# 1NC

## 1

#### Interpretation: Appropriation means controlling property rights in the context of space law.

* The definition is from Black’s Law Dictionary

Su 17 [Jinyuan Su, Professor and Assistant Dean at Xi'an Jiaotong University School of Law, China, “Legality of unilateral exploitation of space resources under international law,” 2017, *International & Comparative Law Quarterly*, Vol. 66, Issue 4, pp. 991-1008, https://doi.org/10.1017/S0020589317000367, EA]

The Outer Space Treaty does not prohibit expressis verbis the extraction of space resources. However, there exists a possibility that the recognition of property rights by a State, which is a party to the Outer Space Treaty, over resources extracted in outer space may conflict with its international obligations under Article II of the treaty, which proscribes the national appropriation of outer space 'by claim of sovereignty, by means of use or occupation, or by any other means'.26 The term 'appropriation' means '[t]he exercise of control over property; a taking of possession'.27

#### Violation: Satellite positioning is not appropriation proper – violating the principle alone is not sufficient.

Matignon 19 [Louis de Gouyon Matignon, PhD in space law from Georgetown University, “ORBITAL SLOTS AND SPACE CONGESTION,” 06/03/19, *Space Legal Issues*, https://www.spacelegalissues.com/orbital-slots-and-space-congestion/, EA]

Near-Earth space is formed of different orbital layers. Terrestrial orbits are limited common resources and inherently repugnant to any appropriation: they are not property in the sense of law. Orbits and frequencies are res communis (a Latin term derived from Roman law that preceded today’s concepts of the commons and common heritage of mankind; it has relevance in international law and common law). It’s the first-come, first-served principle that applies to orbital positioning, which without any formal acquisition of sovereignty, records a promptness behaviour to which it grants an exclusive grabbing effect of the space concerned. Geostationary orbit is a limited but permanent resource: this de facto appropriation by the first-comers – the developed countries – of the orbit and the frequencies is protected by Space Law and the International Telecommunications Law. The challenge by developing countries of grabbing these resources is therefore unjustified on the basis of existing law. Denying new entrants geostationary-access or making access more difficult does not constitute appropriation; it simply results from the traditional system of distribution of access rights. The practice of developed States is based on free access and priority given to the first satellites placed in geostationary orbit.

#### Vote neg –

#### 1 – Limits – they allow banning practices that don’t constitute taking property rights, but do preclude other actors from using the same space – opens the door to almost any practices like mining because those stop other actors from doing the same thing.

#### 2 – Ground – basing appropriation off use instead of ownership kills our DA links based off property rights – think mining good and other private sector good turns. Key on a topic with zero neg generics.

#### Fairness and education are voters – its how judges evaluate rounds and why schools fund debate

#### DTD – it’s key to norm set and deter future abuse

#### Competing interps – Reasonability invites arbitrary judge intervention and a race to the bottom of questionable argumentation – it also collapses since brightlines operate on an offense-defense paradigm

#### No RVIs – A – Encourages theory baiting – outweighs because if the shell is frivolous, they can beat it quickly B – its illogical for you to win for proving you were fair – outweighs since logic is a litmus test for other arguments

## 2

#### Counterplan Text - States ought to

#### - ban anti-satellite weapons

#### - mandate a transition to zero-emissions modes of transportation

#### - ban the use of environmentally harmful housecleaning products

#### - ban ozone-depleting pesticides

#### - ban nitrous oxide

#### That solves

GreenDiary n/d [Environmental News and Blog, “”How to prevent Ozone depletion (and what would happen if we don’t)” https://greendiary.com/5-ways-prevent-ozone-depletion.html]

