EXPO 2020 إكسبو
دبي، الإمـــارات العربيـة المتحـدة
DUBAI, UNITED ARAB EMIRATES

المجلس العالمي
WORLD MAJLIS

WORLD MAJLIS
INSIGHTS FROM SPACE WEEK

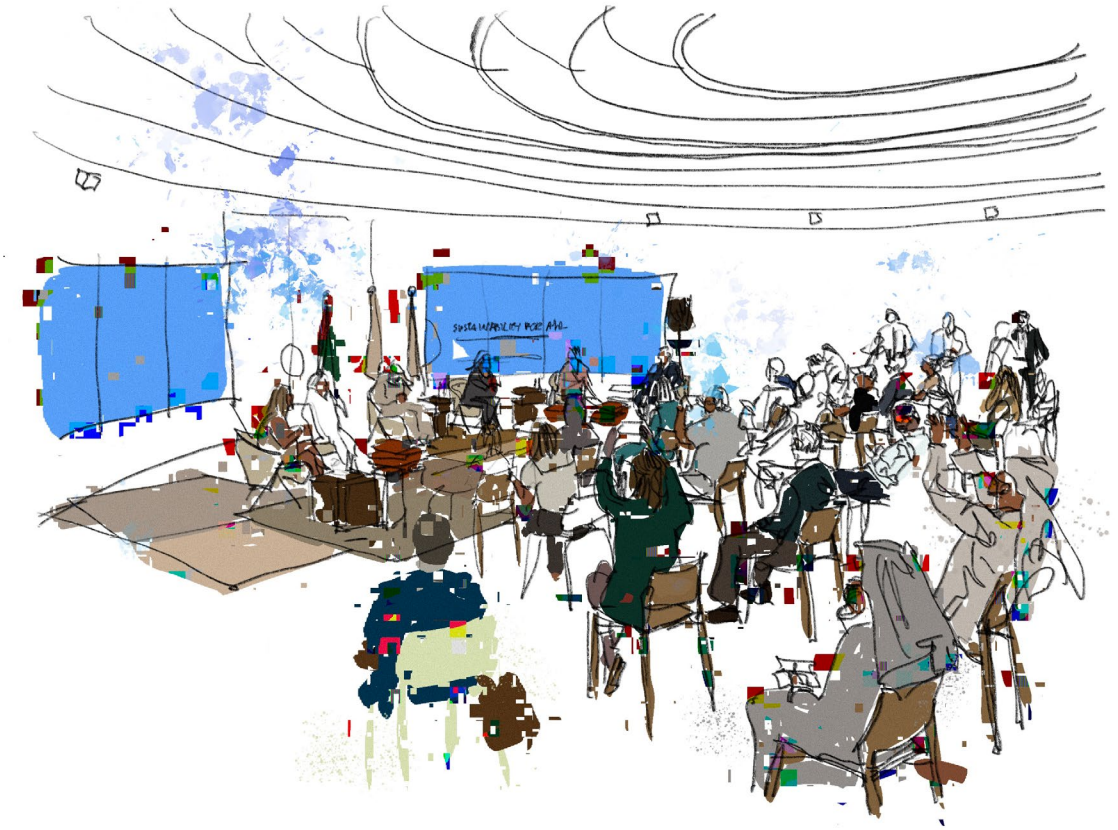
17th TO 23rd OCTOBER 2021

What if space exploration could change the trajectory of humanity?

SUMMARY AND CONTENTS

Deeply rooted in the traditions of the UAE, the majlis is one of the cornerstones of Emirati society, a space that welcomes friends and strangers to share news and ideas.

The Expo 2020 Dubai World Majlis is an inclusive, open and informal conversation space, physical and digital; one that brings together diverse voices from all over the world to reflect on complex challenges for the well-being of people and planet.



Between 17th and 21st October 2021, Expo 2020 hosted five World Majlis to explore the theme of Space through the different lenses of people, planet and innovation.

1 **Powers Out of This World**

Using Space for the Benefit of all Humanity
in collaboration with Italy and Portugal

With incredible opportunities on the horizon, from space mining to off-world settlements, how do we ensure that the benefits of space exploration reach everyone?

2 **Lessons from Space**

Applying Approaches from Space to Fight Climate Change
in collaboration with India and Switzerland

Could living like astronauts help us act more sustainably?
Could we successfully apply these principles in our lives on Earth?

3 **Mission Equality**

Expanding Equal Opportunities in the Space Economy
in collaboration with the Women's Pavilion

What is the importance of space technology to today's economic growth and sustainable development, and how do we ensure that the growth of this sector does not exclude women?

4 **Planet B**

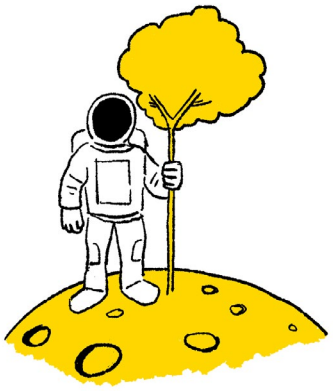
Starting Again But Doing Things Differently
in collaboration with Expo Schools Programme

What mistakes from Earth would we try to avoid, and how would we ensure that people lived in harmony with the planet?

5 **Hope and Perseverance**

Lessons Learnt from the Red Planet for Life on Earth
in collaboration with USA

How can studying the history of how climate change may have transformed the surface of the Red Planet help us learn more about Earth?



PARTICIPANTS

Powers Out of This World

Using Space for the Benefit of all Humanity in collaboration with Italy and Portugal

ITALIA
LA BELLEZZA UNISCE LE PERSONE
BEAUTY CONNECTS PEOPLE
الجمال يجمع الناس

PORTUGAL
EXPO 2020 DUBAI

Terra – The Sustainability Pavilion
17th October 2021

Miguel Belló
CEO, Atlantic International Research Centre (AIR Centre), Spain

Professor Michèle Lavagna
Professor in Flight Mechanics, Politecnico di Milano, Italy

Giorgio Saccoccia
President, Italian Space Agency, Italy

Ricardo Conde
President, Portuguese Space Agency, Portugal

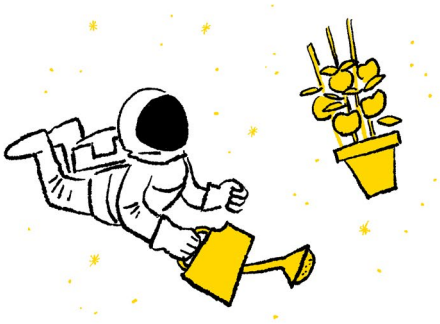
Sergei Krikalev
Executive Director for Human Space Programs of the "Roscosmos" State Space Corporation, Russia

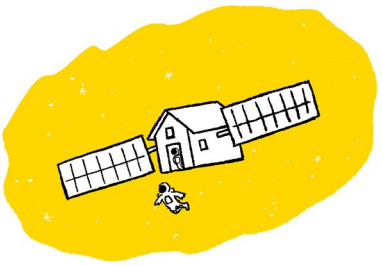
Ibrahim Al Qasim
UAE Space Agency, UAE

Prof Steven Freeland
Emeritus Professor, Western Sydney University and Director, International Institute of Space Law, Australia

Dr Mathias Link
Director – International Affairs & SpaceResources.lu, Luxembourg Space Agency

Saeed Al Gergawi (Moderator)
Director, Dubai Future Academy, UAE





Lessons from Space

Applying Approaches from Space to Fight Climate Change in collaboration with India and Switzerland

India Pavilion
19th October 2021

Emmanuelle David
Executive manager, EPFL Space Center (eSpace), Swiss Insitute of Technlogy (Lausanne), Switzerland

Professor Brian P. Schmidt
AC FAA FRS
Vice-Chancellor and President, The Australian National University, Australia
2011 Nobel Laureate Physics

Naoko Yamazaki
Former JAXA astronaut and second Japanese woman in space Space Policy Committee member, Japan

Professor Claude Nicollier
Honorary Professor, Swiss Federal Institute of Technology Member of Space Innovation (Lausanne), Switzerland

Abdulla Al Shehhi
Acting Head for Space Science and Technology Section, UAE Space Agency, UAE

Saeed Al Gergawi (Moderator)
Director, Dubai Future Academy, UAE

Dr Gioia D. Massa
Project Scientist, NASA Kennedy Space Center, USA

Dr Somanath Sreedhara Panicker
Director of Vikram Sarabhai Space Centre, Indian Space Research Organisation, India

Mission Equality

Women's World Majlis: Expanding Equal Opportunities in the Space Economy in collaboration with the Women's Pavilion

جناح المرأة
WOMEN'S PAVILION

Women's Pavilion
20th October 2021

Dr. Joel Joseph S. Marciano Jr
Director General, Philippine Space Agency, Philippine

Dr Jane Olwoch
Executive Director, Southern African Science Service Centre for Climate Change and Adaptive Land Management, South Africa

Maruška Strah
Executive Director, World Space Week Association, Slovenia

Ksenia Moskalenko
CEO and co-founder of Mission Space, Latvia

Simonetta Di Pippo
Director, United Nations Office for Outer Space Affairs, Italy

Naoko Yamazaki
Former JAXA astronaut, Space Policy Committee member, second Japanese woman in space

Dr. Michaela Musilová
Director, HI-SEAS simulated missions, Hawai'i, Slovakia

Marcos Pontes
Minister Of Science, Technology, Innovation, and Communications, Brazil

Shelli Brunswick (Moderator)
Chief Operating Officer, Space Foundation, US

Planet B

Next Gen World Majlis:
Starting Again But Doing Things Differently
in collaboration with Expo Schools Programme

Terra – The Sustainability Pavilion
21st October 2021

Mohammed Faizaan Ahmed
Delhi Private School – Dubai

Elyazeya Mohammed Al Mansoori
Dubai National School – Dubai

Khaled Alnaqbi
United Arab Emirates University (UAEU)

