# **1NC Strake**

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#### The standard is maximizing expected wellbeing. Two justifications:

#### 1. Policymakers use a utilitarian calculus

**Woller 97** (“An Overview by Gary Woller,” 1997 A Forum on the Role of Environmental Ethics, pg. 10)

Moreover, virtually all public policies entail some redistribution of economic or political resources, such that one group's gains must come at another group's expense. Consequently, public policies in a democracy must be justified to the public, and especially to those who pay the costs of those policies. Such justification cannot simply be assumed a priori by invoking some higher-order moral principle. Appeals to a priorimoral principles, such as environmental preservation, also often fail to acknowledge that public policies inevitably entail trade-offs among competing values. Thus, since policymakers cannot justify inherent value conflicts to the public in any philosophical sense, and since public policies inherently imply winners and losers, the policymakers' duty to the public interest requires them to demonstrate that the redistributive effects and value tradeoffs implied by their policies are somehow to the overall advantage of society.

**2. Respecting every individual entails trade-offs – that requires aggregation of value**

**Cummiskey** 96 (“Kantian Consequentialism,” David Cummiskey [philosophy chair at Bates College], 1996 - http://cmscontent.bates.edu/prebuilt/kantian.pdf)

We must not obscure the issue by characterizing this type of case as the sacrifice of individuals for some abstract “social entity.” It is not a question of some persons having to bear the cost for some elusive “overall social good.” Instead, the question is whether some persons must bear the inescapable cost for the sake of other persons. Robert Nozick, for example, argues that “to use a person in this way does not sufficiently respect and take account of the fact that he is a separate person, that his is the only life he has.” But why is this not equally true of all those whom we do not save through our failure to act? By emphasizing solely the one who must bear the cost if we act, we fail to sufficiently respect and take account of the many other separate persons, each with only one life, who will bear the cost of our inaction. In such a situation, what would a conscientious Kantian agent, an agent motivated by the unconditional value of rational beings, choose? A morally good agent recognizes that the basis of all particular duties is the principle that “rational nature exists as an end in itself” (GMM 429). Rational nature as such is the supreme objective end of all conduct. If one truly believes that all rational beings have an equal value, then the rational solution to such a dilemma involves maximally promoting the lives and liberties of as many rational beings as possible (chapter 5). In order to avoid this conclusion, the non-consequentialist Kantian needs to justify agent-centered constraints. As we saw in chapter 1, however, even most Kantian deontologists recognize that agent-centered constraints require a non-value-based rationale. But we have seen that Kant’s normative theory is based on an unconditionally valuable end. How can a concern for the value of rational beings lead to a refusal to sacrifice rational beings even when this would prevent other more extensive losses of rational beings? If the moral law is based on the value of rational beings and their ends, then what is the rationale for prohibiting a moral agent from maximally promoting these two tiers of value? If I sacrifice some for the sake of others, I do not use them arbitrarily, and I do not deny the unconditional value of rational beings. Persons may have “dignity, that is, an unconditional and incomparable worth” that transcends any market value (GMM 436), but persons also have a fundamental equality that dictates that some must sometimes give way for the sake of others (chapters 5 and 7). The concept of the end-in-itself does not support the view that we may never force another to bear some cost in order to benefit others. If one focuses on the equal value of all rational beings, then equal consideration suggests that one may have to sacrifice some to save many.

## Asteroid Mining – Resource Scarcity

#### Resource scarcity will cause extinction – only asteroid mining solves

Crombrugghe 18 (Guerric Crombrugghe is a Business Development Manager Brussels @ Brussels Capital Region, “Asteroid mining as a necessary answer to mineral scarcity”, LinkedIn, 1/11/2018, <https://www.linkedin.com/pulse/asteroid-mining-necessary-answer-mineral-scarcity-de-crombrugghe>)//NotJacob

We need minerals, and we always will. Yet, our reserves are finite and a 100% end-of-life recycling rate is impossible to achieve. Eventually, new entrants will therefore be required to sustain our system. While the business case for asteroid mining can obviously not be closed with current technologies, it will someday become a necessity. We may as well start preparing ourselves. Scarcity of resources, the challenge of the 21st century According to the World Bank, in 2016 humanity's growth rate was of 1.18% in terms of population, and 2.50% in terms of GDP. Both of these, in turn, drive our staggering resource consumption: there are more of us, and each of us needs more. On the other, the Earth is a closed system, and resources are only available in a finite amount. We all know by now that there is only this much oil & gas, but the same can actually be said for water, arable land, minerals, etc. These two simple observations have sparkled the debate around the scarcity of resources. Even with the best intentions, mathematics teaches us that it is impossible to indefinitely extract resources from a given finite supply [1]. The problem arising in the short-term is the exhaustion of the existing supply. That limit is actually coming in fast. In a paper published in 2007, Stephen Kessler demonstrates that the global mineral reserves are only sufficient for the next 50 years. The figure on the right shows the ratio of known global reserve to global annual consumption, given a rough indication of adequacy in years. It dates from an earlier paper, published in 1994. Since then, the development of environmental-friendly technologies (e.g. batteries, electric engines, etc.) has drastically increased the consumption rate of high-tech metals such as cobalt, platinum, rare earths, or titanium. On the other hand, exploration programs have allowed to discover new deposits, notably of gold and diamond. We will certainly be able to continue to increase - or at least sustain - our reserves, but only temporarily. Recycling and other temporary fixes An obvious solution is recycling, i.e. rejuvenating our stocks. A popular concept to illustrate this idea is that of urban mining: retrieving the ores present in smartphones and other electronic devices. It may prove to be not only more environmental-friendly, be also safer and more cost-effective. Nevertheless, every solution based on recycling is, again, nothing more than a temporary fix, buying us a finite amount of time. The United Nations Environment Programme studied in a report the current recycling rate of 60 metals. More than half of them have an end-of-life recycling rate below 1%, and less than one-third are above 50%. Nickel, for example, is relatively easy to retrieve, with and end-of-life recycling rate of up to 63% under the best conditions. At that rate, less than 1% of the initial stock is available after only 10 cycle. Even with a staggering 99% efficiency, the same 1% limit is achieved in less than 460 cycles. Not bad, of course, but still not enough. Should our hunger for resources continue, and even with the most optimised recycling techniques, a second problem will arise in the longer term: the amount of resources needed at a given time will simply exceed the total available stock. Unless we manage to find growth vectors that do not require raw materials, that tipping point is an impassable limit. Its proximity obviously depends on our consumption rate. Asteroid mining? No matter which way we look at it, we will thus be short on resources, either through sheer exhaustion (i.e. transformation in an unrecoverable form) or because the demand will exceed the total reserves. We can - and should - talk about recycling, dematerialisation, and other more ethically questionable solutions such as bio-engineering. Nonetheless, no matter how good they are, these are only temporary fixes. If we don't radically change our lifestyle, we will sooner or later have to address the elephant in the room: the Earth is a closed system, we need new entrants. How can space help? Short answer: all these minerals can be found in space. Some are difficult to obtain, others are even more difficult, none are straightforward. The most accessible destination is near-Earth asteroids, a reservoir of over 17,000 known - and counting - giant rocks that regularly cross the orbit of our planet. They are commonly classified in three main families. The most interesting one, for our case, is that of the S-type asteroids. These are metallic bodies, containing first and foremost nickel, iron and cobalt, but also gold, ores from the platinum group. But the list doesn't stop there, many other minerals can be found in smaller amounts: iridium, silver, osmium, palladium, rhenium, rhodium, ruthenium, manganese, molybdenum, aluminium, titanium, etc. How do we get there? Let's take an example: Ryugu, formerly known as 1999 JU3. It's a C-type asteroid measured to be approximately one kilometre in size [2]. In addition to nickel, iron and cobalt, it also contains a fair share of water, nitrogen, hydrogen, and ammonia. Its total value is estimated to be approximately 80 billion USD. Fantastic! But how do we get there and, most importantly, how much does it cost? Well, we may have the start of an answer to these questions. Reaching Ryugu is a technological challenge, but it is feasible. In December 2014, the Japanese space agency has launched a spacecraft, Hayabusa2, heading to the asteroid. Its mission includes the collection of a small sample which will be sent back to the Earth, with a landing planned for December 2020. The target for the sample size is at least 100 µg. The total cost of the mission was projected to be around 200 million USD. That's 2 trillion USD per gram. Let's be optimistic and assume that the sample retrieved is pure gold. At today's rate, it is worth 42.5 USD per gram. That's a difference of over 10 orders of magnitude. Some may argue that Hayabusa2 has many other objectives that retrieving a sample. The mission does indeed include multiple landers, thorough scientific investigations, etc. There is actually another asteroid sample return mission underway, which we could you as a second point of comparison: OSIRIS-Rex, from NASA. It's heading for Bennu, also a C-type asteroid, which it will reach in August 2018. Total cost of the mission: 980 million USD. Target sample size: at least 60 g. We achieve thus roughly speaking 16 million USD per gram. Better, but still 6 orders of magnitude off compared to pure gold. It's pretty much as good as it gets with existing state-of-the-art technologies. Not much of a business case. Should we forget about it? Referring back to our earlier conclusion on resource scarcity, we had two options. Either we drastically reduce our resource consumption, to such a degree that reserves can last for longer than humanity itself, or we extend our closed system, the Earth, to nearby asteroids. In the current state of affairs, I am honestly not sure which course of action is the easiest. As they get increasingly rare, the cost of minerals will go up. On the other hand, as explained in a previous article, we can expect the cost of space activities to go steadily down. Step by step, these 6 orders of magnitude will slowly get munched away from both ends, until eventually asteroid mining becomes a viable operation. In other words: it will only become financially interesting once minerals become a thousand times more expensive and space activities a thousand times cheaper. As a point of reference, the introduction of reusable rockets by SpaceX, widely considered as one of the few truly disruptive changes in the aerospace sector in the last few decades, has "only" brought a cost reduction of 30%. While it's clearly amazing, we still need at least 220 innovations of the same calibre [3] before we can make it work (again: assuming the price of minerals simultaneously goes up by a factor of a thousand). It's therefore quite likely that space mining will not take place within our lifetime [4]. How can we accelerate the process? Firstly, we can only celebrate and support the numerous private initiatives which contribute to make that reality happen, either indirectly (e.g. launchers, space systems, etc.) or directly (e.g. in-space manufacturing, lunar exploration, etc.). Shout out to all the folks who manage to keep the flame of space exploration burning while generating profit for their investors. Secondly, space agencies and other institutional actors should continue to act as promoters of pioneering mission such as Hayabusa2, OSIRIS-REx, or DART. We can only regret that the Asteroid Redirect Mission from NASA and the Asteroid Impact Mission from ESA were not funded. From my perspective, these should actually be amongst the top priorities of our space exploration agenda. Not only are they instrumental to our understanding of the solar system, but they are also essential if we want to avoid the same fate as the dinosaurs. It's a question of survival. As a bonus, they also pave the way towards cost-efficient asteroid mining. In the meantime, we might want to consume existing resources a bit more efficiently.

