

Space exploration is going private

The commercialisation of space comes with unknown promise but known risks.



Neil Armstrong landed on the moon in 1969 and delivered his pre-prepared line that became famous: "That's one small step for man, one giant leap for mankind." Except he misspoke. What Armstrong said was nonsense. He meant to say "a man" rather than just "man".

Clive James in his book *Fame in the 20th century* explained that Armstrong's lapse was overlooked because eloquence, even personality, didn't matter. The first man on the moon would be famous "without ever having emerged from obscurity", even if Armstrong was so chosen because he was dispensable to the Apollo 11 mission rather than, as the official line had it, he epitomised the 'right stuff'.^[1] The National Aeronautics and Space Administration supplies a transcript that corrects Armstrong's statement but the accompanying audio shows his slip.^[2]

Whatever. Armstrong's statement rang true. From the start of the space age in 1957 when the Soviet Union's Sputnik satellite orbited the Earth, six-plus decades of mainly US government-funded, -designed and -staffed space exploration has brought many rewards. Apart from stirring national pride and showcasing bravery, space exploration has boosted knowledge of the universe and led to much innovation related to satellites, global positioning and weather forecasting.^[3]

Even if Armstrong blew his line, he was more profound than Jeff Bezos on his return to Earth on July 20 after being blasted into the atmosphere just past the Karman line that, 100 kilometres (62 miles) from Earth, generally marks outer space. "Best day ever," was Bezos's verdict on flying for 10 minutes in a pilotless rocket built by Blue Origin, a company he founded in 2000.^[4]

Perhaps Bezos should have said something more Armstrong-like as did Richard Branson when, nine days before Bezos, he zoomed to an altitude of 80 kilometres in a piloted space plane built by Virgin Galactic, which Branson set up in 2004. "We are at the vanguard of a new space age," Branson said.^[5]

What's new is that an entrepreneur-led drive into space is underway. Bezos and Branson – joined soon perhaps by other private companies^[6] – are vying with Boeing^[7] and Elon Musk's Space Exploration Technologies Corp. to commercialise space.

SpaceX, as Musk's creation of 2002 is known, is ahead. The company in 2015 pioneered reusable rockets, the "single transformative technology shift" driving today's space race because it has slashed launch costs.^[8] Among feats, since 2012, SpaceX has ferried cargo to the International Space Station, Nasa's lab that orbits the Earth. On May 30 last year, SpaceX became the first private company to propel people into space, when it sent astronauts to the space station, the first manned mission there since 2011.^[9] In June this year, to the same destination, SpaceX launched a manned reusable rocket for the first time.^[10] SpaceX, for US\$2.9 billion, is building the 'Starship' for Nasa to land people on the moon for the first time since 1972.^[11]

Many benefits are likely to flow from the commercialisation of space that already amounts to a US\$350 billion industry and one that is forecast to swell to US\$1 trillion by 2040.^[12] Space tourism is likely to grow, after commencing on September 15 when SpaceX launched its first privately funded three-day spaceflight of just tourists; no professional astronaut was aboard a tripe paid for by US businessman Jared Isaacman who said it cost less than US\$200 million.^[13] The standard offering (at US\$450,000 a pop with Virgin Galactic)^[14] will be orbiting the Earth to experience weightlessness and gain an astronaut's view of the world. Another prospect is vacations on commercial space stations – US company Axiom Space is building such a facility that it hopes by 2024 will orbit 400 kilometres above the Earth at 27,000 kilometres per hour.^[15] A later step could be tourist trips to the moon.

A second, and bigger, commercial motivator is adding to the more than 5,000 satellites already orbiting the Earth, a doubling in the past two years as part of efforts to boost economical internet coverage.^[16] SpaceX, for instance, plans to add another 11,000 satellites via its Starlink mega-constellation and has filed for US permission for another 30,000.

