## Solar Flares DA

#### Space superstorms are inevitable in the immediate future – solar maximum makes the risk uniquely high

Kettley 19 [Sebastian Kettley, science reporter citing Dr Kaku, a theoretical physicist at the City College of New York. “Space weather WARNING: 'All hell will break loose' when solar flare CRIPPLES Earth.” January 25, 2019. https://www.express.co.uk/news/science/1077603/Space-weather-warning-solar-flare-hit-earth-michio-kaku-sunspot]

Major solar flares triggered by a solar maximum in [space](https://www.express.co.uk/latest/space) will wreak havoc on Earth and it is only a “matter of time”. Dr Kaku, a theoretical physicist and book author at the City College of New York, has warned modern technology is defenceless against such reckless power. Solar flares are highly-charged streams of gaseous energy particles violently ejected from the Sun out into the solar system. When solar flares strike the atmosphere, they create beautiful displays of light near the North and South Poles, known as aurora. But solar flares also have the power to wipe out communications satellites, disable electronic devices and cause aeroplanes to malfunction. At their worst, solar flares can blow out power stations, disable GPS navigation and ground emergency services. Speaking live on Coast to Coast AM Radio, Dr Kaku said solar flares on this scale are rare – they only strike once every 100 to 200 years. But the last known solar flare this powerful struck 150 years ago, suggesting the planet could be due another solar attack soon. Dr Kaku said: “These are rare events, maybe once in 100 years or once in 200 years, but is it is inevitable.” And once the solar flare does strike, the effects will be much more devastating than the aftermath of Hurricane Katrina. In 1859, a major solar flare struck the planet, lighting up the night skies from the North Pole all the way down to Cuba. The flare was caused by a so-called Coronal Mass Ejection (CME) from the surface of the Sun and has caused one of the largest geomagnetic storms on record. Dr Kaku said: “It’s a matter of time, you know, we’ve had a big one 150 years ago in 1859. We’ve had a huge solar flare that hit the Earth. One of these days one of these solar flares is going to hit the Earth Dr Michio Kaku, Theoretical physicist “Back then they only had telegraph poles but even they got shorted out and you could read the newspaper in Cuba at night by the light of the Northern Lights, the Aurora Borealis, as far south as Cuba. “From that, we physicists can recalculate how big that solar flare of 1859 must have been. “If we were hit by another one like that, it would fry our satellites, communications would go down instantly, power plants would be shorted out, and in the worst case – remember this a worst case scenario – we physicists believe that it could be 20-times worse than Hurricane Katrina. “So image 20 Hurricane Katrinas ravaging the Earth simultaneously and you can begin to estimate the kind of damage if there is a direct hit from one of these solar flares. “And we’re headed toward the maximum, so more flares are going off the Sun – we had a big one last month.” The solar maximum is a period of the tumultuous solar activity during an 11-year-long cycle. During a solar maximum, the highest number of sunspots appears and the amount of energy radiating from the star has been known to change the weather on Earth. According to Dr Kaku, the solar maximum is the most likely window of opportunity for a major solar flare to hit the Earth. He said: “So far we’ve dodged the bullet, so far we’ve been able to miss these sale flares, but these solar flares are like bullets and sunspots are like rifles. “Think of rifles shooting bullets into outer space and missing Earth. “Of course outer space is quite big but one of these days one of these solar flares is going to hit the Earth like what happened in 1858 and all hell can break loose.”

#### Private sector key to early warnings.

USGPO 19’ – Chairwoman Kendra Horn, “SPACE WEATHER: ADVANCING RESEARCH, MONITORING, AND FORECASTING CAPABILITIES”, U.S Government Publishing Office, October 23rd, 2019, [https://www.govinfo.gov/content/pkg/CHRG-116hhrg38122/html/CHRG-116hhrg38122.htm] Accessed 12/14/21

Our Nation's infrastructure is not all that is threatened by space weather events. I proudly represent the Johnson Space Center, the home to NASA's Astronaut Corps. These are the astronauts who currently work on the International Space Station (ISS) more than 200 miles above the Earth's surface and will one day serve on missions to the Moon and Mars. While we have developed techniques and technology to reduce the threats posed by increased radiation exposure due to a severe solar event, we have more work to do to mitigate these hazards to our astronauts. As the Ranking Member of the Space and Aeronautics Subcommittee, I've supported efforts to spur the commercialization of low-Earth orbit by private sector companies. These new entrants into the space economy have a vested interest in protecting their assets. However, they also offer an opportunity to provide data and resources to our Federal agencies as we seek to improve our space weather efforts. As this Committee potentially considers legislation relating to space weather monitoring and research, we must be certain that whatever legislation that we mark up is not a top-down legislative mandate and ensures a role for the commercial sector. The Weather Research and Forecasting Innovation Act, which was passed by this Committee and signed into law 2 years ago, serves as a template for how we could accomplish this. The Weather Act took steps to integrate commercial weather data into NOAA's forecast models, and a similar model should guide us when developing space weather legislation. NOAA is also advancing our research to operations processes. This includes a new program, the Earth Prediction Innovation Center or EPIC. EPIC will use partnerships with academia, the private sector, and relevant agencies to test and validate new capabilities and transition these capabilities from research to operations, thereby improving our existing forecast and warning capabilities. NOAA is also exploring with NASA the potential for a space weather testbed to further accelerate the transfer of research to operations and operations to research. Strong public-private partnerships are essential to maintain and approve the observing networks, conduct research, create forecast models, and supply the services necessary to support our national security and our economic prosperity…NOAA is committed to working toward the growth of the private sector as our national infrastructure and technological base becomes more sensitive to the impacts of space weather, thus demanding more improved space weather services. NOAA will continue to explore partnerships with the commercial and academic community as we work to maintain and improve our operational capabilities. In closing, NOAA appreciates the ongoing support we have received from Congress for our critically important space weather program. We will continue to work with other Federal agencies, the private sector in this effort to develop and strengthen our activities in space weather research and forecasting, and I look forward to answering your questions.

#### Severe space weather is a great filter event that sparks resource wars, economic collapse, grid failure, pandemics, and nuclear miscalc

Loper 19 [Dr. Robert D. Loper, Ph.D. from the Air Force Institute of Technology, Assistant Professor of Space Physics, Spring 2019. “Carrington-class Events as a Great Filter for Electronic Civilizations in the Drake Equation.” Publications of the Astronomical Society of the Pacific. https://iopscience.iop.org/article/10.1088/1538-3873/ab028e/meta]