#### Resource wars go nuclear absent the plan

Wingo 13 - Dennis Wingo is chief executive of Skycorp Inc., a company focused on advanced technologies and systems for space exploration and commercial markets, “Commentary | The Inevitability of Extraterrestrial Mining”, *Space News*, 7/29/2013, https://spacenews.com/36511the-inevitability-of-extraterrestrial-mining/

I am honored to provide the counterpoint to my esteemed colleague Ambassador Roger Harrison’s negative contention concerning the mining of extraterrestrial materials off of planet Earth. Let’s begin with his ending: “The conclusion is inescapable, though liable to be escaped, i.e., that raw materials will never be mined in space and sold profitably within the atmosphere or anywhere else. … Asteroids will continue unvexed in their obits, and the Moon too.” I bring a different quote, from the book “Empire Express,” the story of the intercontinental railroad, from U.S. Army Lt. Zebulon Pike, for whom Pike’s Peak is named: “In various places there were tracts of many leagues, where the wind had thrown up sand in all the fanciful forms of the ocean’s rolling wave, and on which not a spear of vegetable matter existed.” Pike’s visions of sand dunes, pathless wastes and sterile soils were reported, widely read and faithfully believed by geographers. The myth became innocently embellished by subsequent visitors, especially those in the party of Maj. Stephen H. Long, who traversed the whole area in 1820. It was reported to be “an unfit residence for any but a nomad population … forever to remain the unmolested haunt of the native hunter, the bison, and the jackal.” The delicious irony is that Mr. Harrison today lives in the shadow of Pike’s Peak, and the U.S. Air Force Academy where he teaches is in the middle of the confidently prophesied unmolested haunt. When Long’s report was written, the Erie Canal across New York was five years from completion and it was another 31 years before the first railroad was completed across the state. Mr. Harrison’s technical objections are for the most part valid today for his scenario, just as objections to a railroad across the North American continent were valid in the 1820s. However, technology is being developed today that will enable extraterrestrial mining, manufacturing and development just as technology was developed that would enable the creation of the national railroad. Mr. Harrison says it is an illusion that we are running out of resources. He is correct. That is not our claim. The claim is that extraction costs of economically viable terrestrial resources are rising dramatically and may soon exceed the cost of extraction from much more plentiful extraterrestrial sources. Today rapidly advancing costs and diminishing returns are rapidly redefining mining due to diminishing ore grades. This fact is developed in a 2012 distinguished lecture by Dan Wood before the Society of Environmental Geologists, “Crucial Challenges to Discovery and Mining — Tomorrow’s Deeper Ore Bodies.” This is a vitally important issue to solve as resource conflict has been the impetus for most wars in human history. We live in a global civilization of over 7 billion people, which will expand to over 9 billion before plateauing in mid-century. While American politicians are not paying attention to what this means, the rest of the world is noticing. Gross domestic product (GDP) growth and increasing global resource demand are addressed in “Iron Ore Outlook 2050,” a report commissioned for the Indian government. The GDP of the major powers (the United States, Europe, China, India and Japan) is forecast to rise from $48 trillion in 2010 to $149 trillion by 2050. The report’s substance is that with this massive increase in global GDP, an intensifying scramble for metal resources is inevitable. If the trend of resource consumption demand increase continues unabated, there are three likely potential outcomes. The first is collapse, forecast by the “Limits to Growth” school of thought. The second and more likely scenario is fierce national economic competition leading to wars over diminishing resources. The third, and most desirable, is to increase the global resource base by the economic and industrial development of the inner solar system. Mr. Harrison uses cost as the primary reason that extraterrestrial mining will never happen by focusing on a straw man argument related to mining asteroids in orbits far from Earth. Just as the U.S. railroad infrastructure began on shorter routes with lower capital requirements and shorter payback periods, asteroid mining can begin with our nearest neighbor, the Moon, where telepresence robotics, high-bandwidth communications and a short three-day trip for humans negate his premise. We know from the Apollo samples that plentiful metallic asteroidal materials exist in the lunar highlands. We also know from several missions that extensive water, titanium, thorium, uranium, aluminum and native iron all exist on the Moon, in easily separable oxide form. Improvements in remote sensing data from current missions and computer modeling continue to increase the amount of potential asteroidal material on the Moon, increasing confidence in the Moon first premise. The extensive resources of the Moon become the catalyst for an inner solar system-wide economy providing fuel, vehicles and the all-important experience in developing an industrial infrastructure off planet. The asteroids then become the force multiplier of inner solar system development with billions of tons of water, metals and free space energy from solar power. Mars figures in here as well as the second home of humanity, creating further demand for asteroidal resources, and providing something else that is becoming increasingly scarce on the Earth: hope for the future. The technical barriers that Mr. Harrison points to are being overcome just as those of the 19th century were. New technology developments in 3-D printing, additive manufacturing and advanced robotics are breaking down the final barriers to exploiting off-planet resources and indeed the industrial development of the inner solar system. It is not a question if, it is a question of when, and by whom. Just as the Pacific Railway Act of 1862 was a primary catalyst for a century of American economic growth, it should be the role of government to develop policies and concrete legislation to support this development for the continued health of the American economy and the future of all mankind.