One of the easiest ways to reduce damages caused to the ozone layer is by limiting the use of vehicles. This is because vehicular emissions eventually result in the release of smog. This in turn also damages the ozone layer causing it to deteriorate. If you are looking for ways on how to prevent ozone depletion, then you do have certain effective option. You can choose to take the public transport or use a bicycle. Another great way to restrict the use of car is by opting for Car Pooling. If you do want to use a vehicle, then it is recommended to switch to an electric or hybrid vehicle. Even better, you can opt for vehicles that run solely on solar power. Scroll to the end of the article for a list of the same. 2. Use eco-friendly household cleaning products Usage of eco-friendly and natural cleaning products for household chores is a great way to prevent ozone depletion. This is because many of these cleaning agents contain toxic chemicals that interfere with the ozone layer. A lot of supermarkets and health stores sell cleaning products that are toxic-free and made out of natural ingredients. 3. Avoid using pesticides and prevent ozone depletion Overuse-of-pesticides Pesticides may be an easy solution for getting rid of weed, but are harmful for the ozone layer. The best solution for this would be to try using natural remedies, rather than heading out for pesticides. You can perhaps try to weed manually or mow your garden consistently so as to avoid weed-growth. Or else, try Urban Aerofarming, which requires less water, less space and little to no amount of pesticides. To know more about Urban Aerofarms, scroll down. You can check out the different DIY ideas to make your own eco-friendly pesticides at home to prevent ozone depletion. 4. Developing stringent regulations for rocket launches The world is progressing at a drastic pace. As we progress on various scientific discoveries, the need of the hour also requires people to travel out of space. The number of rocket launches has increased drastically. This in turn is equally damaging the ozone layer in many ways. A study shows that the harm caused by rocket launches would outpace the harm caused due to CFCs. At present, the global rocket launches do not contribute hugely to ozone layer depletion. Due to the advancement of the space industry, it will become a major contributor to ozone depletion. All types of rocket engines result in combustion by products that are ozone-destroying compounds that are expelled directly in the middle and upper stratosphere layer – near the ozone layer. 5. Banning the use of dangerous nitrous oxide Ozone-Layer-DepletionIn the late 70’s the world was taken by surprise with a study that triggered a red alert pertaining to the destruction caused to the ozone layer. It had all the necessary information that helped us to understand what exactly was going on. Even the facts and figures mentioned in the study clearly pointed out towards the alarming rate of how the ozone layer was being depleted. Nations around the globe got together in 1989 and formed the Montreal Protocol. The main aim behind this was to stop the usage of CFCs. However, the protocol did not include nitrous oxide which is the most fatal chemical that can destroy the ozone layer and is still in use. Governments across the world should take a strong stand for banning the use of this harmful compound to save the ozone layer. 6. Avoiding Ozonolysis Purifiers Air-Purifier Are we risking our health and environment with the development of new technology? We believe that air purifiers are an effective way to fight air pollutants but they can actually have the harmful effects, which we are not aware of. New technology has allowed companies to make products which can “freshen” air by producing ozone which is not healthy to humans in large quantities. These ozone layers can actually react with existing particles in the air and make them more dangerous.

#### CP solves by implementing arms control measures – their 1AC article

Blatt 20 [Talia, joint concentration in Social Studies and Integrative Biology at Harvard, specialization in East Asian geopolitics and security issues] “Anti-Satellite Weapons and the Emerging Space Arms Race,” Harvard International Review, May 26, 2020, <https://hir.harvard.edu/anti-satellite-weapons-and-the-emerging-space-arms-race/> TG

The second viewpoint calls for an end to the arms race not by winning it but by calling it off entirely, through comprehensive space arms control. Such regulations are complicated and have a long history, but could be a more sustainable solution than an endless proliferation of weapons.

The first iteration of arms control in space came in the 1960s. The 1963 Partial Test Ban Treaty (PTBT) banned nuclear weapons tests in outer space, and the more comprehensive 1967 Outer Space Treaty (OST), considered the cornerstone of peaceful space development, prohibited any military activity on celestial bodies including stationing weapons of mass destruction (WMD) in space. Both treaties are still in effect today, but despite additional treaties in recent decades, there are still no international regulations banning weapons other than WMD in space.

The most recent attempt at an ASAT ban was proposed by Russia and China in 2014. A revision of a draft from 2008, the Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT) was rejected by the United States because it lacked verification and permitted the stockpiling of terrestrial-based ASAT systems. It only banned space-based ASATs, which would enable China and Russia to continue developing ground-launched systems known as direct-ascent ASATs.

The PPWT was an empty solution for an arms race, clearly designed to benefit Russia and China rather than prevent additional weapons development. But a comprehensive agreement that the US, Russia, and China all find satisfactory seems unlikely. The Proposed Prevention of an Arms Race in Space Treaty (PAROS) has been discussed since the 1980s without much progress.