Eastwood et al. (2017), the National Academy of Sciences (2008), and the Royal Academy of Engineering (2013) outline the potential economic impacts of severe space weather. In particular, major direct impacts from a Carrington-class CME could be outlined as including the following. 1. Power grid failure due to destruction of large transformers by geomagnetically induced currents. The large transformers in question here generally cost about $1 million per unit and require about 18 months to manufacture, ship, and install. The National Academy of Sciences (2008) report estimates such a power grid failure would cost $1–2 trillion per year6 and last four to ten years. 2. Outages or failures of LEO (low Earth orbit) space assets due to enhancement of the inner Van Allen belt. A severe solar storm can also cause ionospheric uplift which can dramatically increase satellite drag (Tsurutani et al. 2012). Additionally, LEO spacecraft operation could be disrupted by solar energetic protons (SEPs) generated in the shock of the CME passage through the solar wind (Royal Academy of Engineering 2013). 3. Outages or failures of GEO (geosynchronous equatorial orbit) space assets due to enhancement of the outer Van Allen belt or due to SEPs generated in the shock of the CME passage (Royal Academy of Engineering 2013). 4. GPS outages due to GEO spacecraft outages or failures, or GPS degradation due to ionospheric uplift and enhancement, potentially lasting several days or longer. 5. Communications outages due to high-frequency and ultrahigh-frequency radio blackouts, as well as cellular communication network and internet collapse due to extended power outages beyond the limits of generators and stored fuel. In particular, although optical ﬁber cables are the foundation of much of the global communication network, electrical power is still needed to power optical repeaters and transmitters (Royal Academy of Engineering 2013). 6. Increased radiation doses to astronauts and airline passengers (Royal Academy of Engineering 2013). This is more of a risk for long-haul airline ﬂights or manned spaceﬂight. Major indirect effects could include, but are by no means limited to, the following: 1. water and waste water shortages due to reduced or eliminated pumping from power grid failure; 2. fuel shortages due to reduced or eliminated pumping from power grid failure, which could result in transportation stoppages; 3. food shortages due to transportation stoppages, which could contribute to increased death rates and incite rioting and/or looting; 4. reduced hospital care due to water shortages and power outages, which could contribute to increased death rates and rates of infection; and 5. a years-long power grid and internet degradation or outage might irrevocably damage the global economy, in turn greatly prolonging the time to restore the power grid beyond the estimate of four to ten years. If one recalls major disasters caused by terrestrial weather events like hurricanes Katrina (New Orleans, 2005) and Maria (Puerto Rico, 2017), one can imagine the sorts of major effects on people and life in those areas. The most striking difference is that, whereas humanitarian aid came to bear on these disasters, a Carrington-class event would be a global catastrophe with little or no aid forthcoming. Much greater loss of life could result, and our civilization could be driven back to a much more fractured and pre-electronic one. For the purposes of another planet’s Drake equation, our civilization would be eliminated from the calculation. Conversely, another planet whose electronic civilization were struck by a Carrington-class CME would be eliminated from our calculation. Riley (2012) estimates the probability of another Carringtonclass event occuring within the following decade at about 12%. This estimate preceded the solar storm of 2012, but a good rule of thumb would be to estimate this to be the probability of having a Carrington event during any given solar cycle. Love (2012) and Kataoka (2013) have calculated probabilities in rough agreement, but there are a wide range of probabilities in the literature, ranging from once per 60 years (Tsubouchi & Omura 2007) to once per 500 years (Yermolaev et al. 2018). This work will retain the result of Riley (2012), which is also used in National Academy of Sciences (2008) and Royal Academy of Engineering (2013). This roughly agrees with the “once in a century” designation usually given to the Carrington event. Royal Academy of Engineering (2013) indicates that this designator is not well understood given the relative lack of data, but also that there are several tens of Carrington-class CMEs every century that either miss Earth or have lesser impact due to a northward orientation of the interplanetary magnetic ﬁeld. As shown in Figure 1, such a CME has a very wide angular extent (in the 2012 July event, the CME extended in about a 135° arc from the Sun), which could strike Earth in three out of eight occurrences. There is also some indication that a solar storm could trigger other Great Filter events. Knipp et al. (2016) outlines a solar storm in 1967 May that nearly triggered a nuclear war, as American radar operators initially mistook a solar storm for Soviet jamming. It might also be possible that a Carrington-class event could unleash or exascerbate an infectious disease due to reduced hospital care at a critical time, resulting in a pandemic.

## China DA

#### China challenging US dominance in space – private sector maintains the US’s preeminence

Harding 21 Harding, Luke. "The Space Race Is Back On – But Who Will Win?". The Guardian, 2021, <https://www.theguardian.com/science/2021/jul/16/the-space-race-is-back-on-but-who-will-win>. Luke Harding is a Guardian foreign correspondent. His book [Shadow State](https://guardianbookshop.com/shadow-state-9781783352050.html) is published by Guardian Faber.