#### Private space mining coming now

**Gilbert ’21:** Alex Gilbert is a complex systems researcher and a PhD student in space resources at the Colorado School of Mines. “Mining in Space is Coming”. Milken Institute Review. April 6th, 2021. https://www.milkenreview.org/articles/mining-in-space-is-coming

**Space exploration is back. after decades of disappointment, a combination of better technology, falling costs and a rush of competitive energy from the private sector has put space travel front and center. indeed, many analysts (even some with their feet on the ground) believe that commercial developments in the space industry may be on the cusp of starting the largest resource rush in history: mining on the Moon, Mars and asteroids**. While this may sound fantastical, some baby steps toward the goal have already been taken. Last year, NASA awarded contracts to four companies to extract small amounts of lunar regolith by 2024, effectively beginning the [era of commercial space mining](https://payneinstitute.mines.edu/wp-content/uploads/sites/149/2020/09/Payne-Institute-Commentary-The-Era-of-Commercial-Space-Mining-Begins.pdf). Whether this proves to be the dawn of a gigantic adjunct to mining on earth — and more immediately, a key to unlocking cost-effective space travel — will turn on the answers to a host of questions ranging from what resources can be efficiently. As every fan of science fiction knows, the resources of the solar system appear virtually unlimited compared to those on Earth. There are whole other planets, dozens of moons, thousands of massive asteroids and millions of small ones that doubtless contain humungous quantities of materials that are scarce and very valuable (back on Earth). Visionaries including Jeff Bezos [imagine heavy industry moving to space](https://www.fastcompany.com/90347364/jeff-bezos-wants-to-save-earth-by-moving-industry-to-space) and Earth becoming a residential area. However, as entrepreneurs look to harness the riches beyond the atmosphere, access to space resources remains tangled in the realities of economics and governance. Start with the fact that space belongs to no country, complicating traditional methods of resource allocation, property rights and trade. With limited demand for materials in space itself and the need for huge amounts of energy to return materials to Earth, creating a viable industry will turn on major advances in technology, finance and business models. That said, there’s no grass growing under potential pioneers’ feet. Potential economic, scientific and even security benefits underlie an emerging [geopolitical competition](https://nationalinterest.org/feature/geostrategic-importance-outer-space-resources-154746) to pursue space mining**. The United States is rapidly emerging as a front-runner, in part due to its ambitious Artemis Program to lead a multinational consortium back to the Moon. But it is also a leader in creating a legal infrastructure for mineral exploitation. The United States has adopted the world’s first spaceresources law, recognizing the property rights of private companies and individuals to materials gathered in space.** However, the United States is hardly alone. Luxembourg and the United Arab Emirates (you read those right) are racing to codify space-resources laws of their own, hoping to attract investment to their entrepot nations with business-friendly legal frameworks. China reportedly views space-resource development as a national priority, part of a strategy to challenge U.S. economic and security primacy in space. Meanwhile, Russia, Japan, India and the European Space Agency all harbor space-mining ambitions of their own. Governing these emerging interests is an outdated treaty framework from the Cold War**. Sooner rather than later, we’ll need** [**new agreements**](https://issues.org/new-policies-needed-to-advance-space-mining/) **to facilitate private investment and ensure international cooperation. What’s Out There Back up for a moment. For the record, space is already being heavily exploited, because space resources include non-material assets such as orbital locations and abundant sunlight that enable satellites to provide services to Earth.** Indeed, satellite-based telecommunications and global positioning systems have become indispensable infrastructure underpinning the modern economy. Mining space for materials, of course, is another matter. In the past several decades, planetary science has confirmed what has long been suspected: celestial bodies are potential sources for dozens of natural materials that, in the right time and place, are incredibly valuable. Of these, water may be the most attractive in the near-term, because — with assistance from solar energy or nuclear fission — H2O can be split into hydrogen and oxygen to make rocket propellant, [facilitating in-space refueling](https://www.theverge.com/2018/8/23/17769034/nasa-moon-lunar-water-ice-mining-propellant-depots). So-called “rare earth” metals are also potential targets of asteroid miners intending to service Earth markets. Consisting of 17 elements, including lanthanum, neodymium, and yttrium, these critical materials (most of which are today mined in China at great environmental cost) are required for electronics. And they loom as bottlenecks in making the transition from fossil fuels to renewables backed up by battery storage. The Moon is a prime [space mining target](https://theconversation.com/mining-the-moon-110744). Boosted by NASA’s mining solicitation, it is likely the first location for commercial mining. The Moon has several advantages. It is relatively close, requiring a journey of only several days by rocket and creating communication lags of only a couple seconds — a delay small enough to allow remote operation of robots from Earth. Its low gravity implies that relatively little energy expenditure will be needed to deliver mined resources to Earth orbit. Science Photo Library/Alamy Stock Photo The Moon may look parched — and by comparison to Earth, it is. But recent probes have confirmed substantial amounts of water ice lurking in [permanently shadowed craters](http://lroc.sese.asu.edu/posts/1105) at the lunar poles. Further, it seems that solar winds have implanted significant deposits of helium-3 (a light stable isotope of helium) across the equatorial regions of the Moon. Helium-3 is a potential fuel source for secondand third-generation fusion reactors that one hopes will be in service later in the century. The isotope is packed with energy (admittedly hard to unleash in a controlled manner) that might augment sunlight as a source of clean, safe energy on Earth or to power fast spaceships in this century. Between its water and helium-3 deposits, the Moon could be the resource stepping-stone for further solar system exploration. Asteroids are another near-term [mining target](https://foreignpolicy.com/2016/04/28/the-asteroid-miners-guide-to-the-galaxy-space-race-mining-asteroids-planetary-research-deep-space-industries/). There are all sorts of space rocks hurtling through the solar system, with varying amounts of water, rare earth metals and other materials on board. The asteroid belt between the orbits of Mars and Jupiter contains most of them, many of which are greater than a kilometer in diameter. Although the potential water and mineral wealth of the asteroid belt is vast, the long distance from Earth and requisite travel times and energy consumption rule them out as targets in the near term. Wannabe asteroid miners will thus be looking at smaller near-Earth asteroids. While they are much further away than the Moon, many of them could be reached using less energy — and some are even small enough to make it technically possible to tow them to Earth orbit for mining. Space mining may be essential to crewed [exploration missions to Mars](https://www.sciencedirect.com/science/article/abs/pii/S0032063319301618). Given the distance and relatively high gravity of Mars (twice that of the Moon), extraction and export of minerals to Earth seems highly unlikely. Rather, most resource extraction on Mars will focus on providing materials to supply exploration missions, refuel spacecraft and enable settlement. Technology Is the Difference The prospects for space mining are being driven by technological advances across the space industry. **The rise of reusable rocket components and the now-widespread use of off-the-shelf parts are lowering both** [**launch and operations costs**](https://aerospace.csis.org/data/space-launch-to-low-earth-orbit-how-much-does-it-cost/)**. Once limited to government contract missions and the delivery of telecom satellites to orbit, private firms are now emerging as leaders in developing “[NewSpace](https://www.sciencedirect.com/science/article/pii/S0094576519313451" \t "_blank)” activities — a catch-all term for endeavors including orbital tourism, orbital manufacturing and mini-satellites providing specialized services. The space sector, with a market capitalization of $400 billion, could grow to** [**as much as $1 trillion**](https://milkeninstitute.org/videos/infinity-and-beyond-business-space) **by 2040 as private investment soars.