Fatima Al Blushi
Al Thait High School - Ras Al Khaima

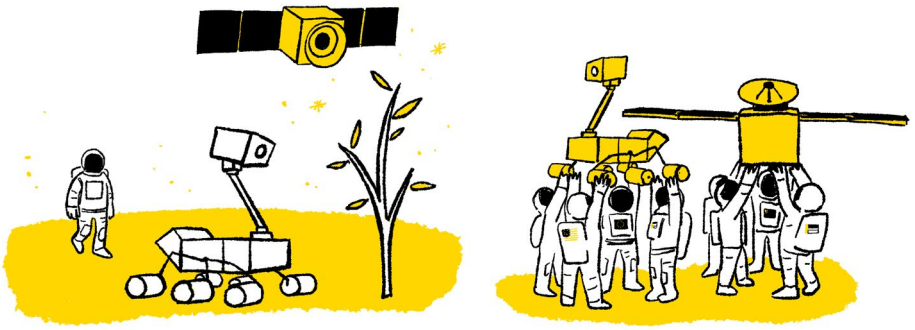
Wasayef Al Zaabi
Jamela Bu Haired - Sharjah

Maya Beleznay
Massachusetts Institute of Technology (MIT)

Mohammed Al Ketbi
Al Dhaid High School – Al Ain

Shouq Qambar
Sharjah American International School – Dubai

Rohan Roberts (Moderator)
Innovator, Author, Entrepreneur, Futurist, Edtech Advisor, Educational Consultant



PARTICIPANTS

Hope and Perseverance

Lessons Learnt from the Red Planet for Life on Earth in collaboration with USA

Terra – The Sustainability Pavilion
21st October 2021

Dr Dimitra Atri
Mars Research Group, Center for Space Science, New York University Abu Dhabi, UAE

Mazlan Othman
Director of the International Science Council, Regional Office for Asia and the Pacific, Malaysia

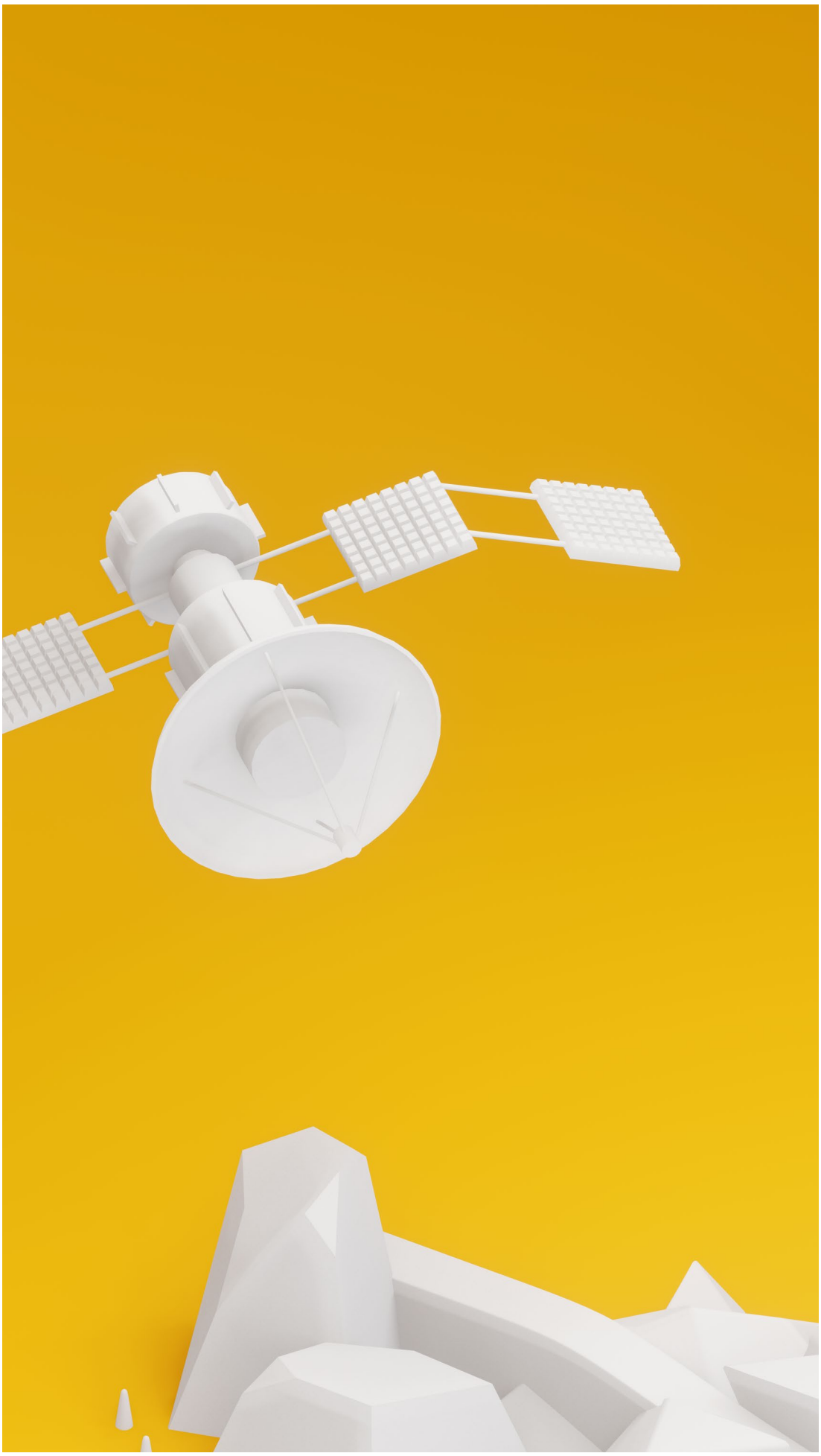
Saeed Al Gergawi (Moderator)
Director, Dubai Future Academy, UAE

Shelli Brunswick
Chief Operating Officer, Space Foundation, US

Omran Sharaf
Project Director, Emirates Mars Mission (Hope Probe), Mohammed Bin Rashid Space Centre, UAE

Dr José A Rodríguez-Manfredi
Scientist, Department of Advanced Instrumentation at INTA - Centro de Astrobiología, Spain

Randy Lycans
Vice President and General Manager, Nasa Enterprise Solutions (Jacobs), USA



SUGGESTED ACTIONS AND INITIATIVES

For Government and Intergovernmental Agencies

COLLABORATIONS BETWEEN NATIONS

Continue UN-scale efforts for good behaviour in space. This includes ensuring there are repercussions for rogue behaviour, as well as more ambitious schemes for human peace and security through space. **[p21, 24, 25]**

New partnerships (building on the work of the Global Conference on Space for Emerging Countries, next in May 2022) within regions or between smaller nations:

- developing better understanding of their similar natural ecosystems **[p48, 49]**
- testing similar space technologies **[p34]**
- answering the same space scientific questions in space, from joint experiments on the International Space Station (ISS) to monitoring weather on Mars **[p52, 53]**

Making the most of global infrastructure rather than owning it: building on each others' capabilities rather than every nation starting their space economy from scratch. This includes sharing satellite and scientific space data **[p33, 49, 54, 56, 57]**

Use these testbeds to develop better governance and ethical frameworks, which works for all nations **[p26, 45]**

INTERNATIONAL MECHANISMS FOR SUSTAINABLE SPACE

Continue the flag system as a way to govern how space is explored, as well as developing national laws that encourage responsible exploration **[p22, 23]**

Invest, or provide tax incentives for innovations that manage the urgent challenge from space debris, such as working with global centres of excellence for satellites that are able to move with more dexterity **[p36, 37, 38, 39]**

Develop consensus processes with the goal of taking the mindset of sustainability into agreements between companies and countries on rules for space mining **[p43, 44, 45]**

For Universities

ACADEMICS SUPPORT AN ACCESSIBLE SPACE SECTOR

Bring space into law, medicine, art and architecture education, as well as providing internships for these graduates **[p27,51,57]**

Set-up transnational space accelerator programmes:

- Make it easier for entrepreneurial scientists to turn their research into space businesses **[p34, 53]**
- Provide thorough technical review for space start-ups and innovations to help avoid investment in a space bubble **[p33]**

For Business

MENTORING FOR NEW PLAYERS

Scale-up mentoring for women and develop new schemes for those returning to work with flexible working arrangements or clear pathways for those bringing skills from other sectors. Access schemes should focus on countries where the space industry is not established **[p28, 31]**

FOCUS ON INNOVATIONS THAT WORK FOR SPACE AND FOR EARTH

Increase the number of schemes that support humans to learn to live in a constrained environment, with analogue missions including people from outside the space industry to understand the lessons for Earth **[p34, 50, 51]**

Champion businesses that use the environment of space to innovate and apply those ideas terrestrially **[p52, 53]**

Connecting the ideas from 39 thought leaders from 18 countries has sparked new lines of inquiry for future conversations and research.

Do we need to go to space or do we just need the idea of space to help humanity think in new ways?

Do the aims of reaching common goals and making room for diverse ideas come into tension?

Would the space economy survive in the future without the dominance of huge contracts with national space agencies?

Are we at the dawn of a space bubble? Could it be avoided?

Are we doing enough to examine the new risks that come from billionaires rather than presidents deciding where the satellites go or who gets to fly into space?

The pale blue dot teaches us a broad view of Earth, but what about the long view - planning for space exploration that can continue over the long term?

Will space become the Wild West or will the ideal of shared, open seas of space win out?

If we can mimic space environments on Earth, are we wasting money by doing experiments in space rather than in laboratories on Earth?

How do we avoid a new data divide between partners in a satellite constellation and those that would find the data useful, but are not in the partnership?

Will countries with less satellite data about themselves suffer because they will lack the insights to make informed decisions?

Context

What if space exploration could change the trajectory of humanity?

In 1968, Apollo 8 took a picture of an Earthrise over the horizon of the moon. Earth appears as less than one pixel in the image of the 'Pale Blue Dot' taken in 1990 by Voyager 1 as it reached a record distance of 6 billion km away. The World Majlis during Space week at Expo 2020 asked if this way of seeing humanity's home planet - this cosmic perspective - changes humanity itself.

What has been gained from exploring outside the Earth, from stretching human ambitions beyond the limits of one gravity and one atmosphere? What lessons can be brought back to Earth? And what opportunities does it bring for doing things differently to how humanity has acted at home?