Liu Boming took in the dizzy view. Around him lay the inky vastness of space. Below was the Earth. “Wow,” he said, laughing. “It’s too beautiful out here.” Over the next seven hours Liu and his colleague Tang Hongbo carried out China’s second spacewalk, helped along by a giant robotic arm. Mission accomplished, the two taikonauts – China’s astronauts – clambered back into their home for the next three months: Beijing’s new space station. The core module of the station, named Tiangong, meaning “heavenly palace”, was launched in April. “There will be more spacewalks. The station will keep growing,” Liu said. Meanwhile, on Mars, a Chinese rover was exploring. Video shows the [vehicle trundling over a rocky surface](https://www.theguardian.com/world/video/2021/jun/27/china-releases-footage-from-its-mars-rover-video). There is even sound: an eerie mechanical groaning. Since landing in May the Zhurong probe has been busy seeking clues as to whether Mars once supported life. There is no answer yet: so far it has travelled just over 410 metres. China is only the second country to land and operate a rover on the red planet, after the US. The frantic tempo of the China National [Space](https://www.theguardian.com/science/space) Administration’s (CNSA) recent programme is reminiscent of the cold war, when Moscow and Washington were superpower rivals scrambling to put the first man in space and land on the moon. Half a century on, space has opened up. It is less ideological and a lot more crowded. About 72 countries have space programmes, including India, Brazil, Japan, Canada, South Korea and the UAE. The European Space Agency is active too, while the UK boasts the most private space startups after the US. Space today is also highly commercial. On Sunday [Richard Branson](https://www.theguardian.com/business/richard-branson) flew to the edge of space and back again in his Virgin Galactic passenger rocket. On Tuesday, Branson’s fellow billionaire Jeff Bezos is due to travel in his own reusable craft, New Shepard, built by the Amazon founder’s company Blue Origin and launched from west Texas. Non-state actors play an increasingly important role in space exploration. Elon Musk’s SpaceX vehicles have made numerous flights to the International Space Station (ISS), and [since last year they have transported people as well as cargo](https://www.spacex.com/human-spaceflight/iss/index.html). Later this year Musk is due to send his own all-civilian crew into orbit – though he isn’t going himself. Even so, space still reflects tensions on Earth. “Astropolitics follows terrapolitics,” says [Mark Hilborne](https://twitter.com/space_security?lang=en), a lecturer in defence studies at King’s College London. Up there anything goes, he adds. “Space governance is a bit fuzzy. Laws are few and very old. They are not written for asteroid mining or for a time when companies dominate.” The biggest challenge to US space supremacy comes not from [Russia](https://www.theguardian.com/world/russia) – heir to the Soviet Union’s pioneering space programme, which launched the Sputnik satellite and got the first human into space in the form of Yuri Gagarin – but from China. In 2011 Congress prohibited US scientists from cooperating with Beijing. Its fear: scientific espionage. Taikonauts are banned from visiting the ISS, which has hosted astronauts from 19 countries over the past 20 years. The station’s future beyond 2028 is uncertain. Its operations may yet be extended in the face of increasing Chinese competition. In its annual threat assessment this April, the office of the US Director of National Intelligence (DNI) described China as a “near-peer competitor” pushing for global power. It warns: “Beijing is working to match or exceed US capabilities in space to gain the military, economic, and prestige benefits that Washington has accrued from space leadership.” The Biden administration suspects Chinese satellites are being used for non-civilian purposes. The People’s Liberation Army integrates reconnaissance and navigation data in military command and control systems, the DNI says. “Satellites are inherently dual use. It’s not like the difference between an F15 fighter jet and a 737 passenger plane,” Hilborne says. Once China completes the Tiangong space station next year, it is likely to invite foreign astronauts to take part in missions. One goal: to build new soft-power alliances. Beijing says interest from other countries is enormous. The low Earth orbit station is part of an ambitious development strategy in the heavens rather than on land – a sort of belt and rocket initiative. According to Alanna Krolikowski, an assistant professor at the Missouri University of Science and Technology, a “bifurcation” of space exploration is under way. In one emerging camp are states led by China and Russia, many of them authoritarian; in the other are democracies and “like-minded” countries aligned with the US. Russia has traditionally worked closely with the Americans, even when terrestrial relations were bad. Now it is moving closer to Beijing. In March, China and Russia [announced plans to co-build an international lunar research station](https://www.theguardian.com/science/2021/mar/10/china-and-russia-unveil-joint-plan-for-lunar-space-station). The agreement comes at a time when Vladimir Putin’s government has been increasingly isolated and subject to western sanctions. In June, Putin and his Chinese counterpart Xi Jinping renewed a friendship treaty. Moscow is cosying up to Beijing out of necessity, at a time of rising US-China bipolarity. These rival geopolitical factions are fighting over a familiar mountainous surface: the moon. In 2019 a Chinese rover landed on its far side – a first. China is now planning a mission to the moon’s south pole, to establish a robotic research station and an eventual lunar base, which would be intermittently crewed. Nasa, meanwhile, has said it intends to put a woman and a person of colour on the moon by 2024. SpaceX has been hired [to develop a lander](https://www.theguardian.com/science/2021/apr/17/nasa-spacex-moon-spacecraft-elon-musk). The return to the moon – after the last astronaut, commander Eugene Cernan, said goodbye in December 1972 – would be a staging post for the ultimate “giant leap”, Nasa says: sending astronauts to Mars. Krolikowski is sceptical that China will quickly overtake the US to become the world’s leading spacefaring country. “A lot of what China is doing is a reprisal of what the cold war space programmes did in the 1960s and 1970s,” she said. Beijing’s recent feats of exploration have as much to do with national pride as scientific discovery, she says. But there is no doubting Beijing’s desire to catch up, she adds. “The Chinese government has established, or has plans for, programmes or missions in every major area, whether it’s [Mars](https://www.theguardian.com/science/mars) missions, building mega constellations of telecommunications satellites, or exploring asteroids. There is no single area of space activity they are not involved in.” “We see a tightening of the Russia-China relationship,” Krolikowski says. “In the 1950s the Soviet Union provided a wide range of technical assistance to Beijing. Since the 1990s, however, the Russian space establishment has experienced long stretches of underfunding and stagnation. China now presents it with new opportunities.” Russia is poised to benefit from cost sharing, while China gets deep-rooted Russian technical expertise. At least, that’s the theory. “I’m sceptical this joint space project will materialise anytime soon,” says Alexander​ Gabuev, a senior fellow at the Carnegie Moscow Centre. Gabuev says both countries are “techno-nationalist”. Previous agreements to develop helicopters and wide-bodied aircraft saw nothing actually made, he says. The Kremlin has been a key partner in managing and resupplying the ISS. US astronauts used Russian Soyuz rockets to reach the station, taking off from a cosmodrome in Kazakhstan, after the Space Shuttle programme was phased out. But this epoch seems to be coming to an end as private companies such as [SpaceX](https://www.theguardian.com/science/spacex) take over. “I expect US-Russian relations to get worse,” Gabuev says, adding that Americans “no longer need” Russia’s help. Moscow’s state corporation for space activities, Roscosmos, has faced accusations of being more interested in politics than space research. Last month the newspaper Novaya Gazeta reported that Roscosmos’s executive director of manned space programmes, former cosmonaut Sergei Krikalev, had been fired. His apparent crime: questioning an official decision to shoot a film on the Russian section of the ISS. The film, Challenge, is about a female surgeon operating on a cosmonaut in space, and has been backed and financed by Roscosmos . It stars Yulia Peresild, who is due to head to space in October with director Klim Shipenko. The launch seems timed to beat Tom Cruise, who is due to shoot his own movie on board the ISS with director Doug Liman[.](https://www.theguardian.com/science/2021/may/13/russia-send-actor-director-iss-shoot-first-movie-space) Krikalev, who spent more than 800 days in space and was in orbit when the USSR collapsed, apparently told Roscomos’s chief, Dmitry Rogozin, that the film was pointless. Rogozin – its co-producer – has called on the west to drop sanctions in return for Russia’s cooperation on space projects. Putin, Rogozin’s boss, appears to not be very interested in other planets, though, and is more concerned with [nature and the climate crisis](https://www.reuters.com/article/us-russia-putin-idUSKCN1LC1X0) these days. “Space is one of the areas that has traditionally transcended politics. The Mir space station worked at a time of east-west tensions. There was symbolic cooperation. Whether this will continue in the future is really up for debate,” Hilborne says. “The US is very sensitive about what happens in space.” Most observers think the US will remain the world’s pre-eminent space power, thanks to its innovative and flourishing private sector. China’s Soviet-style state programme appears less nimble. Despite ambitious timetables, and billions spent by Beijing, it is unclear when – or even if – an astronaut will return to the moon. The 2030s, perhaps? Will they be American or Chinese? Or from a third country? It may well be that the first person to boldly go again doesn’t merely represent a nation or carry a flag. More likely, they will emerge from a lunar lander wearing a spacesuit with a SpaceX logo on the back – a giant leap not only for mankind, but for galactic marketing.

#### US space dominance prevents war with China – deters anti-satellite use and Taiwan intervention

Chow and Kelley 21 Chow, Brian, and Brandon Kelley. "China’S Anti-Satellite Weapons Could Conquer Taiwan—Or Start A War". The National Interest, 2021, <https://nationalinterest.org/feature/china%E2%80%99s-anti-satellite-weapons-could-conquer-taiwan%E2%80%94or-start-war-192135.Brian> Chow is an independent policy analyst (Ph.D. physics, MBA with Distinction, Ph.D. finance) with over 160 publications in space and other national security policies and Brandon Kelley