Perhaps a more feasible solution is a limited test ban treaty: an agreement to stop testing debris-producing ASATs. It has precedent—the PTBT successfully prevented the testing of nuclear weapons in space—and could stave off the worst effects of debris accumulation by eliminating debris-producing tests. Additionally, in the long term, a test ban could reduce countries’ confidence in their ASATs; capabilities atrophy without regular testing, meaning countries would be less likely to base their military strategies on ASATs in the event of a conflict.

By banning specific systems, a test ban treaty is not too vague as to be unenforceable like the PPWT, but it could be limited enough to not affect broader space development. Russia and China might find the terms acceptable; after all, debris threatens their satellites too, and they have a reciprocal interest in reining in US weapons development.

It’s hard to conceive of a future for humanity that does not feature space in some capacity. Big businesses are already pursuing space commerce more aggressively, with visions of space colonies and large scale resource extraction. But the continued, unchecked proliferation of ASATs could close off space entirely—and help induce a nuclear war. Now, more than ever, it remains urgent and imperative that international negotiations reach an arms control treaty.

## 3

#### Starlink is key to Precision Ag – key to food sustainability and increasing food supply to account for exponential population growth.

Greensight 21 3-15-2021 "Can Starlink Save the World by Connecting Farms?" <https://www.greensightag.com/logbook/can-starlink-save-the-world-by-connecting-farms/> (Data Management Consulting Firm)//Elmer

GreenSight innovates in a number of different areas, but one of the areas we are most passionate about is in agriculture. We’ve deployed our drone intelligence systems all over the world at all sorts of different facilities. One of the most challenging has been deployments at farms, and one of the biggest challenges has been connectivity. Connected farms are a requirement to feed the world, and Starlink will make that happen. Most urban and suburban households in the United States have had easy and reasonably inexpensive access to high speed internet access for 20 years. It is easy to forget that the situation is not the same for rural areas of the country. Many areas have no access to high speed, “broadband”, internet access, with some having only dialup internet access in their homes. According to the 2015 FCC broadband report, only 53% of rural households have access to high speed internet, even using low standards for “high” speed. On average farms have even less access, and that doesn’t even include high speed connectivity out in their fields. Cellular service is spotty especially on large farms in primarily agricultural areas, and legacy satellite systems provide slow upload speeds at expensive prices. Utilizing modern internet connected technologies and cloud based systems that require constant, high speed access can be a challenge at best and potentially impossible. A 2016 research study by Goldman and Sachs projected that by 2050, the world’s food production efficiency needs to increase by 50% to support our growing population. This paper backs up this conclusion with a lot of research, but the fundamental conclusion is that farming land area is unlikely to increase nor will the number of farmers. Increased global food production increases must come from productivity boosts. Researchers feel that productivity improvements from chemistry and genomics are unlikely to yield significant increases as they have in the past. They predict that the most likely area for these improvements are with precision farming techniques, notably precision planting and precision application of chemicals and water. The term “Precision Agriculture” was coined in the late 1960s and 1970s in seminal research that projected that in the future farming would be driven by data with inputs and practices varied and optimized based on weather, measurements from the field, and accurate year over year yield measurements. Since then, many tools and technologies have been developed that have made true precision agriculture more and more practical. Precision RTK GPS can guide equipment with precision better than an inch. Drones and satellite mapping of fields using remote sensing can map out health and detect problems with the crops. In field IoT sensors will stream live data (such as our partners Soil Scout). Soil genomics and analysis can analyze macro and micro nutrient content of the soil and track the genetics of the soil microbiome (like our friends at Trace Genomics). Robotic and automated farming equipment (like our partners at Monarch Tractor and Husqvarna are building) can vary applications and planting according to precomputed variable rate application maps. Despite all these breakthroughs, precision farming techniques still have a low penetration. There are many reasons for this (more than could be discussed in this article!) but one of them is inadequate connectivity. Most of these modern technologies rely on access to the internet and in many cases it just isn’t possible. For decades subsidies and programs have been rolled out to improve rural connectivity but the reality is that connecting up far flung areas is expensive, often labor intensive, and consequently from a pure business standpoint does not make sense for the connectivity providers. Even as infrastructure expands to more remote areas, there will always remain large swaths of rural america where conventional connectivity infrastructure is highly impractical. Most of GreenSight’s data processing is done in the cloud. Several gigabytes of imagery data are uploaded from our aircraft after every flight to be processed and delivered to our customers. Our custom artificial intelligence analyses the data and informs farmers to problem areas. From many remote farm fields, uploading can be a slow process. We’ve invested heavily in the portability of our systems and our upcoming next generation aircraft will be capable of onboard processing, but despite this connectivity will still be needed to make data available for farmers and other automated agriculture systems. Advanced sensing systems like ours have to be able to integrate with connected robotic sprayers, harvesters and tractors, unlocking the productivity potential of precision agriculture. Humanity needs precision agriculture, and connected data-driven systems will be a big part of that revolution. Beyond the global necessity, the economics for farmers work too! A 2018 USDA studies indicate that connecting US farmland will unlock $50B in industry revenue. We are extremely excited about Starlink and its potential to bring cost effective internet connectivity to farms and rural areas. Starlink levels the playing field for rural areas, enabling high speed connectivity everywhere. No longer will farmers have to wait for high speed wired connectivity to come to their area or install a complex mesh network on their property. IoT data can be streamed from fields as easily as it now streams from urban homes. Starlink will be a catalyzing force for chance, advancing access to precision agriculture globally and contributing to solving global food challenges.