Private enterprise heading into the cosmos is rekindling and aiding government space efforts. Nasa, as well as employing SpaceX to return to the moon under its Artemis Program, plans more voyages to Mars and intends to search Jupiter's moon Europa for life.^[17] China in May landed a vehicle on Mars for the first time,^[18] two years after the country became the first to land a craft on the far side of the moon.^[19] Beijing and Moscow in June announced plans for a permanent base on the moon,^[20] while about 40 countries now have national space agencies.^[21]



Commercial space efforts are bound to advance scientific knowledge. The hope is that 'microgravity' will allow for unique research that could lead to "discoveries in medicine, materials, and manufacturing previously kept hidden by gravity," in the worlds of Axiom Space.[22] Another motive is to enable people to live beyond Earth. Bezos sees "a future where millions of people are living and working in space".[23] Musk talks of 'terraforming' Mars, by which he means nuking Mars to make the planet habitable for humans.[24]

The commercialisation of space comes with risks and disadvantages that could limit such exploration (ignoring complaints about the cost). The biggest risk is that space travel is dangerous. Much can go wrong with rockets. In September, the US Federal Aviation Administration grounded Virgin Galactic flights pending a probe that Branson's flight went off course during its descent.[25] The International Space Station is showing irreparable cracks.[26] Another danger is that much human debris is swirling around in space and could hit a spacecraft, as occurred in March when a Chinese military satellite broke up after it collided with debris left from a 1996 Russian rocket launch.[27] Fatal events could derail space exploration, as they have in the past.

Another problem is space exploration is likely to intensify global political tensions. Whoever rules space controls an avenue to deliver thermonuclear weapons via ballistic missiles and much else. China's moves into space look likely to intensify Chinese-US rivalry. The US in 2019 created a Space Command as its sixth military sphere to thwart China in space, such as China's ability to laser-cripple the satellites on which depend the US military.[28] A third drawback is the space race will come with environmental damage, especially with respect to climate change from fossil-fuelled rockets. Scientists worry that satellite re-entries from the Starlink mega-constellation could deposit more aluminium into Earth's upper atmosphere than what is done through meteoroids.[29] But rocket numbers would need to soar to make a noticeable difference.

Whatever the doubts or drawbacks about the question, the better economics of space exploration are overriding them. A privately led space adventure has begun that has already notched achievements and, amid controversy and setbacks, is likely to post many more.

To be pedantic, private companies have long helped Nasa (Boeing for more than five decades) while the commercialisation of space could be dated to the turn of the century, so it's not new, just intensifying. The role of Nasa and other government agencies in this private quest shouldn't be underestimated. These private companies will need to be willing to lose much money – the listed Virgin Galactic lost US\$94 million in the second quarter of 2021.[30] A techno-utopian element bordering on the unbelievable pervades the private space quest. Nasa's response to Musk's dreams, for instance, is that it would be impossible to make Mars liveable due to a lack of carbon dioxide,[31] while the technology for space mining is still to be invented. Some, perhaps much, disappointment lies ahead.

No doubt. But the entrepreneurs pioneering today's drive into space are wealthy visionaries who won't be deterred easily. Get set for a space race pursued by people who think they are on a philanthropic mission.

SPACE UTOPIA

In 2015, SpaceX's Falcon 9 rocket blasted off. After 45 seconds, the rocket shed its first stage, which then descended to Earth in a controlled manner to a landing pad. "Welcome back, baby," Musk tweeted.[32] A broadcaster had a better technical perspective of SpaceX's third attempt at the feat: It's like "launching a pencil over the Empire State building, having it reverse, come back down, and land on a shoebox on the ground in a windstorm." [33]

Time has elevated the financial significance of Falcon 9's safe touchdown that day. The feat is taken as the start of economical near-Earth orbit space flight because it ended the era when rockets were dumped or imploded during re-entry into the Earth's atmosphere, even though Nasa's space shuttles were reusable (and Bezos's Blue Origin had landed an unmanned rocket the month before).[34] Companies are now spared the hundreds of millions of dollars it costs to build rockets for each flight. Since 2015, Falcon 9 rockets have recorded 82 landings and 64 have flown again,[35] though some have bungled the touchdown.[36]

US taxpayers are among those benefiting from the improved space economics. SpaceX is ferrying Nasa astronauts and items to and from the International Space Station at far less cost than could the space shuttle that was retired in 2011[37] – Nasa in 2018 said reusable rockets reduced the cost of sending a craft to low Earth orbit by a factor of 20.[38] Nasa is estimated to be saving US\$2 billion by using SpaceX's Falcon Heavy rocket for its mission to Jupiter's moon.[39] Having SpaceX and Blue Origin bid for Nasa contracts is another force driving down costs. Bezos in July, for instance, said Blue Origin would waive up to US\$2 billion in payments over the next two years if Nasa were to award his company a moon-landing contract.[40] (Blue Origin is suing in a federal court to force Nasa to do so.)[41]

