire to understand the world beyond our planet is huge. Organisations across different industries – and not just traditional space industry players – that lack in adaptability and imagination will be left behind.

1 https://www.morganstanley.com/ideas/investing-in-space

Humans will live, work and holiday in space

1. **Space travel will be a collaborative multinational venture.**
2. **Living in space will be easier but not easy.**
3. **Zero gravity – new medical conditions and new treatments.**
4. **Many will experience space – but not all will go.**
5. **You will know an astronaut.**
6. **The human genome will change to support human deep space exploration.**

In 2030 expect society's interaction with space and in particular the Moon to revolutionise. While in recent years we have flirted with the idea of travelling to the Moon commercially, by the end of the decade we will move ahead in leaps and bounds with many having completed this 'once in a life-time' experience.

In a world where leisurely travel to the Moon is viable, expect open discussion of the prospect of people permanently residing on its barren terrain. While it will be a possibility by the end of the decade, the financial, logistical, physical, and psychological implications will mean it's still a hard task for humans to conquer.

Space travel will still be costly and not accessible to all. With technology improving at a rapid speed, virtual reality will play a large role in giving people the experience of space travel. This will be critical to increase interest in space.

While we will need to identify solutions to challenges to enable us to stay in space and on the Moon for longer, easier access to space and increased presence in space will enable us to conduct more medical research in zero gravity. This will provide opportunities to discover new treatments for conditions we thought weren't possible. Furthermore, we may start to see the ability to deliberately alter the human genome to further support humanity's sustained exploration of space.

Deep space exploration

7. **We'll successfully mine the Moon for water by 2030.**
8. **We may finally discover evidence of life in space.**
9. **We'll operate assets remotely on the Moon like mines in the Pilbara.**
10. **Growing and eating food in space will be commonplace.**
11. **Virtual companions will assist with the mental health challenges of long space travel.**
12. **We will look back in time more than 4 billion years.**

As space industry technology continues to improve in the new decade, so will our ability to expand our horizons and more deeply explore all aspects of the solar system, in particular our Moon.

With a much greater appetite to have permanent human residence on the Moon by 2030, there will be a focus on ensuring we are able to use water on the Moon for fuel and life. Through new extraction technology we will be able to separate water into the basic constituents of rocket fuel (hydrogen and oxygen) and support agriculture on the Moon.

Traveling further into space means astronauts will be isolated for extended periods of time. With the assistance of technology, 'virtual buddies' will ensure that these people will stay in a healthy mental state while away from Earth.

New telescope technology will enable us to see the first galaxies being formed after the Big Bang, through projects like the James Webb Space Telescope, which will expand our understanding of the solar system.

We now have a much better idea of what we are looking for on other planets for signs of life. Over the coming decade, missions to other planets like Mars 2020 with the Perseverance rover and Europa Clipper to one of Jupiter's Moons will help determine if we are alone in the universe.

Space business models

13. **Every business will be a space business.**
14. **The leading space businesses of 2030 are start-ups today.**
15. **Long-established terrestrial industries will build a presence in space.**
16. **Government will be a customer of civil space business.**
17. **Multinational co-operation, while challenging, will drive the peace dividend.**
18. **Manufacturing in space will be real and viable.**

Already in 2020, many multi-national businesses are investing in the space sector and understanding how it can add value to their business on Earth. By 2030 we expect all businesses across all industries, whether related or not, to benefit from space, with many having dedicated space teams and resources.

Operations that have long been run on Earth will now take place beyond our planet. Organisations will be trialling experiments – from medical research to manufacturing – in space, introducing new products and solutions into the market. This may include growing tissue and artificial transplants in zero gravity, as well as manufacturing fibre optics for communication.

Rather than space programs being purely government-led, we will see more and more partnerships between the public and private sectors. These partnerships will drive new activities and push technological boundaries as we aim to develop new commercial applications from the sector and make new discoveries about the solar system. Global levels of cooperation will help enhance economic and political ties between nation states.

What were considered to be 'small start-ups' in the space industry in 2020, by 2030 will become the leaders of this sector. As space becomes commercially focused, more businesses will realise the value of space, and new business cases will become viable. The majority of space companies will be valued in the billions of dollars and operate across multiple countries.

Space data comes back to Earth

19. **Space data will become completely commoditised.**
20. **An international regulatory body for space data will be established.**
21. **AI will be commonplace in space.**
22. **Data will not be owned – rather shared.**
23. **Governments will conduct their census from space.**
24. **Personal privacy will be challenged.**

Data collected in space will continue to increase in value over the next decade as volume, variety, velocity and veracity increase. With the increased use of space data, a central international governing body will need to be established, employing new agile approaches to regulation as new issues appear – but getting there will not be easy.

Much of the data collected will be analysed by edge analytics in-orbit to reduce the volume of data that needs to be transmitted to Earth and stored. At the same time, in-orbit relays will increase our transmission capacity to Earth, providing more data to input into analytics. AI will also be used in deep space missions to overcome communications delays due to distance, and help pre-empt and correct problems.

We expect that space data will be prolific, though provide little value on its own. Companies will find real value in generating and selling actionable insights from the data they collect and intersect with other sources. New data will help identify and drive new business opportunities across different industries.

Governments by 2030 may conduct their own census from space rather than by the ten-yearly survey we've become used to filling out. This will enable more precise humanitarian and medical support in developing countries and enable more frequent updates.

Sustainability in space

25. **Sustainability in space will benefit sustainability on Earth.**
26. **There will be a 'CFC moment' in space which will trigger a moratorium on space debris.**
27. **Space ecology will be imperative for our millennial generation.**
28. **Space will get its own legal jurisdiction.**
29. **Space will be forced to accelerate quickly as an operational domain for armed forces.**
30. **A Master's of Space Ecology will be offered at universities.**

Business are already putting sustainability at the forefront of what they do on Earth, and in the years ahead the same will be applied to our activities in space.

Debris in space has long been an area of concern. This will only escalate as we are more active in space, to the point where international agreements will have to be made to find sustainable solutions. The recovery of decommissioned satellites in space will also involve a strategy to recycle and find a new purpose for them. As access to space is opened up and deep space exploration grows, legislation and treaties governing space will need to evolve. Expect space to become its own legal jurisdiction.

Space is already softly militarised, with many countries leveraging it as an operational domain for armed forces. There are however deliberate efforts and treaties to ensure this doesn't become hard militarisation. With the applications possible in space constantly expanding, treaties and regulations must evolve to ensure it is not exploited.

Expect a Master's degree in Space Ecology to become a viable degree for students wishing to have prosperous careers in the sector.

Credit: Planet

"In 2030, we expect to see the rapid uptake and use of space data by everyday people. Our hope is it will become a regular commodity."

Agnieszka Lukaszczyk
Senior Director for European Affairs, Planet

Agnieszka Lukaszczyk

Agnieszka Lukaszczyk is the Senior Director for European Affairs at Planet, an Earth observation company which images the entirety of the planet each day. Prior to joining Planet, Agnieszka worked at the European Commission focusing on space data and policy and was the Brussels Office Director of the Secure World Foundation.

When it comes to Earth observation and what it means for humanity, we are still figuring out what we can do. At the end of the day, satellites are just a tool. They are not an end, they are simply a means to an end, and we are only just at the beginning.

In 2030, we expect to see the rapid uptake and use of space data by everyday people. Our hope is it will become a regular commodity where anybody will have access to it, like the way people currently access the internet on their phones.

However, the key to unlocking the vast potential presented by Earth observation data will be artificial intelligence (AI). The combining of these two elements will be what brings value to the data.

There are so many satellites in space collecting data, it's impossible for the human eye to find the needle in the haystack. We would need an army of people to be able to make use of the data. That's why AI is essential.

With AI we will be able to index the Earth the way Google has indexed the internet. We will be able to find, quickly and easily, the answers to a range of questions such as how many trees have disappeared in the Australian bushfires? How many people reside in a particular country or region? And, how many trees in the north east Amazon have been cut between March and April? Space data will even help us answer the trivial but still deeply relevant questions.

"We are only just at the beginning."

These capabilities will be facilitated by the growth of on-board processing of satellite data which means when the data is downloaded it will be pre-processed, containing only the essence of the information.

Traditionally, when we think of sectors who rely on Earth observation data we think of agriculture, emergency services, government and forestry. But new frontiers in space data will also bring with it a whole new clientele who are not necessarily interested in the images per say but are interested in answers that the images provide. As a result, by 2030 Earth observation companies will not be reliant on only a handful of sectors to survive.

Two challenges still facing the Earth observation industry are the trade-off of privacy and transparency and the need for space sustainability.

Firstly, the resolution for commercial satellite imagery is set at thirty centimetres due to regulations not because of technology limitations. Satellite image resolution could be much higher, though it is not necessary and personal privacy will continue to be important. At the same time some actors are concerned about the transparency of open space data, though people are moving away from these views. At Planet, we believe in a transparent and open world, as the more we know, the better informed we are and therefore the better decisions we can make. By 2030 we will see more transparency, with a move away from classified data.

Secondly, space sustainability is a key issue that will need to be resolved within the next ten years – if not sooner. The growth of Earth observation has seen the rise of mega constellations and the space environment is becoming crowded and potentially dangerous.

My hopeful vision for 2030 is that we can harness the true power of Earth observation to help us solve global issues. The next ten years are crucial for addressing climate change and space will play a vital role in that. In order to achieve this, our approach towards how we address global problems needs to shift from one of national protectionism (i.e. 'America first' or 'buy European') to an 'Earth first' attitude.

Alice Bunn

"What's surprising is that space isn't surprising by 2030."

Alice Bunn is the International Director at the UK Space Agency and Vice Chair of the Council of the European Space Agency, a member of the Board of Directors of the US Space Foundation and co-chairs the World Economic Forum Future Global Council on Space Technology.

There's a legacy viewpoint that space is something you have as part of your national prestige or a vanity project, but by 2030 I see it normalised – a basic commodity rather than a prestigious extra. Everyone will understand the benefits of space.

Space offers unique vantage points and by 2030, it will be recognised that we use them every day. It's remarkable what we can already measure from space and by 2030 the size and resolution of this imaging will be even better. Mapping the effects of climate change from space already provides huge contributions to our understanding, from sea surface heights, temperatures and more recently sea salinity.

A project in Vietnam (supported by the UK through the International Aid Program) predicting the outbreak of mosquito borne diseases was made possible by using imagery from space. If you can measure surface water levels, you can correlate water levels and mosquito population with the outbreak of disease. A vantage point from space over a wide area of water enables the data collection to more accurately make the correlation. And then you start thinking about flood and drought management, and coastal defences – space can provide that unique vantage point.

When we think about travel, we think land, sea or air. By 2030 it's going to be land, sea, air, space or cyber with virtual reality taking us to other worlds. Teleconferencing will no longer feel clunky with pixelated images and odd time delays, rather it will be like you're in the room with your colleagues or clients. We already have a mature telecommunication sector and I predict this will persist with the addition of the technology and experiences space will bring. It will narrow the gap between developed and developing countries. Essentially, space will give us the capabilities to provide everyone on the planet access to the basic digital world. The ability to have ubiquitous access to communicate with the digital world will benefit the public good.

But this all needs cooperation within the international space community. I'm optimistic that by 2030, landing on the Moon will be routine although I'm sceptical we will land on Mars by then. But I am hopeful we will be trying.

I like to compare orbits around the planet to ring roads around major cities. If you break down in a car, you're going to cause a traffic jam but ultimately people are going to be able to clear the road and continue using it quite swiftly. That's not true in space. If you have collisions in space it's going to damage everyone, be it deliberate or accidental. Another very important reason for a cooperative community in space.

Finally, space is full of phenomena that has relevance to life on Earth. Especially the research into microgravity. Why do astronauts come back from a mission in space with weakened immune systems but after a couple of months their immune systems return back to the normal? If we were able to understand this, we may be able to unlock the secret of how bodies can regenerate. Will space unlock the secret to ageing? Equally fascinating is how bats go into deep hibernation and then instantly fly after coming out of hibernation, so their muscle response is immediate. So, if you think about human exploration in deep space, can we apply the science behind bats and recreate that for humans? If so, then if you go into deep hibernation during travel some of these long-distance explorations could be possible.

In 2030, space exploration and travel will no longer be a 'trophy exercise' of single nations, but rather what all nations can achieve through collaboration in space will benefit the whole world. Be it communication for all, new ways of mapping and reporting on climate change or maybe, just the possibility of finding a novel way to combat ageing.

Ariane Cornell

Ariane Cornell is the Director of Astronaut and Orbital Sales at Blue Origin, a rocket manufacturer and spaceflight services company working towards a future of humans living and working in space. She is also a member of the Board of Directors of The Society of Satellite Professionals International.

Do you think space tourism will be a reality by 2030?

I think in the next ten years, suborbital space tourism will have hit its stride, by which point the price point will come down. Suborbital space flights will be available from different locations and from a couple of different companies. Not only will more people be able to experience space, but I think that suborbital space tourism will also bring space into people's periphery – not merely as something that is there but as something that is attainable, touchable and can be experienced, and eventually as something that they can use. This will have significant importance, in the same way that Boeing creating United Airlines about 100 years ago did. I think it's going to lay the seed for orbital space tourism in a prolific way.

While I don't think orbital space tourism will be attainable in the next ten years for most people beyond high-net worth individuals, we're going to see more of it as more companies are getting into orbital human space flights.

What do you see as some of the biggest challenges in the coming ten years?

There are two key challenges ahead for space tourism. First of all, the companies in the market are going to have to prove themselves from a reliability standpoint. Also, I think that ultimately for space tourism to really take off, the price point is going to have to come down.

"Reduction in price will be crucial for space tourism to take off, but so will proving the system and the experience."

With that said, I'm optimistic that even if the price stays high, with more people experiencing space travel and seeing how transformative and cool it is, market interest will grow. When we look at who our potential customers are, there are numerous people who have the means, but you need to have the money and the interest. So, the reduction of price will be crucial for space tourism to really take off, but proving the system and the experience will also be key.

What role do you see the government playing in the sector in 2030?

I think that governments have always and will always play a very important role in space – and I don't see this diminishing in either the civil or military side. However, the kind of role they play may alter by 2030.

For instance, we might see the growth of commercial space companies, which is great, but there will always be an exchange between the private and public sectors. There will be commercial companies pulling in commercial revenue, but I still think that they'll also be pursuing government contracts. As our space capabilities increasingly benefit our lives on Earth, we're going to see more government interest, and governments doubling down on their own capability. This also means doubling down on securing space and securing access to it.

What nations do you think in the next ten years will be the main players in human space flight?

I think there will be several players in the international space community continuing to develop human space flight. Definitely the United States will continue to be a strong player and I don't think Russia is ever going to give up their human space flight capability. The Chinese will also continue their steady pace towards more human space flight. While I don't see the Europeans launching humans in the near term, they will continue having a strong astronaut corps for others to launch into space.

What is a key technological development you think we'll need in the next ten years to really drive the industry?

Reusable rocket technologies will be a game changer in the industry. There was a landmark moment recently where two companies made their landings and subsequently reused their rockets. I think this marked the beginning of changing access to space. The development of reusable rocket technologies would really bring down the costs of space flight, and this in turn, will allow us more access into space. In the next ten years, we're going to get much better at reusability and this will really change the industry.

Carissa Christensen

"Success in the space sector may mean being less identified as a space company."

What have we achieved in the space sector by 2030?

Existing satellite telecommunication, imaging, and navigation/positioning/timing businesses will continue to grow. There are real opportunities to make global telecommunications infrastructure more robust, including dynamically switching space and terrestrial capabilities. For example, if you think about fibre optic cables, sabotage stress associated with these can make having satellites as backups useful.

We are also seeing the interesting use of small satellites in mega constellations for telecommunications. There are multiple companies currently trying to do this and three front-running companies, including SpaceX and Amazon, both having different advantages. SpaceX's system has the advantage being integrated with a launch capability, while Amazon's system is being developed by a company that is in every household and has direct access to over 100 million consumers. Both seek to offer enhanced Telco capability for end users, though it is not yet clear who will triumph and be able to offer services that are reliable and at a compelling price point.

Satellite imagery and remote sensing technologies will really hit their stride. This field has taken a while to find its market, as is often the case when you have implemented new capabilities and seek new customers. By 2030 we'll see satellite imagery fully integrated into financial decision making, policy decision making and a wide range of sectors in the economy.

In ten years' time, what do you think space business will look like?

We're going to see erosion of 'space identity' by some businesses. For example, I'm not sure that Planet really wants to be characterised as a space business so much as an analytics business, that serves a wider range of customers. So, success in the space sector may mean being identified less as a space company and more as an entertainment or logistics or financial analytics company. The fact the company's success is built on space assets is interesting but not the most important point. These companies seek to serve market demand, current or anticipated, and space is just a means to achieve that.