** But despite the high-profile commercial advances, governments still call the shots on the leading edge of space resource technologies. The United States extracted the first extraterrestrial materials in space from the Moon during the Apollo missions, followed by the Soviet Union’s recoveries from crewless Luna missions. President Biden recently borrowed one of the Apollo lunar rocks for display in the Oval Office, highlighting the awe that deep space can still summon. For the time being, scientific samples remain the goal of mining. Last October, NASA’s OSIRIS-REx mission — [due to return to Earth in 2023](https://www.nasa.gov/press-release/nasa-s-osiris-rex-mission-plans-for-may-asteroid-departure) — collected a small amount of material from the asteroid Bennu. In December, Japan returned a sample of the asteroid Ryugu with the [Hayabusa2 spacecraft](https://www.technologyreview.com/2020/12/02/1012890/japan-jaxa-sample-return-mission-hayabusa2-ryugu/). And several weeks later, China’s Chang’e 5 mission returned the first lunar samples since the 1970s. ESA/ Cover Images Sample collection is accelerating, with recent missions targeting Mars. Japan is planning to visit the two moons of Mars and extract a [sample from one](http://mmx.isas.jaxa.jp/en/#:~:text=The%20Martian%20Moons%20eXploration%20(MMX,launch%20in%20the%20mid-2020s.&text=It%20will%20then%20move%20into,sample%20from%20the%20moon's%20surface.). NASA’s robotic Perseverance rover will collect and cache drilled samples on Mars that could later be returned to Earth. Perseverance also carries gear for the unique MOXIE experiment on Mars — an attempt to produce oxygen on the planet with technologies that could eventually extract oxygen for astronauts to breath and refuel spacecraft. To be viable, commercial space mining will, of course, have to operate at a much larger scale than the scientific digs. Whereas all samples collected to date consist of less than one ton of material, a single space mining operation would have to be able to manage hundreds or thousands of tons. Stripped to the basics, the stages of a space mining operation resemble those of terrestrial mining, with prospecting followed by extraction, processing and distribution to users. But the unique conditions of outer space environments make this progression far more daunting. Most space mining targets have little or no atmosphere and experience extreme temperature swings between shade and sunlight. Radiation, from both the sun and cosmic sources, permeates the space environment and threatens electronics — not to mention human health. The most basic technologies needed for space mining are as simple as shovels and drills. But water and other materials that are volatile will have to be extracted using more exotic techniques. The list of challenges goes on. Launching to space is a stressful process, and equipment must survive high acceleration and acoustic forces. Due to orbital mechanics and the immense energies required to navigate large distances, all space missions are limited to minimal payloads. Missions in deep space operate in microgravity — a challenge when mining an asteroid — or reduced gravity on the Moon or Mars. Even the surfaces of celestial bodies pose a challenge to mining machinery, since they consist of unconsolidated rocky materials called regolith instead of more familiar soil. The most basic technologies needed for space mining are as simple as shovels and drills. But water and other materials that are volatile can be extracted using more exotic techniques: on the Moon, [thermal mining](https://www.liebertpub.com/doi/full/10.1089/space.2019.0002) would sublimate ice directly to vapor and trap it in a tent. One of the space mining startups, Transastra, proposes a [similar method](https://www.thespaceresource.com/news/2019/6/transastra-mini-bee) on a far grander scale for small asteroids, trapping the volatile resource in a bag surrounding the whole body. Remember, too, that after space resources are gathered, a supply chain must deliver the material to customers. If you’re curious about the details, check out a 2018 report, [Commercial Lunar Propellant Architecture](https://isruinfo.com/public/docs/Commercial%20Lunar%20Propellant%20Architecture.pdf), which describes a mining cycle to extract water on the Moon, convert it to fuel and deliver it to customer spacecraft. **Before committing billions to the real thing, public and private investors will need to spend millions testing plans in environments that resemble the conditions of outer space. Regolith simulants, vacuum chambers, computer modeling and other aerospace testing equipment are all needed to verify mining technologies can work in space. Beyond space technologies, advances in other sectors could aid space mining missions. Among them: additive manufacturing (3D printing) to support base construction,** [**AI to run robots**](https://theconversation.com/five-ways-artificial-intelligence-can-help-space-exploration-153664) **and even nuclear power reactors to provide large amounts of energy. The Economics of Mining the Cosmos Claims about the economic value of space mining are often nine parts hyperbole. Newspaper headlines point to asteroids like** [**16 Psyche, a 226-kilometer-diameter rock**](https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/16-psyche/in-depth/) **whose iron and nickel resources are estimated to be worth $10 quintillion dollars at current commodity prices (100,000 times the size of the Earth’s GDP). But setting aside the blarney, there really is gold (water? helium-3? praseodymium?) in them thar hills. Neil DeGrasse Tyson famously predicted that the world’s first trillionaire will be a space miner. Great minds seem to agree: many of the major private players in space (a group that includes Jeff Bezos, Elon Musk and Richard Branson) are billionaires prepared to risk a whole lot of money to add a few more zeros to their net worth.** That said, a common joke in this new industry (as in many others) is that the best way to become a millionaire in space is to start as a billionaire. Even with recent commercial advances, the cost of putting a payload into space remains very high, and the elasticity of demand for space-mined resources is uncertain. A chicken-egg problem underlies all NewSpace activities, but especially mining: without space miners supplying materials, there will be no customers. But without customers, there is no incentive to mine. James Vaughan Even NASA’s solicitation for four companies to extract lunar regolith on the Moon and sell samples to the agency underscores the nascent nature of mining: NASA is paying no more than $15,000 for a half-kilo, a fraction of a fraction of the cost of such a mission. Large asteroid valuations, like that of 16 Psyche, also do not reflect market realities, since delivering large quantities of expensive commodities like platinum or gold would crash market prices. Markets for such metals are small on a mass basis, and it is [not clear](https://link.springer.com/article/10.1007/s13563-020-00231-6) that Earth markets provide sufficient demand to support enough space mining to Second Quarter 2021 55 justify the fixed costs of production. In broad terms, the uses of space resources can be broken into two categories: return to Earth or use in space. Early startups, like Planetary Resources and Deep Space Industries, focused on mining metals with the goal of selling them back on Earth. However, the market uncertainty was [a major factor in the decline of](https://www.technologyreview.com/2019/06/26/134510/asteroid-mining-bubble-burst-history/) both industry leaders. In the long term, production in space to supply Earth could drive massive growth in the space industry — but not with commodities competing with terrestrial production. Rather, Earth markets are likely to be most receptive to the exotic: specialized materials and alloys manufactured in microgravity conditions, large-satellite services such as [space-based solar power](https://www.globalpolicyjournal.com/blog/21/10/2019/emerging-competition-space-solar-power), or unique products like helium-3. The latter two are particularly promising, as they could provide large contributions to global decarbonization after 2050. In the near term, what’s found in space will stay in space. The support of crewed and robotic exploration with on-site resource utilization — plausibly, on the Moon in the 2020s and [Mars in the 2030s](https://www.sciencedirect.com/science/article/abs/pii/S0032063319301618) — has the greatest promise to jumpstart space mining. Construction of Moon bases from local materials could greatly reduce mass requirements. If water-derived propellant is developed at a competitive price, it could find a ready market in spacecraft heading from low-earth orbit to geosynchronous orbit or deep space. Of course, questions about the economic value of space resources assume that property rights are well-defined and assured. Space law on property rights is developing quickly. But many questions remain, exacerbating economic uncertainties. Aspects of the accords exclude major space players like Russia, China and India. They provide for “safety zones” around mining sites, raising fears about exclusion of other countries from prime locations. You’re Stepping On My Regolith As human industrial activity spreads into the high frontier, disputes over ownership and governance follow. Outer space is beyond the territorial jurisdiction of any nation, meaning [international law is the basis for space law and space-resources law](https://www.hoganlovells.com/~/media/hogan-lovells/pdf/2018/the_development_of_natural_resouces_in_outer_space_august_2018.pdf). The primary governing treaty for international space law, the [Outer Space Treaty of 1967](https://history.nasa.gov/1967treaty.html), prohibits appropriation of celestial bodies, such as the Moon or asteroids, by individual nations. **Whether space mining is allowed under the treaty remains highly contentious. Drafted at the height of the Cold War to head off an arms race in space and a “land” rush, the Outer Space Treaty did not envision the private and commercial ventures of today. The non-appropriation clause prevents nations from claiming celestial bodies by planting a flag or by occupying an area.