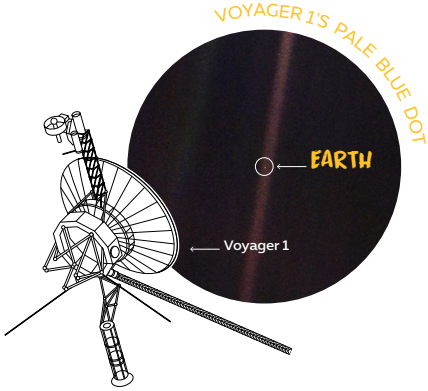
These questions are more important now that we are witnessing recent changes to powers in space: how many more companies and countries have, in different ways, access to this cosmic perspective.

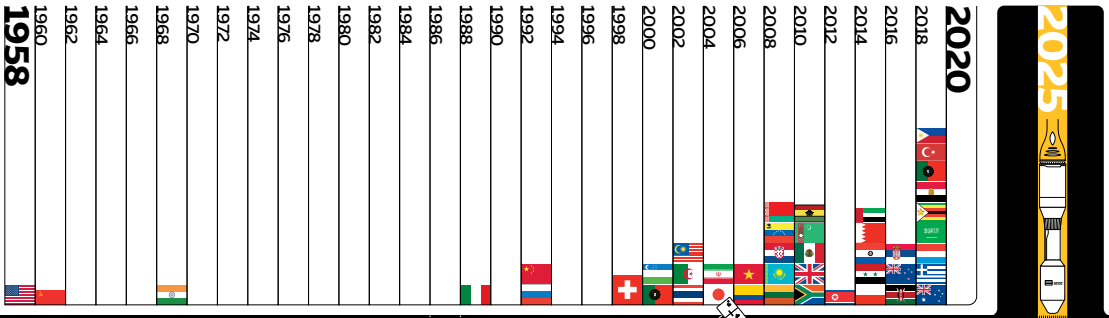
"Pictures are taken and transmitted down to the ground nearly daily. I think this is a huge factor in making people aware of the beauty, on the one hand, but also the fragility of planet Earth... Seeing the paper thin atmosphere around the Earth is something that all astronauts see and it is something that is breathtaking."
Prof Claude Nicollier

During the era of superpowers in space, bookended by these two images, the fascination with seeing Earth from afar was often connected with criticisms of the egotism of those dominant nations. Carl Sagan, who asked NASA to take the Voyager 1 image and also coined its name, later wrote: "our posturings, our imagined self-importance, the delusion that we have some privileged position in the Universe, are challenged by this point of pale light."

"I THINK IT'S VERY IMPORTANT THAT WE SHOULD SEE OUR EARTH IN A COSMIC PERSPECTIVE. THE TWO MOST ICONIC PICTURES EVER TAKEN FROM SPACE ARE PROBABLY THE PICTURE TAKEN FROM THE APOLLO PROGRAM ORBITING THE MOON AND THE PALE BLUE DOT. THESE HAVE SHOWN US HOW FRAGILE THE EARTH IS, AND HOW WE NEED TO THINK OF IT IN COOPERATION."

Lord Martin Rees
Astronomer Royal, Emeritus Professor of Cosmology & Astrophysics, Cambridge, OM FRS





The growth in national space agencies

Many more countries will be involved in space exploration in the next 50 years compared to the space race of the previous 50 years.

Over the past ten years, more than 20 countries have established a national space agency, and the number of countries with at least one satellite in orbit has increased from 50 to 82 in only a decade.

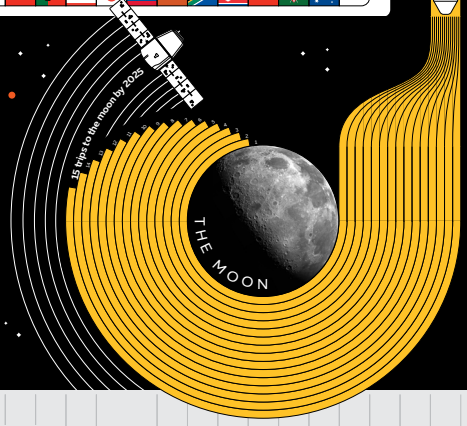
Fifteen missions to the Moon by eight different agencies are planned by 2025.

2yr increments

SPACE MINING

The 2020 Artemis Accords are a framework that provides rules for mining and other activities to extract resources from the Moon, Mars, and other astronomical objects.

As of June 2021, 12 countries have signed the Accords:
Australia, Brazil, Canada, Italy, Japan, Luxembourg, New Zealand, the Republic of Korea, Ukraine, United Arab Emirates, UK and USA.



Emerging spacefaring nations

EMERGING SPACEFARING NATIONS

Countries establishing autonomous capacities to access, operate in space, and benefit from a range of space activities.

Today, it is the fragility of Earth viewed from space that dominates discussions.

The Apollo 8 photography was taken less than 18 months before the first Earth day celebrations to increase awareness of the need for environmental protection. But only recently has the connection between vulnerable Earth seen from space and the need to protect the ecosystems it supports been consistently part of public discussion.

This strong connection between the challenges on Earth and challenges for space is core to a new era of space exploration that is only just starting. The motivation to conquer space has been replaced by the twin focuses of, one, benefiting all humanity and, two, encouraging entrepreneurship.

There are over 70 countries with satellites in orbit. Space tourism is taking off and there is an ever growing interest in mining other planets and asteroids - space today is big.

There is also work to do to ensure that the space economy grows healthily without over-inflated expectations of cutting edge technology. That work will also need to ensure that the family of organisations involved in space keeps growing, remaining open and inclusive.

With the International Astronautical Congress in Dubai the week after Expo 2020's Space Week, much of the global space policy and space innovation community were in the city for a couple of weeks. The buzz that came with this could be felt across the Expo site. Indian satellite entrepreneurs were showing their kit to Swiss Astronauts and Mars architects from LA were swapping ideas with Slovenian economic policy advisors.

But there was also a refrain heard in response to why people knew each other already: "space is small". The space industry does include many sets of skills and nations. But the general consensus that it should be diversified further: not only an industry of rocket engineers, but also doctors, architects and artists.

However, at this moment in time, forging a full time career in space remains a privilege.

There is some advantage to this. Deciding how humans engage with new environments is a big decision. International treaties on peaceful use of outer space have been fairly successful in avoiding space wars, space pollution or space looting. Good decision-making by a small number of people has benefitted the rest of humanity.

How should decision-making about space expand to include a wider range of interests while still providing the core protections the UN has provided for decades? Perhaps governance with more participants will ensure the space sector does truly benefit everyone? Or does it risk being dominated by commercial interests rather than societal ones?

These are the difficult questions that arise at the start of a new era of excitement about exploring the expanses of space with a bigger family of nations and companies.

Thinking differently about space

The growing family of countries and companies in space is exciting. The relationship between innovations for a sustainable Earth and innovations for space is increasingly beneficial for both. But to make the most of this, humanity needs to ensure that it makes progress beyond the behaviours that led to a unsustainable environment on Earth.

"Right now the space race has moved from competing between countries to competing between companies. SpaceX is competing with Blue Origin and Virgin Galactic. It has become a privatised environment. So if we were to colonise Mars, would it be a capitalist environment or would it be communalism?"
Mohammed Faizaan Ahmed

It can seem like there are two extreme potential futures for humans in space: a space industry rebuilt by many and that benefits many; or an industry where a new clique of power players win out.

But the future will likely be somewhere between the two. Compromises between different systems of power are part of life on Earth. The same is plausible in space. There are some valuable lessons from learning to sustain life on Earth that will be helpful as humans continue to explore beyond the planet's surface. In the same way that companies and countries are responding to the shared challenges of climate change, space sustainability is an agenda both can get behind.

"We're talking about two things. We're talking about the sustainability of space, and we're talking about sustainability as a global objective."
Ibrahim Al Qasim

Two meanings for space sustainability

The motivation to sustain an environment, rather than ruining it, can be applied to the environment in space and on Earth. In 2020, the Portuguese Space Agency hosted a forum for countries in the Atlantic region called 'Clean Oceans with Clean Space'.This brought together both the community with interests in sustaining the oceans and those keen to better manage space debris. This captures both meanings of space sustainability: for space and for Earth.

For space

Space sustainability means learning lessons from how humans have damaged Earth, and doing better not to damage environments outside this planet. One of the key issues here is the increasing amount of space debris in low earth orbit, mainly working satellites or decaying components of spacecrafts.

The flag system used to mark the ownership of ships outside national waters has also been adopted in space. Spacecraft fly under the flag of a particular country. Instead of countries owning part of space, they own just the vehicle they travel in.

But there is increasing interest in mining rare elements or the re-emergence of discussions about owning strategic territory on the moon. With this comes the risk of the equivalent of pirates on the seas or, more flatteringly, prospectors in the Wild West. If commercial ventures choose not to respect the history of the flag system, what will replace the last 50 years of cooperation on the peaceful use of outer space?

Space is an opportunity to do things better than humans did on Earth, but also the risks of making the same mistakes humans made on Earth but at a larger scale.

For Earth

Space sustainability also means ensuring billions of dollars spent on space are also helping to ensure that Earth is a healthy environment that continues to support thriving ecosystems.

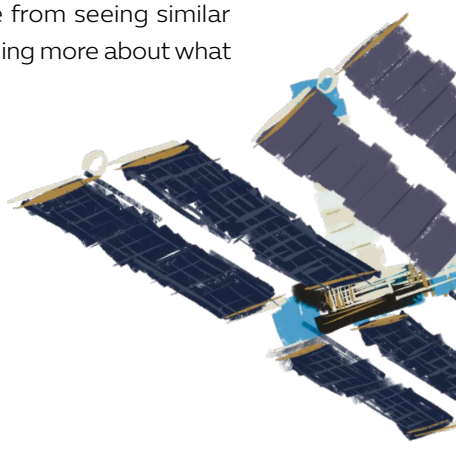
Space innovations have brought economic value back to other sectors. Today, technology for space plays a significant role in many of the sectors supporting a greener planet.

Of the 169 targets in the UN Global Goals, 40% require infrastructure that relies on space technology.

Over 50% of the metrics we use to monitor climate change come from satellite information

Satellites play a major role in monitoring the changes caused by climate change, but are only just reaching the stage where they can predict extreme weather events.

Beyond this, new medicine and new agriculture has been created thanks to the different environments of space. Some of these innovations come from the challenge of developing human-support systems for space travel. Some of them come from seeing similar environments to Earth, like Mars, and understanding more about what is possible for biology back on Earth.