We are also going to see more markets driven by commercial end users and increasingly flexible government customers in engaging commercial companies to meet their needs. But in 2030 governments are still going to be very important customers for space businesses.

Carissa Christensen is the Chief Executive Officer and founder of Bryce Space and Technology. Christensen is an internationally-recognised expert on the space industry. She serves on the World Economic Forum Global Future Council, the Advisory Council of the Aerospace Corporation's Centre for Space Policy and Strategy, and the National Research Council Space Technology Industry-Government-University Roundtable, which advises NASA. Christensen is a Fellow of the American Institute of Aeronautics and Astronautics. She is also an active investor who serves on several early stage boards.

Do you see venture capital getting returns in ten years?

With venture investments in a new area, there's a surge of investment and then companies either succeed or do not. Failure rates are high. Even when many individual companies fail, there is generally forward movement in the sector. I like to point to the dot-com bubble which was profoundly disruptive, with huge inconsequence to investors and highly-visible business failures. But, if we look around the world now, we're certainly not living in a dot-com free universe. E-business has transformed our world.

So, there's a difference between outcomes in terms of the performance that a given investor sees and the overall growth of the sector. The money going into technology and capabilities right now in innovative companies may or may not advantage investors today who are supporting those companies. But there's a high probability that the investment will advantage future users of the resulting capability.

There has also been disproportionately less investment in ground segment to date, which I expect will be filled in the coming ten years.

The ability to easily leverage alternate capabilities from different satellite providers across the spectrum will be a compelling value proposition for many customers.

What do you think collaboration will look like in 2030?

We'll see greater use of space for national security purposes. Space capabilities underpin the security of nations, their competitors and their allies. Space is being recognised for its growing military and intelligence importance.

So, important assets become a source of tension. This will result both in more focus on national space systems and, because space assets are costly, more interest in opportunities for allied countries to share. We'll see more collaboration among allies in developing, deploying, and using space systems for national security purposes.

On the commercial side, we will see the integration of smaller, niche companies into larger companies. For space activities, the general benefits of network effects, costs of technology development and maintaining systems are factors that push towards larger organisations on an infrastructure level. In ten years, we're going to continue to see space dominated by larger companies.

How do you think we'll see space applied into our daily lives by 2030?

By 2030 probably the biggest transformation coming to our daily lives is the integration of AI using data analytics as a routine part of how cities, business, utilities, entertainment and infrastructure operate, with machines making more and more decisions and executing those decisions with few humans in the loop. Space systems will play a critical part by providing unique data and enabling ubiquitous global connectivity.

Chris Boshuizen

"Space is going to go big again."

Chris Boshuizen is an Operating Partner at Data Collective VC, an investment firm specialising in data-driven science and engineering companies. Chris was also the co-founder of Planet, a company providing global mapping of Earth from space daily. He was previously a Space Mission Architect at NASA Ames Research Center. Chris co-created Phonesat, a spacecraft built out of a regular smart phone that demonstrated that space was within reach of regular people.

What the space industry will look like by 2030 really depends on the development of advanced technologies that we don't have yet. Will we make technological developments in the areas of materials science, precision navigation and human space flight that will really drive the industry forward toward meeting our goals of venturing into deep space missions and unmanned space exploration? Or will our innovation stall, leaving us in exactly the same place that we are today?

Currently the space industry presents a somewhat even playing field. Advances such as high-quality semiconductors from the cost-conscious mobile phone industry, 3D printing of parts on the ground and access to the spare capacity of large rockets via ridesharing opportunities have allowed more people than ever before to fly things in space – smaller nations, universities, school groups, and even individuals can now take part and space is no longer the domain of a few superpowers. But these advances are widely available, so a lot of the activities people chose to do in space are the same. We mostly build small satellites and vehicles, because this is what the technology affords, but what if a technology comes along that allows us to build bigger things at cheaper prices? Some companies, like Made in Space, are working with new

technologies like 3D printing things directly in space, which is much harder than on the ground, and that may see a real commercial breakthrough, allowing us to move from launching things we've built on Earth into space to actually building things in space.

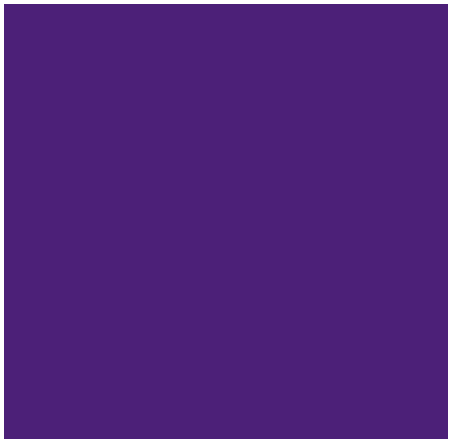
Another area I believe will change over the next ten years is our navigation systems, which are quite immature. In Star Wars, droids are so capable they are flying around spaceships. That type of autonomous control is something we couldn't comprehend on the International Space Station – we'd never let a free-flying robot preform an automated task outside! Solving some of these issues in precision navigation begins with the development of more precise control thrusters, propulsion systems and software systems, and this will really open the doors to even more innovation in the sector. Precision navigation and space assembly go hand-in-hand. If we can implement really good precision navigation systems, we could more comfortably assemble large, more complex structures in space.

Space tourism and long-term travel into space is very exciting, but presently it is still expensive and frankly quite inaccessible. SpaceX and Blue Origin are trying to chip away at this problem, but there is still an extremely long way to go. Advancements in human occupied vehicle technologies are not transformational, and I would be very surprised if there are any serious human space activities by 2030. There are a lot of other technologies that need to be developed first before we can establish safe deep space exploration and commercial space travel.

I believe in the last decade we've been riding a wave which was the real start of commercial space, where people really started to believe that they could have space companies. This cycle was driven through innovation – from the utilisation of off-the-shelf, high performance, lower-cost hardware for building small satellites and small launch vehicles. All of this meant that space projects were cheaper and more affordable for companies without heavy reliance on the government anymore. Innovation was a key factor in the past and it will continue to play a significant role. I see the industry progressing at a steady state until another big technological breakthrough comes along to disrupt it. If something really interesting and innovative comes along, I think we'll see an explosion of ideas and investments coming along to really drive the industry.

Because of this even technological playing field, I see investors in the sector having some losses in the short-term; there are just too many companies trying the same ideas for them all to be successful. I'm not too worried about the investment climate in the industry in 2030 though as there will be breakthroughs that lead to new ideas. In the ten-year timescale, as new tech comes into play, and as the needs of people on Earth change, these companies will get funded and be successful, and investors will see returns on their investments.

Finally, the deeper understanding we have of the data around us through the AI and machine learning tools that are being created will have a major impact on the space industry. These tools help us make sense of the increasing amounts of data we're collecting, and space, a new frontier of data collection, will only benefit from these innovations. There's already a lot of Earth observation data being gathered, we've got CubeSats being utilised for research purposes out in space, gathering lots of data. Hopefully, by 2030 we will become much better at understanding all of this data to help us in our goals to better understand space.



But with observational data on Earth improving, on a global level there will definitely be security and privacy issues coming up. We're currently in a transitional phase of our society where gathering Earth observation and surveillance data might just become part of the fabric of a new technological society. But alongside the benefits of this influx of data will be drawbacks, namely in privacy. We're in the midst of a mini cultural revolution. Will people reject this sort of large-scale data gathering, sacrificing its benefits for the sake of our privacy? Or will we learn to accept it and take the benefits that come with it? Only time will tell.

Credit: NASA

"Space travellers will go further and space missions will be deeper and longer with advancements in medicine and technology. The space travel we envisage in 2030 means people, who would previously be 'disqualified' as astronauts, will now be fee paying tourists."

Josef Schmid
Flight Surgeon, NASA

"Space is critical to the way we live and work every single day."

Christian Davenport is a staff writer at the Washington Post covering the space and defence industries for the financial desk. Christian is a recipient of the Peabody Award in 2010 and was on teams that were finalists for the Pulitzer Prize in 2005, 2010 and 2011. He has also authored two books "The Space Barons: Elon Musk, Jeff Bezos and the Quest to Colonize the Cosmos" and "As You Were: To War and Back with the Black Hawk Battalion of the Virginia National Guard."

Christian Davenport

This year, in the Washington Post, I predicted a year of, "significant moments in space exploration: NASA astronauts flying from United States soil for the first time since 2011; the first paying tourists traveling to the edge of space; rockets sending hundreds of satellites into Earth orbit to beam the internet to remote parts of the globe; and the first serious steps toward returning a human being to the surface of the Moon."

By 2030, I see a self-sustaining economy based in space. Space is critical to the way we live and work. The blue dot on our phone, showing us (and others) where we are, the time code signals that banks use to synchronise payments and an avalanche of data waiting to be analysed and used.

The first step is more efficient and reliable access. There is a burgeoning commercial space industry that will only expand in the coming decade with companies like SpaceX charging less to get more technology up into space while trying to make space exploration more sustainable by developing technologies to re-use their rockets.

NASA, under the leadership of the White House, is pushing to return to the Moon by 2024. This is a hugely ambitious effort that will require not only a lot of money and support from the United States Congress (their current budget request is US$28.6 billion by fiscal year 2023), but also international partnerships. Just in the year ahead we could have NASA, through Boeing and SpaceX, restoring human space flight from the United States. We could also see companies like Blue Origin and Virgin Galactic begin taking people on space tours.

But human space flight is tricky, particularly when you are developing new vehicles from scratch. The Commercial Crew Program for NASA aimed to put astronauts into orbit by 2017 and Richard Branson has been talking about space tourism for years. Despite no flights yet, they appear to be very close to doing both. Virgin Galactic have now had two successful trips to space, Blue Origin has launched its suborbital vehicle multiple times and the SpaceX test flight of its Dragon Spacecraft was successful.

Beyond the technical challenges, there are also political ones. Right now, the space program, nicknamed Artemis, is being pushed by the Trump administration. If there is a change in leadership, then the direction may change. Recent history records multiple policy changes – the Bush administration pushed a return to the Moon, President Obama focused on going to an asteroid and Mars and most recently President Trump has pursued the Moon then Mars agenda. New administrations often have different priorities and perhaps that's why the Trump administration is moving so fast. What they don't want is another program where goals are set-out, money is spent and rockets are developed to then have the program scrapped. Putting all political biases aside, if the US goes through with Artemis, I think it's possible to get humans back on the Moon within ten years, something we haven't seen since 1972.

By 2030, the number of satellites in space will also increase. Satellite technology has developed in the past decade causing the size and cost of satellites to decrease. Commercial space companies are putting constellations of satellites into low-Earth orbit. There's an estimated three to four billion people without access to the internet. This can be solved with satellite constellations. SpaceX aims to put up a few hundred satellites by the

end of this year, as are companies like Amazon. I'm optimistic that by 2030, through space technology we will achieve global internet connectivity.

Large satellite constellations facilitating internet access could generate a lot of money if they are successful, but it is also risky. Companies have tried and failed before. Large scale manufacturing and launching of satellites is still expensive and once companies have succeeded in launch, there are other risks involved. Space is big but it's getting more crowded and there are concerns about operators and their ability to prevent collisions.

The risk is there's nobody who has the authority to tell satellite operators what to do in space. The US Air Force tracks spacecraft and debris and can give satellite operators warnings if there's risk of collision, although they can't force companies to move their satellites onto another course. The Space Safety Coalition has gathered companies together to try to create best practices, so we are seeing some steps to address this issue. But this is a protocol rather than a law, so adherence to the code will be another step.

Finally, by 2030 countries will start to think about space as a war domain, like land, air and sea. The Trump administration is already talking about the 'Space Force'. There are real concerns about how vulnerable assets are in space and other countries have shown they have the ability to target them. The Pentagon is committed to make sure they have the systems in place to protect their assets.

This is a really interesting time to be a space reporter with the media playing an important role in the sector. The coming years are going to be unpredictable and incredibly exciting. The reality is we don't know what's going to happen in the future. In the end we will just have to wait and see.

Dan Nevius

Dan Nevius is the co-founder and CEO of Analytical Space. Founded in 2016 and based in Cambridge, Massachusetts, Analytical Space focuses on addressing how to quickly bring large amounts of remote sensing data down to Earth using a network of data relay satellites.

"Near real-time data transmission in LEO is going to enable more actionable applications of space."

What can we expect for the space sector over the next ten years?

It will be a pretty exciting decade for space. The industry is gathering a lot of momentum and now has commercial solutions for many of the pieces of basic infrastructure that allow new capabilities to be developed quickly on top of them. Government groups like NASA, and even defence agencies, are working more with commercial space companies, and start-ups are becoming increasingly key to their innovation strategies.

I think the next ten years will be huge for Analytical Space as we can build the in-orbit communication infrastructure needed to get better connectivity for commercial and governmental remote sensing assets.

In addition, as costs for space-based platforms continue to come down remote sensing startups will be able to focus on building ideal data sets for smaller target markets and that information will be able to arrive to the end user on an actionable timescale.

What role do you see AI playing in filtering the data collected from space vs. what is actually transmitted to Earth?

As computational power on these platforms increases you have the ability to do edge computing. There are applications where that makes a lot of sense, especially ones that have well defined analysis and are not too computationally expensive. However, there's also huge value in trying to get down as much data as possible, because you can use it as training data to develop new machine learning algorithms. The more training data you have, the more applications you can then start to model.

What is perhaps an unlikely development, but one you are still hopeful for in the next ten years?

As an early member of Planetary Resources, I still have hopes for eventual asteroid or lunar mining. It is energetically expensive to explore the solar system if you have to fight Earth's gravity all the time. As a precursor to that and along those same lines I am also hoping we'll see the combination of two really interesting developments – spin launch and in-space manufacturing. Instead of designing satellites to the constraints of the launch vehicle, if we could launch bulk building material that can withstand thousands of Gs and then manufacture in orbit it would open up the design space for new spacecraft concepts and could dramatically reduce costs. It would be a huge leap in how satellites are built and could have ripple effects across the industry.

What are some of the challenges the space industry still has to overcome?

Recently space is being talked about more broadly as a new domain of war, whereas previously space was seen as a kind of global commons. That could lead to some interesting geo-politics that may actually accelerate space development but it obviously

creates less stability for the space environment when it comes to solving shared issues such as space debris or spectrum management. These affect everyone operating in space.

More specific challenges exist depending on the sub industry. A key challenge for remote sensing operators that Analytical Space work with is how we overcome the geographic limitations to connectivity in space. There are only so many places where you can place ground terminals, with 70 percent of the Earth covered by oceans. On top of that, sensitive data can only be downlinked within specific regions due to security concerns. Analytical Space is focusing on creating infrastructure where you can relay data in orbit to specific locations with low latency and high data rates which will enable new applications where the sensor is either very data intensive (like SAR or Hyperspectral) or where the information has an expiration date.

What does a space business of the future look like?

The biggest change that we are already starting to see play out is that the barriers to developing, launching and operating hardware in orbit will come down significantly. Much of the infrastructure to enable this now exists, which means that companies can now specialise on a specific piece of the value chain and outsource things like satellite manufacturing, launch and communications. As a result, new ideas will be able to be tested at a much faster rate, the pace of innovation will accelerate and space will have an increasing role in our lives on Earth whether it is telecommunication, geointelligence or space tourism. In addition to the explicit space businesses that operate hardware in orbit there will be increasingly more businesses who have space in their supply chain and depend on those in-orbit assets on a daily basis.

Dylan Taylor

"A trillion dollar space economy."

In the range of ten to 20 years' time, we are expecting to see a trillion dollar space economy. Now that we have reliable, inexpensive launch, we effectively have built the space elevator which enables many new business models to be viable, particularly those with data and analytics as foundational components.

I see the use of space data and the products and services you can derive from it taking about ten years to fully build out. This is very similar to the internet phenomenon and the time it took to develop. In 2030 we will have a hyperspectral, ubiquitous, always on data collection mechanism through all of the constellations of satellites which are currently being developed.

Dylan Taylor is the Chairman and CEO of Voyager Space Holdings, a privately held global holding company acquiring and operating companies in the space exploration industry. In addition, Dylan is a leading angel investor in the space sector investing in over 50 early-stage companies. He is also former Global President of Colliers International and founder of the global non-profit Space for Humanity.

The convergence of all of the data these assets generate, with better cloud infrastructure and the addition of better AI and machine learning will enable better products and services that are predictive and thus hugely value creating. This will have profound impact on Earth. The extensive cell infrastructure we have today is likely to be greatly diminished in ten years' time, with almost all data transmission being space-based.

Today we are dependent on space – most of the business plans built in the tech community for the iPhone are reliant on the GPS constellation. In 2030, the vast majority of our commerce will be facilitated through space-based assets, and this will have far reaching implications.