#### Food Insecurity goes nuclear – escalates multiple hotspots.

Cribb 19 Julian Cribb 8-23-2019 “Food or War” <https://www.cambridge.org/core/books/abs/food-or-war/hotspots-for-food-conflict-in-the-twentyfirst-century/1CD674412E09B8E6F325C9C0A0A6778A> (principal of Julian Cribb & Associates who provide specialist consultancy in the communication of science, agriculture, food, mining, energy and the environment. , His published work includes over 8000 articles, 3000 media releases and eight books. He has received 32 awards for journalism.)//Elmer

Future Food Wars The mounting threat to world peace posed by a food, climate and ecosystem increasingly compromised and unstable was emphasised by the US Director of National Intelligence, Dan Coats, in a briefing to the US Senate in early 2019. 'Global environmental and ecological degradation, as well as climate change, are likely to fuel competition for resources, economic distress, and social discontent through 2019 and beyond', he said. 'Climate hazards such as extreme weather, higher temperatures, droughts, floods, wildfires, storms, sea level rise, soil degradation, and acidifying oceans are intensifying, threatening infrastructure, health, and water and food security. Irreversible damage to ecosystems and habitats will undermine the economic benefits they provide, worsened by air, soil, water, and marine pollution.' Boldly, Coats delivered his warning at a time when the US President, Trump, was attempting to expunge all reference to climate from government documents. 23 Based upon these recent cases of food conflicts, and upon the lessons gleaned from the longer history of the interaction between food and war, several regions of the planet face a greatly heightened risk of conflict towards the mid twentyfirst century. Food wars often start out small, as mere quarrels over grazing rights, access to wells or as one faction trying to control food supplies and markets. However, if not resolved quickly these disputes can quickly escalate into violence, then into civil conflagrations which, if not quelled, can in turn explode into crises that reverberate around the planet in the form of soaring prices, floods of refugees and the involvement of major powers — which in turn carries the risk of transnational war. The danger is magnified by swollen populations, the effects of climate change, depletion of key resources such as water, topsoil and nutrients, the collapse of ecosystem services that support agriculture and fisheries, universal pollution, a widening gap between rich and poor, and the rise of vast megacities unable to feed themselves (Figure 5.3). Each of the world's food 'powderkeg regions' is described below, in ascending order of risk. United States In one sense, food wars have already broken out in the United States, the most overfed country on Earth. Here the issue is chiefly the growing depletion of the nation's mighty ground- water resources, especially in states using it for food production, and the contest over what remains between competing users — farmers, ranchers and Native Americans on the one hand and the oil, gas and mining industry on the other. Concern about the future of US water supplies was aggravated by a series of savage droughts in the early twentyfirst century in the west, south and midwest linked to global climate change and declining snow- pack in the Rocky Mountains, both of which affect not only agriculture but also the rate at which the nation's groundwater reserves recharge. 'Groundwater depletion has been a concern in the Southwest and High Plains for many years, but increased demands on our groundwater resources have overstressed aquifers in many areas of the Nation, not just in arid regions', notes the US Geological Survey.24 Nine US states depend on groundwater for between 50 per cent and 80 per cent of their total freshwater supplies, and five states account for nearly half of the nation's groundwater use. Major US water resources, such as the High Plains aquifers and the Pacific Northwest aquifers have sunk by 30—50 metres (100—150 feet) since exploitation began, imperilling the agricultural industries that rely on them. In the arid south- west, aquifer declines of 100—150 metres have been recorded (Figure 5.4). To take but one case, the famed Ogallala Aquifer in the High Plains region supports cropping industries worth more than US $20 billion a year and was in such a depleted state it would take more than 6000 years to replace by natural infiltration the water drawn from it by farmers in the past 150 years. As it dwindles, some farmers have tried to kick their dependence on ground- water other users, including the growing cities and towns of the region, proceeded to mine it as if there was no tomorrow.25 A study by Kansas State University concluded that so far, 30 per cent of the local groundwater had been extracted and another 39 per cent would be depleted by the mid century on