Learning the lessons of civilizations on Earth

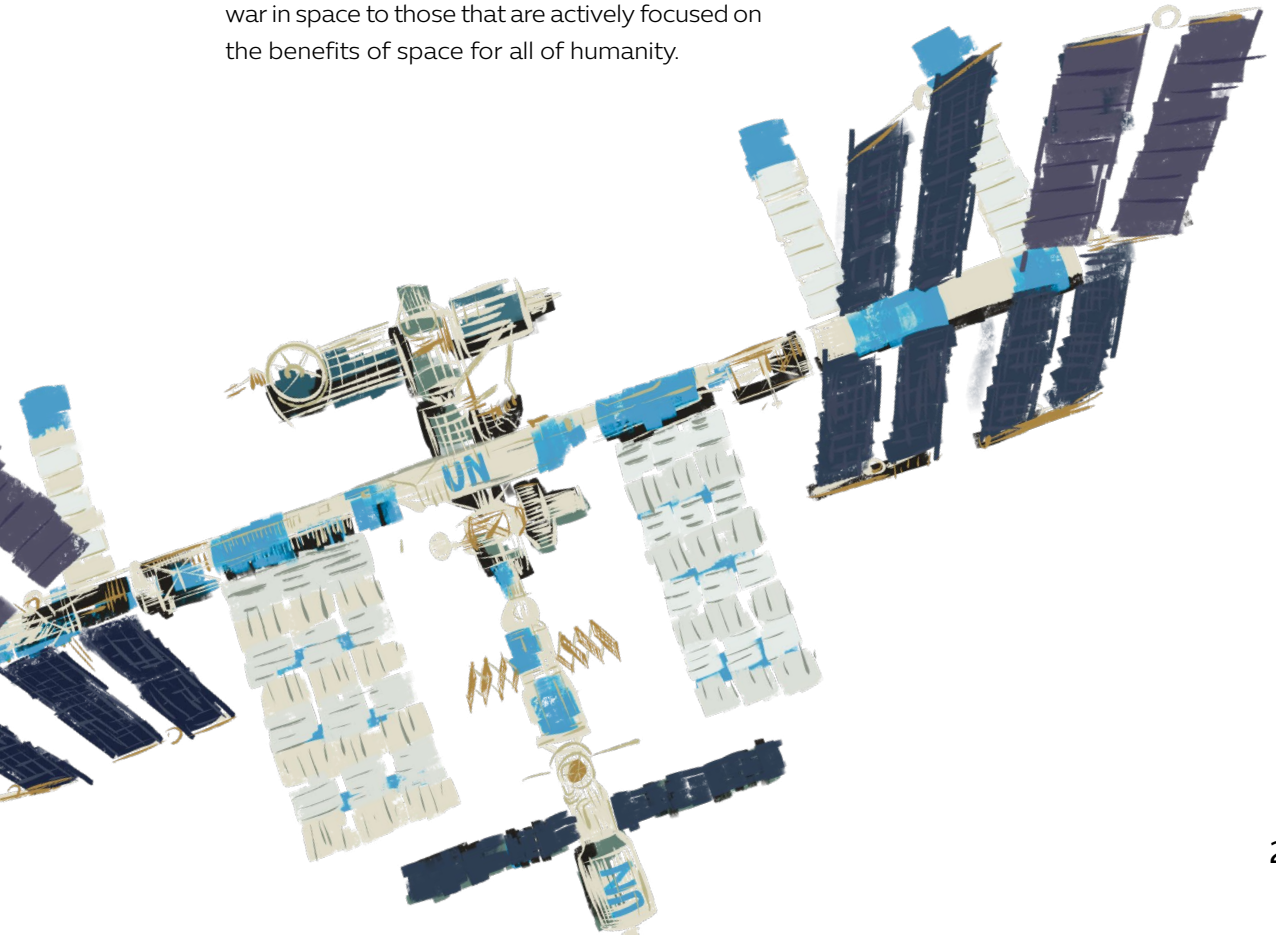
Following the establishment of the Committee on the Peaceful Uses of Outer Space (COPUOS) by the UN General Assembly in 1959, the 1960s and 1970s agreements on governing humans in space revolved around cooperation at a time when conflict in space was a pressing concern. Space law comes from that era, and has been successful at meeting these goals.

In this way, humanity exploring space has learnt the lessons of the destruction caused by war on Earth. But it has not been successful at creating a sustainable environment in space or on Earth.

The idea of a UN-run space station was suggested as a symbol of the change in mindset that is needed: a house in space aimed solely at activities for the benefit of all humans.

Prof Claude Nicollier took this idea further with his proposal of a Committee on the Sustainable Uses of Outer Space (COSUOS). This would signal the break away from policies focused on avoiding war in space to those that are actively focused on the benefits of space for all of humanity.

"In 2014, the UN General Assembly passed a resolution which they call PAROS: the Prevention of an Arms Race in Outer Space. It's really important, vital, that we do that. But why don't we also talk about promoting a peace race in space ... If we can change that mindset through language as well as through action, then I think we are well on the right track to move forward in a cooperative way."
Prof Steve Freeland



SECTION 1

The first half of the report looks more closely at how to bring humans together under the shared inspiration of space, ensuring diverse interests are brought to the table, but also that rules are strong enough to avoid making the same mistakes that selfish interests led to on Earth.

Coalitions for space with a seat for everyone

The way that humans manage space exploration needs to learn the lessons of centuries of civilizations on Earth. Decisions need to respect a wide range of interests: national, commercial and community. But space law also needs to be strong enough to police renegade actors.

The growth of space-faring nations and commercial interests in space has made the home of global agreements of peaceful use of outer space - the UN Office of Outer Space Affairs - a busy place. As countries move into space, they are also interested in having a seat at the table where decisions are made about how to govern human behaviour in space.

There are now many working groups and committees on issues and opportunities in space, from space debris in Earth's orbit to the rules for interplanetary missions. These encourage participation from countries and companies, but many of the mechanisms in the background were built in an era with few space powers.

So there is an increasing volume of conversation about new kinds of space laws and new, often faster, ways of agreeing on them.

"We need more discussions, more cooperation with a diverse set of people in terms of background: bringing engineers, lawyers, government officials, economists all together; in terms of geography, in terms of different countries where they come from; in terms of organisations, both from the public and private sector."
Dr Mathias Link

There are already those that are finding their way around the UN processes.

There have been agreements between groups of countries, like the Artemis Accords or satellite data sharing between Brazil. Russia, India, China and South Africa.

New technologies have been launched into space without clear rules for their management, like mega-constellations of small communications satellites that could further litter the crowded space around the Earth.

And there are some countries that are willing to launch satellites without keeping to the international guidelines that they should be built to decay within 25 years. They are taking advantage of the opportunity of operating a space port that is willing to launch cheaper but less sustainable craft.

Space needs diverse imaginations

"It is inside our genetics, our drive, our desire to learn more, to explore, to expand."
Shelli Brunswick

"This is really part of our genome. We have some genes that make us explore. We are looking for answers. So from the very beginning of humanity we started looking at the sky trying to look for answers."
Dr José A Rodríguez-Manfredi

All humans look up at the stars, but it has been very few that have had the privilege of working on space exploration. This is changing for the better. The space sector is becoming more global and more inclusive.

Exploration is a common human instinct. Whether travelling on the ocean or into space, it is part of human curiosity to want to find out more about what's beyond the horizon or up in the sky.

Part of the purpose of the UAE Hope Mission to put a satellite on Mars was to inspire the next generation of Emiratis to share in the excitement of such an ambitious goal and encourage them to follow the instinct to explore.

"There are cave paintings and carvings and ancient statues from every culture who were looking up at the stars. I think that is our common root."
Maya Beleznay

Creativity is core to the space sector

Humans have always looked up to space as that final frontier, inspiring creative works and firing up the imaginations of many generations before those that managed to travel into space.

But space is not just inspiration for creative work. The challenge of going to space helps humans to think creatively and to come up with new innovations. Engineering built for spacecraft has often also been more successful than previous technology at solving problems on Earth. For example, in the 1990s, Nasa's Jet Propulsion Laboratory team came up with the camera-on-a-chip as a way to reduce the size of equipment going to space. Today the same sensors are found in most of the world's camera phones.

Different ideas in different people

Part of encouraging the creativity needed to explore space successfully is allowing humans the space and time to think about a problem in a new way. There needs to be diverse perspectives, who bring with them new innovative ideas.

It is hard to find a path into space

Space is still primarily an expensive hi-tech sector, which until recently only existed in a small number of countries. This means it is often hard for a promising engineer or entrepreneur to see a path into the industry, or to see anyone from their background as a role model or mentor.

As collaborations in space increase in size and number, they create different entry points into the space industry. There will be room for people from many nations to forge a path into the sector, and act as mentors for the next generation.

Diverse participants help achieve shared goals

The complexity of missions with many partners and cultures creates risks, but ultimately it will connect space exploration more directly to the goals of all of those groups. By working together, the successes of the mission are more likely to reach a larger group of people in more countries around the world.

The project also becomes a reminder of the commonalities between humans rather than the differences. At a basic level, the images that come back to Earth do not separate into the nations. But it also illustrates that humans can work successfully towards a shared goal.

جناح المرأة
WOMEN'S PAVILION

Women's World Majlis: Mission Equality

"The space sector thrives with innovation, and that's what diversity brings to the table... I work with engineers from around the world, and the engineering is the same, but their thinking processes are different."
HE Sara Al Almiri

"If you see someone who looks like you, you say to yourself - 'if she can do it, I can do it'."
Dr Jane Olwoch

"Humans can be the weakest link of the space mission if we don't respect each other's differences and if we don't communicate well. But if we do communicate well, we're empathic and understand that everyone has a different point of view and a different background, the human link can actually be the strongest link."
Dr Michaela Musilová

"One of the most impressive things about the International Space Station for me is not the technology - interestingly, because I am the Minister of Science and Technology. But it is the way we work together with different cultures, different religions, different languages. Everyone working towards one goal: to make good for this planet."
Marcos Pontes

Best practice

"It's not just about the science and technology, but also about winning the hearts of the people."
Mazlan Othman

Malaysia's Astronaut programme

The Malaysia Astronaut programme aimed to engage more of the public in space. It was run as a public competition with national media and television coverage. It was part of a strategy by the new space agency in the country to excite as many people as possible about their work, and encourage the next generation to think about space as a career option.