Bezos's efforts are part of his drive to populate space and extract resources from space. He is reported to have assembled "the best space-resources team in the industry" to help people live on the moon and send material back to Earth.[42] In what could well be taken as the start of the space-mining industry, Nasa in 2020 handed contracts to four companies to extract small amounts of lunar regolith, loose material that covers rock, by 2024.[43] In August, Nasa conducted its first drilling of Mars, to a depth of seven centimetres, as part of a search for microbial life on the planet.[44] Nasa in 2022 intends to launch a mission to investigate the Psyche asteroid, a unique metal asteroid that orbits the Sun between Mars and Jupiter that some say could contain US\$10 quintillion of iron (that will presumably be claimed by whomever reaches it first).[45]

Space proponents say that microgravity will mean moon dwellers could create items that can be made only in space. Others talk of asteroid mining, whereby either resources are extracted and sent to Earth or asteroids are directed at Earth for extraction there. Others talk up space-based solar power; China has announced plans for a solar power station in orbit by 2040.[46] One day earth-controlled robots could mine the moon for water, which can become a rocket fuel once split into hydrogen and oxygen. They could mine for helium-3, another rocket fuel, and the rare-earth minerals that are used in electronics.[47] Nasa is making soil for space habitats by seeding asteroids with fungi.[48]



Morgan Stanley said satellite technology and space exploration could help assess and address climate change and sustainability on Earth. The benefits could flow to food security as imagery and weather-monitoring boost agricultural yields and farmer efficiency, the US bank says. Space-based aid could help greenhouse-gas monitoring, open remote areas to renewable-energy harvesting, help utilities manage renewable loads, and boost access to the internet for billions of people.[49]

Among advocates, the promise of space is essentially limitless.

SPACE DYSTOPIA

In 1985, US teacher Christa McAuliffe became a national celebrity when she beat more than 11,000 other applicants to win a seat on the space shuttle Challenger. When McAuliffe was asked if she was nervous, she repeated what she had been told: that the shuttle was as safe as an airplane. The Challenger blasted off on 28 January 1986, one of the coldest mornings ever at Cape Canaveral, Florida. The rubber O-rings that sealed the shuttle's rocket boosters didn't work as well in cold weather – a problem known to Nasa officials. The O-rings failed. The Challenger exploded during lift-off. But McAuliffe and her six crewmates didn't die immediately. The crew compartment sheared from the rest of the shuttle and rose for another 20 seconds, then fell for more than two minutes before smashing into the ocean at 333 kilometres an hour and killing all on board. The shuttle program was suspended for two years.[50]

The program was suspended for another two years in 2003 when the space shuttle Columbia fell apart on re-entering the Earth's atmosphere, killing its seven astronauts. Nasa's Apollo program from 1961 to 1972 had two notable disasters. In 1967, the crew of three on Apollo 1 choked to death when a fire erupted during a prelaunch test. In 1970, Apollo 13 abandoned landing on the moon and nearly failed to return to Earth after an oxygen tank exploded and destroyed the module's ability to provide electrical power.

The reality is that today's ventures are as dangerous. In 2014, a Virgin Galactic space craft disintegrated during a test flight, killing the co-pilot.[51] Only nine days after Bezos's flight, Nasa and Boeing abandoned the launch of Boeing's crewless Starliner space capsule due to valve problems,[52] which followed a botched launch in 2019 due to a software error.[53] Longer flights in space risk confronting 'solar flares', the most powerful explosive events in the solar system.[54] A fatal event could end, or at least suspend, today's space race.

An uninterrupted space race comes with concerns too. The exploration comes with "violent potential", in the words of Daniel Deudney, a professor of politics at the US-based Johns Hopkins University who wrote *Dark skies: Space expansion, planetary geopolitics and the end of humanity* that argues against the space optimism of Bezos, Branson, Musk et al. "What is going

to be the likelihood that we'll have – as we have on Earth – wars and violent rivalries?" he asks, especially if descendants of Earth develop over time, possibly with genetic engineering, into different species.[55]

The surge into space has led to calls for revamped multilateral pacts to manage any arms race, space debris, satellite traffic and resource extraction, amid warnings present treaties, such as the Committee on the Peaceful Uses of Outer Space[56] of 1959 and the Outer Space Treaty[57] of 1967 that sit with the UN, are outdated.