existing trends in withdrawal and recharge.26 Over half the US population relies on groundwater for drinking; both rural and urban America are at risk. Cities such as New Orleans, Houston and Miami face not only rising sea levels — but also sinking land, due to the extraction of underlying ground- water. In Memphis, Tennessee, the aquifer that supplies the city's drinking water has dropped by 20 metres. Growing awareness of the risk of a nation, even one as large and technologically adept as the USA, having insufficient water to grow its food, generate its exports and supply its urban homes has fuelled tensions leading to the eruption of nationwide protests over 'fracking' for oil and gas — a process that can deplete or poison groundwater — and the building -of oil pipe- lines, which have a habit of rupturing and also polluting water resources. The boom in fracking and piping is part of a deliberate US policy to become more self-reliant in fossil fuels.27 Thus, in its anxiety to be independent of overseas energy suppliers, the USA in effect decided to barter away its future food security for current oil security — and the price of this has been a lot of angry farmers, Native Americans and concerned citizens. The depletion of US groundwater coincides with accelerating climate risk, which may raise US temperatures by as much as 4—5 oc by 2100, leading to major losses in soil moisture throughout the US grain belt, and the spread of deserts in the south and west. Food production will also be affected by fiercer storms, bigger floods, more heatwaves, an increase in drought frequency and greater impacts from crop and livestock diseases. In such a context, it is no time to be wasting stored water. The case of the USA is included in the list of world 'hot spots' for future food conflict, not because there is danger of a serious shooting war erupting over water in America in the foreseeable future, but to illustrate that even in technologically advanced countries unforeseen social tensions and crises are on the rise over basic resources like food, land and water and their depletion. This doesn't just happen in Africa or the Middle East. It's a global phenomenon. Furthermore, the USA is the world's largest food exporter and any retreat on its part will have a disproportionate effect on world food price and supply. There is still plenty of time to replan America's food systems and water usage — but, as in the case of fossil fuels and climate, rear-guard action mounted by corporate vested interests and their hired politicians may well paralyse the national will to do it. That is when the US food system could find itself at serious risk, losing access to water in a time of growing climatic disruption, caused by exactly the same forces as those depleting the groundwater: the fossil fuels sector and its political stooges. The probable effect of this will, in the first instance, be a decline in US meat and dairy production accompanied by rising prices and a fall in its feedgrain exports, with domino effects on livestock industries worldwide. The flip-side to this issue is that America's old rival, Russia, is likely to gain in both farmland and water availability as the planet warms through the twentyfirst century — and likewise Canada. Both these countries stand to prosper from a US withdrawal from world food markets, and together they may negate the effects of any US food export shortfalls. Central and South America South America is one of the world's most bountiful continents in terms of food production — but, after decades of improvement, malnutrition is once more on the rise, reaching a new peak of 42.5 million people affected in 2016. 28 'Latin America and the Caribbean used to be a worldwide example in the fight against hunger. We are now following the worrisome global trend', said regional FAO representative Julio Berdegué. 29 Paradoxically, obesity is increasing among Latin American adults, while malnutrition is rising among children. 'Although Latin America and the Caribbean produce enough food to meet the needs of their population, this does not ensure healthy and nutritious diets', the FAO explains. Worsening income inequality, poor access to food and persistent poverty are contributing to the rise in hunger and bad diets, it adds.30 'The impact of climate change in Latin America and the Caribbean will be considerable because of its economic dependence on agriculture, the low adaptive capacity of its population and the geographical location of some of its countries', an FAO report warned.31 Emerging food insecurity in Central and Latin America is being driven by a toxic mixture of failing water supplies, drying farmlands, poverty, maladministration, incompetence and corruption. These issues are exacerbated by climate change, which is making the water supply issue worse for farmers and city people alike in several countries and delivering more weather disasters to agriculture. Mexico has for centuries faced periodic food scarcity, with a tenth of its people today suffering under-nutrition. In 2008 this rose to 18 per cent, leading to outbreaks of political violence. 