Japan's Mentorship for female space engineers

At Japan's space agency - JAXA - senior female engineers are paired up with junior female engineers to support them to achieve ambitious goals. The UN and many other bodies provide similar schemes for women entering the space industry.

Emerging questions for future conversations

Do we need to go to space or do we just need the idea of space to help humanity think in new ways?

Do the aims of reaching common goals and making room for diverse ideas come into tension?

Entrepreneurs in space

Satellites and technologies for national space missions are developed by companies around the world. A few rich entrepreneurs are taking on a new domain that was previously dominated by national space programmes - building rockets and sending humans into space.

"The Mars Missions, Elon Musk and SpaceX - it has inspired the next generation of individuals who want to come into the space industry. For many years space was not being pursued. It was not exciting. But over the last 5-10 years you've seen passion for this industry. We're inspiring scientists, technologists, engineers and mathematicians. But we're also inspiring entrepreneurship and innovation."
Shelli Brunswick

Globally, the space economy was valued at nearly $424 billion in 2019. 95% of this value came from goods or services produced in space for use on earth: the space-for-earth economy.

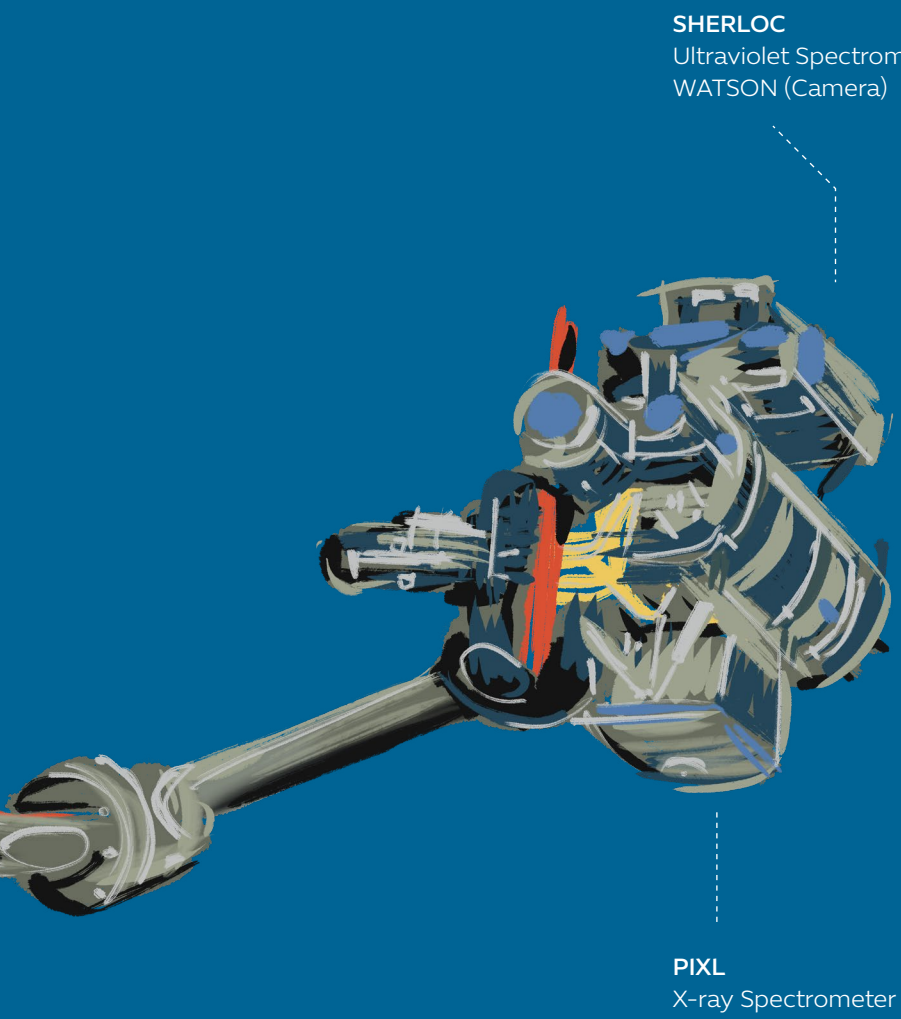
National space missions continue to dominate space exploration outside the Earth's orbit, which is why only the remaining 5% of the space economy comes from commercial activity in the space-for-space economy.

Mars missions with many partners

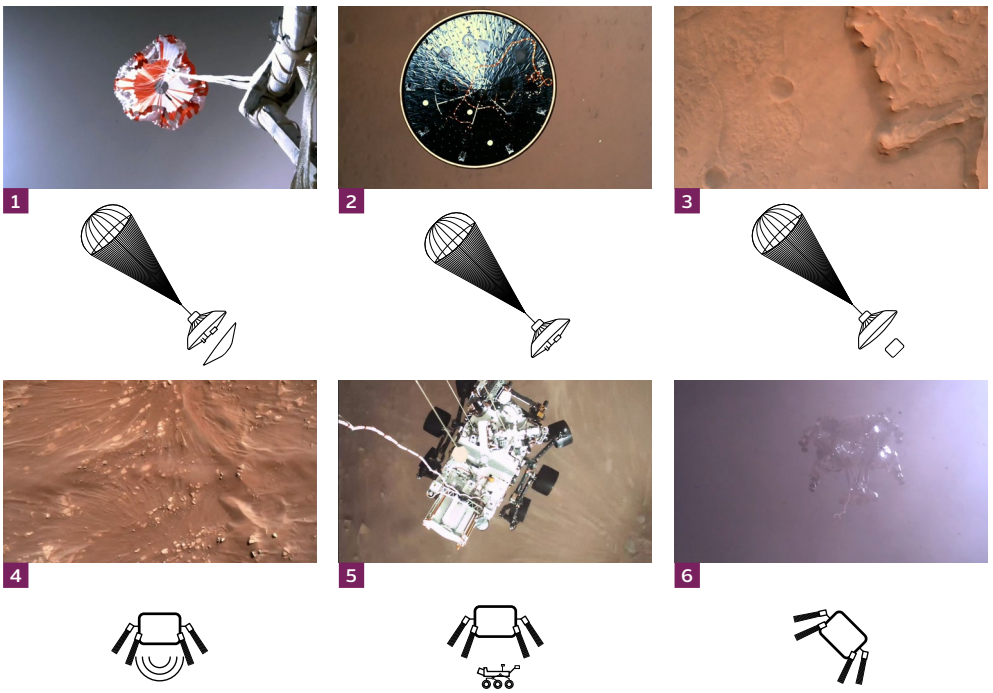
NASA's Perseverance rover started collecting data and samples from the surface of Mars in February 2021. This mission continued the tradition of collaborative work, particularly with universities and companies providing the scientific components of the rover.

There are seven scientific instruments on Perseverance, with university partners from the US, Norway and Spain leading each project.

Two of the seven instruments on the Nasa Mars rover, Perseverance



Specialist teams within companies built much of the hardware and software. For example, Jacobs science team built a new calibration device to check the SHERLOC camera's feed. The camera uses the colour of minerals brought with it from Earth to compare to the colours seen on Mars. So the camera can double check that it hasn't been damaged or that part of the new environment is leading it to misinterpret the materials on the martian surface. This was the first time this global engineering company has built technology for Mars.



Source: NASA

Nasa's Perserverance rover landed on Mars in one process, executed with a single set of commands. But behind the project is a complex web of researchers and companies that make the scientific mission possible.

SpaceX recycled rockets

Private companies like SpaceX, Boeing, Blue Origin, and Virgin Galactic hope to put many more people in space in the future. The space planes used for these suborbital journeys will be re-used over and over again. SpaceX's Falcon 9 reusable rockets have also kick-started a new market in recycling the launchers sending humans and equipment into orbit. They reuse components that make up to 70% of the original cost of a rocket.

The Falcon 9 is the first commercial system to graduate from the role of supporting a nation programme to independently delivering launches for many nations and satellite firms.

Access to space made easier and cheaper

With global access to commercial partners like SpaceX, costs of space-based projects are coming down rapidly. In Australia, a satellite system to detect bushfires in real time was previously a 20 year and $5 billion mission. The estimate now is more like five years and hundreds of millions of dollars. India's 2014 Mars Orbiter cost $74 million. This was famously less than the film Gravity, which came out the same year.

The UAE's Hope mission was completed in six years and cost about $200 million, thanks to the partners they were able to bring together rather than starting from scratch. In 2022 the Emirates Lunar Mission will launch a rover built with Japanese company iSpac.

The risk of a space bubble

With this entrepreneurial environment, there is intensifying competition, as well as big bets on risky technology. Both the market in constellations of small satellites and space resource extraction have seen a decade of investment without significant returns as of yet. There is still work to do to ensure that the space economy grows healthily without over-inflated expectations of cutting edge technology.

Best practice

"We provide her the support, so she can go out and do it: take time off if she wants to - there'll be no disadvantage to her; provide her the money that she needs to prototype things; connect her to people who want to invest in her company; and get her training on how you become an entrepreneur."
Prof Brian Schmidt

Australian support for researchers to become entrepreneurs

A simple way to encourage more space entrepreneurs is giving researchers easy ways to leave the laboratory and build a company using their technology, without forfeiting their academic career. Australian National University provides customised support for its space researchers to take this route.

Analogue missions provide practice ground

Rather than going to the moon or Mars, analogue missions find areas on Earth that simulate some of the conditions in space. Entrepreneurs can test their ideas without the costs of launching them into space.

The Hawaii Space Exploration Analog and Simulation (HI-SEAS) is an analog habitat for human spaceflight to Mars. Not only does it test the psychological and physical strain on humans, but also some of the robotics that could be used. They have tested Honeybee Robotics mining robots that could be used for extracting minerals, microbes or water on Mars.

Emerging questions for future conversations

Would the space economy survive in the future without the dominance of huge contracts with national space agencies?

Are we at the dawn of a space bubble? Could it be avoided?

Avoiding space debris

Rapidly increasing space debris in the Earth's orbit risks leaving no path for future missions. Humans need to apply lessons from a cluttered Earth to space exploration.

Governments in the 20th Century made rules for peaceful exploration off the planet. But with this focus on space missions far away, they forgot to manage spacecraft in Earth orbit.