On July 1, 2021—the one-hundredth birthday of the Chinese Communist Party—[President Xi Jinping](https://asia.nikkei.com/Politics/Full-text-of-Xi-Jinping-s-speech-on-the-CCP-s-100th-anniversary) declared that China will “[advance peaceful national reunification](https://nationalinterest.org/blog/reboot/could-taiwan%E2%80%99s-terrain-stop-chinese-invasion-its-tracks-191919)” with Taiwan. It would be easy to dismiss such statements as mere political rhetoric: certainly, Taiwan would never willingly accede to Chinese demands to rejoin the fold. But China’s rapidly advancing anti-satellite (ASAT) capabilities could open up another avenue: deterring United States intervention on Taiwan’s behalf in order to coerce reunification without firing a shot. If current trends hold, then China’s [Strategic Support Force](https://ndupress.ndu.edu/Portals/68/Documents/stratperspective/china/china-perspectives_13.pdf) will be capable by the late 2020s of holding key U.S. space assets at risk. [Chinese military doctrine](https://nationalinterest.org/blog/reboot/nowhere-earth-will-be-safe-us-china-war-172523), statements by senior officials, and past behavior all suggest that China may well believe threatening such assets to be an effective means of deterring U.S. intervention. If so, then the United States would face a type of “Sophie’s Choice”: decline to intervene, potentially leading allies to follow suit and Taiwan to succumb without a fight, thereby enabling Xi to achieve his goal of “peacefully” snuffing out Taiwanese independence; or start a war that would at best be long and bloody and might well even cross the nuclear threshold. This emerging crisis has been three decades in the making. In 1991, China watched from afar as the United States used space-enabled capabilities to obliterate the Iraqi military from a distance in the first Gulf War. The People’s Liberation Army quickly set to work developing capabilities targeted at a perceived Achilles’ heel of this new [American way of war](https://nationalinterest.org/feature/secrets-and-lies-role-truth-great-power-information-warfare-170579): reliance on vulnerable space systems. This project came to fruition with a direct ascent [ASAT weapons test](https://fas.org/sgp/crs/row/RS22652.pdf) in 2007, but the test was limited in two key respects. First, it only reached low Earth orbit. Second, it generated thousands of pieces of long-lasting space junk, provoking immense [international ire](https://spacenews.com/u-s-official-china-turned-to-debris-free-asat-tests-following-2007-outcry/). This backlash appears to have taken China by surprise, driving it to seek new, more usable ASAT types with minimal debris production. Now, one such ASAT is nearing operational status: spacecraft capable of rendezvous and proximity operations (RPOs). Such spacecraft are [inevitable](https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-12_Issue-2/Chow.pdf#page=22) and cannot realistically be limited. The United States, European Union, China, and others are developing them to provide a range of satellite services essential to the [new space economy](https://www.morganstanley.com/ideas/space-economy-themes-2021), such as in situ repairs and refueling of satellites and active removal of space debris. But RPO capabilities are dual-use: if a satellite can grapple space objects for servicing, then it might well be capable of grappling an adversary’s satellite to move it out of its servicing orbit. Perhaps it could degrade or disable it by bending or disconnecting its solar panels and antennas all while producing minimal debris. This is [a serious threat](https://nationalinterest.org/feature/can-america-lose-china-189020), primarily because no international rules presently exist to limit close approaches in space. Left unaddressed, this lacuna in international law and space policy could enable a prospective attacker to pre-position, during peacetime, as many spacecraft as they wish as close as they wish to as many high-value targets as they wish. The result would be an ever-present possibility of sudden, bolt-from-the-blue attacks on vital space assets—and worse, on many of them at once. China has conducted at least [half a dozen tests of RPO](https://swfound.org/media/207179/swf_chinese_rpo_fact_sheet_apr2021.pdf#page=3) capabilities in space since 2008, two of which went on for years. Influential space experts have noted that these tests have plausible peaceful purposes and are in many cases similar to those conducted by the United States. This, however, does not make it any less important to establish effective legal, policy, and technical counters to their offensive use. Even if it were certain that these capabilities are intended purely for peaceful applications—and it is not at all clear that that is the case—China (or any other country) could at any time decide to repurpose these capabilities for ASAT use. There is still time to get out ahead of this threat, but likely not for much longer. China’s RPO capabilities have, thus far, lagged about five years behind those of the United States. There are reasons to believe this gap may close, but even assuming that it holds, we should expect to see China demonstrate an operational dual-use rendezvous spacecraft by around 2025. (The first instance of a U.S. commercial satellite docking with another satellite to change its orbit occurred in [February 2020](https://news.northropgrumman.com/news/releases/northrop-grumman-successfully-completes-historic-first-docking-of-mission-extension-vehicle-with-intelsat-901-satellite).) At the same time, China is expanding its capacity for rapid spacecraft manufacturing. The [Global Times](https://www.globaltimes.cn/page/202101/1213345.shtml) reported in January that China’s first intelligent mass production line is set to produce 240 small satellites per year. In April, [Andrew Jones](https://spacenews.com/china-is-developing-plans-for-a-13000-satellite-communications-megaconstellation/#:~:text=China%20is%20developing%20plans%20for%20a%2013%2C000%2Dsatellite%20megaconstellation,-by%20Andrew%20Jones&text=HELSINKI%20%E2%80%94%20China%20is%20to%20oversee,the%20country's%20major%20space%20actors.) at SpaceNews reported that China is developing plans to quickly produce and loft a thirteen thousand-satellite national internet megaconstellation. It is not unreasonable to assume that China could manufacture two hundred small rendezvous ASAT spacecraft by 2029, possibly more. If this happens, and Beijing was to decide in 2029 to launch these two hundred small RPO spacecraft and position them in close proximity to strategically vital assets, then China would be able to simultaneously threaten disablement of the entire constellations of U.S. satellites for missile early warning (about a dozen satellites with spares included); communications in a nuclear-disrupted environment (about a dozen); and positioning, navigation, and timing (about three dozen); along with several dozen key communications, imagery, and meteorology satellites. Losing these assets would severely degrade U.S. deterrence and warfighting capabilities, yet once close pre-positioning has occurred such losses become almost impossible to prevent. For this reason, such pre-positioning could conceivably deter the United States from coming to Taiwan’s aid due to the prospect that intervention would spur China to disable these critical space systems. Without their support, the war would be much bloodier and costlier—a daunting proposition for any president. Should the United States fail to intervene, the consequences would be disastrous for both Washington and its allies in East Asia, and potentially the credibility of U.S. defense commitments around the globe. Worse yet, however, might be what could happen if China believes that such a threat will succeed but proves to be wrong. History is rife with examples of major wars arising from miscalculations such as this, and there are many pathways by which such a situation could easily escalate out of control to a full-scale conventional conflict or even to nuclear use. This Catch-22 of so-called “peaceful reunification” on the one hand and catastrophic miscalculation on the other is entirely preventable. To do so, however, the United States must act now. To deter such pre-positioning and provide a clear framework for how to handle it if it does occur, the United States should immediately begin coordinating with its allies to establish shared understandings for the rules and operations of [warning](http://npolicy.org/article_file/Space_and_Missile_Wars.pdf#page=136)/[self-defense](https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-14_Issue-4/Chow.pdf#page=5) zones in orbit. Additionally, the United States should develop and deploy [bodyguard spacecraft](https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-14_Issue-4/Chow.pdf#page=6) to monitor and enforce such rules. The United States cannot afford to wait; once the potential threat arrives, it will already be too late.

#### US-China war goes nuclear – leads to power vacuum, econ collapse and extinction

Sharman 17 (Jon Sharman, “US would go into any war with China with 'unparalleled violence', warn experts’” 2017. The Independent. February 5, 2017. http://www.independent.co.uk/news/world/americas/us-china-war-be-end-of-life-earth-nuclear-weapons-apocalypse-steve-bannon-donald-trump-white-house-a7561821.html.)

While the prospect remains relatively remote, experts have told The Independent they believe such a conflict would be catastrophic, throwing the entire globe into turmoil and potentially ending "life as we know it on Earth". The United States would likely win because sending China's untested forces against the might of America's military would be like pitching farmers against Achilles and his warriors, said one, but even a conventional military victory would be a strategic disaster. It would set off a global economic crisis and create a potential power vacuum inside defeated China "the like of which we can't imagine". Mr Bannon said war would erupt in the South China Sea in "five to 10 years". He said: "They’re taking their sandbars and making basically stationary aircraft carriers and putting missiles on those. They come here to the United States in front of our face—and you understand how important face is—and say it’s an ancient territorial sea." The US and China have been engaged in a back-and-forth dispute over military build-up and territorial claims in the region for some years. In December the US said it would base its deadliest fighter jets in Australia, and days later China seized an unmanned US Navy drone. It followed a diplomatic spat around then-President-elect Trump's congratulatory phone call with Taiwan's Prime Minister Tsai Ing-wen, which broke with decades of US policy. Mr Trump has been forthright about China's influence, blaming it for the loss of American jobs. The war of words recently heated up when a Chinese military official was quoted as saying talk of war with the US under Mr Trump "are not just slogans, they are becoming a practical reality". Trevor McCrisken, associate professor of politics and international studies at the University of Warwick, said that if war broke out "we would be looking, I would imagine, at World War Three". He said: "I really do think that would be the end of life as we know it on Earth. "From a global strategic risk level I would say the last thing you want is war between the United States and any of the major powers because of the risks of escalation, obviously the potential for nuclear weapons to be used. The likelihood of nuclear exchange between the two principals involved is high."

## CP

#### CP: The United Nations should establish an orbital use fee for all satellites and use the money received to pay for debris cleanup

Vergoth 20 Vergoth, Karin. "Solving The Space Junk Problem". CU Boulder Today, 2020, <https://www.colorado.edu/today/2020/05/26/solving-space-junk-problem>. Karin Vergoth is a CIRES-NOAA Science Writer.