Mars is the likely point of confrontation after the moon. Simon Morden, author of the upcoming *The red planet: A natural history of Mars*, warns governments and space pioneers need to decide what they want to do with the planet. "Any crewed mission will be at the end of the most precarious supply line in history," he says. Crews will thus need to rely on what resources Mars can offer "which is why future planned missions to Mars rely heavily on the anodyne-sounding practice of in situ resource utilisation". He suggests that to protect Mars an international agreement is needed similar to the Antarctic Treaty effective 1961 that saves that continent for science. "It's almost inevitable that, if we do nothing, the default (read guaranteed outcome) will be a chaotic and exploitative land grab." [58]

Then there are the pollution concerns. The risks for the Earth relate largely to climate change. Rockets are propelled by the fossil fuels such as kerosene that emit carbon dioxide, chlorine and other chemicals. The problem is the pollutants including soot are emitted into the upper atmosphere and can destroy the ozone layer, while heat released closer to Earth can act like greenhouse gases. The greater the number of space flights, the greater the damage and the bigger the political problem confronting the space adventurers.[59]

When it comes to pollution in space, the immediate environmental concern is the amount of debris the space race will add into orbit that, if nothing else, increases the chance of collisions. Nasa estimates more than 100 million pieces of space junk are spinning around the earth.[60] The US Department of Defense tracks about 27,000 pieces of 'space junk' that have wrecked satellites (which only puts more debris in space).[61] One solution is that of Japanese firm Astroscale, which is testing magnetic satellites that can help remove debris.[62] A longer-term concern is damage by humans to planets on which they live, work and exploit.

Such challenges and no doubt setbacks are part of the space race. At the moment, though, the space joyriders are empowered. Without ever misspeaking, space superhero Buzz Lightyear from *Toy Story* probably best sums up the enthusiasm of Bezos, Branson and Musk and others as they seek to emulate the space heroes of yesterday. "To infinity and beyond."