From here, we have a relatively quick path to a multi-trillion dollar space economy. The way I think about it is, we have roughly an US$80 trillion global economy. If you have nearly perfect, real-time information about nearly all elements of the Earth, and it is continuously being fed into a cloud to process the information in real-time, you are able to make predictive recommendations. Could you make the global economy three percent more efficient as a result? The answer is pretty clearly yes and right there you have US$2.4 trillion in value creation.

I see the investment landscape in the space sector evolving over the next ten years as well. Retail investors are going to seek opportunities in space, and we have already seen that through the excitement that Virgin Galactic's stock has generated. Venture is essentially growth equity that sits between angel capital and traditional private equity and the public market. I believe the role of venture will remain, however the industry will be less reliant on it, while private equity will remain largely unsuited to the space sector as you are dealing with an operational challenge rather than a purely capital one.

There are still some challenges in achieving that scale. Many companies in the space sector are smaller, founder-led companies with highly technical people, but they don't always know how to build a US$1billion business. Obviously if you have a launch capability, space craft capability and data and analytics capability all as part of the same enterprise, you are capable of doing much more valuable missions than just launch for example. There are bonus points for building capability and building scale.

We have recently created Voyager Space Holdings to address this challenge. We plan to build base infrastructure and get multiple companies to fly in formation in a way that is more elegant. The Voyager model is to have a permanent capital structure, where we take a majority stake in companies, without the need to constantly raise money and return it to our investors within five years. The dream is that we can undertake any mission that people conceive. With this model we can push the envelope of what's possible, particularly in building space-based infrastructure.

The missions already being undertaken in the space sector are going to result in people living on the Moon in 2030 and I think that is going to be very powerful. When people look up at the Moon and think that there are actually humans living up there, I think that will dramatically shift our world view. It will create inspiration for STEM education in a way we haven't seen since Apollo.

Elizabeth Jens

Elizabeth Jens is a propulsion and systems engineer at the NASA Jet Propulsion Laboratory (JPL), which constructs and operates planetary robotic spacecraft and conducts space missions. She has hardware on NASA's Mars 2020 rover, Perseverance, due to launch in July 2020.

When I look ahead to 2030, and what could be the biggest impact of us as a species, I believe that there's a reasonable chance of us knowing if we are alone in the universe and discovering the origins of life on Earth.

That's a big statement, I know. But we're already making huge progress in the deep space exploration field. In July 2020, NASA JPL will launch our Perseverance Rover mission, which will – for the first time since the Viking missions in 1975 – actively search for life on Mars. And we have a much better idea today of what we're looking for than ever before. For instance, we know that Mars was a much warmer and wetter planet, had a magnetic field to give protection from radiation and could have been habitable. We are also enhancing exploration capabilities, including taking a helicopter with us. This will be a whole new way to explore the planet and may enable us to cover a much broader area than we have been able to before with rovers, giving us more scope for new discoveries.

It will be exciting to see what we learn from this mission. And the samples that we're able to take back and study on Earth could give us insights into what constitutes life itself. We may discover that life on Mars is similar to that of Earth and perhaps even that life on our planet could have originated from Mars – and that in fact we're all fundamentally Martian!

"Deep space exploration could help us discover the origins of life on Earth by 2030."

Beyond Mars, there are other missions and areas of space to explore that could make us rethink our place in the universe. Take Europa Clipper as an example, our next mission to the Jupiter system and – more specifically – to Europa, one of Jupiter's Moons. Europa is particularly interesting as it has an ice shell, and there is evidence that there is a salty ocean that could have enough to heat and energy from tidal flexing to support life. Life there might also be similar to some forms of life on Earth. And then there's Titan, one of the moons of Saturn, on which the conditions are near the triple point of methane, just like water here on Earth, suggesting that this moon could support life as well. If this is true, life there would likely be very different and completely alien to us.

The impact of these discoveries on how we see ourselves and the universe more broadly will be very interesting.

Deep space missions could also provide us with solutions to challenges we face on Earth. Venus, for example, has conditions resulting in an extreme runaway greenhouse effect. Studying the planet can help us to understand what, if the worst happens, the future could hold for Earth and, more optimistically, what we can do to avoid it from happening here.

Space research on improving life-support systems can also have huge value on Earth, from water recycling to CO^2 removal, or any technology that can facilitate a closed system, where we use our resources in perpetuity instead of wasting them. We are a long way away from this but if we work towards it, we can make progress to both preserve our planet but also enable these longer space missions.

We humans are explorers by nature, whether it's historically been within our own little celestial body or beyond with the Apollo programme. And it's this passion to explore and discover that triggers a lot of commercial entities to drive their own space programs. This passion also makes them commit to the long timeframes to develop hardware, overcome technology challenges and embark on the missions themselves.

These new players will transform the space sector in the next ten years, pushing boundaries beyond just what we do here on Earth and likely making exploration progress much faster.

A major challenge that we must address in the years ahead will be to ensure collaboration and alignment between space agencies globally and the commercial sector, especially as everyone will have different ambitions and priorities. For instance, how do we align our research for finding life on Mars with projects to send humans to the planet, which could impact these discovery missions by introducing life? Planetary protection will be crucial to ensure we don't record false positives.

We will need to work together across companies and countries. If we can maintain the alignment for human exploration between governments and commercial entities, together we can achieve more – and there's so much that can learn and discover in space in the next ten years.

All opinions expressed here are her own, and do not represent the opinion or policy of NASA, JPL, or Caltech.

"The challenges will be enormous and the rewards available for all humanity."

Flavia Tata Nardini is the CEO and Co-Founder of Fleet Space Technologies, a start-up which aims to transform Earth from Space by connecting the Internet of Things around the world using a massive fleet of small low-cost satellites. She is a Board Member of the South Australian Entrepreneurship Advisory Board and was previously a Co-Founder and CEO of LaunchBox.

Flavia Tata Nardini

In the next ten years space will open up in a way never seen before. Mars seems within our reach and this time it will not be government or big industry that gets us there. The challenges will be enormous and the rewards available for all humanity.

When you look back to the years leading up to the Apollo mission – the United States, through their space agency NASA, prepared to complete what was previously thought impossible. While getting man on the Moon was a collaborative effort, it was the US government who had both hands on the throttle and took the recognition for the achievements. Fast-forward 50 years and the quest for Mars is going to be very different.

This time it will no longer be government led but an interactive and often interdependent relationship between start-ups and businesses. Australia will have an important role to play in space exploration and colonisation with its expertise in the development and use of remote asset management.

I believe getting to Mars is a distinct possibility and expect, in the next ten years, to see society much more involved in the quest. With these future missions being a collective effort more industries will be involved, from energy corporations to mining companies. It's these companies not used so heavily in the past that will enable us to set up a colony on Mars and I can't wait to see it. Start-ups will be a big part of it as well. While we can no longer say that SpaceX is a start-up, perhaps Elon Musk's passion for space was a catalyst for all of the NewSpace companies that we are seeing. So just as in the past it was a race to the Moon led by governments, now it will be a start-up race to develop the right technologies to see us on Mars.

While Mars will be the forefront of our aspirations over the next decade, I also see a continual development in satellite technology and how we use them. With nano-satellites already being manufactured, I expect this to be key to our advancements. The satellites we manufacture at Fleet are all involved in the Internet of Things (IoT). We do IoT from space with the ability to view, monitor and measure large areas of the Earth's surface. If you consider the bushfires in Australia, how can you monitor them by just looking horizontally? Only in space can you get the real perspective.

In the end, it is about the huge quantity of data these satellites absorb and what we do with it. Helping industry to be more efficient with water, food, crops and livestock. Maybe I might be naive or ambitious enough to think the biggest climate issues can be partly solved from space with the ability to remotely check and verify that changes are happening and interventions working. The beauty of it is that this is not constrained by infrastructure on the ground and remote areas are just as accessible as built up cities.

With Mars (and the Moon) being so remote, many of the skills and technologies we use on Earth will also be needed when we get there. Australia, with its internationally renowned reputation for outstanding remote asset management, will play an instrumental role in the quest with much attention on how Australia uses remote management, especially in mining and agriculture.

However we need to be cognisant of the level of due diligence needed in moving forward with this goal. On a personal level, visiting Mars reminds me of Christopher Columbus discovering the Americas. While

Columbus' discovery was amazing, much of what he discovered was exploited for its resources and not properly or sustainably maintained. We need to make an extra effort to ensure this doesn't occur on a planet like Mars, a planet whose potential we still know little about.

One of the things that brings me a lot of confidence came from my experience talking at last year's panel event, Australia's race for space. I saw lots of young people interested in space, which is great news for the future. One thing I urge these young people to do is to place a focus on the construction and implementation of new technology in space.

If you asked an expert ten years ago what was the best course of action going forward in reaching space, they probably would have said that we need to build better rockets and equipment. I am of the opinion that we are behind where we need to be with software. This is a software driven economy and space will be the same. The other thing holding us back is better battery technology. We are getting so much better with so many things that were just a dream ten years ago but without storable power to drive them, many will be useless in space.

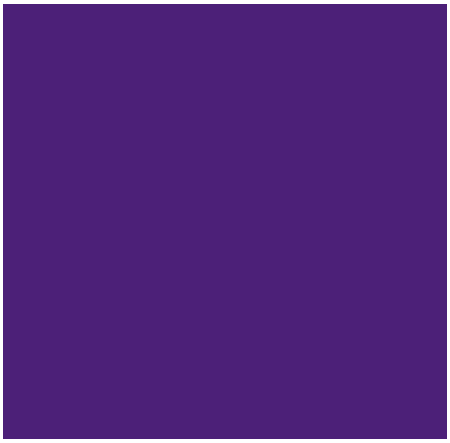
I am still confident. If asked about my ultimate dream it would be that the race to space spills over into aviation and in the next ten years I can go to Mars, but more importantly I can go home to Rome in under an hour. Now that would be really cool.

"The private sector will play as prominent a role as government agencies in shaping the future of space exploration and applications for Earth."

Susmita Mohanty
Co-founder and CEO, Earth2Orbit

Genevieve Bell

Dr Genevieve Bell is the Director of the 3A Institute (3Ai) and a Distinguished Professor at the Australian National University (ANU) as well as a Vice President and Senior Fellow at Intel Corporation. She is a cultural anthropologist, technologist and futurist best known for her work at the intersection of cultural practice and technology development.



I find it hard to talk about 2030 without putting it in a broader context. For me, one of the most interesting things about space is not the place it occupies literally, but the place it occupies in our imaginations. Our imaginings of space travel are hardly new stories; in my doctoral research, I came across a lovely essay written more than 100 years ago by a Native American boarding school student who wrote about going to the Moon. It's interesting to think about why the idea of propelling our bodies into space has been such a preoccupation of the Western science fiction narrative for so long. What is it about the idea of space that is so perennially seductive? What is the role of space in our imaginations? Is it a safety valve, the notion that we get to reset and try again? Is it somewhere where we won't have all the same complications, a blank space that we can fill with new stories?

Even as we start to imagine what space will be like in 2030, we are living in times that previous generations already imagined for us. We are in a moment in time where a whole lot of the science fiction we grew up with is 'now'—Blade Runner was set in Los Angeles in November 2019 and we're well past The Terminator's Judgment Day. Space is a destination that has been predetermined for us, and how we think about the future is profoundly coloured by a whole series of stories we've already told.

Australia's place in these stories is a distinctive and complicated one. We have a 60 to 80 thousand year legacy of people imagining and transacting with a broad ecosystem of which the stars were no small part of. The indigenous people of this country understood the movement of the stars, they tracked constellations in space to inform when they did certain things. There were stories about how the stars came to be and about what those pieces of space meant to them.

There's something interesting about notions of perspective too. That moment when Buzz Aldrin sees the Earth as it's rising from a point of view that hadn't previously been seen by people. His description of this is beautiful, and it's a beautiful set of images that are captured, and it represents a very literal perspective shift. There is something fascinating about what a different point of view can give you. Once you can see everything from space, what does that mean? The capacity of low orbit satellites to see back to Earth, and the granularity of what they can see is very different than what we have seen previously. 20 years ago, you could see a backyard square, by now you're down to what is on the phone screen in your hand. Then there is more sensor technology overlaying that, and the possibilities are quite extraordinary.

It used to be that if someone was taking your picture, you knew it was happening. Now there's a whole series of objects that can sense you, and it is not knowable to you. So there'll be issues about sensor technology, about data, data provenance, where that data is being stored and under what circumstances, how long it's stored for, who gets access to it.

On one hand, there will be arguments that say this technology will allow us to sense fire breakouts in real time and target resources; we're going to be able to track trafficked goods and manage this; we're going to be able to look at wildlife that's endangered and manage its perimeters. But this same technology creates points of vulnerability.

"We've had a long and complicated relationship with space."

Take an Australian example: we want to be able to protect the canyon in which the Wollemi pine live from bushfire. How would you balance the tension between wanting to be able to find fires and fight them, along with wanting to be able to protect a prehistoric plant that exists in one place only, whose location has been kept secret for more than 15 years? Because you know that if you disclose it, it would make it vulnerable. There is a balance about what it means to be seen and who gets to be unseen, and what is necessary to keep things secret.

My suspicion is that, by 2030, there will have been some emergent moments where we start to ask the question of what systems do we need to manage this? People are not often good at speculating who will be the non-traditional users of technology, and what other uses they might put it to that wouldn't have been imagined.

Inbal Becker-Reshef

Dr Inbal Becker-Reshef is the Program Director of NASA Harvest, NASA's Applied Sciences Food Security and Agriculture Program. Inbal's work is focused on the application of satellite information for agricultural monitoring from the field to global scales, supporting decisions in food security and agricultural markets. She is Program Scientist at the GEOGLAM Secretariat and a Co-Director of the Centre for Global Agricultural Monitoring Research at UMD.

NASA Harvest is truly a demonstration of public, private and research collaboration – a nexus that many find hard to bridge. The consortium of partners is improving the use of satellite data to address food security and agriculture problems globally, from small-holder farmers to large corporates.

So, what does 2030 look like?

2030 is simply not that far away.

If you consider how rapidly satellite-driven agricultural monitoring has evolved over the last ten years, picturing it in ten more years is a continuation and acceleration of this revolution.

In 2030 we will see much more widespread and diverse adoption of satellite data and products across the agricultural sector for driving real time decision-making, whether for guiding policies, informing trade, producing agricultural statistics, implementing sustainability commitments, mitigating impending food shortages, advancing precision agriculture, or providing farmers financial services. I anticipate a greater flow from 'research' into 'operations'. This will be enabled by the trend towards free and open data sharing, increased data quality, higher spatial resolution, and faster revisit time of satellite observations combined with advances in machine learning and cloud computing alongside large investments by the public and private sectors.

This uptake and routine integration of satellite information across the agricultural sector will help inform decisions that enable our food production systems to meet increasing food and caloric demand sustainably, even in the face of a changing climate and scarce resources.

In many ways we are already starting to see the impact of these technological advances and open data sharing developments. Take programs such as Copernicus, or the proliferation of small satellite constellations. These are already successfully disrupting the way in which satellite data is being used. Where 250m spatial resolution data was the standard for global monitoring just six years ago, today the European Copernicus program is providing free and open 10m resolution imagery globally every 2-5 days, and small-sat constellations are providing inexpensive daily imagery at 3-5m resolution. With these new capabilities, we are moving towards monitoring our dynamic planet on a daily basis at the scale of individual fields or paddocks. This is a clear demonstration of a paradigm shift towards open data policies and more accessible data from both government and privately owned constellations and infrastructure serving industry and the public alike. This has allowed faster innovation and an ability to meet the needs of agricultural end users more quickly.

To continue to feed this advance, it is important that by 2030 we have widely adopted open data policies for high quality, high volume Earth observation with high spatial and temporal resolution. But even more so, we will need to ensure that we have the readily accessible infrastructure and platforms to process this data to deliver actionable information across the sector. To do so, we will need to take advantage of the growth in cloud computing, machine learning and artificial intelligence; and will likely need to rely on expanded industry investments to enable this.

"Data driven, precision agriculture for a food secure Earth."

We are likely to see increased frequency of extreme weather events, and we need to make sure there is enough food for everybody while managing our land use sustainably. Why is it so important that decision-making capabilities are enabled for agriculture?

The forecasts are well known: we need to produce nearly 50 percent more food by 2050 to feed nearly ten billion people, yet we are already at near 100 percent agriculturally suitable land-use capacity. We will continue to experience extreme weather conditions, and extreme events will become more frequent. We will need innovation to be able to feed the world sustainably. In the next decade, I foresee that Earth observation data and the associated information services will help increase

the productivity of existing agricultural systems, while simultaneously reducing agriculture's environmental impact.

For example, precision agriculture is increasingly using satellite data to improve fertiliser use, help manage water resources and enable sustainable crop intensification. Additionally, commercial start-ups have been able to develop interfaces and platforms to process this satellite-sourced data and provide services used by farmers, straight into their tractors and machinery.