Space is getting crowded. Aging satellites and space debris crowd low-Earth orbit, and launching new satellites adds to the collision risk. The most effective way to solve the space junk problem, according to a new study, is not to capture debris or deorbit old satellites: it’s an international agreement to charge operators “orbital-use fees” for every satellite put into orbit. Orbital use fees would also increase the long-run value of the space industry, said economist Matthew Burgess, a [CIRES Fellow and co-author of the new paper](https://cires.colorado.edu/news/solving-space-junk-problem). By reducing future satellite and debris collision risk, an annual fee rising to about $235,000 per satellite would quadruple the value of the satellite industry by 2040, he and his colleagues concluded in a paper published today in the [Proceedings of the National Academy of Sciences](https://www.pnas.org/content/early/2020/05/20/1921260117). “Space is a common resource, but companies aren’t accounting for the cost their satellites impose on other operators when they decide whether or not to launch,” said Burgess, who is also an assistant professor in environmental studies and an affiliated faculty member in economics at CU Boulder. “We need a policy that lets satellite operators directly factor in the costs their launches impose on other operators.” Currently, an estimated 20,000 objects—including satellites and space debris—are crowding low-Earth orbit. It’s the latest tragedy of the commons, the researchers said: Each operator launches more and more satellites until their private collision risk equals the value of the orbiting satellite. So far, proposed solutions have been primarily technological or managerial, said Akhil Rao, assistant professor of economics at Middlebury College and the paper’s lead author. Technological fixes include removing space debris from orbit with nets, harpoons, or lasers. Deorbiting a satellite at the end of its life is a managerial fix. Ultimately, engineering or managerial solutions like these won’t solve the debris problem because they don’t change the incentives for operators. For example, removing space debris might motivate operators to launch more satellites—further crowding low-Earth orbit, increasing collision risk, and raising costs. “This is an incentive problem more than an engineering problem. What’s key is getting the incentives right,” Rao said. A better approach to the space debris problem, Rao and his colleagues found, is to implement an orbital-use fee—a tax on orbiting satellites. “That’s not the same as a launch fee,” Rao said, “Launch fees by themselves can’t induce operators to deorbit their satellites when necessary, and it's not the launch but the orbiting satellite that causes the damage.” Orbital-use fees could be straight-up fees or tradeable permits, and they could also be orbit-specific, since satellites in different orbits produce varying collision risks. Most important, the fee for each satellite would be calculated to reflect the cost to the industry of putting another satellite into orbit, including projected current and future costs of additional collision risk and space debris production—costs operators don’t currently factor into their launches. “In our model, what matters is that satellite operators are paying the cost of the collision risk imposed on other operators,” said Daniel Kaffine, professor of economics and RASEI Fellow at CU Boulder and co-author on the paper. And those fees would increase over time, to account for the rising value of cleaner orbits. In the researchers’ model, the optimal fee would rise at a rate of 14 percent per year, reaching roughly $235,000 per satellite-year by 2040. For an orbital-use fee approach to work, the researchers found, all countries launching satellites would need to participate—that's about a dozen that launch satellites on their own launch vehicles and more than 30 that own satellites. In addition, each country would need to charge the same fee per unit of collision risk for each satellite that goes into orbit, although each country could collect revenue separately. Countries use similar approaches already in carbon taxes and fisheries management. In this study, Rao and his colleagues compared orbital-use fees to business as usual (that is, open access to space) and to technological fixes such as removing space debris. They found that orbital use fees forced operators to directly weigh the expected lifetime value of their satellites against the cost to industry of putting another satellite into orbit and creating additional risk. In other scenarios, operators still had incentive to race into space, hoping to extract some value before it got too crowded. With orbital-use fees, the long-run value of the satellite industry would increase from around $600 billion under the business-as-usual scenario to around $3 trillion, researchers found. The increase in value comes from reducing collisions and collision-related costs, such as launching replacement satellites. Orbital-use fees could also help satellite operators get ahead of the space junk problem. “In other sectors, addressing the tragedy of the commons has often been a game of catch-up with substantial social costs. But the relatively young space industry can avoid these costs before they escalate,” Burgess said.

## Case

### AT Debris

#### Ban on appropriation prevents solutions

Trapp 13 Trapp, Timothy. TAKING UP SPACE BY ANY OTHER MEANS: COMING TO TERMS WITH THE NONAPPROPRIATION ARTICLE OF THE OUTER SPACE TREATY. UNIVERSITY OF ILLINOIS LAW REVIEW, 2013, https://www.illinoislawreview.org/wp-content/ilr-content/articles/2013/4/Trapp.pdf, Accessed 4 Jan 2022. Justin received his B.A. in Creative Writing from North Carolina State University in 2008 and his J.D., summa cum laude, from The University of Illinois College of Law in 2013, where he was elected to the Order of the Coif, a Rickert Award Recipient, and served as articles editor of the University of Illinois Law Review.

In general, space debris consists of “man-made objects in outer space, other than active or otherwise useful satellites, when no change can reasonably be expected in these conditions in the foreseeable future.”46 As of January 2011, there were approximately 16,000 space objects catalogued by the U.S. Space Surveillance Network, only about 3,500 of which were functional spacecraft.47 This leaves approximately 12,500 pieces of catalogued debris.48 Interestingly, though spacecraft, mission-related objects, and rocket bodies increased fairly linearly since the start of the space age, fragmentation debris has drastically increased since 2007, jumping from approximately 4,000 pieces to approximately 7,000 pieces in the span of a year.49 While this is due in large part to China’s testing of an anti-satellite weapon in space,50 it is also certainly due in part to the replicating nature of fragmentation debris.51 For instance, in February 2009, an operational commercial U.S. satellite collided with a defunct Russian satellite, resulting in about 400 pieces of new debris.52 This, intuitively, creates about 400 new chances for functional spacecraft to be damaged or destroyed. For something to stay in orbit, it has to move very, very fast (from three to eight kilometers per second, or about 6,700 to 18,000 miles per hour, depending on the altitude of the object).53 This is due to the physics that governs orbital mechanics.54 Even in orbit, objects still feel the pull of Earth’s gravity.55 In essence, objects in orbit are constantly falling. Because the Earth is round, however, an object is able to counterbalance the effect of gravity by moving forward fast enough to match the rate of its fall.56 But this requires a fantastic amount of speed, up to about thirty times that of a commercial airliner.57 While intuitive that a collision between two satellites travelling at this speed would be catastrophic, it is also the case that a small object could cause massive damage at this speed.58 The amount of damage caused by the collision of two objects is a function of the objects’ momentum, which is the product of an object’s mass and velocity.59 Because of this, even a very small object can be extremely damaging if it is travelling fast enough.60 For example, an average sized brick travelling at three kilometers per second (or about 6,600 miles per hour), which is on the lower end of the orbital speeds, would have as much momentum as a large horse travelling at about thirty-three mph.61 Not only does space debris carry a large amount of momentum, but it is also often small enough that its impact will be concentrated into a small area, thus maximizing damage to that area.62 This makes debris very dangerous to sophisticated machinery, such as satellites and spaceships that have various small parts that can be incredibly vulnerable. Furthermore, debris does not vanish when it impacts or destroys a functional spacecraft. Instead, it multiplies: the collision creates more debris, and these new pieces of debris will fly out in multiple directions, cluttering space even more.63 This, in turn, makes orbital space that much more cluttered and dangerous, which leads to more collisions, and the cycle continues.64 If this problem is not dealt with, the amount of orbital debris could continue to increase until it makes certain parts of orbit unusable or unnavigable, even without the addition of more functioning spacecraft into orbit.65 The costs of space debris are not limited to merely the loss of functioning spacecraft. There is also the cost of shielding spacecraft from possible debris collisions.66 This cost is two-fold: not only do launching parties have to spend the money to actually research and develop adequate shielding for their spacecraft, they also have to spend extra money for fuel to carry the objects into space.67 The cost of maneuvering out of the path of debris similarly enters into the equation in two ways.68 Maneuvering requires extra fuel and thus detracts from what could have been used to further the actual purpose of the spacecraft.69 Furthermore, for maneuvering to even be effective, there must be prior warning that a collision with debris is imminent.70 This requires a monitoring system, which requires its own resources to develop the necessary surveillance technology as well as to catalog and monitor debris.71 Though the dangerous and replicative nature of the space debris problem is well understood, the nature of the space resource makes it difficult to regulate this problem. First, space is a common resource, which subjects it to falling into a tragedy of the commons.72 Second, because entities are not allowed to appropriate property in space, governing bodies find it difficult to enforce regulations in space that may help to stem the debris problem.