By Michael Collins, Investment Specialist

- [1] Clive James. 'Fame in the 20th century.' Pages 123 to 124. Penguin Books. 1994.
- [2] NASA. 'July 20, 1969: One giant leap for mankind.' nasa.gov/mission_pages/apollo/apollo11.html
- [3] See NASA. International Space Exploration Coordination Group. 'Benefits stemming from space exploration.' September 2003. nasa.gov/sites/default/files/files/Benefits-Stemming-from-Space-Exploration-2013-TAGGED.pdf
- [4] 'Jeff Bezos blasts into space on own rocket: Best day ever!' The Washington Post. 21 July 2021. washingtonpost.com/business/bezos-riding-own-rocket-on-companys-1st-flight-with-people/2021/07/20/29791bf8-e92c-11eb-a2ba-3be31d349258_story.html
- [5] Virgin Galactic. 'Virgin Galactic successfully completes first fully crewed spaceflight.' 11 July 2021. virgingalactic.com/articles/virgin-galactic-successfully-completes-first-fully-crewed-space-flight/
- [6] Companies in Japan are interested. See Japan's Lunar Industry Vision Council. 'Toward the planet 6.0 era.' July 2021. ispace-inc.com/wp-content/uploads/2021/07/LIV_EXECUTIVE-SUMMARY_FINAL_20210710_EN_0712_2MB.pdf
- [7] Boeing Space Launch System is the Boeing arm focused on space. Boeing in space. 'The future of space is built here.' boeing.com/space/
- [8] Morgan Stanley. 'Space: Investing in the final frontier.' 24 July 2021. morganstanley.com/ideas/investing-in-space
- [9] NASA. 'Demo-2: Launching into history.' 1 June 2020. nasa.gov/image-feature/demo-2-launching-into-history_t
- [10] National Geographic. 'SpaceX launches first astronauts on reused rocket.' 23 April 2021. nationalgeographic.com/science/article/spacex-launches-first-astronauts-on-a-reused-rocket
- [11] SpaceX. 'Starship to land NASA astronauts on the moon.' 16 April 2021. spacex.com/updates/starship-moon-announcement/index.html. Musk says this could happen before 2024. See 'Elon Musk says SpaceX ready to land humans on moon 'probably sooner' than 2024.' Newsweek. 15 August 2021. newsweek.com/elon-musk-spacex-ready-humans-moon-sooner-2024-1619475
- [12] CNBC. 'Bank of America expects the space industry to triple to a \$1.4 trillion market within a decade.' 4 October 2020. cnbc.com/2020/10/02/why-the-space-industry-may-triple-to-1-point4-trillion-by-2030.html
- [13] See, The Atlantic. 'Finally, a private spaceflight with a billionaire you've never heard of.' 13 September 2021. theatlantic.com/science/archive/2021/09/spacex-inspiration4-private-crew/620056/. See also, SpaceX. 'SpaceX to launch Inspiration4 mission to orbit.' 1 February 2021. spacex.com/updates/inspiration-4-mission/index.html
- [14] Virgin Galactic. 'Virgin Galactic announces second quarter 2021 financial results.' 5 August 2021. investors.virgingalactic.com/news/news-details/2021/Virgin-Galactic-Announces-Second-Quarter-2021-Financial-Results/default.aspx
- [15] See Axiom Space website. axiomspace.com/axiom-station. The facility will orbit 250 miles above the earth at 17,000 miles per hour.
- [16] Nature.com. 'Satellite mega-constellations create risks in low earth orbit, the atmosphere and on earth.' 20 May 2021. nature.com/articles/s41598-021-89909-7. Other companies with plans to launch satellites in numbers include Amazon, Chinese state firm GW, UK-based OneWeb and TéléSAT of Belgium.
- [17] NASA. Artemis Program. 'Humanity's return to the moon.' nasa.gov/specials/artemis/. See NASA. Europa Clipper mission. europa.nasa.gov/ See also 'NASA perseveres through pandemic, looks ahead in 2021.' 5 January 2021. nasa.gov/feature/nasa-perseveres-through-pandemic-looks-ahead-in-2021
- [18] Xinhua. 'China succeeds in first Mars landing.' 15 May 2021. xinhuanet.com/english/2021-05/15/c_139947277.htm
- [19] Xinhua. 'China's Chang'e-4 probe soft-lands on the Moon's far side.' 3 January 2019. xinhuanet.com/english/2019-01/03/c_137716800.htm
- [20] Xinhua. 'China, Russia invite international partners in lunar research station cooperation.' 17 June 2021. xinhuanet.com/english/2021-06/17/c_1310011788.htm
- [21] UN. Office for Outer Space Affairs. 'World space agencies.' un.org/osa/en/ourwork/space-agencies.html
- [22] Axiom. 'Why space?' axiomspace.com/why-space
- [23] 'About Blue Origin'. blueorigin.com/about-blue
- [24] Space.com. 'Elon Musk floats 'nuke Mars' idea again (and he has T-shirts). 17 August 2021. space.com/elon-musk-nuke-mars-terraforming.html
- [25] Reuters. 'US grounds Virgin Galactic flights pending mishap probe.' 3 September 2021. reuters.com/business/aerospace-defense/us-bars-virgin-galactic-rocket-plane-flights-pending-mishap-probe-2021-09-02/
- [26] The Times. 'Cracks in International Space Station cannot be repaired, Russia claims.' 1 September 2021. thetimes.co.uk/article/cracks-in-international-space-station-cannot-be-repaired-russia-claims-59dhbzs6r
- [27] Space.com. 'Space collision: Chinese satellite got whacked by hunk of Russian rocket in March.' 16 August 2021. space.com/space-junk-collision-chinese-satellite-yunhai-1-02
- [28] US Defense Intelligence Agency. 'Challenges to security in space.' January 2019. dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf See Department of Defense. US Space Command. spacemil.mil/#/. See also 19FortyFive (a US-based publication focused on national security). 'Don't let China turn space into the new South China Sea.' August 2021. 19fortyfive.com/2021/08/dont-let-china-turn-space-into-the-new-south-china-sea/
- [29] Nature.com. Op sit.
- [30] Virgin Galactic. Second quarter result 2021. Op sit.
- [31] 'Inventory of CO2 available for terraforming Mars.' Nature magazine. 1 August 2018. nature.com/articles/s41550-018-0529-6.epdf
- [32] Twitter. @elonmusk. 22 December 2015. twitter.com/elonmusk/status/679127406813188097
- [33] National Geographic. 'Touchdown! SpaceX rocket makes a perfect upright landing.' 23 December 2015 nationalgeographic.com/science/article/151222-spacex-landing-rocket-video-space.