Monitoring agriculture across space and time using Earth observation satellites allows us to measure the impact of decisions and policies—for example, we can measure the adoption rate of conservation practices, or impact of policies on cropping intensification or expansion.

In 2030, decision-making capabilities driven by accessible, timely, and open data and derived insights are going to be key to feeding the world and the continued agricultural revolution – across both small and large scale farming operations.

What is holding us back? What are the challenges?

Firstly, while Earth observation data is increasing rapidly, to be able to get to a desired future state we are going to need to better collaborate across the public and private space and technology sectors and to ensure close stakeholder engagement.

We have seen a huge amount of innovation come out of the private sector which has helped spur the revolution in agricultural monitoring. Both government-funded and private sector research are developing high quality data capture mechanisms and analytics, providing insights faster than traditional approaches. To continue to cultivate the agricultural revolution, we will need to find useful, productive pathways to operationalise these innovations in a way that is useful to end-users.

NASA Harvest is an experimental program that is trying to work in this private, public and end user nexus, investigating and developing collaborations between the three groups to increase the chances for adoption and traction.

Secondly, and perhaps most importantly, in this 'big-data' era we cannot benefit from the increased quality and quantity of Earth observations without high quality and accessible ground data, which is critical for developing and validating satellite products such as crop type maps and crop yield estimates. This is an area where private, public and end user collaboration could have the most impact.

As satellite data and tools become more accessible to a wide range of users (rather than limited to remote sensing experts and researchers), it will be critical to develop standards and mechanisms to ensure the quality of the products and insights derived from satellite data. In addition, as new satellites are launched it will be important to ensure interoperability across data streams. The benefits of interoperability are already being demonstrated: for example, Sentinel-2 and Landsat data have been combined to enable interoperable use, and we need to facilitate more of this data harmonisation.

If we can address these challenges we will be able to unlock the huge potential that Earth observation data offers to inform local to global decisions on policy development and fiscal decision making, and enhance market transparency in support of agriculture and food security. For example, in Uganda, NASA Harvest's work with the Office of the Prime Minister has been able to develop alerts for in-season crop stress from drought that trigger the release of government funding to proactively mitigate the impacts on food security and consumption in the long-term, rather than post-fact.

We are starting to see regulation, such as the Common Agriculture Policy in Europe, requiring the use of Earth observation data to monitor and ensure compliance. I expect this type of uptake of satellite data to continue and expand to other countries in the next ten years.

We are starting this decade amidst a revolution in Earth observation capabilities as well as analytic and computational capabilities, which holds great promise for realising the benefits of satellite Earth observation data for agriculture and food security in the next ten years.

James Morhard

"As a species, we're explorers. It's in our DNA."

James Morhard is the 14th Deputy Administrator of NASA. He helps provide overall leadership, planning and policy direction and is also responsible for articulating and representing NASA's vision. Prior to his tenure with NASA, Morhard was the U.S. Senate Deputy Sergeant at Arms.

What do you think we will have achieved in the space sector by 2030?

This is a pivotal time for NASA. I look at this as one campaign with three domains: first, our focus over the next ten years is to expand the economy in low-Earth orbit, getting to the Moon and staying there sustainably to learn so that we can hopefully land on Mars in the 2030s.

Second, the United States aims to get the first woman and next man on the Moon by 2024. This time, it's more than flags and footprints. We are going sustainably, not just to go there, but to stay there for longer. By doing so, we can build our understanding on what we need to get into deep space; our third domain.

On Earth, we are limited by the "rocket equation." As the payload weight increases, so does the amount of propellant you need. This is the same on the Moon, but due to the Moon only having 1/6 of Earth's gravity, it's a lot easier to launch from there. So, if we are physically and economically able to mine the water ice on the Moon and convert it into hydrogen to fuel rockets, then we can go further into deep space. If we are able to achieve this endeavour, it will decrease the cost of space exploration.

What are some of today's challenges you see us solving in the next decade?

We haven't built a human landing system like that of Apollo in over 50 years and we're currently reviewing the options on how best to approach it. Those who worked on the Apollo program aren't with us anymore. So, we've got to reinvent a lot of what has been done.

To get to the Moon, we have the Space Launch System (SLS) rocket, the Orion capsule and the ground systems. But the challenge now is to create the Lunar Gateway – a command post that will orbit the Moon and could be a transfer point to get to the Moon, as well as a point to get to deep space.

Another challenge we're facing is safety and logistics. I'm not worried about our astronauts performing what they've been trained to do. But I need to make sure that I can get them there safely and keep them alive when in deep space with the challenge of radiation, food supplies, blood flow, and bone and muscle degradation. Humans are the most fragile element of space exploration, and safety is such a key factor to think about. This will all have to be solved for us to achieve our space ambitions.

What do you see the role of government in space being in ten years' time?

For the US, we can't do this without commercial and international partnerships, they play a huge role. As our discretionary spending is

being squeezed, we need to leverage our commercial partners to expand competition in the space economy. With the Apollo program, we developed it, we built it and we operated it. Now, we're helping companies develop the technologies and the hardware and we want to be a customer.

Australia is a great example of a key international partnership. Its great robotic mining capabilities could be extremely helpful on the Moon. Again, we're not looking to own these things, we're looking to be one of the many customers that want that service.

What are some of the benefits of space to life on Earth in ten years' time?

A key focus of NASA's mission is studying the Earth. For instance, we recently launched the Solar Orbiter to gather important data on solar weather and take never before seen photos of the Sun. The orbiter will be looking at the Heliosphere which is the immense magnetic bubble containing our solar system, solar wind, and the entire solar magnetic field. It extends well beyond the orbit of Pluto and protects us from solar radiation and flares.

We're trying to better understand our planet to benefit life here on Earth. Solar phenomenon, such as the 1859 Carrington Event which damaged our telegraph wires and impacted compasses, will have a much larger impact today than it did then. If we get another event such as this, with the amount of technology we have today, it could be very bad for power grids, our mobile devices and much more. There is enormous value in scientific missions such as Solar Orbiter, as well as others like Psyche and Bennu, both of which will study asteroids.

I see a lot being done for biology and medicine through NASA. Some of our work on pancreatic cancer and Alzheimer's is quite personal to me, having lost my dad to pancreatic cancer and my mum having had dementia. Currently on the International Space Station, NASA astronauts are doing

research on the creation of tissue for organ production and mass retinal implant production. I also expect we'll see a proliferation of commercial space stations in low Earth orbit that's going to allow for a lot more research.

What's your dream for the space sector and NASA in 2030?

If you Google NASA and blue dot, there's a famous picture of just a dot in space, which is a picture of the Earth from space. That gives you the appreciation that we're just a dot really and makes you wonder is there even an edge to the universe…

I hope that we're going to keep learning. As a species we're explorers, it's in our DNA. We're always going to want to push our boundaries further out because we're curious to understand who we are and where we came from. My dream for 2030 is to keep exploring and learning as we go further and further into space.

Jan Wörner

"Travelling forward. Fascination, inspiration and motivation."

As a young man, I dreamt of being an astronaut. Astronauts are the eyes and ears of space. Long before Life Magazine published the famous photo by Bill Anders of the fragile blue and white planet, the three men of the Apollo 8 crew had already experienced it. Anders described the moment as, "in a darkened room with only one visible object, a small blue-green sphere about the size of a Christmas-tree ornament." I am not an astronaut, but my dream of space lives with me every day.

As I look towards 2030, my first thought is, ten years is not really enough time to imagine or predict where we will be in space. Most programs' time frame is far greater than this including ESA programs.

So where do I think we will be? In this matter, my opinion differs from others and is best explained through ESA's four pillar narrative. The record budget voted last November at the Space 19+ Council in Seville will allow breakthrough discoveries about the Earth, our Solar System and the whole Universe, while making the responsible choice to strengthen the efforts to safeguard our planet and its immediate space environment.

The first pillar is Science and Exploration.

Dr Jan Wörner is the Director General of the European Space Agency (ESA). Prior to starting his role in 2015, he was a civil engineer, university professor and president of Technische Universität Darmstadt. He also served as chairman of the executive board of the German Aerospace Centre DLR.

Science is mandatory for every member of ESA – everyone participates. Exploration is optional. Science looks at the stars and other phenomena far away from the Earth. Exploration is closer to home, it brings us to low Earth orbit, the Moon and Mars.

The next is, Applications, Earth Observation, Telecommunications and Satellite Navigation.

The third is Enabling and Support. This is where we create and develop new technologies and run space transportation.

The fourth is a new one: Safety and Security. It deals with space hazards such as solar flares, space debris and asteroids and also with Earthly disasters such as Earthquakes, floods, hurricanes, etc. or any disaster where communication means are affected, including a cyber-attack.

As we look to the future we will see more and more private ownership and access with small fleets of company focused – commercial satellites. In telecommunication it is even more commercially focused. Navigation is more difficult. There is the general use of navigation and with this comes the need for security. In the next 30 years what remains with the public agencies will be science exploration and all safety and security aspects. The rest will become commercial.

Agencies like ESA are looking towards collaboration with industry. A customer, buying services like space debris removal. A broker, a long way from our origins, bringing different actors together in a common activity.

One question I am asked is, how do we convey the benefits of space?

Space is an infrastructure. Many see this as boring, just roads and bridges. But personally I see infrastructure as integral to everyday life. Just as we need space, for weather prediction, navigation, climate change assessment and telecommunications. But it is also an enabler – beyond just technical solutions.

To make it easier to see these I developed three 'destinations of space' in no particular order; society, economy and environment.

Space influences society. The Apollo missions fascinated the world. Space is captivating especially the science and the exploration missions. Fascination is a positive emotion that leads to inspiration and motivation. This was my story – inspired by space – a civil engineer building dreams in structures – something better for our society.

Space benefits the economy. Developing industry, this is part of ESA's convention, developing European industry and making it competitive on the global market. Competitiveness is the answer to the destination economy.

The third is environment, the surface of the Earth including climate change and all around it. Missions have responsibility to the Earth and the space around the Earth.

These three are the value of space.

To look at it another way, we asked the European people what they thought they would like to contribute to space. The mean answer was €287 per year per person. Interestingly our 'ask' for Space19+ was only €8 per person. So we definitely have potential.

From space we can observe, of course, but we can also take action. We can be strong player in the fight against climate change. Climate change is an example of thinking about something rather than just 'doing it'. We first had to discover there was climate change. And we found it not on Earth but on Venus where we observed a greenhouse effect. So we thought, "could this also be happening on Earth?" Discovery is number one.

Monitoring is next. We monitor some 26 parameters, climate variables, to allow us to see what is really happening.

The next is to raise awareness. The data is there, but you have to explain it, so politicians and the general public really understand. Astronauts can do this – they can express their feelings for this shiny planet in the darkness of the universe. Their observations and emotion helps people understand.

The final is to mitigate; this is what we must do now. The technology of solar cells, a provider of clean energy, was first developed for space. Navigation from space satellites allows us to go the shortest, the fastest and now the greenest routes from A to B. Space could see aircraft congestion reduced with more efficient routes and queuing to reduce emissions and space will help aircraft fly at altitudes that minimise contrails and their impacts on the climate.

Space is also a geopolitical equaliser. As we aspire again to the Moon I dream of a 'Moon Village'. A village is a place where different actors come together to create something bigger. I'm not thinking of colonising the Moon, because to live together in a tin can on a dusty planet should not be the future for anyone. Aspiring to leave this planet and live on another is a poor excuse for not taking care of Earth.

Jason Crusan

"Forward to the Moon - an opportunity for all."

Over the past decade, organisations have focused on commercial space flights to the edge of space, low Earth orbit, to the Moon and beyond. Upon reflection, it has been a lot tougher than expected and has taken more time than everyone thought it would. With continual improvements in technology and an increased societal desire to reach space, it is my view that by the end of the decade, people can look forward to regular flights to the edge of space, commercial space stations, the complete transition to small satellites providing a wide array of new services, and the Moon's surface being explored from every angle. Interestingly too, it will not just be "state sponsored astronauts" who have ventured into space and onto the Moon, it will be high-net-worth individuals, artists, engineers and storytellers who will share the story of space from their diverse perspectives and in so doing, foster further exploration and care of our home planet.

Right now, how we fuel our travel and even life in space presents an interesting challenge. By way of example, we will need hydration to live and propellant to travel. If we solve the problem of transporting water into space by releasing the stores on the Moon - we will have a solution to both. Splitting hydrogen and oxygen molecules through electrolysis provides oxygen to breathe, a propellant to travel and in its original form, water to sustain life. Interestingly, that is the same technology we use for hydrogen production on Earth and so I see so many technical overlaps between the roadmaps we see in space and those related to the energy transition on Earth. The consequence of this is that space travel and the technology to enable living on the Moon have a benefit for all.

Jason Crusan is the Vice President of Technology at Woodside Energy. With over 20 years' experience in the space industry and as a former director at NASA, Jason is passionate about the opportunities that space provides for a sustainable future.

In the past, space was extraordinarily expensive. GEO satellites were built 'not to fail' with large amounts of money spent on redundancy that created a vicious circle of increasing costs. Now the standardisation of CubeSats and small satellites, for example (originally designed and built for research), we are seeing this industry sector transforming. Satellite costs have dropped to fractions of the original price and so too has the risk coefficient. CubeSats have evolved to mega constellations of small satellites supporting Earth observations and/or communications promoting more and more investment, further driving down the cost of space. It is the organisations associated with these types of technology that will influence more of what we do in space - challenging more than we ever thought possible. It is this realm of possibility that has now created a global and robust space industry.

Australia's space industry is only in its infancy. This is an economic advantage to Australian industries - we have a diverse set of industry players whose research, development and technology investments are complementary to those of the space industry. So instead of founding a new space robotics autonomous remote operations company, Woodside has helped establish the Australian Remote Operations for Space and Earth (AROSE) consortium – consisting of the people who already do remote autonomous operations. At Woodside, we are advancing our remote operations and autonomy for Earth capabilities. We have every belief that this can be leveraged into space.

While there are some companies that are purely space orientated, all companies will see space as a medium to acquire data and facilitate communication. New collaborations are starting to form, for example in agriculture planning, if you do not have a space acquired data set or hyper-spectral imagery, you are missing a major data segment to advance your business. As such, we will see agricultural companies merging and partnering with companies that have space capabilities and thereby improving farming methods and production.

A mission to Mars is a bit of a fantasy unless we know how to harvest resources to get to and from Mars along the way. I have always been a big supporter of using the Moon to get to Mars. I believe that we will use resources from the Moon to actually get to Mars. If you only want to repeat the past and just go to the Moon, you would not put any infrastructure on or around the Moon, you'll just go to the surface of the Moon and bring everything with you for each trip. If you want go to the Moon and have the sustained ability to go somewhere else as well, you will put in orbital depots around the Moon and surface infrastructure in place to enable the staging of propellants and the space ships that will take us beyond the Earth-Moon. The robotic probes that we have already sent to Mars are telling us a lot about the Mars environment and the history of potential life. Perhaps by 2030 we will know.

"The missions already being undertaken in the space sector are going to result in people living on the Moon in 2030. When people look up at the Moon and think that there are actually humans living up there, it will dramatically shift our world view."

Dylan Taylor
Chairman and CEO, Voyager Space Holdings

Josef Schmid

Dr Josef Schmid is a Flight Surgeon at NASA and a Major General in the United States Air Force Reserves. He is the former lead for Space Medicine Training, responsible for training medical students, other flight surgeons, astronaut crew medical officers and biomedical engineers. He is also the former Lead for the Electronic Medical Record system. He has been a crew surgeon for shuttle missions STS-116, STS-120 and for the long duration missions to the International Space Station. He became an aquanaut during a 12 day mission to NOAA's undersea Aquarius habitat. Dr Schmid is also the Co-director for the Aerospace Medicine Residency at the University of Texas Medical Branch, Galveston.

Space travel is no mean feat. It takes tremendous energy to hurtle your body through space at 17,500 miles per hour and then you need to dissipate this energy when you return. How do you do that safely?

By 2030, many more people will want to and be able to fly on sub-orbital, orbital and maybe even lunar orbital flights. They may even land on the Moon.

'Astronauts' will no longer be the young, fit and healthy; rather older people, and even people with medical conditions will be flying in zero gravity. Space travellers will go further and space missions will be deeper and longer with advancements in medicine and technology enabling these people to fly. The space travel we envisage in 2030 means people, who would previously be 'disqualified' as astronauts, will now be fee paying tourists.

The increase in space travel will open up unbelievable benefits and opportunities.

Zero gravity is actually a good analogue for how the body develops. In the womb, the foetus is in zero gravity and it is here that the heart, lungs and kidneys develop. Understanding how the cells come together to form tissues and how the tissues form structures and then how they interact with other organs in the body all happens in zero gravity. This introduces the possibility – and potential opportunity – of growth of new organs and the repair of others in space.