#### Non-unique – anti-satellite tests main source of debris

Pultarova 21 Pultarova, T., 2021. Space debris from Russian anti-satellite test will be a safety threat for years. [online] Space.com. Available at: <https://www.space.com/russia-anti-satellite-test-space-debris-threat-for-years> [Accessed 12 January 2022].  She later took a career break to pursue further education and added a Master's in Science from the International Space University, France, to her Bachelor's in Journalism and Master's in Cultural Anthropology from Prague's Charles University.

Space debris created by a Russian anti-satellite missile test will pose a threat to satellites in low Earth orbit as well as astronauts aboard the International Space Station for years to come, experts reveal. The anti-satellite (ASAT) test targeted the defunct Soviet surveillance satellite Cosmos 1408, which orbited at an altitude of about 404 miles (650 kilometers) above Earth. The 2-ton spacecraft, dead since the mid-1980s, broke apart into at least 1,500 trackable fragments immediately upon the strike, creating a large cloud of debris. The space debris has forced the astronauts and Russian cosmonauts aboard the International Space Station (ISS) to repeatedly take refuge in their transport vehicles. Experts now warn that this space debris will remain a danger for years to come, threatening satellites in low Earth orbit (LEO), the heavily used region of space closest to Earth, as well as space station crews. In addition to the 1,500 trackable fragments generated by the test, the event also created hundreds of thousands of smaller pieces that are invisible to Earth-based observers, the U.S. Space Command (USSC), which is responsible for military operations in outer space, said in a statement.  "USSPACECOM's initial assessment is that the debris will remain in orbit for years and potentially for decades, posing a significant risk to the crew on the International Space Station and other human spaceflight activities, as well as multiple countries' satellites," USSPACECOM said in the statement. In fact, about half of the fragments might fall to Earth "within the next couple of years" but the remainder might remain hurtling through space for "more than a decade," Hugh Lewis, head of the Astronautics Research Group at the University of Southampton, the U.K., and Europe's leading space debris expert told Space.com. "Once the fragments are catalogued, I am expecting to see many close passes with satellites and other objects across quite a wide range of LEO, demonstrating the consequences for space safety," Lewis said. "I would not be surprised if the ISS had to make collision avoidance maneuvers for at least the next couple of years as a direct result." Preliminary calculations suggest that the cloud of debris will increase the number of avoidance maneuvers performed by satellite operators all over the world by more than 100% in the next few years, Tim Flohrer, head of the European Space Agency's (ESA) Space Debris Office, told Space.com.  "The peak can be even significantly higher than 100%," Flohrer added. "In this 400 to 500 kilometer altitude, the fragments will not survive long. We expect them to decay slowly over months and years so the risk increase will still be significant after one or two years." In addition to the impact that this debris will continue to have on the International Space Station, SpaceX's internet-beaming mega-constellation Starlink, currently comprising nearly 1,850 satellites, also orbits in the affected region, Flohrer added.  Experts and military leaders appeared shocked by the act, which will affect long-term safety of all operations in low Earth orbit. "Russia has demonstrated a deliberate disregard for the security, safety, stability, and long-term sustainability of the space domain for all nations," U.S. Army General James Dickinson and U.S. Space Command commander, said in the USSC statement. "The debris created by Russia's DA-ASAT will continue to pose a threat to activities in outer space for years to come, putting satellites and space missions at risk, as well as forcing more collision avoidance maneuvers." In a statement to Russia's news agency Interfax, the Russian Defense Ministry confirmed the test but claimed its debris does not present any risk to orbiting spacecraft. "On November 15 of this year, the Russian Defense Ministry successfully conducted a test, as a result of which the inoperative Russian Tselina-D spacecraft, which had been in orbit since 1982, was struck," the Russian Defense Ministry said, according to Interfax. "The United States knows for certain that the resulting fragments did not represent and will not pose a threat to orbital stations, spacecraft and space activities in terms of test time and orbit parameters." Russia's space agency Roscosmos issued a separate statement on Tuesday (Nov. 16) morning, which, however, does not directly mention the ASAT test. "For us, the main priority has been and remains to ensure the unconditional safety of the crew," Roscosmos said in the statement. "Adherence to this principle is laid both in the basis for the production of space technology in Russia and in the program of its operation." While its impact and consequences has drawn far more concern, this is not the first ASAT test in recent years. In 2019, India conducted an anti-satellite missile test, which, however, targeted a satellite much closer to Earth, at about 175 miles (282 km). Most of the debris created by that strike therefore entered Earth's atmosphere within weeks or months, according to the Carnegie Endowment for International Peace.  The impact of the Russian ASAT test, however, will be much more serious due to the higher altitude of the target satellite. Debris from an ASAT test conducted by China in 2007, which targeted a satellite at an even higher altitude of 540 miles (865 km), is still a major source of collision hazard in low Earth orbit today.

**Low Probability – 0.1% chance of a collision.**

**Salter 16** [(Alexander William, Economics Professor at Texas Tech) “SPACE DEBRIS: A LAW AND ECONOMICS ANALYSIS OF THE ORBITAL COMMONS” 19 STAN. TECH. L. REV. 221 \*numbers replaced with English words] TDI

The probability of a collision is currently low. Bradley and Wein estimate that the maximum probability in LEO of a collision over the lifetime of a spacecraft remains below one in one thousand, conditional on continued compliance with NASA’s deorbiting guidelines.3 However, the possibility of a future “snowballing” effect, whereby debris collides with other objects, further congesting orbit space, remains a significant concern.4 Levin and Carroll estimate the average immediate destruction of wealth created by a collision to be approximately $30 million, with an additional $200 million in damages to all currently existing space assets from the debris created by the initial collision.5 The expected value of destroyed wealth because of collisions, currently small because of the low probability of a collision, can quickly become significant if future collisions result in runaway debris growth.