2 In 2013, 52 million Mexicans were suffering poverty and seven million more faced extreme hunger, despite the attempts of successive governments to remedy the situation. By 2100 northern Mexico is expected to warm by 4—5 oc and southern Mexico by 1.5—2.5 oc. Large parts of the country, including Mexico City, face critical water scarcity. Mexico's cropped area could fall by 40—70 per cent by the 2030s and disappear completely by the end of the century, making it one of the world's countries most at risk from catastrophic climate change and a major potential source of climate refugees.33 The vanishing lakes and glaciers of the high Andes confront montane nations — Bolivia, Peru and Chile especially — with the spectre of growing water scarcity and declining food security. The volume of many glaciers, which provide meltwater to the region's rivers, which in turn irrigate farmland, has halved since 1975.34 Bolivia's second largest water body, the 2000 square kilometres Lake Poopo, dried out completely.35 The loss of water is attributed partly to El Niho droughts, partly to global warming and partly to over-extraction by the mining industries of the region. Chile, with 24,000 glaciers (80 per cent of all those in Latin America) is feeling the effects of their retreat and shrinkage especially, both in large cities such as the capital Santiago, and in irrigation agriculture and energy supply. Chile is rated by the World Resources Institute among the countries most likely to experience extreme water stress by 2040.36 Climate change is producing growing water and food insecurity in the 'dry corridor' of Central America, in countries such as El Salvador, Guatemala and Honduras. Here a combination of drought, major floods and soil erosion is undermining efforts to raise food production and stabilise nutrition. Food production in Venezuela began falling in the 1990s, and by the late 2010s two thirds of the population were malnourished; there was a growing flood of refugees into Colombia and other neighbouring countries. The food crisis has been variously blamed on the Venezuelan government's 'Great Leap Forward' (modelled on that of China — which also caused widespread starvation), a halving in Venezuela's oil export earnings, economic sanctions by the USA, and corruption. However, local scientists such as Nobel Laureate Professor Juan Carlos Sanchez warn that climate impacts are already striking the densely populated coastal regions with increased torrential rains, flooding and mudslides, droughts and hurricanes, while inland areas are drying out and desertifying, leading to crop failures, water scarcity and a tide of climate refugees.37 These factors will tend to deepen food insecurity towards the mid century. Venezuela's climate refugees are already making life more difficult for neighbouring countries such as Colombia. Deforestation in the Brazilian Amazon has, in recent decades, removed around 20 per cent of its total tree cover, replacing it with dry savannah and farmland. At 40 per cent clearance and with continued global warming, scientists anticipate profound changes in the local climate, towards a drying trend, which will hammer the agriculture that has replaced the forest.38 Brazil has already wiped out the once- vast Mata Atlantica forest along its eastern coastline, and this region is now drying, with resultant water stress for both farming and major cities like Säo Paulo. Brazil's outlook for 2100 is for further drying — tied to forest loss as well as global climate change — increased frequency of drought and heatwaves, major fires and acute water scarcity in some regions. Moreover, as the Amazon basin dries out, if will release vast quantities of C02 from its peat swamps and rainforest soils. These are thought to contain in excess of three billion tonnes of carbon and could cause a significant acceleration in global warming, affecting everyone on Earth. 39 Latin America is the world capital of private armies, with as many as 50 major guerrilla groups, paramilitaries, terrorist, indigenous and criminal insurgencies over the past half century exemplified in familiar names like the Sandanistas (Nicaragua), FARC (Colombia) and Shining Path (Peru). 