"We have pollution in the desert, in swamps, everywhere. And unfortunately the same way we have the same in space."
Sergei Krikalev

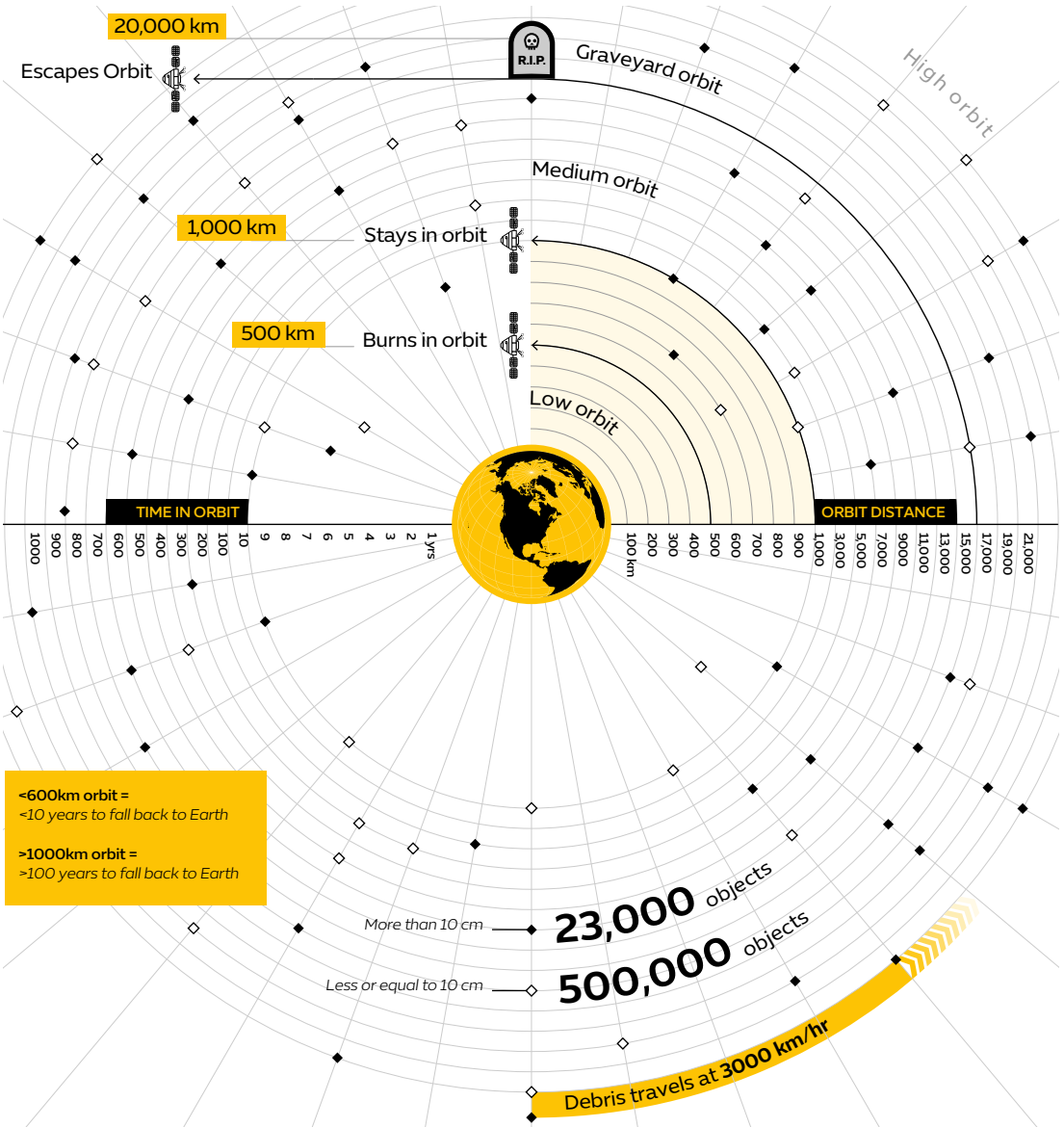
There are now more than 23,000 objects larger than 10cm circling the Earth. About 1,000 of these represent operational spacecraft; the rest are orbital debris. There are another 500,000 particles between 1 and 10 cm in diameter. Even these smaller objects are an issue because they are travelling at speeds of 3000 km/hr.

These pose a serious threat to rockets leaving the Earth and to other satellites.

Objects in orbits below 600 km normally fall back to Earth within several years. At altitudes of 800 km, the time for orbital decay is often measured in decades. Above 1,000 km, orbital debris normally will continue circling Earth for a century or more.

History of space debris
Despite a history of high-profile events that have warned of the dangers of space debris, satellite launches have only increased. More than this, countries continue to launch anti-satellite missions to blow up satellites, creating thousands of pieces of extra debris.

AVOIDING SPACE DEBRIS BY RECYCLING SATELLITES



The History of space debris

2016
2009
2007
1996
1970

1970s – 1980s:
The USSR and the USA launched satellites with nuclear power. More than 30 still orbit the earth.

1996:
A French satellite, Cerise, was hit and damaged by debris from a French rocket that exploded a decade earlier.

2007:
China purposefully exploded FengYun-1C with a missile to test their anti-satellite system, increasing the trackable space object population by 25%.

2009:
Russian satellites Iridium 33 and Kosmos-2251 flew into each other - the first collision between two satellites.

2016:
ESA nearly lost the €280 million satellite Sentinel-1A due to a collision with a bullet-sized piece of space debris.

"With these mega constellations going into place, it's going to be impossible to have anything launch at some point. And I think if every country decides to build its own constellation, I think it's going to be very challenging to maintain that sustainability."
Ibrahim Al Qasim

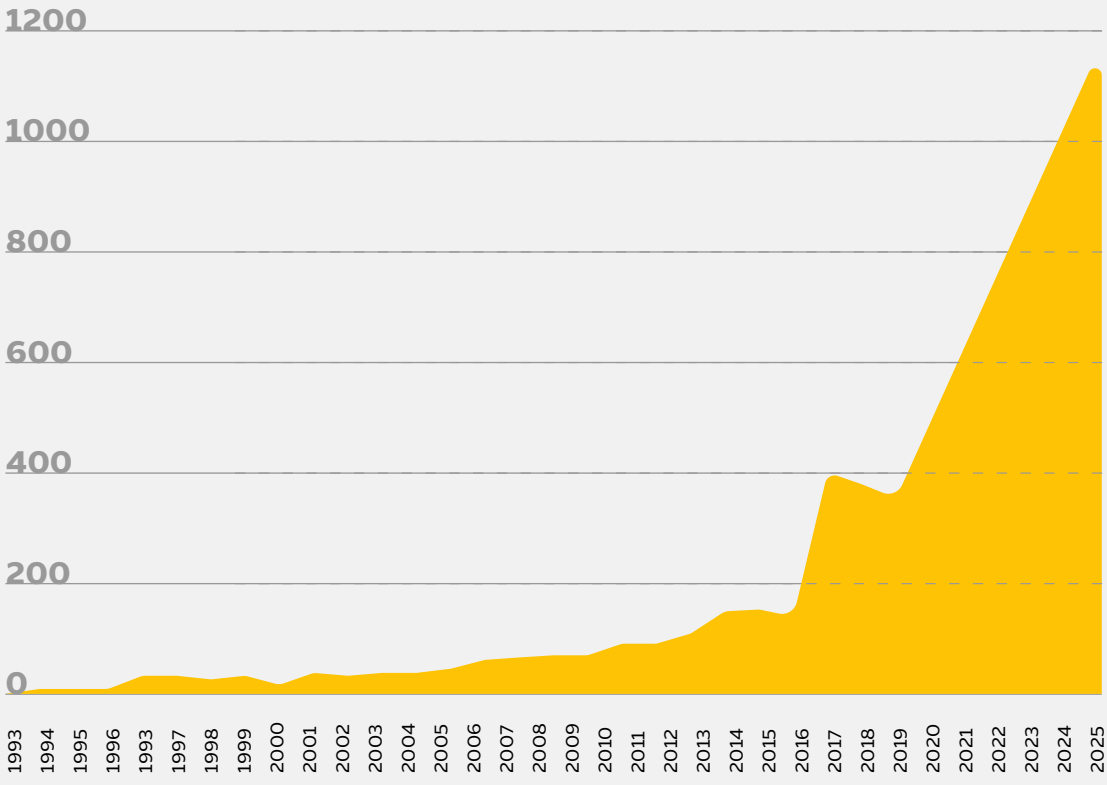
Swarms of small satellites

The most significant increase in satellites in the coming decades comes from mega-constellations of tiny satellites. Companies hope that these swarms will provide better communication and imaging coverage of the Earth, with less sophisticated technology relative to large satellites, but better real time information, resilience if one satellite fails and the ability to change their configuration to focus on particular regions.

These satellites are in low earth orbit: less than a 1000km. But that still means that many of these, those above 800km, could circle the Earth for decades without burning up in the atmosphere. Legislation sets guidelines that a satellite should remove itself or decay due to its orbital height within 25 years. But this is not a strict law, and space ports are not required to check satellites are able to do this.

Total Number of Satellites*

in orbit



*Source: Union of Concerned Scientists, 2019

Best practice

Collision avoidance

Large craft in space today predict when they will hit space debris and maneuver to avoid it in advance.

For the International Space Station, these maneuvers require about 5 hours to plan and execute using the station's Russian thrusters or the propulsion systems on one of the docked spacecraft. The International Space Station has conducted 29 debris avoidance maneuvers since 1999, including three in 2020.

Repairing and refueling

There is an emerging global industry in robotics for docking with current satellites, repairing and refueling them so that they do not become debris in busy orbits. This includes removing some to graveyard orbits 30,000 or more km from Earth. Others are redirected into the Earth's atmosphere in order to burn up there.

DARPA, the European Space Agency, Astroscale of Japan and others are developing refueling spacecraft.

Self-removing systems

In the future there is hope for systems that make decisions for themselves about how and when to avoid collisions. This involves complex criteria, including how much a mission would be shortened by using up fuel to avoid debris. But ultimately, it is a similar system to air traffic control on Earth.

The European Space Agency ran a competition to build better computer models for avoiding space debris automatically. The Spacecraft Collision Avoidance Challenge asked data scientists to use space debris position data from 2015 to 2019 to develop a model for how and when collisions are likely to occur. Eventually, this kind of model could be used by satellites to automatically avoid potential collisions.