"The sky is no longer the limit."

Treatments for medical conditions that accelerate in space may also lead us towards prevention and a cure for these diseases. Astronauts can lose one percent of their bone per month when they don't exercise, and when they do exercise the bone may position itself in a new manner into the cortex of the bone. This may be similar to the impact of when people are bed ridden, and elderly people who are at risk of fractures. So understanding and treating this will not only have a benefit for space travellers but terrestrial benefits as well.

Presuming you have avoided colliding with space debris you have now landed on the Moon, what do you need to do to keep healthy?

The Moon is dusty, not dusty like your home, but rather Moon dust is produced from micrometeoral hits, which occur regularly. Other 'dust' is sharp and if this gets into your lungs or eyes it could cause damage. It's hard to defend yourself against those. If it hits your spacesuit, how are you going to repair it instantly? And then there's radiation. On Earth, we're protected by the Van Allen belt and also by our own atmosphere. On the Moon, there are no protections. We will have to find a way to defend against not only background radiation, but also the constant risk of coronal mass ejection or other events from deep space which may deliver a more lethal exposure.

I believe there are four steps to mitigate these risks.

First of all, prevention – identifying potential risks early on and keeping everyone who is going to fly healthy. Next, we need to prepare for what we cannot prevent. AI and other technologies will play a key part here, looking at past medical issues in orbit and on land, augmenting our ability to recognise potential medical issues through diagnosis, testing and potentially assisting with treatment.

We also need to empower and support our astronauts, equipping them with the skills and knowledge to be able to make quick decisions and act fast when issues arise.

The opportunities for cooperation and peace are absolutely paramount and that's what got me excited way back when I saw the Apollo Soyuz. As long as we cooperate on an international level, we'll have more chance for peace and the human race will advance.

And finally, when packing for a trip, AI can help us prepare, analysing from past missions and from reams of available health data informing what we need and what can be used for multiple purposes, from IV fluids to surgical tools that can also be used to repair broken equipment. This is the exciting part, using what we know from the past through the use of technology to find new solutions.

Finally, psychosocial support is something that is overlooked, but it is an important issue. We send people to extreme environments in dangerous and isolated locations. Space can be lonely and communication often difficult. Think of how much we communicate through touch and smell. How we deal with mental health will be vital.

In the absence of a physical counsellor, AI may have a role. Changes in behaviour can be picked up by AI with the potential of developing appropriate and effective support.

When it comes to the future of space, the sky is no longer the limit. I'm excited about what the next ten years will bring – and with the medical progress we make in space, we will see tangible benefits on Earth. To make it successful, we need to ensure cooperation between all players.

The views expressed are those of the author and do not reflect the official policy or position of NASA, the US Air Force or the US Government.

Karen Andrews

The Hon. Karen Andrews MP is the Minister for Industry, Science and Technology in the Australian Government, a role that she's had since August 2018. She represents the Division of McPherson in Queensland and is a member of the Liberal National Party.

"One of the great challenges is bringing the community with us on the journey."

Moving towards 2030, Australians have plenty to look forward to with a rapidly growing space industry. In the words of our Prime Minister, The Hon. Scott Morrison MP, "space captures the imagination and inspires us all. It develops new technologies that improve life on Earth, offering huge economic and job opportunities." These opportunities are only going to continue to grow. Australians will be surprised by the variety of people and businesses who will benefit from this emerging ecosystem, with the sector tripled in size to AU$12 billion a year with job opportunities for 30,000 people.

Space is already a big part of our day to day lives, with the integration becoming more pronounced. The evolution of technologies from space are growing at a rapid rate, presenting incredible opportunities for Australian people and business. For example, satellite positioning technology and the work to improve the accuracy of positioning services from metres to centimetres is very exciting, benefitting developments in autonomous vehicles and making them closer to reality.

One of the great challenges is bringing the community with us on the journey. Space is awe-inspiring but we need to make sure every day Australians can see themselves as part of the story. We need people to know job opportunities are not just for astrophysicists and engineers but also for our tradies, from electricians to boiler-makers.

The benefits are real and tangible – whether it's helping our farmers manage their crops, better mapping bushfires or getting our ride share to pick us up from the right spot.

By 2030 it will not just be space businesses but the businesses that support those space businesses that will grow. Gilmour Technologies, a rocket company in Queensland, has over 300 local small and medium sized businesses that form part of their supply chain making their space projects come to life.

It's these flow-on effects that make space such an exciting industry proposition that will continue to grow the Australian economy.

The space sector is no longer just the domain of governments, it's a fast-growing and fiercely commercial sector, driven by the falling costs of launch and rapid technology development.

Engagement between the public and private sectors is central to the space sector thriving in Australia. The Australian Space Agency is designed to be the welcome mat for international partners who want to engage with our businesses.

One of the Australian Space Agency's key roles is to open up a dialogue with Australian businesses and universities. Their headquarters at Lot

Fourteen in Adelaide allows Agency staff to walk around and engage with industry partners also based there, like the Smartsat CRC and Myriota.

In order to continue growth in the industry, the Australian Government is investing AU$150 million into Australian business to help them be part of NASA's return to the Moon and then on to Mars.

Our AU$15 million International Space Investment (ISI) initiative will also back strategic space projects that build relationships with international space agencies for the benefit of the Australian space industry.

In addition to supporting the transformation of our space industry into new supply chains, more international agreements are being signed to open doors for Australian industry to tap into global markets. Our most recent agreements are with the likes of NASA, Germany and the European Space Agency.

In closing, Australians have much to look forward to looking towards 2030. Continual investment in the space industry is helping us make better business decisions, improve our productivity, open up our markets, create new jobs, and build our skills. It is literally revolutionising how we do business and how we live.

For the first time in Australia's history, we will have a national space agency that will co-ordinate all these activities, and bring Australia's businesses to the world. The Agency will showcase our incredible talents. It will open the door for our businesses to create jobs by working on the biggest missions in the world. And I am confident it will also help Australians see the endless possibilities of careers in space – and inspire our younger generation to pursue STEM studies.

I look forward to the exciting months and years ahead – as the Australian Space Agency takes shape and becomes a permanent part of our economy.

Larry Marshall

"New frontiers of the space industry will open up."

Australia's geographic location in the southern hemisphere has always been attractive for space related activities. Profound transformation of space technologies alongside increasing demand for space-based services will drive the emergence of a new space age, and with it, many new opportunities for the growth of Australia's own space sector.

Our country's attributes of large land mass, low light and electromagnetic interference will be capitalised on, with integration into global value chains. By 2030, Australia will be developing positioning services and technology, Earth observation calibration, validation and data analytics, provision and management of world-class space tracking facilities and space situational awareness activities to leverage and underpin our natural advantages.

Over the next decade, the space value chain will broaden, covering upstream activities which focus on ground systems, launch and operating objects in space, together with downstream activities that utilise space data and technologies across a range of applications.

Innovation at the downstream end of the space value chain will lead to an expansion of the applications for space derived data and services, creating new businesses, new industries and new ways to solve grand challenges. We'll see breakthrough solutions in areas like precision agriculture, environmental management from forests to reefs, mining, and many other sectors.

'Space 2.0' will continue to change the industry, based on the introduction of miniaturised, low cost technologies, and more sustainable and reusable systems, with improved power and propulsion on the horizon. Convergence with advances in high-performance computing, materials, robotics, and increased data exchange, including through artificial intelligence and advanced analytics will continue to push transformation.

New frontiers of the space industry will open up, including space-based tourism, energy, manufacturing, asteroid mining, deep space missions and living 'off world' in closed-loop systems. Australia as an established supplier of R&D to international space agencies will be embedded in the NASA Artemis mission to the Moon.

Data derived from space will provide a unique view not available from other sources. Australia will be operating satellites as national research facilities to inform our Earth observation monitoring and management practices.

Innovative space technologies, services and business models will be game-changing for the space industry, but also transformative to on-Earth industries through diffusion of innovations into everyday life. Completely new disruptive industries will be enabled, such as 'data mining' industries that derive value from space data.

The deluge of data is amplified by space, almost beyond our ability to cope – at CSIRO alone we already receive more data from space than the global internet generates! And globally, the daily volume of data generated will continue to increase, driven by increased sensorisation and digitalisation across industries, governments and households.

Dr Larry Marshall is a scientist, technology innovator, business leader and the Chief Executive of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's National Science Agency and innovation catalyst. Prior to joining CSIRO in 2015, he was the Managing Director and Founder of a number of companies in biotechnology, telecommunications, semiconductors and venture capital.

So artificial intelligence will need to step up and help us turn that deluge from commodity or worse, waste – into genuine insights and actionable decisions.

Data exchange and associated big data analytics will be creating significant value across industries. When used intelligently, the larger variety, access speed, and volumes of data from space-based platforms will allow for more informed decision-making and increased productivity. This will require a step-change in data analysis techniques including artificial intelligence, machine learning and on-board processing.

National research agencies like CSIRO will continue to lead the technical research sector and operate our national research facilities. We will continue with the 'deep tech' research that is too expensive for small companies, and work with SMEs who will take the products of our research to market here and overseas and support the commercialisation pathway of the research including spin-outs from CSIRO.

Our 2030 integrated end-to-end Australian space value chain, with both domestic and international customers, will continue to be strengthened by Australia's well-established relationships, like with NASA, for the national benefit.

I'm looking forward to more Australian lives benefiting from technologies developed for space missions. I remember when we got excited about food and drink products that astronauts ate and drank, but amplify that into more life-changing technologies that tackle environmental, industrial and energy challenges.

Australia has grown industries from our natural resources, like agriculture and manufacturing, which will be critical to developing solutions from the resources we find on other planets. The new materials we create to solve problems in space could in turn help us transform commodity markets based on raw materials into unique and higher margin, value-added products for national export.

To grow the national space industry, Australia must take advantage of its natural advantages and strengths, and align them with industry trends. To fully exploit these advantages requires investment in key foundational enablers, including infrastructure, business ecosystems and R&D capabilities.

The success of our space industry will depend on our ability to inspire and to demonstrate the connection between the space economy, its impact on the lives of Australians and the competitiveness of the nation's industries. Growth of Australian space ventures will see more opportunities to both spin in leading Australian technologies and capabilities, and to spin out space derived technologies into everyday life.

Growing our nation's space industry requires an innovative culture and ambition to challenge and inspire our future generations.

CSIRO is an integral link between public research and commercial industry. Technology diffusion and knowledge transfer is a key driver for space exploration, and R&D is the applicability of these technologies to land-based industries and daily life.

To fully exploit the value of space technology, the industry must be connected with all established Australian industry sectors. A dedicated forum focused on translation of these technologies into other industries could help fast-track international collaborations and technology and knowledge transfer both into and out of space programs.

For example, the impetus for deep space missions to make equipment smaller, lighter and more robust is particularly useful for the mining industry.

Alongside commercial market development, judicious government procurement of locally developed space innovations will encourage and help build Australia's space industry and help to maintain a critical mass of capabilities in the country.

For example, continued open government repositories for data are critical for development of value-adding space-derived services.

Australia has many strengths to leverage as we grow our national space industry – we bat above our weight in scientific and technological expertise, and we have many natural assets in our landscape. But space is a global industry and Australia is a new and small player, so to engage and ultimately compete we must grow our international network by strengthening existing partnerships and forging new ones based on common interests, shared values, and reciprocal benefit.

I am confident we have exciting and unique expertise to offer the world, but we must always make sure Australia benefits along the way.

There is a risk that we try to boil the ocean – forgetting how small we are compared to space and to the international space community. We need to focus on where we can be really valuable and differentiated, if we don't focus, we'll smear out like the proverbial bug hitting the windshield of the rocket as it flies past us.

Megan Clark

"In 2030 we will have created jobs we can only dream about today."

Dr Megan Clark is the Head of the Australian Space Agency and a director of Rio Tinto, CSL Limited and CARE Australia. Prior to this, she was Chief Executive of the CSIRO, Director at NM Rothschild and Sons (Australia) and Vice President of Technology and subsequently Vice President of Health, Safety and Environment at BHP Billiton.

The next ten years holds great opportunity for Australia in terms of its role in space. By 2030, we will be participating in joint space missions with commercial partners and international space agencies such as NASA and the European Space Agency. Australia will use its unique position in the Southern Hemisphere to be home to ground stations in every state and territory to send commands and receive information from satellites and space craft in low orbit. Australia will be a critical geographical location for communication with space, not just in our lowest orbit and middle orbit, but also as part of the lunar communication network. I'm certain that we will have live feeds from Mars and from the International Space Station, which will beam right to the main street of Australia, inspiring our next generation.

Remember, Australians are innovators, we're the country that invented Wi-Fi. Australia can play a pivotal role in the next generation of communication technology as we use laser light to communicate in space and between space and Earth. Australia is a big island with large remote areas. By 2030 space will be a ubiquitous part of our communication networks linking our land, sea and airspace. Our trains, trucks and airborne taxis will know their precise positioning to within centimetres using global positioning satellites and mobile phone networks.

The third area where Australia will participate actively in space is in using our knowledge in robotics in remote asset management. Put simply, we will utilise the maintenance and operations robots we already use in the oil and gas industries – but on other planets. The robots will assist with the work we know we must do on the Moon and Mars. The future will see us bring these advances in working remotely, back to our shores, allowing Australia to continue to position itself as the leader of remote operations, as we are today.

While some may be concerned about the impact of technology on jobs – I feel we'll actually be creating jobs, jobs we can't fully imagine today. Jobs building and controlling robots that are not on Earth, but on the lunar or Martian surface or on celestial bodies that we're exploring. By 2030, many kids will be going into these jobs thinking that they are quite normal.

We often think of the space industry as being focused in STEM. In reality, there is actually such as broad range of opportunities that if those interested in joining the industry keep their eyes open, they will be quite surprised to see that there is a place for all. For example, philosophers and ethicists will be needed to analyse the impact of possible discoveries of life in space; lawyers to draw-up multi-lateral agreements as we cooperate in space; communication specialists as we enable longer and deeper space missions; and electricians to set up these connections. There are an extraordinary number and range

of jobs required. For those keen to be involved, giving advice to our younger generation now, I think the most important thing is to stay curious, learn about what the industry is doing and make sure that you follow your passion.

But to be able to achieve our ambitions for 2030, there are areas where we need technology to advance. Firstly, for missions of longer duration we desperately need larger rockets and novel propulsion systems, which can refuel while in orbit. As well, one of the biggest challenges we will face while working on Mars will be the exposure to radiation. The International Space Station sits only about 400km from the Earth, meaning that it is within the shadow of our magnetic field. When we go beyond that towards Mars and the Moon, we will be in a realm where we are not so well protected. While water is a good barrier to radiation, and possibly part of the solution, this issue has not been fully solved for human missions yet.

Much of what we do in space is being automated as seen on the International Space Station, which was of course originally designed to be for humans. We will have automated lunar gateways orbiting the Moon and missions to other planets. However, space exploration goes into something much more innate in human nature. I do think people will continue to be part of our exploration programs. For years we have sent rovers, orbiters and satellites to space, providing insights to space that we have never seen before, however this has never really quenched our thirst for truly 'human' space exploration.

Certainly by 2030, I'm hoping that we'll look back and reflect on a growing, robust and vibrant space industry in Australia. We'll have jobs that we couldn't have dreamed of for our kids to pursue. I hope we'll look back from the Moon and Mars and know that we've been at all times safe as we explore and expand into space, that we've never lost an Australian leaving Earth, in space or coming back, and that we have operated in that environment as a very responsible global (galactic) citizen.

Nikolai Khlystov

"Space will become much more visible and accessible."

What big changes do you think we'll see in the space sector in 2030?

I think it will be no surprise to space enthusiasts that there will be an increase in commercial activity, including space tourism that will get space into the headlines and into people's minds. As people can start to afford it, we're going to start meeting people who have actually been able to take a trip to space. We'll see the launch of large satellite constellations which will also introduce risks, particularly relating to orbital debris. There's a good chance we'll land people on the Moon by 2030. We may even see countries or commercial actors start to establish a permanent base.

These factors are going to make space much more visible and accessible to the general public, and especially to children and how they perceive the sector. The next ten years are going to have a profound cultural impact.

How do you think we ensure a sustainable future and what does that look like in ten years' time?

One of the biggest risks we have is sustainability. The orbital debris issue is very serious and it is important to work on several different fronts to pre-empt and to tackle the debris issue.

It is going to be really important for the large constellations that are proposed to have robust management systems, to be autonomous and able

Nikolai Khlystov is the Lead for Future of Mobility Platform at the World Economic Forum and also manages the Global Future Council on Space Technologies, which brings together global multi-stakeholder experts in the space sector. Passionate about the potential of humankind to expand its existence beyond Earth by conquering new frontiers, Nikolai is a thoughtleader and promoter of space exploration.

to respond quickly to any incidents. Hand in hand with the development of this is active debris removal, and how to take satellites out of orbit.