- [34] See National Geographic. 'How SpaceX became NASA's go-to ride into orbit.' 12 November 2020. nationalgeographic.com/science/article/how-spacex-became-nasas-go-to-ride-orbit
- [35] SpaceX. Falcon 9. spacex.com/vehicles/falcon-9/
- [36] Cnet. 'SpaceX Falcon 9 missed its landing last month because of a hole in the boot.' 1 March 2021. cnet.com/news/spacex-falcon-9-missed-landing-last-month-because-of-a-hole-in-a-boot/
- [37] Forbes. 'Why SpaceX is a game changer for NASA.' 4 June 2020. forbes.com/sites/niallmccarthy/2020/06/04/why-spacex-is-a-game-changer-for-nasa-infographic/
- [38] NASA Technical Reports Server. 'The recent large reduction in space launch cost.' 8-12 July 2018. ntrs.nasa.gov/citations/20200001093. See also Nextbigfuture.com. 'SpaceX starship is bigger and cheaper than the external shuttle tank.' 28 May 2020. nextbigfuture.com/2020/05/spacex-starship-is-bigger-and-cheaper-than-the-external-shuttle-tank.html
- [39] arsTECHNICA. 'SpaceX to launch the Europa Clipper mission for a bargain price.' 24 July 2021. arstechnica.com/science/2021/07/spacex-to-launch-the-europa-clipper-mission-for-a-bargain-price/
- [40] Blue Origin. 'Open letter to administrator Nelson.' 26 July 2021. blueorigin.com/news/open-letter-to-administrator-nelson
- [41] 'Jeff Bezos's Blue Origin files suit in federal court as it pursues a campaign to win a slice of NASA moon contract.' 16 August 2021. The Washington Post. (Bezos owns the Post.) washingtonpost.com/technology/2021/08/16/blue-origin-spacex-rivalry-lawsuit-nasa/
- [42] arsTECHNICA. 'Blue Origin has a secret project named 'Jarvis' to compete with SpaceX.' 27 July 2021. arstechnica.com/science/2021/07/blue-origin-is-developing-reusable-second-stage-oth-er-advanced-projects/
- [43] NASA. 'Construction with regolith.' 6 March 2017. nasa.gov/api/citations/20170002067/downloads/20170002067.pdf
- [44] NASA. 'Assessing Perseverance's first sample attempt.' 11 August 2021. mars.nasa.gov/mars2020/mission/status/320/assessing-perseverances-first-sample-attempt/ See WIRED. 'Why Perseverance's first Mars drilling attempt came up empty.' 12 August 2021. wired.com/story/why-perseverances-first-mars-drilling-attempt-came-up-empty/
- [45] NASA. Mission pages. 'Psyche overview.' nasa.gov/mission_pages/psyche/overview/index.html. See Financial Times. 'Space mining: black holes await investors.' 14 August 2021. ft.com/content/7ede2b1e-2872-4c04-b0ba-0a6486ea9ee
- [46] China Daily. 'Scientists envision solar power station in space.' 27 February 2019. chinadaily.com.cn/a/201902/27/W55c75c8b3a3106c65c34eb8e3.html
- [47] Milken Institute Review. 'Space mining is coming.' 26 April 2021. milkenreview.org/articles/mining-in-space-is-coming
- [48] NASA. 'Making soil for space habitats by seeding asteroids with fungi.' 26 February 2021. nasa.gov/directorates/spacetech/niac/2021_Phase_I/Making_Soil_for_Space_Habitats/. See also Scientific American. 'Future space travel might require mushrooms.' 3 August 2021. scientificamerican.com/article/space-travels-most-surprising-future-ingredient-mushrooms/
- [49] Morgan Stanley. Ideas. 'Does Earth's future depend on space?' 10 July 2020. morganstanley.com/ideas/space-earth-sustainability
- [50] Kevin Cook, author of 'The burning blue: The untold story of Christa McAuliffe and NASA's Challenger disaster.' Henry Hold & Co. August 2021. This excerpt is from 'The case against space tourism.' 22 July 2021. The Wall Street Journal. wsj.com/articles/blue-origin-spacex-bezos-musk-galactic-branson-tourism-space-11626968962
- [51] c|net. 'Branson on Virgin Galactic crash: Space flight is hard – but worth it.' 1 November 2014. cnet.com/news/branson-on-virgin-galactic-crash-space-is-hard-but-worth-it/
- [52] Boeing. Tweet from @BoeingSpace. 4 August 2021. twitter.com/BoeingSpace/status/1422716652727250945
- [53] 'Boeing space flight postponed after mishap at space station.' 29 July 2021. The Wall Street Journal. wsj.com/articles/boeing-space-flight-postponed-after-mishap-at-space-station-11627589940
- [54] NASA. 'What is a solar flare?' nasa.gov/content/goddard/what-is-a-solar-flare
- [55] Aie.org. Blog post. 'Space expansion, planetary geopolitics and the end of humanity. My long read q&a with Daniel Deudney.' 19 June 2021. aie.org/economics/space-expansionism-geopolitics-and-the-future-of-humanity-my-long-read-q-a-with-daniel-deudney/. See also World Political Review. 'Colonising space is not the solution to our problems here on earth.' 26 July 2021. worldpoliticsreview.com/articles/29832/despite-dreams-of-colonization-space-won-t-solve-our-problems-on-earth
- [56] United Nations. Office for Outer Space Affairs. 'Committee on the Peaceful Uses of Outer Space.' un.org/osa/en/ourwork/copuos/index.html
- [57] United Nations. Office for Disarmament Affairs. The Outer Space Treaty is formally the 'Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.' treaties.unodha.org/t/outer_space
- [58] Simon Morden. 'We are on the brink of a new space race – it's time to talk about Mars.' 9 August 2021. independent.co.uk/voices/mars-nasa-space-race-b1898113.html. The red planet: A natural history of Mars. Simon Morden. To be published by Elliott & Thompson September 2021.
- [59] See The Guardian. 'How the space race could be one giant leap for pollution.' 19 July 2021. theguardian.com/science/2021/jul/19/billionaires-space-tourism-environment-emissions. See also, 'The rise of space tourism could affect earth's climate in unforeseen ways, scientists worry.' 26 July 2021. space.com/environmental-impact-space-tourism-flights
- [60] NASA. Office of inspector general. 'NASA's efforts to mitigate the risks posed by orbital debris.' 27 January 2021. Page 3. oig.nasa.gov/docs/IG-21-011.pdf
- [61] Science and history. 'Space is getting crowded with junk.' 3 July 2021. sciencendhistory.blogspot.com/2021/07/space%20debris%20in%20orbit.html
- [62] Spacenews. 'Astroscale complete first test of satellite capture technology.' 25 August 2021. spacenews.com/astroscale-complete-first-test-of-satellite-capture-technology/