**Time frame – Kessler effect 200 years away**

**Stubbe 17** [(Peter, PhD in law @ Johann Wolfgang Goethe University Frankfurt) “State Accountability for Space Debris: A Legal Study of Responsibility for Polluting the Space Environment and Liability for Damage Caused by Space Debris,” Koninklijke Brill Publishing, ISBN 978-90-04-31407-8, p. 27-31]

The prediction of possible scenarios of the future evolution of the debris population involves many uncertainties. Long-term forecasting means the prediction of the evolution of the future debris environment in time periods of decades or even centuries. Predictions are based on models84 that work with certain assumptions, and altering these parameters significantly influences the outcomes of the predictions. Assumptions on the future space traffic and on the initial object environment are particularly critical to the results of modeling efforts.85 A well-known pattern for the evolution of the debris population is the so-called Kessler effect’, which assumes that there is a certain collision probability among space objects because many satellites operate in similar orbital regions. These collisions create fragments, and thus additional objects in the respective orbits, which in turn enhances the risk of further collisions. Consequently, the num ber of objects and collisions increases exponentially and eventually results in the formation of a self-sustaining debris belt aroundthe Earth. While it has long been assumed that such a process of collisional cascading is likely to occur only in a very long-term perspective (meaning a time 1 n of several hundred years),87 a consensus has evolved in recent years that an uncontrolled growth of the debris population in certain altitudes could become reality much sooner.88 In fact, a recent cooperative study undertaken by various space agencies in the scope of i a d c shows that the current l e o debris population is unstable, even if current mitigation measures are applied. The study concludes: Even with a 90% implementation of the commonly-adopted mitigation measures [...] the l e o debris population is expected to increase by an average of 30% in the next 200 years. The population growth is primarily driven by catastrophic collisions between 700 and 1000 km altitudes and such collisions are likely to occur every 5 to 9 years.89

#### The CP solves – ensures private companies take down satellites and funds clean up efforts.

### AT Mining

#### Biomining of asteroids effective – won’t need to draw asteroids in

Cockell et al. 20 Cockell, C.S., Santomartino, R., Finster, K. et al. Space station biomining experiment demonstrates rare earth element extraction in microgravity and Mars gravity. Nat Commun 11, 5523 (2020). https://doi.org/10.1038/s41467-020-19276-w Charles Cockell FRSE is a British astrobiologist who is professor of astrobiology in the School of Physics and Astronomy at the University of Edinburgh and co-director of the UK Centre for Astrobiology. Rosa Santomartino. Postdoc researcher, Space Microbiology, University of Edinburgh

This study investigated the use of microorganisms to extract a group of economically important elements (fourteen REEs) from basalt rock, a material found on the Moon and Mars[36](https://www.nature.com/articles/s41467-020-19276-w#ref-CR36),[37](https://www.nature.com/articles/s41467-020-19276-w#ref-CR37),[38](https://www.nature.com/articles/s41467-020-19276-w#ref-CR38), under simulated Mars and Earth gravity on the International Space Station (ISS). Microgravity was investigated as the lowest gravity level possible to explore the effects of a lack of sedimentation on bioleaching, to understand the role of gravity in influencing microbe–mineral interactions in general, and to gain insights into industrial biomining on asteroids and other very low gravity planetary objects. A true Earth gravity ground control experiment was also performed. The presence of the bacterium S. desiccabilis was found to enhance mean concentrations of leached REEs in all gravity conditions investigated and these enhancements were significant in simulated Mars and Earth gravity on ISS compared to the non-biological controls. Although the S. desiccabilis microgravity samples reached higher mean concentrations than the microgravity non-biological controls for all REEs, the difference was not statistically significant. The statistical result is interpreted to be caused by the greater standard deviations in the leached concentrations of elements in the microgravity biological experiment and non-biological controls and the loss of one of the microgravity control samples owing to contamination, rather than an effect of microgravity on biological leaching. The lack of a significant difference in the final concentrations of REEs leached by S. desiccabilis when the different gravity conditions were compared is surprising since microgravity has been reported to influence microbial processes[39](https://www.nature.com/articles/s41467-020-19276-w#ref-CR39),[40](https://www.nature.com/articles/s41467-020-19276-w#ref-CR40). However, the results are consistent with our observation that final cell concentrations did not differ between the different gravity conditions in the three microorganisms[31](https://www.nature.com/articles/s41467-020-19276-w#ref-CR31). One reason for the lack of statistically significant differences in final concentrations of REEs between gravity conditions might be that the bacterial cultures had sufficient nutrients to reach their maximum cell concentration[31](https://www.nature.com/articles/s41467-020-19276-w#ref-CR31), regardless of the different sedimentation rates in each gravity, thus achieving similar leaching concentrations. Hence, the experiments showed that, with the appropriate nutrients, biomining is in principle achievable under a wide range of gravity conditions. The mechanism for the REE bioleaching in Sphingomonas desiccabilis is unknown. It was not caused by bulk acidification of the growth medium, since the ground experiments showed that the medium had a slightly basic pH profile during the experiment. The microorganism is a prolific producer of extracellular polysaccharide (EPS) and these compounds are known to enhance bioleaching in other organisms by complexing ions in EPS moieties such as uronic acid[41](https://www.nature.com/articles/s41467-020-19276-w#ref-CR41),[42](https://www.nature.com/articles/s41467-020-19276-w#ref-CR42). A greater biological enhancement in the leaching of heavy compared to light REEs was observed, a pattern consistent with observations by Takahashi et al.[43](https://www.nature.com/articles/s41467-020-19276-w#ref-CR43) in laboratory cell cultures and natural microbial biofilms. The authors suggested that phosphate moieties on the cell or EPS might preferentially bind heavy REEs, a distinct property of these biologically produced materials. We also note that the authors suggested that heavy REE enrichments could potentially be used as a biosignature for the activities of life. Beyond applications to biomining, our experiments showed the preferential enhancement of heavy REEs in the liquid phase including in simulated Martian gravity, indicating the production of a potential biosignature under altered gravity, with implications for example for additional methods to test the hypothesis of life on Mars. Enhanced REEs associated with pelleted S. desiccabilis cells compared to the other two species was not observed. The reduced pH caused during fixation and sample preparation may have unbound any REEs attached to cell surfaces in all three species. Alternatively, the majority of the REEs may have bound to the extracellular EPS or have been released directly into solution. We have observed S. desiccabilis by confocal microscopy to form biofilms on the surfaces and at the edges of cavities on the basalt more pervasively than B. subtilis and C. metallidurans under these growth conditions, which could have enhanced cell-mineral interactions and thus leaching of REEs into solution. The analysis of REEs within biofilms did not form part of this study since we wished to separately examine the biofilms non-destructively. Unavoidable in this experiment was the potential for continued leaching after fixation and during storage, when the pH was reduced in the chamber. However, during storage, the temperature was kept at 2.1 °C on the ISS and below 7.1 °C during sample return to reduce leaching activity[44](https://www.nature.com/articles/s41467-020-19276-w#ref-CR44). Furthermore, a similar reduction of the pH occurred in the non-biological control samples. In contrast to S. desiccabilis, B. subtilis demonstrated less mean leaching in the biological experiments than the non-biological controls in all three gravity conditions. This cannot be attributed to cells attached to the rock retarding ion release since the microorganisms did not form substantial biofilms on the surface of the rock and the final cell biomass was lower than in the case of S. desiccabilis[31](https://www.nature.com/articles/s41467-020-19276-w#ref-CR31). As the pH was likely to be similar to the other organisms during the course of the experiment as shown by our ground-based post-flight pH experiment, differences in pH during the experimental phase cannot explain the results. An alternative explanation could be a chemical effect of cell exudates, such as ligands that retarded leaching or the solubility of REEs. However, despite its previously demonstrated bioleaching activity[45](https://www.nature.com/articles/s41467-020-19276-w#ref-CR45),[46](https://www.nature.com/articles/s41467-020-19276-w#ref-CR46), and cell wall absorption of REEs[47](https://www.nature.com/articles/s41467-020-19276-w#ref-CR47), Kucuker et al.[48](https://www.nature.com/articles/s41467-020-19276-w#ref-CR48) showed that B. subtilis was not able to extract tantalum, a transition metal considered similar to a REE, from capacitors. C. metallidurans did not enhance leaching of REEs. In a 3-month preparatory phase for the BioRock experiments, the leaching of elements from crushed basalt by this organism on the Russian FOTON-M4 capsule was investigated[49](https://www.nature.com/articles/s41467-020-19276-w#ref-CR49). In this experiment, C. metallidurans enhanced copper ion release, but other rock elements did not show significantly enhanced leaching. Although the microorganism was suspended in mineral water, the results are consistent with those reported here. In none of the experiments was a cerium anomaly[50](https://www.nature.com/articles/s41467-020-19276-w#ref-CR50) observed. Unlike other REEs that are all trivalent, cerium can be oxidised to the less soluble Ce4+ state, which can cause differences in precipitation and concentration compared to other REEs. The experiments were performed under oxic conditions. However, once the cerium was leached from the rock, its oxidation state would not necessarily have changed its presence in the bulk fluid, potentially explaining the lack of an anomaly. Comparing the Earth gravity simulation on the ISS with the ground-based experiments (true 1 × g control), no significant difference was observed between biological experiments with B. subtilis and C. metallidurans, but there was a significant difference between the S. desiccabilis biological experiments and between the non-biological controls, with ground-based leaching significantly less in some REEs compared to the Earth gravity simulation on the ISS. Simulated gravity in space is not exactly the same as 1 × g on Earth as shear forces induced by centrifugation in space can create different physical conditions. Furthermore, because of the small radius of the centrifuge rotor in KUBIK, gravity forces vary across the culture chamber. We also note that the ground experiment had a 0.46 °C higher temperature offset than the KUBIKs on the ISS during the main experimental phase. The experiment on the ISS involves the launch and download to Earth of the samples, which could influence them in ways that cannot be easily predicted. Nevertheless, the general trends observed in Earth gravity experiments with respect to biologically enhanced leaching for the three organisms were conserved in space. Our experiment has several differences with any proposed large-scale biomining activity. The basalt rock was not crushed in order to investigate biofilm formation on a flat, contiguous but porous rock surface, another main goal of the BioRock experiment. This may have influenced the total percentage of REEs extracted from the rock, which was generally less than 5 × 10−2 %. These leaching rates would likely be higher with crushed rocks, which on Earth have been shown to result in leaching efficiencies of REEs of 8.0 × 10−3% to several tens of percent under optimised conditions[51](https://www.nature.com/articles/s41467-020-19276-w#ref-CR51),[52](https://www.nature.com/articles/s41467-020-19276-w#ref-CR52). Furthermore, we did not stir our reactors as we wanted to investigate the effects of microgravity and Mars gravity on cell growth in the absence of artificial mixing. Understanding which parameters would require adjustments to enhance the process as well as upscaling of the reactor would be the next step. Our experiment demonstrates that the leaching capacities of the three different microorganisms on the Earth[53](https://www.nature.com/articles/s41467-020-19276-w#ref-CR53),[54](https://www.nature.com/articles/s41467-020-19276-w#ref-CR54) were similar in space. Thus, Earth-based ground experiments provide reliable insights into the biomining capacities of specific organisms in space. Yet, our experiments also confirm that it is important to be careful in the selection of microorganisms for space biomining operations. Basaltic material was investigated because it is common on the Moon and Mars[36](https://www.nature.com/articles/s41467-020-19276-w#ref-CR36),[37](https://www.nature.com/articles/s41467-020-19276-w#ref-CR37),[38](https://www.nature.com/articles/s41467-020-19276-w#ref-CR38). Our experiment suggests that other materials could return even higher yields. For example, lunar KREEP rocks have unusually high concentrations of REEs[55](https://www.nature.com/articles/s41467-020-19276-w#ref-CR55),[56](https://www.nature.com/articles/s41467-020-19276-w#ref-CR56). We did not test lunar gravity (0.16 × g) directly, but it lies between microgravity and Mars gravity. Our results therefore likely reflect the potential efficacy of biomining operations under lunar gravity. We suggest the construction of REE biomining facilities in the Oceanus Procellarum and Mare Imbrium regions of the Moon, where KREEP rocks are abundant. The principle we demonstrate could be applied to other materials of economic importance for In-Situ Resource Utilisation (ISRU). For example, meteoritic material has been shown to be compatible with microbial growth[26](https://www.nature.com/articles/s41467-020-19276-w#ref-CR26),[57](https://www.nature.com/articles/s41467-020-19276-w#ref-CR57),[58](https://www.nature.com/articles/s41467-020-19276-w#ref-CR58),[59](https://www.nature.com/articles/s41467-020-19276-w#ref-CR59),[60](https://www.nature.com/articles/s41467-020-19276-w#ref-CR60) and thus our microgravity experiments show the potential for biomining in low gravity asteroid environments. In conclusion, our results demonstrate the biological mining of economically important elements in space, specifically REEs and in different extraterrestrial gravity environments. The experiments also demonstrate the novel REE bioleaching ability for the mesophilic, biofilm-forming, and desiccation-resistant bacterium S. desiccabilis, which could be used in biomining applications. From a technical point of view, our experiment also demonstrated the principles of a miniature space biomining reactor. The experiment thus shows the efficacy of microbe–mineral interactions for advancing the establishment of a self-sustaining permanent human presence beyond the Earth and the technical means to do that.