On the assurance side, the guidelines need to be strengthened. A lot of experts in the field feel that the guidelines are too relaxed at this point, that the '25-year rule' for time to de-orbit does not correspond to the reality of the 21st century.

There are aspects that the industry will build from the bottom up instead of waiting for formal guidelines or regulations. I believe the industry is interested in doing the right thing and will start taking action voluntarily to ensure the overall health of orbits. That makes sense on a commercial side, as well as for sustainability. Orbits are difficult to clean up, so one or two accidents could really ruin it for decades if not centuries to come.

Another big threat — a threat and opportunity — is the resource race. By 2030 we could see public or private actors planning missions to asteroids or the Moon for resource extraction. Guidelines are needed to prevent a 'wild west' scenario in space: how can those resources be used, and who has a right to them. We need to ensure that there is opportunity for the commercial sector to develop that industry, but that it is done sustainably.

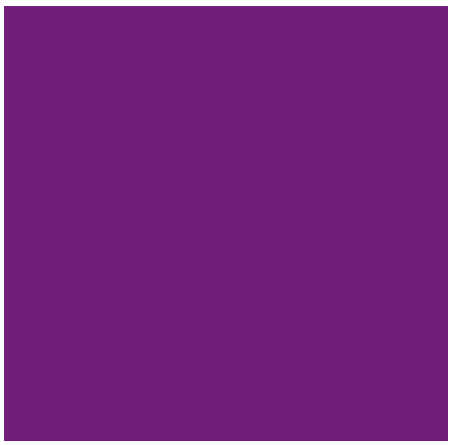
In ten years' time what sort of space businesses do you think we'll see?

Space tourism will be a big thing over the next ten years. I think we'll have a range of offerings in sub-orbital space, including high-altitude balloons. That might be a more accessible option that gets people closer to space. Space hotels could take off, we could even start seeing the first of these taking shape or launching by 2030.

In terms of productivity, there are large constellations with hundreds of satellites planned, and that's going to provide for some exciting opportunities and connectivity. Linked to that on the business front, is the active removal of old satellites, rocket bodies and large pieces of debris.

Servicing, repairing and refuelling as a business is going to grow, and with that you'll have additional innovation technologies that come online for on-orbit servicing, which is going to support the growth of the sector and future developments.

Launch of course is going to support all of these developments. Launch providers of different sizes are trying to develop the optimal launch vehicle. Reusability is going to be a big commercial factor, and I think that's going to become the norm by 2030.



What do you think the role of groups like the Forum will be in the coming decade for the space sector?

This is an area where you see multi-stakeholder collaboration increasing - commercial actors of different sizes, government bodies, the UN, various foundations and even private individuals - who are becoming active in the field. The Forum can support the development of formal processes and the development of various and best practice guidelines, but also provide a more informal, neutral platform for multi-stakeholder engagement and collaboration. The Forum can provide the means where these stakeholders can come together to discuss the issues and opportunities where each of them plays a role. Everybody has a voice in such an environment and that builds trust.

"When you see the Earth from space, it feels like the Earth is our spacecraft and the people that inhabit it are its crew. Such a view convinces us we need to look after our Earth and protect it."

Pamela Melroy
Adviser, Australian Space Agency
Former NASA Astronaut

Nobu Okada

"...take action now for a sustainable space."

Nobu Okada is the Founder and CEO of Astroscale. Founded in 2013, Astroscale is developing solutions for active debris removal services to mitigate the growing and hazardous build-up of debris in space.

What can we expect for the space sector in the next ten years?

The space sector is expanding rapidly in terms of investment, innovation, utilisation and discovery. In the next ten years society will reap untold benefits from this growing interest in space, but there will be consequences. This rapid expansion will lead to one of two scenarios: a sustainable space environment or an unsustainable one. The density of objects in space is approaching a critical level already and when we add thousands more satellites in the near future, the potential for collisions that lead to a proliferation of debris becomes more likely. It is crucial to take action now, otherwise we will head in the direction of an unsustainable future.

What do you think are the key challenges to achieving sustainability in space?

To use an analogy, if we look at any highway and there is a broken-down car, roadside assistance services will remove the car so that it is not a hazard to other vehicles. To facilitate this, there are road rules, a traffic control system and a car removal service. The same systems can be applied to space. The orbital "highways" are already very congested with more than 23,000 pieces of debris larger than ten centimetres in diameter and hundreds of millions that are smaller. We need more clear space traffic management, which includes better awareness of the orbital environment, and safe and reliable debris removal technology. The space community is taking steps forward on both of these topics as there are global discussions on developing more accurate and transparent observations – also called space situational awareness (SSA) – and companies like ours are working on the technology and policies to facilitate active debris removal (ADR).

Do you think we'll be able to achieve agreement over the next ten years on what space laws should exist?

Compared to six or seven years ago, we have seen a proliferation of regulatory discussions around the world. If we look back two to three years ago, only the United Nations and the Inter-Agency Space Debris Coordination Committee (IADC) had intense discussions about space debris matters. Now we see trade associations, industry coalitions, academia, and sometimes even individual countries coming together to create rules and guidelines, so the awareness of the issue has greatly improved. One of the things that makes me more confident about the future is that in June 2019, the United Nations Committee on the Peaceful Uses of Outer Space approved Guidelines for the Long-term Sustainability of Outer Space Activities. Of course, these are just guidelines, but it's generally quite difficult to get a unanimous agreement on international matters, so I think it shows that the UN is a

good platform to obtain international consensus on global issues. I'm more optimistic about the future now as we've seen some progress compared to several years ago.

How do you think we will overcome some of the cost-related challenges to achieving space sustainability?

If a service costs a lot then people will be reluctant to use it. We need a reasonably priced debris removal service and we are getting there. If we use the example of chlorofluorocarbons (CFCs), everybody knew that CFCs were depleting the ozone layer but at the time there was no technology to replace it. Thanks to innovation, companies came up with alternatives to CFCs, and at first, they were very expensive. However, governments came together and cooperated to regulate the removal of CFCs and as a result, the alternatives became affordable. I believe cost-effective debris removal solutions will become the incentive for countries to agree on the next steps for a sustainable space. In 2020, Astroscale will launch the world's first commercial debris removal technology demonstration using magnetic capture technology. After researching various options, we decided that magnets are the most light-weight, minimally intrusive and low-cost solution for capturing objects. At least one constellation provider has the same opinion - in December 2019, OneWeb announced that they will mount docking plates on their satellites for debris removal which are compatible with magnets. This is a step in the right direction for the standardisation of best practices on how to be a responsible player in space.

What will debris removal activities look like in 2030?

In 2030, I hope to see debris removal as routine work in space, much like waste management on the ground. We want it to be so routine that we eventually don't make headlines for simply taking out the trash. As for Astroscale, we also want to expand our business to in-orbit servicing. Let's say ten percent of satellites become defunct in space. First, we must address the defunct satellites by removing them from orbit, but the next question is how can we help make sure the remaining 90 percent of active satellites stay active? With in-orbit services such as life extension, satellite relocation, repair and refuelling, we can prevent these satellites from becoming debris in the future. I think this is going to become quite a big market.

Pamela Melroy

"Australia's astounding progress as an international player in space."

Pamela Melroy is an adviser to the Australian Space Agency and Director of Space Technology and Policy at Nova Systems. She is also a retired United States Air Force Colonel and test pilot, former NASA Astronaut and Shuttle Commander and has spent over 38 days in space.

By 2030 there will be substantial changes in the role of government within the space sector. We should expect to see space becoming much more commercialised. You only have to look back to 2010 in the United States when just a few people had heard of or understood commercial space - it seemed highly unlikely to many that we could have commercial achievements in something as technically challenging as going to space. Today though, it's a completely different ballgame. Organisations such as Virgin Galactic are beginning to become big players and this trend will only continue over the next ten years as it has in other transportation-related industries.

While commercial ventures into space will become more common, government support will continue to play a role. For example, in less than two years since forming their own space agency, Australia has already taken steps that can be described as nothing short of astounding. One of the things that I always tell people is that all space agencies have challenges. At some point Australia will have the same problems as other more mature space agencies, the effect being that they get to the same collective point, all wrestling with the future together. At that point, Australia will be firmly embedded in the Global Space Community as a big player.

I'm convinced we will see interesting technologies and ideas in the coming decade. The mining, oil, gas and remote asset management sectors are the crown jewels in Australia's technology arsenal; I expect these industries will be translated into space.

When it comes to skills, all kinds of engineering will continue to be very important within the space industry. I also think that cyber and automation technologies will have greater importance to the sector within the next ten years. These are exciting times for our next generation!

Past human spaceflight programs have had enormous challenges around life support systems. They are still bespoke, exquisite designs, and firmly tied to the spacecraft. The Holy Grail is a self-contained life support system that you could put into any spacecraft that would allow humans to thrive.

Another technological issue we will likely face is being able to maintain effective communication networks, especially over long distances such as between space and Earth. To meet the connectivity objectives required in space, we will have to improve the robustness of networks so that continual communications dropouts do not occur. Business depends on it.

With autonomous technology on the rise, some immediately equate that to the loss of jobs. I think instead we should be looking for the up-scaling and growth in the type of jobs that support automated outcomes, such as vehicles and decision-making systems, many of which are jobs that don't necessarily require a university degree.

I would argue a challenge we have is that the people that currently maintain important sub-systems in the space sector have university degrees – I believe we need to move away from this as a baseline requirement. We need to design and establish a space work force of the future which isn't exclusively tertiary educated, one more open to talent of all types.

Another challenge we face is ensuring regulation is fair and equitable, particularly around the use of resources in space. This will allow all to thrive and enable commercial industry to undertake major infrastructure enhancements which will benefit everyone – on terms that are predictable and fair. We currently rely on space regulations dating back to the 1960's, I think we will require new thought leaders to drive the dialogue around the most responsible way to use resources on/from the Moon, Mars and elsewhere in our solar system.

When you reflect on our world, it's hard not to conclude that there may be national security challenges arising over the next ten years. While effective discussion and dialogue will help mitigate these, the rising capabilities and competing interests of major powers as they seek to control space will again see the need for effective legal parameters.

Today, China has a rover on the far side of the Moon and a lunar communications relay. This is the start of a push that many believe will continue. Such actions – from multiple nations – will have national security implications that are difficult to predict and respond to.

There has been a tendency to silo and isolate commercial, civil and national security space. I believe we have to think about it as a more integrated strategy – what is it we are trying to achieve as a whole? What are the capabilities we collectively need to develop? If we have routine space commerce back and forth between the Earth and the Moon, and you have a commercial version of GPS and multiple entities performing activities on the surface of the Moon, how do you together protect commerce? What happens if your scientific outpost has a dispute related to access to a resource that is required to keep humans alive? How do we work through that? Having a globally integrated approach is the major challenge that all governments face.

Finally, while I do not believe that space travel will begin to become affordable to the wider public by 2030, the new and evolving world of virtual and augmented reality will help give people a deeper understanding of what space is actually like, especially around the environment and how we look after it. When you see the Earth from space, it feels like the Earth is our spacecraft and the people that inhabit it are its crew. Such a view convinces us we need to look after our Earth and protect it in order to keep it healthy. I can confirm this through my own personal experience seeing the Earth from just that perspective.

Peter Beck

"I hope that access to space will be completely democratised"

Where do you think the space industry will be in 2030?

Space is quite cyclical in its advancements. Every decade or so there's a big project that takes place. At the moment, it is the proliferation of small satellites in low Earth orbit providing internet services. I think there will be huge numbers of spacecraft in orbit, and a lot of the terrestrial services that we utilise today will be provided in orbit, with low latency, and be prolific anywhere on the planet.

That's the positive outlook. However, some would say that the space industry is in a bubble right now and while that bubble may not burst, it's certainly going to deflate a bit. The potential downside of the bubble is that extra-terrestrial constellations fail to be economic and are outpaced by the terrestrial rollout of services such as 5G – the space industry falls into a slight recession as it has done in previous cyclical decades. The benefit with the kind of dedicated small satellite launch we've made possible, is that it's faster, easier and more affordable to get new technology on orbit to try new things and develop new capabilities to replace obsolete ones, those on the ground and in space.

Generally, people in the space sector are very optimistic about what the future holds for space and the technologies being developed.

What do you think launch frequency will look like in 2030?

Rocket Lab's Electron was the fourth most launched vehicle in the world last year, following China's Long March, Russia's Soyuz and SpaceX's Falcon 9. And we launched six times. If you look back to the 1960's, there were around 20 launch pads active at Cape Canaveral alone, all firing up Atlas, Titan and Delta rockets. So, we've got some way to go before we get back to the 1960's rate of launch.

I certainly hope access to space by 2030 is completely democratised. It shouldn't have the level of complexity that it has now. Provided the market stays buoyant, you're going to see a continual drive of increased launch frequency and easier access.

If you build the internet in space and it's accessible, we're never turning that off. We may be maintaining up to 30,000 spacecraft in orbit, and that requires a very high launch frequency. These kinds of space applications, these very large infrastructure builds are going to drive launch frequency.

Peter Beck is the founder and CEO of Rocket Lab, a leading US and NZ based launch and small-satellite service provider specialising in low cost access to space.

What will help bring down the cost of launch by 2030?

Production and reusability are the two elements that are going to have the biggest impact on cost. The more you produce something, the cheaper it gets. The more you fly, the cheaper it gets. For us, the majority of the composite work is fully automated, which helped to bring down the time of production from hundreds of hours to just 12. We 3D print all of our rocket engines and have done since day one. 3D printing as a technology in space propulsion has been revolutionary.

It's going to be challenging to make a massive jump all the way through to aircraft-like reusability. But I do think we will see reusability as the norm and at least some attempts at complete vehicle reusability.

Will new types of fuels play a role in bringing down cost?

Governments have spent billions of dollars and decades researching this. Take the highest energy combination on the periodic table: hydrogen and oxygen. The space shuttle used hydrogen and oxygen, and there are no new elements that are going to yield more chemical energy than what we've already got. The hydrogen and oxygen combustion devices we have are operating at 98 percent combustion efficiency. You can argue there's another two percent there, but that's not an order of magnitude. My personal view is the way you achieve an order of magnitude is to walk away from burning fuel – it is a crude way to propel yourself. The rocket engines of the future are not going to look like the rocket engines of today. They're going to be microwave or laser transmitted energy.

If you think about chemical combustion, the highest exhaust velocity that you can achieve is only a miniscule fraction of the speed of light. If you go up into space and you accelerate for an eternity, you'll only ever reach the exhaust velocity of those combusted products. We need propulsion that has exhaust velocities higher than that. Ion propulsion can potentially be a greater fraction of the speed of light. Laser propulsion, where you beam a laser onto the back of spacecraft, may reach as high as 0.25 the speed of light. There needs to be new technologies to support the bigger ambitions we have. But that's getting a little beyond a decade of research.

What does Rocket Lab look like in 2030?

Very different to what we look like now. We're trying to make space access really easy. Launch has been a huge barrier which we believe we've solved. We're now transitioning from a launch company to a space company and have started building our own satellites. The next barrier is helping companies reach their ultimate use case for space. For example, if you're building a spacecraft to take pictures, you actually just want the pictures. You don't want to have to design, build and operate the spacecraft.

I want commercial entities to worry about the revenue that they want to generate from space and governments to worry about the capabilities that they need. In my opinion, anything else should be a commodity including the spacecraft and launch. Without having to build your own constellation or build your own spacecraft, then we can throw a sensor on one of our platforms and provide that information. It's really taking the next step towards democratising space. It's not just about launch, it's not just about spacecraft, it's about how we make data access and information from space easy.

This is an incredibly exciting time. As I was growing up I always used to wish I was born in the Apollo era because I figured that was the most prestigious and best time there in was space. But I honestly believe today is that time, because you just see so much innovation. We've flown high school students' spacecraft, we flew the first Australian academic spacecraft. While I think there are big bets being placed and maybe not all those bets are going to come off, it's a net upwards trend.

Rebecca Cowen-Hirsch

"To innovate beyond what we cannot even begin to imagine today."

For a long time, ten years was not considered a distant horizon in the satellite realm. Today, with technology advancing faster than ever before, the cost of deploying space assets reducing significantly and the growing competitive environment, we are seeing a significant acceleration of timelines throughout our industry. We successfully forecast these trends within Inmarsat and have been well-positioned to invest ahead of the demand curve. By 2030, we'll have more buyers, a greater range of applications and users more focused on the betterment of lives for people who today don't even consider how dependent they already are on space.