"So it will be, for sure, for robotics for what is already there and not regulated. But then to think of different technological solutions for new spacecraft to be self removing ... Let's also build satellites with artificial intelligence on board to react to new and not known environments like debris in orbit. So it's an opportunity we have to learn from our mistakes."
Prof Michèle Lavagna

Emerging questions for future conversations

Are we doing enough to examine the new risks that come from billionaires rather than presidents deciding where the satellites go or who gets to fly into space?

The pale blue dot teaches us a broad view of Earth, but what about the long view - planning for space exploration that can continue over the long term?

Don't forget the asteroids

In the development of new technologies for managing space debris, there have also been new ways of thinking about repelling asteroids near Earth or during interplanetary missions.

1 **Technique 1: Kinetic approach**

Argotec in Turin has built LICIACube, the first satellite built in Italy to travel to deep space. It will travel to the Didymos asteroid with the American probe DART. DART will smash into the asteroid in the first full-scale test of the kinetic impact technique for repelling asteroids. LICIACube will take pictures to assess the impact of DART on Didymos's trajectory.

2 **Technique 2: Explosion**

The explosion of satellites into many small debris has helped rethink the potential negative effects of exploding asteroids.

3 **Technique 3: Heated paint**
The painted part of a satellite heats up in the sun, pushing it in the opposite direction.

The gold mine in space resources

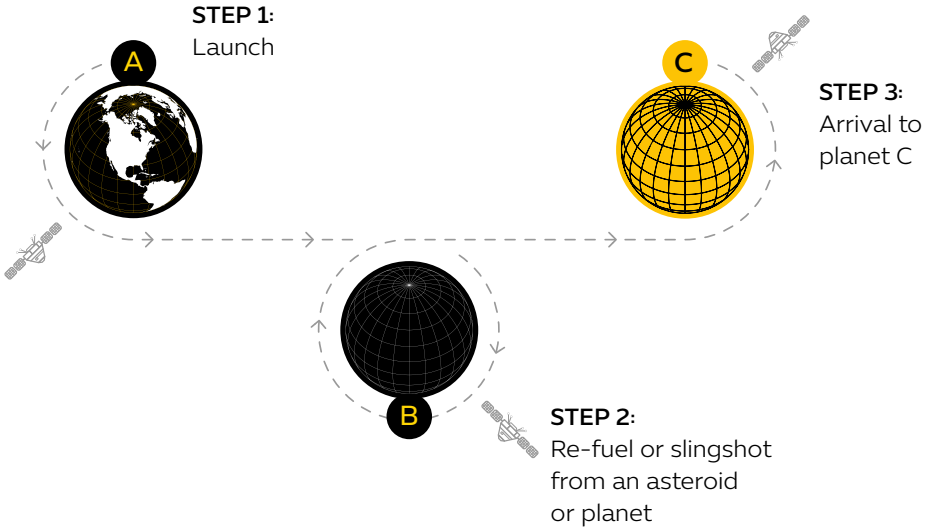
The moon and asteroids offer abundant sources of elements that are rare on Earth. Commercial space mining has the potential to turn huge profits. It tests current laws about whether people can own anything from space.

Celestial bodies are potential sources for natural materials. To support long distance human space missions, asteroids and planets might act like stepping stones from Earth to other planets.

Finding water at these locations would be most valuable for those missions. Water can be split into hydrogen and oxygen to make rocket propellant, facilitating in-space refueling.

There has also been a lot of interest in the potential bounty from rare earth metals on asteroids, intending to sell them back on Earth. Today, rare earth elements are mainly mined in China at great environmental cost. They are critical for the components in most electronic devices.

Asteroid mining missions are high-risk and high-reward. The cost of one mission is estimated at almost $3 billion (based on the costs of a discontinued NASA mission). A small achondrite asteroid in the our solar system's asteroid belt could contain as much as $50 billion of platinum.



A decade ago, asteroid mining saw significant investment into two private companies: Planetary Resources and Deep Space Industries. But the pace of innovation has tapered off.

Scientific missions to better understand the elements on the moon and asteroids have continued however, with several recent missions. In 2020, NASA collected a small amount of material from the asteroid Bennu, due to return to Earth in 2023. In the same year, Japan returned a sample of the asteroid Ryugu and China returned the first lunar samples since the 1970s.

There is also US Government support for small scale commercial missions, with four NASA contracts awarded for extracting lunar soil by 2024.

Prospectors in a gold rush

Government support for commercial mining is also an opportunity to manage the extraction of valuable resources from space. Rather than the wild west, there is potential for a more regulated, responsible market.

Companies, for the moment, need this support to help manage the risks of these missions. But in the future, regulation could also help avoid flooding markets with rare commodities and then losing the expected returns on a mission because the price collapsed.

Best practice

Luxembourg's Space Resources Act

In 2017 Luxembourg developed the first European legal and regulatory framework for the space mining industry, describing the authorisation and supervision procedures for missions aiming to explore and use natural resources in space.

Along with this law, Luxembourg is home to the European Space Resources Innovation Centre. This facility supports experiments with the technology needed for mining as well as developing and debating the economic models for successful commercial missions. The small country offered up to $200 million for space start-ups in 2016, and now 50 space companies are based there.

The Artemis Accords

iSpace Europe, the Luxembourg-based arm of the Japanese company, is one of the four working with NASA to bring back samples from the Moon under the Artemis programme.

Alongside that programme, 12 countries have signed up to the Artemis Accords that try to clarify the rules for resource extraction in space. International space law is not clear on whether a country can grant property rights to natural resources extracted in space.

This could be the first step towards a much needed international framework.

Without certainty at an international level, there is still opportunity for exploitative and irresponsible mining efforts. Having learnt the importance of property rights on Earth and the dangers - despite the excitement - of a gold rush, this is an urgent problem to solve.

"Other countries like Japan and the UAE have also enacted national laws on this topic, but we all know that this is not enough. We have to find an international framework on this. I'm very pleased to see that discussions at the United Nations on this particular field have also progressed in a, very rapid and positive way."
Dr Mathias Link

Emerging questions for future conversations

Will space become the Wild West or will the ideal of shared, open seas of space win out?

SECTION 2

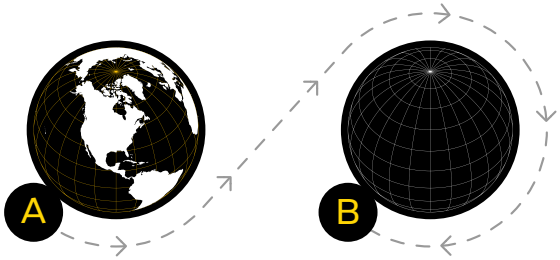
The second half of the report looks more closely at how going to space can also help humanity sustain and improve life on its home planet.

Space exploration should help life on Earth for generations to come

"Exploring planet B is amazing, but at the same time we should really focus on living on Earth."
Elyazeya Mohammed Al Mansoori

Space exploration provides innovations in food, environmental sciences and human health that improve life on Earth as well. There are renewed calls to prioritise these reasons for going to space, which can get lost in the excitement to explore further afield.

Younger people are very aware of the urgent challenges on Earth and want to ensure space exploration helps with those challenges. Ensuring Earth can sustain human life was top of their agenda. But there were also discussions about remembering to explore Earth, and the lessons it still has to teach humanity.

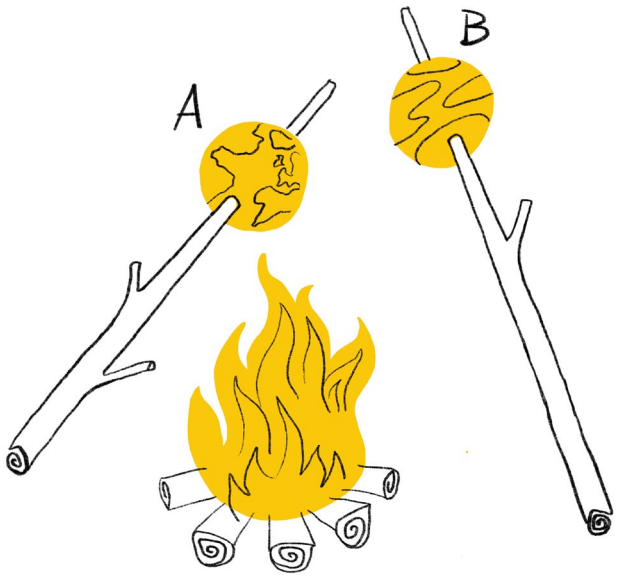


The parallels between Earth and Mars

"If the farm next to me all of a sudden goes dry and dead, I would want to know what happened there. Why? Because it is going to affect me eventually. It is about my survival. So as humanity also, this is one of the reasons we need to understand what is happening around us beyond Earth."
Omran Sharaf

Environments on Planet B are a testbed for extreme conditions on Planet A.

The argument for going to Mars was summed up in the similarities between Mars and Earth. The chemistry of extreme environments on Mars is a useful model for how Earth could change as temperatures become more extreme. If Mars is the farm next door, where life no longer survives, then one of the reasons to visit is to find out what could happen on humanity's own farm, Earth.



So the reason to go to Planet B, Mars, is to better understand what could happen to Planet A, Earth.

Best practice

ExoMars 2022

The ExoMars programme will deliver a Russian surface platform and European rover to Mars. The rover will be the first mission to combine the capability to move across the surface and to study Mars at depth. It will collect samples with a drill down to a depth of 2m. These underground samples are more likely to include signals of the chemistry of Mars when it supported lifeforms.

This is combined with modelling back on Earth. At New York University Abu Dhabi, researchers study the chemistry of Mars in experiments that simulate Martian conditions, including in the area of Mars targeted by the ExoMars 2022 mission.

This combination of sample collection and reconstruction in a laboratory help understand how Mars used to support life and how it could again in the future.

Open data on Mars weather forecasts

Also at New York University Abu Dhabi, scientists look at data from satellites circling Mars to better understand the atmosphere and weather patterns on Mars. Data from the UAE's Hope mission will be used to complement this ongoing research, which has a particular focus on how weather and space affects weather on Mars.