** However, it does not clearly prohibit owning and using resources once they are extracted from a celestial body. Indeed, other parts of the treaty imply that such use is allowed. Past and ongoing missions by the United States, the Soviet Union, Japan and China to acquire scientific samples have never been seriously challenged as violating the treaty. A second international treaty that would explicitly establish global governance of commercial space mining, the [Moon Agreement](https://www.spacelegalissues.com/the-1979-moon-agreement/), has been broadly rejected by most countries — and all countries with the means and motive to mine in space. The United States has long held that the Outer Space Treaty permits commercial resource extraction. It is taking a leading role in establishing space mining as allowed under both national and international law. Recognizing the ambitions of Planetary Resources and Deep Space Industries (two startups with big plans), in 2015 Congress passed and President Obama signed [the world’s first national space-resources law](https://www.liebertpub.com/doi/10.1089/space.2017.0008). The law recognized the rights of U.S. residents to own materials gathered in outer space, but does not claim U.S. or private ownership of celestial bodies. Although now guaranteeing property rights, the United States has yet to establish a clear regulatory system to authorize such missions. The Trump administration built on these early activities by including space mining as part of its broader prioritization of space exploration, and specifically by supporting a plan to return astronauts to the Moon with the Artemis Program. An [April 2020 Executive Order](https://aerospace.org/sites/default/files/2020-04/EO%2013914%20Space%20Resources%206Apr20.pdf) reiterated the U.S. commitment to space-resources-development property rights, repeated the U.S. rejection of the Moon Agreement and solicited international cooperation. Other administration activities bolstered the foundation for space mining, including national policies on planetary protection and [space nuclear power](https://aerospace.org/sites/default/files/2020-12/Space%20Policy%20Directive%206%20-%20Nuke%20Power%20&%20Propulsion%2016Dec20.pdf). Other nations are following the U.S. lead in developing space-resources law and policy. As noted earlier, Luxembourg has passed a space mining law of its own, [prioritizing space resources](https://space-agency.public.lu/en/space-resources/the-initiative.html) and forming partnerships with space agencies worldwide. The United Arab Emirates is moving toward a similar law, as the country looks to space as part of the oil-drenched state’s modernization plans. As Japan continues scientific sampling missions, its government is currently [considering a space mining law](https://www.japantimes.co.jp/news/2020/11/06/national/science-health/japan-bill-space-samples/) of its own. The nature of China’s space ambitions isn’t easy to decipher, but [space mining and lunar exploration](https://www.thecairoreview.com/wp-content/uploads/2019/05/cr33-global-forum.pdf) are clearly part of the strategy. Indeed, many U.S. advocates of space mining point to Chinese ambitions as a reason for the United States to get out ahead of the pack of liberal democracies with space capabilities. The ungoverned nature of outer space and lack of national ownership plainly create the possibility of conflict. Even if companies have rights to own a resource when they extract it, they do not necessarily have rights to a resource while it remains in place. If two companies from different nations want to mine the same area, both technically have the right to do so. “First come, first serve” may work for one nation’s activities, but nothing prevents ventures from another country building adjacent mines, with attendant economic and operational risks. The international nature of space exacerbates the lack of ownership, as disputes between companies from separate countries become a matter of international relations. To begin addressing these challenges, the United States negotiated the Artemis Accords in 2020, a multilateral agreement to guide near-term lunar exploration. Signatories of the accords include many U.S. space partners: the United Kingdom, Luxembourg, UAE, Australia, Canada, Japan, Italy and Ukraine. Much of the accords are natural extensions of the Outer Space Treaty and are a welcome development. For example, one provision provides for interoperability between different nations’ space technologies. But other aspects of the accords are problematic. They currently exclude major space players like Russia, China and India. They provide for “safety zones” around mining sites, which raises fears about exclusion of other countries from prime locations and de facto national appropriation. The number one environmental threat to crew and satellite safety in low-earth orbit is not the harsh conditions of outer space but rather [space debris](https://www.nature.com/articles/d41586-018-06170-1) from decades of lightly regulated space activities. Beyond questions of resource governance, environmental problems are emerging due to NewSpace activities. The number one environmental threat to crew and satellite safety in low-earth orbit is not the harsh conditions of outer space, but rather [space debris](https://www.nature.com/articles/d41586-018-06170-1) from decades of lightly regulated space activities. A growing population of space junk and the rise of satellite mega-constellations, like SpaceX’s Starlink, are increasingly crowding orbits and threatening collisions. Mega-constellations are also negatively impacting astronomy by adding light pollution. Lunar pollution may not be far behind. Here’s another headache in the making. In 2019, the non-profit Arch Mission Foundation [smuggled a cargo of tardigrades](https://www.thespacereview.com/article/3783/1) — tiny animals that can survive extreme environments — to the Moon without regulatory approval, raising planetary protection concerns among astrobiologists. These early space environmental issues, and [their lack of clear policy resolution](https://spacenews.com/viasat-asks-fcc-to-perform-environmental-review-of-starlink/), are early harbingers of environmental disputes in outer space. The environmental impacts of space mining activities remain speculative, but they could undermine the safety of crewed and robotic missions. The Apollo missions revealed that landing or launching from the Moon can spew large amounts of lunar regolith long distances, perhaps even into lunar orbit. Regolith is coarse and, without a lunar atmosphere to slow it down or break it up, ejected regolith could damage distant spacecraft. Mining activities themselves could similarly cause regolith dust issues. More broadly, mining activities could [cause contamination](https://www.nature.com/articles/d41586-020-03262-9) of local areas of interest, impacting scientific value. With proposals to conduct space mining with bacteria, the tardigrade incident raises questions about how commercial activities might complicate the search for life or even threaten fragile extraterrestrial systems with human-delivered invasive species. Solutions are emerging. In December 2020, the U.S. took a leading role with Congress’ passage of the “[One Small Step to Protect Human Heritage in Space Act](https://spacepolicyonline.com/news/president-signs-law-protecting-lunar-heritage-sites/).” The bill provides initial protections to Apollo and lunar heritage sites, a framework for future environmental and social protections. The Century of Space Mining? Although uncertainties remain high, sooner or later space mining promises to greatly accelerate space exploration and bolster terrestrial economies. While industrial activities in space may well cause conflict with scientific priorities, the infrastructure created in its development could serve science with orbital refueling, reduced mission costs, space manufacturing and, more generally, deeper knowledge of how to operate in space environments. There will no doubt be plenty of slips twixt cup and lip. But while, just a few decades ago, it was easy to dismiss the idea of space industry in general and space mining in particular as the stuff of science fiction, the worm has definitely turned. **Today, it is pretty clear that space mining — along with its attendant exploration and industrialization — is coming soon.**