40 Many of these drew their initial inspiration from the international communist movement of the mid twentieth century, while others are right-wing groups set up in opposition to them or else represent land rights movements of disadvantaged groups. However, all these movements rely for oxygen on simmering public discontent with ineffectual or corrupt governments and lack of fair access to food, land and water generally. In other words, the tendency of South and Central America towards internal armed conflict is supercharged significantly by failings in the food system which generate public anger, leading to sympathy and support for anyone seen to be challenging the incumbent regimes. This is not to suggest that feeding every person well would end all insurgencies — but it would certainly take the wind of popular support out of a lot of their sails. In that sense the revolutionary tendency of South America echoes the preconditions for revolution in France and Russia in the eighteenth and twentieth centuries. Central Asia The risk of wars breaking out over water, energy and food insecurity in Central Asia is high.41 Here, the five main players — Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan and Kyrgyzstan — face swelling populations, crumbling Soviet-era infrastructure, flagging resource cooperation, a degrading land- scape, deteriorating food availability and a changing climate. At the heart of the issue and the region's increasingly volatile politics is water: 'Without water in the region's two great rivers — the Syr Darya and the Amu Darya — vital crops in the down- stream agricultural powerhouses would die. Without power, life in the upstream countries would be unbearable in the freezing winters' , wrote Rustam Qobil. Central Asia's water crisis first exploded onto the global consciousness with the drying of the Aral Sea — the world's fourth largest lake — from the mid 1960s43, following the damming and draining of major rivers such as the Amu Darya, Syr Darya and Naryn. It was hastened by a major drought in 200844 exacerbated by climate change, which is melting the 'water tower' of glacial ice stored in the Tien Shan, Pamir and Hindu Kush mountain ranges that feed the region's rivers. The Tien Shan alone holds 10,000 glaciers, all of them in retreat, losing an estimated 223 million cubic metres a year. At such a rate of loss the region's rivers will run dry within a generation.45 Lack of water has already delivered a body blow to Central Asia's efforts to modernise its agriculture, adding further tension to regional disputes over food, land and water. 'Water has always been a major cause of wars and border conflicts in the Central Asian region', policy analyst Fuad Shahbazov warned. This potential for conflict over water has been exacerbated by disputes over the Fergana valley, the region's greatest foodbowl, which underwent a 32 per cent surge in population in barely ten years — while more and more of it turned to desert.46 The Central Asian region is ranked by the World Resources Institute as one of the world's most perilously water-stressed regions to 2040 (Figure 5.6). With their economies hitting rock bottom, corrupt and autocratic governments that prefer to blame others for their problems and growing quarrels over food, land, energy and water, the 'Stans' face 'a perfect storm', Nate Shenkkan wrote in the journal Foreign Policy 47 Increased meddling by Russia and China is augmenting the explosive mix: China regards Central Asia as a key component of its 'Belt and Road' initiative intended to expand its global influence, whereas Russia hopes to lure the region back into its own economic sphere. Their rival investments may help limit some of the problems faced by Central Asia — or they may unlock a fresh cycle of political feuding, turmoil and regime change.48 A 2017 FAO report found 14.3 million people — one in every five — in Central Asia did not have enough to eat and a million faced actual starvation, children especially. It noted that after years of steady improvement, the situation was deteriorating. This combination of intractable and deteriorating factors makes Central Asia a serious internal war risk towards the mid twentyfirst century, with involvement by superpowers raising the danger of international conflict and mass refugee flight. The Middle East The Middle East is the most water-stressed region on Earth (see Figure 5.5 above). It is 'particularly vulnerable to climate change. It is one of the world's most water-scarce and dry regions, with a high dependency on climate-sensitive agriculture and a large share of its population and economic activity in flood-prone urban coastal zones', according to the World Bank. 49 The Middle East — consisting of the 22 countries of the Arab League, Turkey and Iran — has very low levels of natural rainfall to begin with. Most of it has 600 millimetres or less per year and is classed as arid. 'The Middle East and North Africa [MENA] is a global hotspot of unsustainable water use, especially of ground- water. In some countries, more than half of current water withdrawals exceed what is naturally available', the Bank said in a separate report on water scarcity. 