Currently, approximately 80 percent of the roughly US$400 billion global space economy is commercial space activity*, and this will only continue to expand over the next ten years. And in doing so, there will be applications that are much broader than just navigation and well beyond satellite communications. These new applications span from known knowns such as on-orbit servicing and debris removal, known unknowns such as space weather predictions, precision farming and environmental assessments, and finally, unknown unknowns, which leverage the vast amount of space data available to create solutions that we cannot possibly anticipate.

Rebecca Cowen-Hirsch is the Senior Vice President for Government Strategy and Policy at Inmarsat Government Inc. Rebecca is responsible for establishing Inmarsat's strategic direction with respect to the US government and has worked in defence, aerospace and executive leadership over the past twenty-five years.

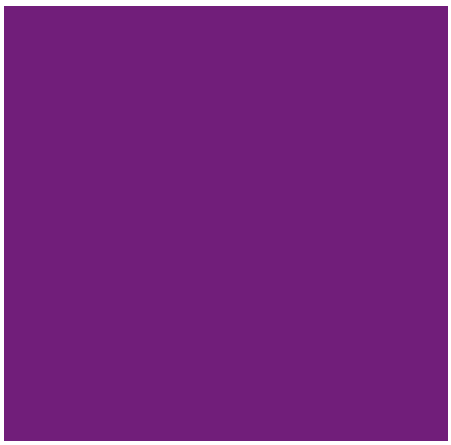
In terms of new innovations in the satellite communications space, we will have a whole range of additional services that can be consumed by a much broader range of international stakeholders. By 2030, technology will allow for optics to have a different ground architecture that supports satellite communications or services. As a result, we expect there to be an integration between the space segment, the terrestrial segment and the wireless segment, with communications flowing between satellite communication, terrestrial communication or wireless, whichever is more appropriate for that particular application, atmospheric condition or regulatory environment.

Satellite communications will also play a foundational role in any future Cislunar economy which will be very interesting to watch and hopefully play a role in. In the next ten years we will really see what it means to do Cislunar. The question of whether there is an economic and imperative route to Cislunar still remains to be seen. However, one thing is clear, it is not possible to accomplish any of these missions without resilient, reliable communications.

The two key challenges still facing the space industry are firstly, space situational awareness and secondly, the role of government.

The need for space situational awareness will only become more pertinent as space becomes more crowded. By 2025, it is predicted that there will be 25,000 additional satellites in space, the vast majority in low Earth orbit, and with the forecast arrival of space tourism, the risk of a collision will only increase. Once you have people in space, the risk increases dramatically. That is why space situational awareness and debris mitigation is key to the success of the space sector over the next ten years.

Directly related to this, is the role of government in the space sector. In the past, governments were out in front in terms of space innovation, investment and technology. More recently, we have seen a pivot towards the commercial sector, where innovation, technological advances and the capital available to industry now outpaces government. This shift, however, does not alleviate the governmental responsibility to create regulatory and policy frameworks so that standards of behaviour can be established and impressive objectives such as the pursuit of economic opportunity and freedom of navigation are equally available to any nation. Otherwise, the commercial industry may do what is in its best business interest, which may or may not be in the best interest of shared global value. Ultimately, it will need to be an international coalition of likeminded nations that establish norms, because there is no sovereignty in space.



Looking forward to the future, in order to sustain momentum, a very significant and continued investment is required into the talent and skills behind these advancements. So, being able to invest in the next generation of scientists, technologists, engineers and advocates who can continue to innovate beyond what we cannot even begin to imagine today is more important than ever before. This investment is going to payback in economic prosperity, global impact and can provide benefits to mankind on a daily basis.

**Source: The Space Report 2019 Q3, Space Foundation*

Rick Ambrose

In 2030 we will have a vibrant space economy, with space exploration and the presence of humans in space at the core. There's a lot that needs to happen to make this a reality, and it's my hope that by then, we've got at least dozens of people living on the Moon and small ferries of ships back and forth.

While we can get onto the Moon quickly with our current technologies, the real issue is keeping astronauts out there. Even on the International Space Station we have trouble with supplies, especially water. And that's why if we want to stay in space for a sustained period of time, we need to come up with new systems of communication and navigation as well as localising the supply of raw materials.

When you travel out into deep space, you have to anticipate the unexpected. How do you handle food and water resources? How do you manage different medical impacts in zero gravity? Doctors will be well-trained on these missions, but this knowledge still needs to be developed. Looking further towards settlements in space, can we produce agriculture on the Moon? And how do we support tourists? These are all the things we need to master before we achieve sustainable journeys into space, and some, like agriculture in space, may even be beyond ten years.

"We will have astronauts sustainably living on the Moon in ten years."

Rick Ambrose is the Executive Vice President of Lockheed Martin Space with four decades of experience in the defence and aerospace industry. He is also a National Association of Corporate Directors Governance Fellow, a Fellow of the American Institute of Aeronautics and Astronautics and an International Academy of Astronautics Full Academician.

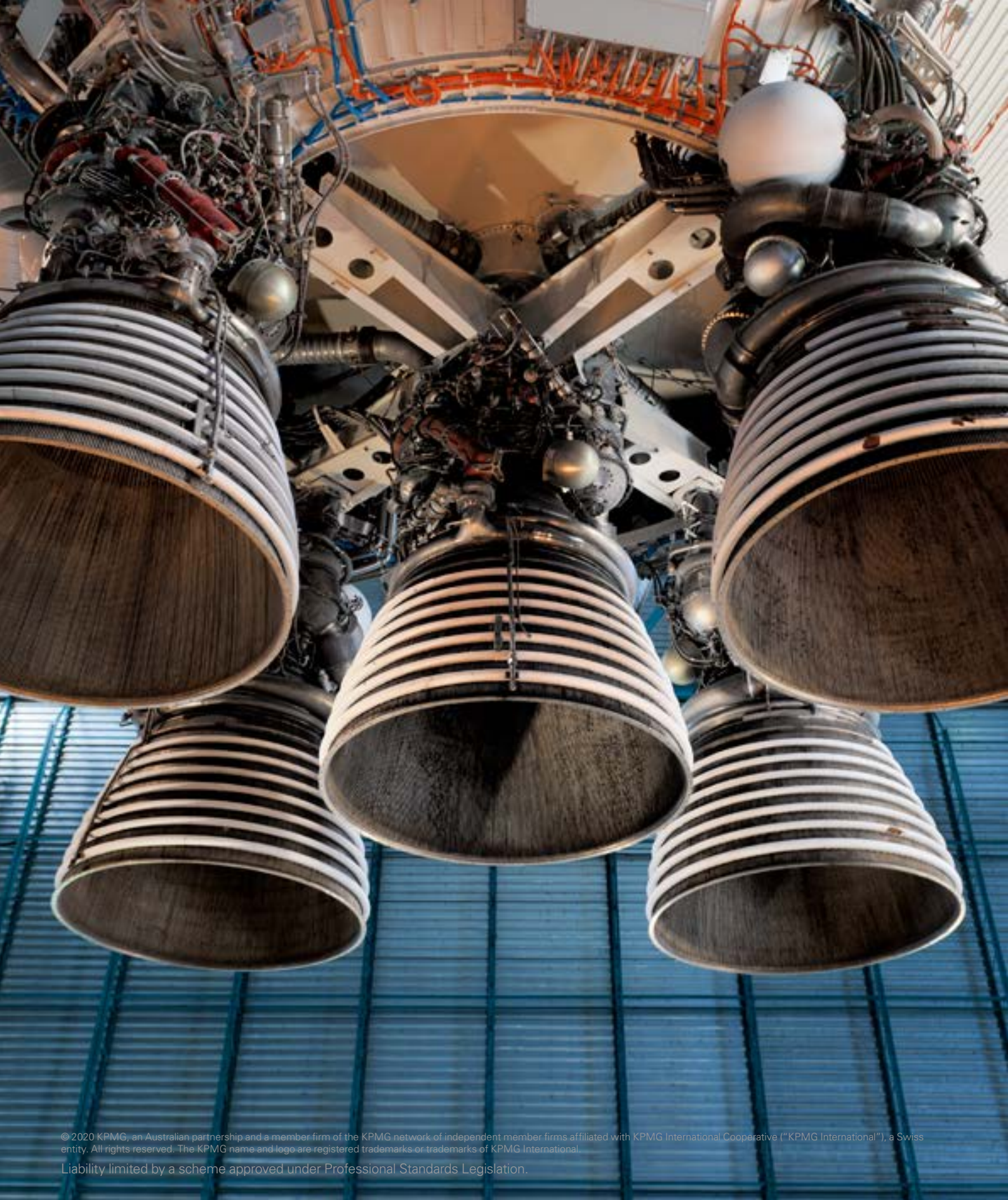
Going to the Moon is important because, just like the Apollo missions, there are endless discoveries we can make. In the next ten years, we're going to experience quite a few breakthroughs with materials. We can learn from these and rapidly evolve the technology before we go further away. At first, we're going to have to source a lot of the supplies from Earth, but we'll eventually start to develop the technologies to actually build in space. Some people are focused on manufacturing in zero gravity, which I'd love to see happen – but doing this will be tough.

Communication and navigation will also be essential areas for us to develop in the coming decade. In the early days, having two to four satellites in orbit around the Moon will enable us to communicate with astronauts and help them navigate with 10m accuracy. This will reduce risk of injury from walking off a cliff, for example. We'll also face these challenges when going to Mars, and we'll need to develop infrastructure there as well.

AI is an area I think will produce great developments in the coming decade and ultimately support long distance communication. At Lockheed Martin, we're already running basic AI algorithms in space, such as our experimental satellite called Pony Express 1. This will enable AI, data analytics, cloud networking and advanced satellite communications. Essentially, we're trying to use Pony Express 1 to learn how to anticipate a problem and perform predictive actions before the problem manifests. In ten years' time, I see this kind of technology being routine onboard satellites.

Additionally, with Digital Twin technology, we have an integrated system of production and operational data from an 'as-built' system that is analysed and can deliver predictive capability using advanced machine learning and data analytics to come to life. This allows our customers to visualise how a corresponding physical twin will perform a specific mission. One stress scenario we're looking at is what happens if people on Mars have a major crisis? These problems will happen fast, and you can't call back to Earth with 'Houston, we have a problem'. That's why we're thinking about how we put a tool in the hands of astronauts with predictive AI to alert them and correct the problem. And we're currently running 4th Gen Digital Twin technologies on large satellites for the US Government. The next step? My team has a term called 'Cognisant Digital Twins', which means it has an AI or machine learning algorithm inside it aggregating data. Even the individual twins that have AI can now come together using broader AI aggregation of the whole system. And I think that's well within ten years.

Space is an exciting place. How do we unlock the secrets of the solar system, universe and how life is formed? I often tell people that when I was in school, I thought 'Earth is so special. It's the only place in the solar system with water'. But now we find water everywhere – we just didn't know how to look for it before. That's part of the nature of science and exploration. You keep learning and improving. But it also tells you that you have to build in a lot of agility and flexibility, because you're going to encounter unknowns and whatever you do, you have to keep people safe. I think the first time we find water – true water – in deep space, there's a high probability we'll find some form of life, and I can't think of anything more exciting than that.



"As I was growing up I always used to wish I was born in the Apollo era because I figured that was the most prestigious and best time there was in space. But I honestly believe today is that time, because you just see so much innovation."

Peter Beck
CEO, Rocket Lab

Ruth Pritchard-Kelly

"This is what humans do, they go for the stars, literally."

We are in Space 3.0. The next ten years hold a lot of potential for satellite communications that will transform the world as we know it today.

Unquestionably, by 2030 being remote will no longer mean being disconnected. We will have worked the kinks out of broadband from space so that regardless of where you are – whether on land or on a plane; at sea or under the sea – you will be connected. And that's pretty amazing.

The holy grail of space age communications – that is, going from outer space directly to a personal hand-held device – is the goal for engineers to achieve by 2030. Today, with power and life limitations, viable service from outer space has not been achieved. But that doesn't mean that it can't be done. The invention of the transistor 75 years ago transformed the way we listened to music – from anywhere, even on the beach! So why can't there be a similar shift in communications over the next ten years?

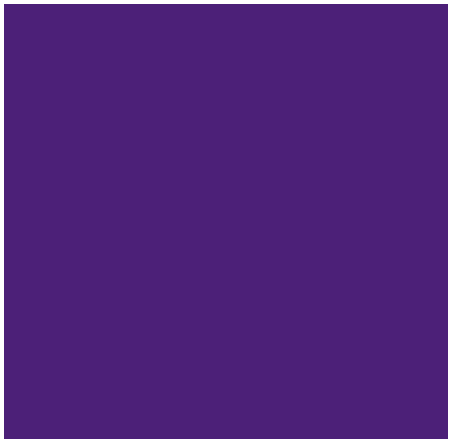
And who says that it has to be satellites that enable communication? Personally, I think that there are other space age technologies and platforms that could be viable – such as balloons and drones – and maybe we'll even decide that something that's in air space as opposed to outer space is the most effective way to get access connectivity. Most likely, it's going to be a combination of technologies.

Ruth Pritchard-Kelly is the Vice President for Regulatory Affairs for OneWeb with over 25 years of experience in the commercial communications satellite industry. She oversees a global team who work to reform regulatory and spectrum policies internationally, specifically on behalf of the newer non-geostationary satellite constellations such as OneWeb.

In a highly populated urban area, you won't need access in space, you'll have great terrestrial connectivity, whether it's wireless or wired (with fibre optic). Issues around WIFI will also have been worked out to stop us from being suddenly disconnected as is often the case today. People talk about the last mile, but often it's just the last metre!

The opportunity that enhanced connectivity offers to help those in developed countries to get a decent education and job is something I'm very passionate and excited about. Think about it. Instead of travelling overseas – often risking their lives – they will be able to get a degree from Harvard or Sydney University by logging in anywhere and getting the qualification they need to work in a financial hub, for which they will not need to be in New York, London or Tokyo. These hubs have come about due to density of population. But when you no longer need to be in a place physically to be connected, why couldn't your financial centres be anywhere in the world?

One of the big kinks that we need to be clear on is what is the best architecture for us to use? Traditional satellites are in geostationary orbit – orbiting at the same speed as the Earth – enabling them to cover a third of the globe. It's a very efficient technology. However, they are too far away resulting in a communications delay. We need to be much closer, and they call that non-geostationary. But frankly, there are an infinite number of ways to be non-geostationary.



Regulation will also need to adapt to the new era. Regulations for traditional satellites are written in very specific, technical language. When regulations are so specific, it's hard to update them when a new technology comes along. Part of my job is to try to help regulators to be less focused on the specifics of technologies and more focused towards providing a certain service level.

Debris is one of the biggest issues facing the space industry – and we've got to solve it by 2030. Outer space is vast and although debris is not yet a problem, the proliferation of small satellites and objects at low orbits may become a problem because these are not controllable. A lot of the small satellites that are being designed have no propulsion or controls. Designers say they're only going out for a short time, but that's how long it takes for an accident to happen - there will likely be a huge market coming up for debris removal companies.

When space exploration first started, it was inconceivable that more than a couple of governments would be able to be involved. But within ten years it was private companies that really got involved, with the communication companies putting up satellites in space. And now, we're at the point where we have individual billionaires with the money and desire to go to space. They've all got their own rockets and are building satellites and their own tourism vehicles and they want to go to Mars.

Currently, there's a gold rush mentality when it comes to space. Many people think they're going to literally find gold on asteroids or the Moon, and they're willing to risk a lot to get there to find out. I can't speak to that, I haven't really researched that industry, but people are going to try. This is what humans do, they go for the stars, literally.

Salem Humaid Al Marri

Salem Humaid Al Marri is the Assistant Director General for Scientific and Technical Affairs and Head of the UAE Astronaut Program at the Mohammed Bin Rashid Space Center in the United Arab Emirates (UAE). He has over ten years' experience in the space industry and one of his major goals is to achieve domestic satellite development through Emirati engineers.

"Investing in space is investing in humanity."

What do you think we can achieve in the space industry in the next ten years?

I think that we will definitely see the return of humans to the Moon. This is very achievable based on the investments we are seeing globally, specifically by NASA and the European Space Agency. I also think countries like the UAE that have formed space agencies more recently, will play a role in these programmes.

Furthermore, I see the industry's reliance on governments decreasing over the next ten years. With companies like SpaceX and Boeing coming into play, we can already see how space is becoming more commercialised. I also believe space tourism companies such as Virgin Galactic and Blue Origin will be quite active by 2030, however, actually achieving commercial space tourism will be difficult and might be further than ten years away.

Finally, the number of people that have gone into space will drastically increase in the coming ten years. In the history of human spaceflight (the past 60 years) there have been approximately 500 people that have gone into space. I see this number doubling or even tripling by 2030.

What do you see as some of the challenges we will face in getting humans into space?