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

Hlimi 14 (Tina Hlimi is a 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>)//NotJacob

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 to maintain and even improve their standard of living through increased technologies, consumption and population growth.

#### Warming causes extinction

Kareiva 18 ― Peter Kareiva, director of the Institute of the Environment and Sustainability at UCLA, Professor in Environment and Sustainability at UCLA, Ph.D. in ecology and applied mathematics from Cornell University, 2018. (“Existential risk due to ecosystem collapse: Nature strikes back”, Futures, Volume 102, September 2018, Available Online at: <https://www.sciencedirect.com/science/article/pii/S0016328717301726> Accessed 8-17-2019)

In summary, six of the nine proposed planetary boundaries (phosphorous, nitrogen, biodiversity, land use, atmospheric aerosol loading, and chemical pollution) are unlikely to be associated with existential risks. They all correspond to a degraded environment, but in our assessment do not represent existential risks. However, the three remaining boundaries (climate change, global freshwater cycle, and ocean acidification) do pose existential risks. This is because of intrinsic positive feedback loops, substantial lag times between system change and experiencing the consequences of that change, and the fact these different boundaries interact with one another in ways that yield surprises. In addition, climate, freshwater, and ocean acidification are all directly connected to the provision of food and water, and shortages of food and water can create conflict and social unrest. Climate change has a long history of disrupting civilizations and sometimes precipitating the collapse of cultures or mass emigrations (McMichael, 2017). For example, the 12th century drought in the North American Southwest is held responsible for the collapse of the Anasazi pueblo culture. More recently, the infamous potato famine of 1846–1849 and the large migration of Irish to the U.S. can be traced to a combination of factors, one of which was climate. Specifically, 1846 was an unusually warm and moist year in Ireland, providing the climatic conditions favorable to the fungus that caused the potato blight. As is so often the case, poor government had a role as well—as the British government forbade the import of grains from outside Britain (imports that could have helped to redress the ravaged potato yields). Climate change intersects with freshwater resources because it is expected to exacerbate drought and water scarcity, as well as flooding. Climate change can even impair water quality because it is associated with heavy rains that overwhelm sewage treatment facilities, or because it results in higher concentrations of pollutants in groundwater as a result of enhanced evaporation and reduced groundwater recharge. Ample clean water is not a luxury—it is essential for human survival. Consequently, cities, regions and nations that lack clean freshwater are vulnerable to social disruption and disease. Finally, ocean acidification is linked to climate change because it is driven by CO2 emissions just as global warming is. With close to 20% of the world’s protein coming from oceans (FAO, 2016), the potential for severe impacts due to acidification is obvious. Less obvious, but perhaps more insidious, is the interaction between climate change and the loss of oyster and coral reefs due to acidification. Acidification is known to interfere with oyster reef building and coral reefs. Climate change also increases storm frequency and severity. Coral reefs and oyster reefs provide protection from storm surge because they reduce wave energy (Spalding et al., 2014). If these reefs are lost due to acidification at the same time as storms become more severe and sea level rises, coastal communities will be exposed to unprecedented storm surge—and may be ravaged by recurrent storms. A key feature of the risk associated with climate change is that mean annual temperature and mean annual rainfall are not the variables of interest. Rather it is extreme episodic events that place nations and entire regions of the world at risk. These extreme events are by definition “rare” (once every hundred years), and changes in their likelihood are challenging to detect because of their rarity, but are exactly the manifestations of climate change that we must get better at anticipating (Diffenbaugh et al., 2017). Society will have a hard time responding to shorter intervals between rare extreme events because in the lifespan of an individual human, a person might experience as few as two or three extreme events. How likely is it that you would notice a change in the interval between events that are separated by decades, especially given that the interval is not regular but varies stochastically? A concrete example of this dilemma can be found in the past and expected future changes in storm-related flooding of New York City. The highly disruptive flooding of New York City associated with Hurricane Sandy represented a flood height that occurred once every 500 years in the 18th century, and that occurs now once every 25 years, but is expected to occur once every 5 years by 2050 (Garner et al., 2017). This change in frequency of extreme floods has profound implications for the measures New York City should take to protect its infrastructure and its population, yet because of the stochastic nature of such events, this shift in flood frequency is an elevated risk that will go unnoticed by most people. 4. The combination of positive feedback loops and societal inertia is fertile ground for global environmental catastrophes. Humans are remarkably ingenious, and have adapted to crises throughout their history. Our doom has been repeatedly predicted, only to be averted by innovation (Ridley, 2011). However, the many stories of human ingenuity successfully addressing existential risks such as global famine or extreme air pollution represent environmental challenges that are largely linear, have immediate consequences, and operate without positive feedbacks. For example, the fact that food is in short supply does not increase the rate at which humans consume food—thereby increasing the shortage. Similarly, massive air pollution episodes such as the London fog of 1952 that killed 12,000 people did not make future air pollution events more likely. In fact it was just the opposite—the London fog sent such a clear message that Britain quickly enacted pollution control measures (Stradling, 2016). Food shortages, air pollution, water pollution, etc. send immediate signals to society of harm, which then trigger a negative feedback of society seeking to reduce the harm. In contrast, today’s great environmental crisis of climate change may cause some harm but there are generally long time delays between rising CO2 concentrations and damage to humans. The consequence of these delays are an absence of urgency; thus although 70% of Americans believe global warming is happening, only 40% think it will harm them (http://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/). Secondly, unlike past environmental challenges, the Earth’s climate system is rife with positive feedback loops. In particular, as CO2 increases and the climate warms, that very warming can cause more CO2 release which further increases global warming, and then more CO2, and so on. Table 2 summarizes the best documented positive feedback loops for the Earth’s climate system. These feedbacks can be neatly categorized into carbon cycle, biogeochemical, biogeophysical, cloud, ice-albedo, and water vapor feedbacks. As important as it is to understand these feedbacks individually, it is even more essential to study the interactive nature of these feedbacks. Modeling studies show that when interactions among feedback loops are included, uncertainty increases dramatically and there is a heightened potential for perturbations to be magnified (e.g., Cox, Betts, Jones, Spall, & Totterdell, 2000; Hajima, Tachiiri, Ito, & Kawamiya, 2014; Knutti & Rugenstein, 2015; Rosenfeld, Sherwood, Wood, & Donner, 2014). This produces a wide range of future scenarios. Positive feedbacks in the carbon cycle involves the enhancement of future carbon contributions to the atmosphere due to some initial increase in atmospheric CO2. This happens because as CO2 accumulates, it reduces the efficiency in which oceans and terrestrial ecosystems sequester carbon, which in return feeds back to exacerbate climate change (Friedlingstein et al., 2001). Warming can also increase the rate at which organic matter decays and carbon is released into the atmosphere, thereby causing more warming (Melillo et al., 2017). Increases in food shortages and lack of water is also of major concern when biogeophysical feedback mechanisms perpetuate drought conditions. The underlying mechanism here is that losses in vegetation increases the surface albedo, which suppresses rainfall, and thus enhances future vegetation loss and more suppression of rainfall—thereby initiating or prolonging a drought (Chamey, Stone, & Quirk, 1975). To top it off, overgrazing depletes the soil, leading to augmented vegetation loss (Anderies, Janssen, & Walker, 2002). Climate change often also increases the risk of forest fires, as a result of higher temperatures and persistent drought conditions. The expectation is that forest fires will become more frequent and severe with climate warming and drought (Scholze, Knorr, Arnell, & Prentice, 2006), a trend for which we have already seen evidence (Allen et al., 2010). Tragically, the increased severity and risk of Southern California wildfires recently predicted by climate scientists (Jin et al., 2015), was realized in December 2017, with the largest fire in the history of California (the “Thomas fire” that burned 282,000 acres, https://www.vox.com/2017/12/27/16822180/thomas-fire-california-largest-wildfire). This catastrophic fire embodies the sorts of positive feedbacks and interacting factors that could catch humanity off-guard and produce a true apocalyptic event. Record-breaking rains produced an extraordinary flush of new vegetation, that then dried out as record heat waves and dry conditions took hold, coupled with stronger than normal winds, and ignition. Of course the record-fire released CO2 into the atmosphere, thereby contributing to future warming. Out of all types of feedbacks, water vapor and the ice-albedo feedbacks are the most clearly understood mechanisms. Losses in reflective snow and ice cover drive up surface temperatures, leading to even more melting of snow and ice cover—this is known as the ice-albedo feedback (Curry, Schramm, & Ebert, 1995). As snow and ice continue to melt at a more rapid pace, millions of people may be displaced by flooding risks as a consequence of sea level rise near coastal communities (Biermann & Boas, 2010; Myers, 2002; Nicholls et al., 2011). The water vapor feedback operates when warmer atmospheric conditions strengthen the saturation vapor pressure, which creates a warming effect given water vapor’s strong greenhouse gas properties (Manabe & Wetherald, 1967). Global warming tends to increase cloud formation because warmer temperatures lead to more evaporation of water into the atmosphere, and warmer temperature also allows the atmosphere to hold more water. The key question is whether this increase in clouds associated with global warming will result in a positive feedback loop (more warming) or a negative feedback loop (less warming). For decades, scientists have sought to answer this question and understand the net role clouds play in future climate projections (Schneider et al., 2017). Clouds are complex because they both have a cooling (reflecting incoming solar radiation) and warming (absorbing incoming solar radiation) effect (Lashof, DeAngelo, Saleska, & Harte, 1997). The type of cloud, altitude, and optical properties combine to determine how these countervailing effects balance out. Although still under debate, it appears that in most circumstances the cloud feedback is likely positive (Boucher et al., 2013). For example, models and observations show that increasing greenhouse gas concentrations reduces the low-level cloud fraction in the Northeast Pacific at decadal time scales. This then has a positive feedback effect and enhances climate warming since less solar radiation is reflected by the atmosphere (Clement, Burgman, & Norris, 2009). The key lesson from the long list of potentially positive feedbacks and their interactions is that runaway climate change, and runaway perturbations have to be taken as a serious possibility. Table 2 is just a snapshot of the type of feedbacks that have been identified (see Supplementary material for a more thorough explanation of positive feedback loops). However, this list is not exhaustive and the possibility of undiscovered positive feedbacks portends even greater existential risks. The many environmental crises humankind has previously averted (famine, ozone depletion, London fog, water pollution, etc.) were averted because of political will based on solid scientific understanding. We cannot count on complete scientific understanding when it comes to positive feedback loops and climate change.