Data from multiple missions combined using advanced computing techniques is building an increasingly accurate model of weather on Mars. This data set is also shared publicly, and used by researchers around the world as well as students.

Learning to live in a constrained environment

There are lessons from space travel for how to live with few resources. There are also lessons from Earth for how to use what's around you to survive in space.

"What we are learning is that space is like a microcosm of what we can do here on Earth, and we can learn from that."
Dr Gioia D. Massa

Space travel requires humans to take everything with them that they will need to survive. The calculations of what it takes to support human life are also helpful for thinking about living more carefully on Earth.

On the International Space Station, water is transformed into oxygen and hydrogen and then the oxygen is used in the air for astronauts to breathe. A large fraction of the fluids are recovered and reused, including urine and perspiration. It can cost up to $43,000 to send a water bottle into space. So the more water that is recycled, the longer a mission can continue and the lower the budget needs to be for that mission.

$43,000 to send a water bottle to space

"Whether you're on the moon or Mars, you try to live from the land."
Prof Claude Nicollier

The principle of striving to live within the means of local ecosystems, to encourage a more sustainable lifestyle, is helpful when thinking about living on other planets.

If humans lived on the moon, they could use the ice inside the craters on the south pole to extract oxygen or silicate in moon rocks in order to reduce the amount of resources that need to be brought from Earth.

Martian habitats would need to be built in situ. 3D printing becomes an attractive option because the equipment needed is easy to transport and doesn't require specialist construction skills to operate. It is also easy to print repairs or spare parts if things break.

Best practice

"They went for a week into a cave in the Swiss mountains to reproduce life on the moon. And I think for them it was a great lesson to apply how to live in a closed environment - to bring the food that they need. They also took up the challenge to have a vegan diet up there."
Emmanuelle David

Swiss students practice living like they are on another planet

This experiment is unlike some of the expensive, long term Mars simulators on Earth. It demonstrates that developing awareness of how to live with finite resources, using the inspiration of living outside Earth, is an activity that many more people could take part in.

"We're working with them on not just rote exercises, but actually citizen science. They're conducting research that's helping to fuel our space exploration and space research. But at the same time, it's giving them an awareness of science and of the earth and of plants and where their food comes from."
Dr Gioia D. Massa

NASA's Growing Beyond Earth project

Instead of learning about the history of space science, education programmes are switching to offering young children the opportunity to take part in science themselves. Some of the most successful connect the challenges of food and energy security on Earth with space.

Over 12,000 US school children are growing vegetables at school in systems similar to the one on the International Space Station. This provides data used by NASA scientists who are developing technologies for growing food crops for long-duration missions into deep space.

The aim is to nurture future talent working on the biggest challenges of their generation by encouraging innovative thinking from a young age.

Biological innovation created between earth and space

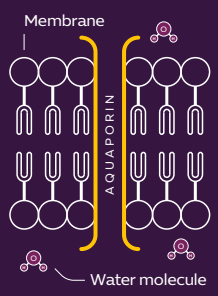
Close-to-Earth experiments now bringing quick benefits to industry on Earth.

The International Space Station and now the Chinese Space Station are successful incubators for science and engineering practices that are immediately beneficial back on Earth.

Often it is not the same use case on earth as in space, but it is the way that space provides a radically different environment that can then spark the idea for how to do something differently on Earth.

Best practice

"With filter water technology from space with the biology down here, we realized we could continue to tune and improve how they turn dirty water into clean water."
Prof Brian Schmidt



Aquaporins to clean dirty water

Aquaporins are proteins present in all life forms. They have been used to filter water with 100% reuse on the International Space Station. Biologists at the Australian National University have worked out how to manipulate aquaporins very precisely to do a variety of tasks.

In particular, they are able to extract fertiliser out of contaminated water and then reuse the fertiliser. With high drought conditions in Australia, this is a valuable invention.

Rare earth metals are used in most electronic devices, but extracting them from nickel requires acid bleaching. Aquaporins could be used to help with this extraction without the need for the pollutants in the acid.

"It's become a technology that is widely used around the world, but it's also something that's been used a lot now in space crop production because it works very well for our purposes as well. So there tends to be a nice synergy and partnership with some of these technologies."
Dr Gioia D. Massa

Fertilisers for food on the space station and on Earth

NASA's food production in space uses a controlled release, polymer coated fertiliser that releases nutrients slowly. It was developed with NASA research and financial support. But the innovator who worked with NASA was focused on developing better fertilisers for Earth: ones that did not cause algae bloom in waterways downstream of farms.

The relationship was mutually beneficial, developing a product for space and Earth at the same time.

Cancer science that is easier in space

Petri dish in space

Normal petri dish

Cancer cells in space form three-dimensional tumours in petri dishes in the microgravity of spaces. There are much more like tumours that grow inside human bodies that the flat tumours that grow in labs on Earth.

NASA's laboratory on the International Space Station is also being used to test cancer drugs in these three dimensional cell cultures.

Emerging questions for future conversations

If we can mimic space environments on Earth, are we wasting money by doing experiments in space rather than in laboratories on Earth?

A satellite data economy built by everyone

A fast-growing opportunity for many countries and companies to use satellite data to make better decisions about supporting sustainability on Earth.

The growth in space-for-earth technology means more than just a global network of telecommunication satellites. It means that humans can understand their planet using satellite monitoring better than ever before. Over 50% of the metrics used to monitor climate change come from satellite information.

With this comes an enhanced ability to make evidence-based decisions about the planet.

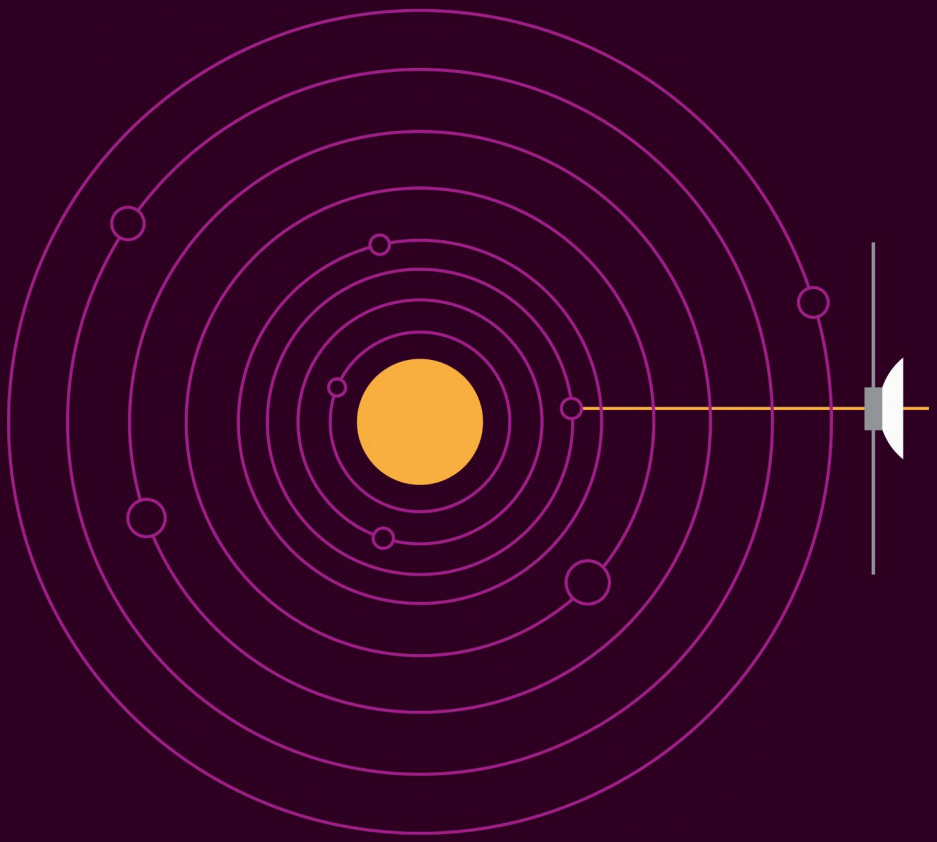
Data from satellites can be combined to create applications that can help farmers, fishermen or policy makers to understand how their industries are changing the natural environment. Many start-ups are working in this area.

Data can also be used to understand extreme weather incidents, and is starting to be used to predict them and inform policy responses ahead of emergencies.

Emerging data alliances

There are new alliances built to share important satellite data between groups of companies and nations. The UAE's KhalifaSat is part of the PanGeo Alliance, the only virtual constellation of submetric – very high resolution - satellites. With satellites in different orbits, the constellation takes images of the same area several times a day. It can provide real-time information for disaster response. Efforts like this could lead to powerful partnerships able to provide internet and real-time images for parts of the world that were previously badly covered by satellites.

At the same time, they could also create new divides between those involved in the partnership and those excluded. Data is widely shared during emergencies, but ongoing monitoring information is at risk of being caught up in these agreements.



A SATELLITE DATA ECONOMY
BUILT BY EVERYONE

"This technology gives us the capability to realise that we are making so much change in the environment, like the temperature rise that has happened in the last hundreds of years or even the emissions that are happening from anthropogenic or other activities on earth."

Dr Somanath Sreedhara Panicker

Best practice

Swiss Space4Impact Initiative

This initiative helps space startups linked with the UN Global Goals to find investors.

One example is companies that use Internet of Things technology - and therefore the latest telecommunication satellites - to help farmers monitor crops more precisely.

This new initiative sees a lot of potential in this area, for companies to invest more in products that align with global goals, but also using shared data to create new applications that help business owners make more sustainable choices.

Fishing data in India

India has special observation platforms that combine environmental and space data in key ecosystems around the country.

This includes looking at the sea color and the sea surface temperature for key fishing areas. These factors are good predictors of where there are schools of fish. There are kiosks in the fishing area where fisherman can go in the morning to find out where fish are that day.

This has improved the yield for small fishing vessels, as well as reducing the fuel used in these industries.

Monitoring extreme weather in Japan

Since 2018, Japan has been able to predict severe storm conditions, reducing the damage caused by those events.

The Himawari-8 satellite sends infrared radiation luminance data, which can be used to model weather patterns in areas under heavy cloud cover for the first time.

Emerging questions for future conversations

How do we avoid a new data divide between partners in a satellite constellation and those that would find the data useful, but are not in the partnership?

Will countries with less satellite data about themselves suffer because they will lack the insights to make informed decisions?