I believe that one of the biggest challenges is developing the technologies for people to remain in space for sustained periods of time. Astronauts on board the International Space Station are around two to three hours from home and protected by the Earth's atmosphere. We need to keep astronauts comfortable, healthy and safe and this requires systems to manage water, energy and food. We've been to the Moon before and can reuse the technology to get there but staying there for a sustained period is the biggest challenge. The next ten years will play a big part in developing technologies to achieve sustained journeys into space, but I think actually achieving these solutions might be further than ten years away.

What is UAE's vision for the space industry for 2030?

Currently, the UAE is investing in space; we look at space as a way of investing in science and technology in a way that it can come back and benefit people on the ground, not just in the UAE but humanity in general. Our major vision is the 'Mars 2117 Project' – a 100-year vision for the UAE to lead international efforts in establishing a human colony on Mars. There are many steps involved in achieving this goal and we have a number of missions already in train as a means to reaching this goal.

One of these is the Emirates Mars Mission where we aim to launch an orbiter to Mars by 2021. The probe will

conduct analysis on the atmosphere of Mars hoping to give insight into its Martian atmosphere. This will be data that has never been produced before and will be ground-breaking data in assisting our mission. The more we are able to study the Martian atmosphere, the more you're able to understand it and potentially this information will be key in our goal of setting up human colonies on Mars.

Another focus area is water, energy and food; three components vital to supporting human life anywhere. These areas line up with international challenges here on Earth where securing our own food, water and energy are common challenges. Any technologies or research that is done towards that aim for deep space exploration can directly benefit humanity on Earth.

Essentially, I see countries like the UAE, with more modest investments in Space compared to say Russia and the USA, working collaboratively with the international space industry to achieve big objectives. By 2030 I definitely see the UAE playing a significant role within the international community of space.

What role do you think governments have to play in the space industry in the next ten years?

I think it's very important for governments to help nurture a space industry in their countries in the upcoming years. With the commercialisation of the industry with small to medium enterprises coming into the equation and contributing significantly to the industry, I believe that it's important for governments to invest and support businesses. Governments should see that these investments will help sustain growth and ultimately come back into the country in their contributions to the space missions.

Steven Freeland

Steven Freeland is Professor of International Law at Western Sydney University, specialising in Commercial Space Law, and previously the Dean of the School of Law. He has also been an advisor to the Australian, New Zealand, Norwegian and several other governments on issues relating to national space legislative frameworks and policy and has represented the Australian Government at the United Nations Committee on the Peaceful Users of Outer Space (UN COPUOS) meetings. He has recently been appointed by UN COPUOS to co-chair multilateral discussions on the exploration, exploitation and utilisation of space resources at the forthcoming meeting of the UN COPUOS Legal Subcommittee in Vienna in 2020.

"The Three plus Four C's of Space."

Space is an extraordinary and multi-faceted area, encompassing at the same time issues of a scientific, cultural, strategic, commercial, military, economic, exploratory, social and religious nature, depending on one's frame of reference. In essence, the future of humanity is inextricably tied to our ability to ensure a viable long-term future for space activities. At a minimum, this requires consensus on the most appropriate legal and regulatory frameworks necessary to promote the ongoing safety, security and sustainability of space.

Space is also hard, and despite our remarkable technological progress, we need to understand that each stage of progression brings with it many challenges, which are sometimes conflicting. A careful balancing is required when agreeing on the appropriate frameworks to apply to new technology. This is highlighted, for example, by our increasing awareness of the risks associated with space debris and, in that context, the future management of proposed large constellations of small satellites. Space debris has become a growing problem over time. If we maintain a 'business as usual' approach, the increasing proliferation of debris threatens the very future of humankind's relationship with space.

The emergence of large (some commentators rather disparagingly refer to them by the descriptor 'mega') constellations of small satellites offers great benefits, but we must avoid being 'seduced' by just that side of the ledger without developing an effective way to manage the way they will alter the paradigm of space as we know it. After all, if the well-publicised plans of just a few large corporations come to fruition, the number of objects launched into space over the coming years will dwarf the number thus far launched since the 1957 Sputnik 1 mission by a factor of up to ten times.

Just in the past few months we have seen several 'near misses' in space. Last September, the European Space Agency undertook a conjunction avoidance measure when faced with an abnormally high possibility of a collision with one of the Starlink small satellites. In late January 2020, we were all watching helplessly as two much larger 'dead' satellites – IRAS and GGSE-4 – passed within metres of each other. NASA often moves the International Space Station when it calculates a higher than normal risk of collision with debris. We are increasingly likely to see more potentially serious situations in the coming years.

While there are some widely-accepted and practical mitigation guidelines in place, as well as promising developments with regards to remediation, each proposed solution brings with it other questions. Most significantly, these technological measures will never resolve the issue in the absence of responsible behaviour by all space actors.

To add to the already complex technical challenges, as we debate the most effective space debris mitigation and remediation measures, many difficult geopolitical, policy and legal questions also arise. Who is going to pay for space debris removal? Whose responsibility is it? And, as some states will argue, if a state develops the capability to remove or deflect space debris, how can we be sure that the same technology will not be used to do the same to another country's 'live' satellites?

Further, as more objects are sent into orbit, and we increase our ability also to return them to Earth for reuse – itself a potentially important mitigation

measure - we will need an improved and, importantly, coordinated space, air, sea and ground traffic management regime. To remain sustainable in space, we must ultimately develop a unified traffic management system and we will need it soon.

Then and now: what regulation is required for the future?

Up until now, the fundamental principles and behavioural guidelines for most space activities have emanated from international and multilateral organisations such as the UN COPUOS. In June 2019, that body adopted some important Space Sustainability Guidelines, which represents another positive move forward. Yet, the discussions leading to this consensus took ten years - regulation at the multilateral level is typically slow moving.

In an increasingly burgeoning commercial space environment, countries are at the same time developing their own national space laws. These national regulatory frameworks typically not only reflect the international obligations of the relevant state but go further in an effort to enhance its indigenous space capability, industry and independence. The development of national space law and policy will become more prevalent in the coming decade.

As more countries and their actors seek to be involved in space activity and the use of space broadens through even more diverse potential activities such as resource utilisation and on-orbit servicing, national space law are the mechanism by which countries regulate those non-governmental entities and persons within their jurisdiction to further promote responsible behaviour, while still accommodating innovation and entrepreneurship.

However, even as we shift towards this new normal, the international law principles will remain highly relevant, and will become even more so through their implementation into the national legal sphere. Multilateral consensus will always be required for essential, large and globally important space issues.

Will common interests drive regulation?

Space has become increasingly dual-use, meaning that the historical divide in the regulation of peaceful – as opposed to non-peaceful - uses of space is no longer a reflection of reality. The use of space for both civil and defence applications shines a different light on the need for agreed frameworks and norms of behaviour.

Despite obvious terrestrial tensions and geopolitical differences, the major space nations generally have very significant common interests in maintaining a stable space environment. None of them stand to gain if certain 'red lines' of behaviour are crossed. Whilst this is easily stated, it is much harder for some elements within those countries to publicly accept. Already we hear that space is 'just another war fighting domain', or that (quite wrongly) it is simply to be regarded as the 'wild wild west'. The carefully calibrated regulatory and behavioural frameworks that have served us well in space for 60 years clearly debunk such claims.

In the end, we need to engage with each one of the multiple facets of space and not just reflect on what might be the loudest voices in the room. There are many voices to be heard. Space is so much more than the well-worn mantra of 'Contested and Congested and Competitive'. It is also 'Communal and Cooperative and Collaborative and Commercial'.

By changing the language of space, we can unlock and promote the notion of common interest. In the end, any legal framework around space is designed to promote these common interests, so as to ensure that space remains sustainable and that humanity can therefore garner the benefits that responsible uses of space give rise to.

There is a lot at stake here. If our actions lead to a 'tragedy of the commons' situation in space, it will be the large and most powerful countries that will suffer the most. They are the most dependent on space, they have the greatest competitive advantage through their use of space, and they are therefore the most vulnerable if our ability to access space is compromised. In the end, of course, we will all suffer, but the power of common interests, even among States that are not on friendly terms, must be recognised so that we will not all be 'lost in space'.

Susmita Mohanty

"In the 21st century the space race will not be between nations, but between private companies."

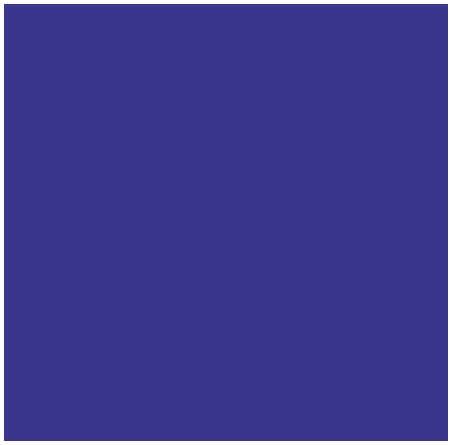
In the 21st century the space race will not be between nations, but between private companies. The private sector will play as prominent a role as government agencies in shaping the future of space exploration and applications for Earth. We've already seen this happen. A slew of start-ups worldwide have started to go beyond building CubeSats to developing sophisticated satellites, affordable rockets, green propulsion, new-age materials, 3D printing, space catapults, debris mitigation technologies and so on. These new entrants will define the way we use, explore, exploit, monitor and conserve space. By 2030, it's likely that Virgin Galactic will have flown paying tourists on sub-orbital flights, while Blue Origin and SpaceX will attempted their debut missions to the Moon and Mars.

Photo courtesy of Siddharth Das

Dr Susmita Mohanty is a spaceship designer and serial space entrepreneur. She is the co-founder and CEO of Earth2Orbit, India's first private space start-up. She has cofounded and led two other companies, MoonFront in San Francisco [2001-2007] and LIQUIFER in Vienna [2004-ongoing]. Prior to turning entrepreneur, she did a brief stint at NASA and worked for the International Space Station program at Boeing.

Nation states will also have made considerable progress in the next ten years. China will have landed humans on the Moon and mastered soft-lunar-landing through a series of robotic missions that include recent successes in 2013 and 2019. India will have a mini-space station in Low Earth Orbit (LEO) and will be getting acquainted with the challenges of living and working in LEO. Indian Space Research Organisation's (ISRO) current lead as provider of reliable, affordable, frequent access to LEO for private satellite constellation companies will be challenged by start-ups from China and the USA. India's core focus will continue to be leveraging its space assets to improve the quality of life of its 1.3 billion people.

By 2030, NASA won't have to depend on the Russian Soyuz to ferry its astronauts to LEO, but will have regularised the use of SpaceX's Crew Dragon. Russia's leadership in the space arena may well decline due to funding issues. NASA will phase out the International Space Station (ISS) in favour of its Artemis program which will attempt to land humans on the lunar South Pole. It is difficult to say whether Russia and the non-US ISS partners – European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), Canadian Space Agency (CSA) – can continue to sustain the ISS after the focus shifts to Artemis. ESA, JAXA, CSA are also part of the American Artemis program.



The USA, Europe and China will lead in supporting their space start-up ecosystems, while Japan and India will lag due to conservative national space policies and lack of an aggressive commercial mindset.

There are also huge issues that may emerge. By 2030, with the addition of several new satellite constellations, the menace of near-Earth orbital debris will have peaked and the crisis will mirror the current climate crisis on Earth, worrisome and out-of-control. Not only will these constellations further exacerbate the problem of orbiting debris, but will also likely kill Earth-based astronomy as we know it. On the positive side, affordable internet access will become available planetwide. Power efficient high-throughput satellites will become the new normal. With further advancements in quantum computing, some of the data processing can start happening onboard satellites before being beamed down to Earth. Private companies will start offering in-orbit debris capture, de-orbiting, graveyard-ing, and refuelling services.

In the coming decade, space-faring nations and the United Nations Office for Outer Space Affairs (UN-OOSA) will be compelled to upgrade the outdated 1967 Outer Space Treaty with the goal of mitigating the growing menace of space debris through enforceable laws. They will also address issues regarding space resource mining and ownership through a new international treaty that could override unilateral legislation by USA and Luxembourg. Exclusive ownership of communication bandwidth by private companies will probably attract national security and global monopoly concerns. Prominent companies will run the risk of being broken up.

Finally, as climate takes its toll on our planet, our activities in space may help us understand and reduce its impact. Earth Observation (EO) Analytics will mature and be used widely for diverse use cases including those related to climate-adaptation and climate-action. Cities and countries will leverage 'open-source' satellite imagery from Landsat and Sentinel constellations to create their own 'data cubes' and applications. If done right, EO Analytics can help propel humanity towards a planet-friendly and climate-smart future. This will be crucial in the years ahead.

Tory Bruno

"Towards a space economy."

Tory Bruno is a rocket scientist, who worked at Lockheed Martin before becoming CEO of United Launch Alliance (ULA) in 2014. ULA is the nation's premier launch services provider and has successfully delivered more than 135 missions to orbit with 100 percent mission success.

Let's presume by 2030 we have a permanent presence on the Moon, infrastructure is in place and now there are real economic opportunities in space.

The landscape of space is changing. An area once dominated by government is now open to all businesses and organisations to invest. With a continually expanding window for commercial infrastructure due to improvements in technology, expect to see organisations over the next ten years dramatically increase their level of investment.

We already see space is now a contested domain and by 2030 expect a momentous shift into countries viewing space with a lens of heightened national security. Currently governments are working closely with business as providers of space technology. This collaborative partnership originally saw investment from government and a lot of innovation from industry. So the strictly military security missions we saw funded by governments moved into public private partnerships where the private sector supplied a larger proportion of the funding than government.

As we move towards 2030, the defence and security needs of governments will force a shift, a separating of capabilities secured from the technologies of commercial spacecraft and commercial launch to more bespoke defence and security needs. As the government's requirements become more specific, business will no longer be able to recover the costs of these partnerships and governments will once again be the primary funding partner.

When I move to the cislunar side, the funding ratio will revert because of the tremendous natural resources that exist on the Moon and asteroids within reach of the lunar surface. Here we have the game changing potential to manufacture goods in microgravity - goods unable to be manufactured here. The potential to unlock this value is enormous, so the infrastructure needed for business to profit will fuel a more profitable partnership for business with government.

Everyone in the industry is talking about Low Earth Orbit (LEO) constellations or proliferated LEO – a term used to describe large numbers of small satellites in LEO. Initially it looked like this would be huge with thousands of small satellites in constellations, each one requiring a separate launch with the potential of replenishing, when one failed with a micro launcher. But the economics of this doesn't really work. It is much better to initially launch more than needed, so when they fail there is already another to take over. One of the cool things about a proliferated LEO constellation is it's inherently robust, but if two or three small satellites fail at once then we have a problem with a blank space circling the Earth. Many start-ups saw this as a potential money maker with many

seeking venture capital to build micro launchers – at the last count more than 150 companies. We will need these, but probably only two or three, the rest just won't get up and the venture capital lost.

Finally without fuel in space, long haul space flight will be tricky. I predict in ten years, NASA will have a gateway station in orbit and permanent research facilities on the ground. The lunar poles are rich in deposits of water ice, some ten billion or so metric tons at each pole. Easily converted to rocket fuel (hydrogen and oxygen), with the opportunity to sell propellant in space. This is research well worth pursuing. Initially 'fuel' you buy in orbit will be as expensive as bringing it from Earth, but the right, primarily government funded, infrastructure will revolutionise this.

This infrastructure is being jumpstarted by government with private enterprises co-investing, taking advantage of excess capability. Benefiting from the research and infrastructure to build capacity, fuel will be a commercial traded commodity, allowing more interplanetary research and empowering the future of 'space mining'. This investment will be the catalyst for a growing economic future as we proceed towards a space economy.

"From space we can observe, of course, but we can also take action. We can be a strong player in the fight against climate change... aspiring to leave this planet and live on another is a poor excuse for not taking care of Earth."

Jan Wörner
Director General, European Space Agency

Mike Kalms
Space and Defence Industry Lead
Partner, KPMG Australia
T: +61 3 9288 6426
E: mkalms@kpmg.com.au

Jacob Hacker
Space Industry Account Lead,
KPMG Australia
T: +61 2 9346 5886
E: jhacker1@kpmg.com.au

James Mabbott
National Lead Partner,
KPMG Innovate, KPMG Australia
T: +61 2 9335 8527
E: jmabbott@kpmg.com.au

Sofia Lanfranconi
Manager, KPMG Innovate,
KPMG Australia
T: +61 2 9273 5607
E: lsofia@kpmg.com.au

Acknowledgments:

This report was very much a team effort.

A special thank you to Linda Davies, Nathan Hassett, Nayanatara Samarasekera, Olivia Reeves, Liam Stow, Alana Kunz, Jacques Joubert, Sophie Finemore, Evie Murdoch, Peter Schroeder, Steve Beckey, James Arnott, Steve Cen, Zac Parkhill and Amy Congalton for their help in making it possible.

KPMG.com/au/30voicesonspace

May 2020 | 473286337IGH