#### Ocean acidification and global pollution cause extinction

Harvey 19 – Fiona, Environmental Correspondent for the Guardian, " 'Shocking' state of seas threatens mass extinction, say marine experts", *The Guardian*, 6/20/2019, <https://www.theguardian.com/environment/2011/jun/20/marine-life-oceans-extinction-threat>

Fish, sharks, whales and other marine species are in imminent danger of an "unprecedented" and catastrophic extinction event at the hands of humankind, and are disappearing at a far faster rate than anyone had predicted, a study of the world's oceans has found. Mass extinction of species will be "inevitable" if current trends continue, researchers said. Overfishing, pollution, run-off of fertilisers from farming and the acidification of the seas caused by increasing carbon dioxide emissions are combining to put marine creatures in extreme danger, according to the report from the International Programme on the State of the Ocean (Ipso), prepared at the first international workshop to consider all of the cumulative stresses affecting the oceans at Oxford University. The international panel of marine experts said there was a "high risk of entering a phase of extinction of marine species unprecedented in human history". They said the challenges facing the oceans created "the conditions associated with every previous major extinction of species in Earth's history". "The findings are shocking," said Alex Rogers, scientific director of Ipso. "As we considered the cumulative effect of what humankind does to the ocean, the implications became far worse than we had individually realised. This is a very serious situation demanding unequivocal action at every level. We are looking at consequences for humankind that will impact in our lifetime, and worse, our children's and generations beyond that." The flow of soil nutrients into the oceans is creating huge "dead zones", where anoxia - the absence of oxygen - and hypoxia - low oxygen levels - mean fish and other marine life are unable to survive there. Hypoxia and anoxia, warming and acidification are factors present in every mass extinction event in the oceans over the Earth's history, according to scientific research. About 55m years ago, as much as half of some species of deep-sea creatures were wiped out when atmospheric changes created similar conditions. In recent years, human effects on the oceans have increased significantly. Overfishing has cut some fish populations by more than 90%. Pollutants, including flame-retardant chemicals and detergents are absorbed into particles of plastic waste in the sea, which are then ingested by marine creatures. Millions of fish, birds and other forms of life are choked or suffer internal ruptures from ingesting plastic waste. During 1998, record high temperatures wiped out about 16% of the world's tropical coral reefs. The scientists called on the United Nations and governments to bring in measures to conserve marine ecosystems. Dan Laffoley, of the International Union for the Conservation of Nature, said: "The world's leading experts on oceans are surprised by the rate and magnitude of changes we are seeing. The challenges for the future of the oceans are vast, but unlike previous generations we know what now needs to happen. The time to protect the blue heart of our planet is now, today and urgent".

#### Ozone depletion causes extinction – Previous extinctions and scientific modelling proves

Broadley et. Al 18 - Michael W. Broadley, Peter H. Barry , Chris J. Ballentine , Lawrence A. Taylor and Ray Burgess, School of Earth and Environmental Sciences, The University of Manchester, Manchester, UK. 2 Department of Earth Sciences, University of Oxford, Oxford, UK. 3 Department of Earth and Planetary Science, The University of Tennessee, Knoxville, TN, USA. 4Present address: Centre de Recherches Pétrographiques et Géochimiques, Vandoeuvre-Lès-Nancy, France, " End-Permian extinction amplified by plumeinduced release of recycled lithospheric volatiles", *Nature Geoscience Journal*, 8/27/2018, https://www.nature.com/articles/s41561-018-0215-4