Important Information: This material has been delivered to you by Magellan Asset Management Limited ABN 31 120 593 946 AFS Licence No. 304 301 ('Magellan') and has been prepared for general information purposes only and must not be construed as investment advice or as an investment recommendation. This material does not take into account your investment objectives, financial situation or particular needs. This material does not constitute an offer or inducement to engage in an investment activity nor does it form part of any offer documentation, offer or invitation to purchase, sell or subscribe for interests in any type of investment product or service. You should read and consider any relevant offer documentation applicable to any investment product or service and consider obtaining professional investment advice tailored to your specific circumstances before making any investment decision. A copy of the relevant PDS relating to a Magellan financial product or service may be obtained by calling +61 2 9235 4888 or by visiting www.magellangroup.com.au.

This material may include data, research and other information from third party sources. Magellan makes no guarantee that such information is accurate, complete or timely and does not provide any warranties regarding results obtained from its use. This information is subject to change at any time and no person has any responsibility to update any of the information provided in this material. Statements contained in this material that are not historical facts are based on current expectations, estimates, projections, opinions and beliefs of Magellan. Such statements involve known and unknown risks, uncertainties and other factors, and undue reliance should not be placed thereon.

Any trademarks, logos, and service marks contained herein may be the registered and unregistered trademarks of their respective owners. This material and the information contained within it may not be reproduced, or disclosed, in whole or in part, without the prior written consent of Magellan. TP053

✉ info@magellangroup.com.au

☎ +61 2 9235 4888