#### Asteroid mining solves environmental terrestrial mining impacts—particularly ocean acidification and global warming

Hlimi 14 – Tina, International Secretariat Member and Health & Hazards Coordinator for the Centre for International Sustainable Development Law (CISDL) in Montreal, Quebec, “THE NEXT FRONTIER: AN OVERVIEW OF THE LEGAL AND ENVIRONMENTAL IMPLICATIONS OF NEAR-EARTH ASTEROID MINING”, Annals of Air and Space Law Vol. 39, 2014, <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2546924> \*edited for gendered language

In addition to demystifying the legal doctrine governing outer space natural resource appropriation it is also necessary to weigh the benefits and detriments of space-faring activities. Foremost, States around the world are developing at unprecedented rates and the human population is mounting in conjunction with demand for natural resources to sustain the current and newly established western standard of living. One of the fastest growing nations, China, is experiencing unhindered growth facilitated by fossil fuel use from coal and extensive mining. This has caused substantial water, soil and air degradation. In the face of these troubles, NEA mining could be the key to preserving the Earth's bounty and replenishing contaminated water supplies. The influx of natural resources could thwart the burning of dirty coal and fossil fuels, thereby mitigating the effects of climate change, such as, rising sea level, atmospheric pollution, melting of sea ice and rising temperatures. NEA harvesting could also protect the ocean and the fragile and largely unexplored deep seabeds 123 from oil and gas drilling. It could furthermore protect ecosystems from rare-earth mineral mining predominantly used to fuel the electronics sector. 124 NEA mining is especially pertinent as China restricted its global exports of rare-earth minerals in 2009, incongruously citing the need to protect the environment. Unfortunately, the supply cuts have forced dependent States like Japan, the United States and South Korea to heighten rare-Earth mineral exploration. This accordingly led to Japan's 2011 discovery of rare-earth minerals in the ocean-bed deposits of the Pacific Exclusive Economic Zone (PEEZ) thereby necessitating risky, deep-sea mining techniques, which may result in marine pollution if not carefully designed and developed. Other States, which have joined the environmentally destructive rare-earth mineral exploration movement include India, Canada, Tanzania, Australia, Brazil and Vietnam., There is accordingly much competition and exploration for rare-earth minerals which could result in significant exploitation of untouched areas like the PEEZ seabed and Mongolia.125 Other regions which may soon be targeted for mineral and hydrological resources include Antarctica and the Arctic. With the advent of technological advances, environmentally destructive practices such as refining may soon occur in outer space, sparing the Earth of pollution. 126 Accordingly, NEA mining is a viable technology for preserving the Earth's environment by curbing atmospheric and marine pollution, enhancing water supply and quality and mitigating the effects of climate change; all while allowing humankind [people] to maintain and even improve their standard of living through increased technologies, consumption and population growth.

#### Non-unique – their card talks about NASA wanting to develop this technology which shows even in the aff world there will still be asteroids dragged into earth’s orbit.

#### Won’t happen – high risk deters companies from doing this to avoid public blowback.

#### Turn – companies will develop less resource intensive ways to mine asteroids – dragging the asteroid will be to expensive especially with more effective ways to mine like biomining.