Ozone depletion during the end-Permian crisis is considered to have led to the decline in the dominant terrestrial plant species at the time, followed by the rapid expansion of opportunistic lycopsids36. The global distribution of preserved microspores from these emerging lycopsids exhibits features indicative of a failure in the normal development process of the spores. The global dispersion of these mutagenic spores suggests that this was a reaction to global stress factors that are unlikely to be related to changes in global temperature from the release of gases such as SO2 and CO2 during SFB emplacement4 . Experiments on the effects of end-Permian UVB regimes on modern conifers led to fivefold increases in both the occurrence of mutagenic malformations and complete sterilization37. This would have caused widespread deforestation and the collapse of the terrestrial biosphere, indicating that ozone depletion was a major contributing factor in the end-Permian mass extinction event4,37. The peak occurrence of mutagenic spores occurs before the rapid negative shift in δ13C in end-Permian carbonates that is attributed to the extinction of calcified marine life36. The δ13C excursions coincide with a change from predominantly extrusive to intrusive eruptions of the Siberian LIP1 . The emplacement of sills into volatile-rich sediments was considered to have released vast quantities of volatiles including CO2 and halocarbons gases to the atmosphere, leading to rapid climate change and ozone depletion1,5 . However, from the palynological evidence36 it is clear that a reduction in terrestrial biodiversity was occurring before the onset of marine extinction. Furthermore, evidence for reduced sedimentation rates prior to the Permo-Triassic boundary indicates that there was global eustatic sea-level regression, potentially caused by falling global temperatures and the onset of glaciation38. The rapid decrease in temperatures has been linked to the emission of SO2 to the atmosphere during the eruptive phase of the SFB7 . The concurrent timing of the eruptive phase of the SFB and the palynological evidence for ozone depletion is not consistent with the idea that degassing of sedimentary brines during later intrusive phases of igneous activity were the primary source of halogens causing ozone destruction. As we have shown in this study, the majority of halogens in the SFB were added during plume–lithosphere interaction, followed by their subsequent release to the atmosphere during explosive eruptions. Sulphur enrichments, co-existing with halogens in SFB28, may also have been derived from the SCLM (Fig. 4c). Evidence for a decline in terrestrial species before the PermoTriassic boundary therefore suggests that the release of halogens and gaseous sulphur species, and the subsequent decrease in ozone and global temperatures, respectively, were the predominant factors in initiating the end-Permian mass extinction. The change in eruptive phase from explosive to intrusive may have played a role in extending the extinction from a mainly terrestrial phenomenon to a global event.

### Space Col DA

#### Space Colonization is key to human survival

Kovic 18 (Marko Kovic is the co-founder and president of the Zurich Institute of Public Affairs Research, “Why space colonization is so important”, Nov 10, 2018, https://medium.com/@marko\_kovic/space-colonization-why-nothing-else-matters-a877723f77d4)//NotJacob

Should humankind exist in the future? Should the future existence of humankind be as good as possible in as many ways as possible? If your answer to these two questions is Yes, then there is a topic that you should care about a lot: Space colonization. Why, you might wonder, does space colonization matter, possibly more than anything else, as the title of this article claims? Because the future of humankind directly and completely dependent on whether and how we manage to colonize space. Space colonization is a double-edged sword. On one hand, the creation of permanent and self-sustainable human habitats beyond Earth is unavoidable if humankind is to exist in the long-term future. On the other hand, however, space colonization could bring about a catastrophically bad future if we colonize space in a bad way. That future that might be worse than one in which humankind does not exist. Space or bust: Why we must reach for the stars Why should we pursue space colonization in the first place? Don’t we have more pressing problems today, on Earth? Yes, we do have many problems on Earth today, and we should try to solve them. But space colonization is just that: A strategy for dealing with certain problems. An the problems that space colonization would be dealing with are, arguably, among the greatest problems of them all: Existential risks; risks that might lead to the extinction of humankind [1]. Currently, all of our proverbial existential eggs are in the same basket. If a natural existential risk strikes (for example, a large asteroid colliding with Earth) or if a man-made existential risk results in a catastrophic outcome (for example, runaway global warming [2, 3]), all of humankind is at risk because humankind is currently limited to planet Earth. If, however, there are self-sustainable human habitats beyond Earth, then the probability of an irreversibly catastrophic outcome for all of humankind is drastically reduced. Investing in space colonization today could therefore have immense future benefits. Using resources today in order to make space colonization possible in the medium-term future is not a waste, but a very profitable investment. If humankind stays limited to Earth and if we go extinct as a consequence of doing so, then we will all the billions of life years and billions of humans who might have come to exist — and who would have experienced happiness and contributed to humankind’s continued epistemic and moral progress. Taking space colonization more seriously today does not, of course, mean that we should only pursue space colonization and ignore everything else that is bad in the world. We should continue dealing with current global problems and, at the same time, invest greater resources into space colonization. At this point in our history and our technological development, even modest amounts of resources directed at space colonization would go a long way, such as public funding of basic research. Additionally, it is very likely that technological advances in the domain of space colonization would improve our lives in other ways as well thanks to technology transfer [4] — investing in space colonization today would probably be a win-win situation. So the situation seems clear: We must pursue space colonization and try to spread beyond Earth as fast as possible. Unfortunately, there is a catch: Yes, we must colonize space if humankind is to survive, but space colonization itself is very risky. So much so that bad outcomes of space colonization might be even worse for humankind than “merely” going extinct.

#### Failing to prioritize space colonization results in a loss 10^29 potential human lives per second

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As I write these words, suns are illuminating and heating empty rooms, unused energy is being flushed down black holes, and our great common endowment of negentropy is being irreversibly degraded into entropy on a cosmic scale. These are resources that an advanced civilization could have used to create value-structures, such as sentient beings living worthwhile lives. The rate of this loss boggles the mind. One recent paper speculates, using loose theoretical considerations based on the rate of increase of entropy, that the loss of potential human lives in our own galactic supercluster is at least ~10^46 per century of delayed colonization.[1] This estimate assumes that all the lost entropy could have been used for productive purposes, although no currently known technological mechanisms are even remotely capable of doing that. Since the estimate is meant to be a lower bound, this radically unconservative assumption is undesirable. We can, however, get a lower bound more straightforwardly by simply counting the number or stars in our galactic supercluster and multiplying this number with the amount of computing power that the resources of each star could be used to generate using technologies for whose feasibility a strong case has already been made. We can then divide this total with the estimated amount of computing power needed to simulate one human life. As a rough approximation, let us say the Virgo Supercluster contains 10^13 stars. One estimate of the computing power extractable from a star and with an associated planet-sized computational structure, using advanced molecular nanotechnology[2], is 10^42 operations per second.[3] A typical estimate of the human brain’s processing power is roughly 10^17 operations per second or less.[4] Not much more seems to be needed to simulate the relevant parts of the environment in sufficient detail to enable the simulated minds to have experiences indistinguishable from typical current human experiences.[5] Given these estimates, it follows that the potential for approximately 10^38 human lives is lost every century that colonization of our local supercluster is delayed; or equivalently, about 10^29 potential human lives per second. While this estimate is conservative in that it assumes only computational mechanisms whose implementation has been at least outlined in the literature, it is useful to have an even more conservative estimate that does not assume a non-biological instantiation of the potential persons. Suppose that about 10^10 biological humans could be sustained around an average star. Then the Virgo Supercluster could contain 10^23 biological humans. This corresponds to a loss of potential equal to about 10^14 potential human lives per second of delayed colonization. What matters for present purposes is not the exact numbers but the fact that they are huge. Even with the most conservative estimate, assuming a biological implementation of all persons, the potential for one hundred trillion potential human beings is lost for every second of postponement of colonization of our supercluster.[6] II. THE OPPORTUNITY COST OF DELAYED COLONIZATION From a utilitarian perspective, this huge loss of potential human lives constitutes a correspondingly huge loss of potential value. I am assuming here that the human lives that could have been created would have been worthwhile ones. Since it is commonly supposed that even current human lives are typically worthwhile, this is a weak assumption. Any civilization advanced enough to colonize the local supercluster would likely also have the ability to establish at least the minimally favorable conditions required for future lives to be worth living. The effect on total value, then, seems greater for actions that accelerate technological development than for practically any other possible action. Advancing technology (or its enabling factors, such as economic productivity) even by such a tiny amount that it leads to colonization of the local supercluster just one second earlier than would otherwise have happened amounts to bringing about more than 10^29 human lives (or 10^14 human lives if we use the most conservative lower bound) that would not otherwise have existed. Few other philanthropic causes could hope to match that level of utilitarian payoff.