50 'The climate is predicted to become even hotter and drier in most of the MENA region. Higher temperatures and reduced precipitation will increase the occurrence of droughts. It is further estimated that an additional 80—100 million people will be exposed by 2025 to water stress', the Bank added. The region's population of 300 million in the late 2010s is forecast to double to 600 million by 2050. Average temperatures are expected to rise by 3—5 oc and rainfall will decrease by around 20 per cent. The result will be vastly increased water stress, accelerated desertification, growing food insecurity and a rise in sea levels displacing tens of millions from densely popu- lated, low-lying areas like the Nile delta.51 The region is deemed highly vulnerable to climate impacts, warns a report by the UN Development Programme. 'Current climate change projections show that by the year 2025, the water supply in the Arab region will be only 15 per cent of levels in 1960. With population growth around 3 per cent annually and deforestation spiking to 4 per cent annually... the region now includes 14 of the world s 20 most water-stressed countries.'52 The Middle Fast/North Africa (MENA) region has 6 per cent of the world's population with only 1.5 per cent of the world's fresh water reserves to share among them. This means that the average citizen already has about a third less water than the minimum necessary for a reasonable existence — many have less than half, and populations are growing rapidly. Coupled with political chaos and ill governance in many countries, growing religious and ethnic tensions between different groups — often based on centuries-old disputes — a widening gap between rich and poor and foreign meddling by the USA, Russia and China, shortages of food, land and water make the Middle East an evident cauldron for conflict in the twentyfirst century. Growing awareness of their food risk has impelled some oil-rich Arab states into an international farm buying spree, purchasing farming, fishing and food processing companies in countries as assorted as South Sudan, Ethiopia, the Philippines, Ukraine, the USA, Poland, Argentina, Australia, Brazil and Morocco. In some food-stressed countries these acquisitions have already led to riots and killings.53 The risk is high that, by exporting its own food—land—water problems worldwide, especially to regions already facing scarcity, the Middle East could propagate conflicts and government collapses around the globe. This is despite the fact that high-tech solar desalination, green energy, hydroponics, aquaponics and other intensive urban food production technologies make it possible for the region to produce far more of its own food locally, if not to be entirely self-sufficient. Dimensions of the growing crisis in the Middle East include the following. Wars have already broken out in Syria and Yemen in which scarcity of food, land and water were prominent among the tensions that led to conflict between competing groups. Food, land and water issues feed into and exacerbate already volatile sentiment over religion, politics, corruption, mismanagement and foreign interference by the USA, China and Russia. The introduction of cheap solar-powered and diesel pumps has accelerated the unsustainable extraction of groundwater throughout the region, notably in countries like Libya, Egypt, Saudi Arabia and Morocco. 54 Turkish building of new dams to monopolise waters flowing across its borders is igniting scarcity and potential for conflict with downstream nations, including Iraq, Iran and Syria. 55 Egypt's lifeline, the Nile, is threatened by Ethiopian plans to dam the Blue Nile, with tensions that some observers consider could lead to a shooting war. 56 There are very low levels of water recycling throughout the region, while water use productivity is about half that of the world as a whole. There is a lack of a sense of citizen responsibility for water and food scarcity throughout the region. Land grabs around the world by oil-rich states are threatening to destabilise food, land and water in other countries and regions, causing conflict. A decline in oil prices and the displacement of oil by the global renewables revolution may leave the region with fewer economic options for solving its problems. There is a risk that acquisition of a nuclear weapon by Iran may set off a nuclear arms race in the region with countries such as Saudi Arabia, Syria and possibly Turkey following suit and Israel rearming to stay in the lead. This would translate potential food, land and water conflicts into the atomic realm. Together these issues, and failure to address their root causes, make the Middle East a fizzing powder keg in the twentyfirst century. The question is when and where, not whether, it explodes — and whether the resulting conflict will involve the use of weapons of mass destruction, including nuclear, thus affecting the entire world. China China is the world's biggest producer, importer and consumer of food. Much of the landmass of the People's Republic of China (PRC) is too mountainous or too arid for farming, but the rich soils of its eastern and southern regions are highly productive provided sufficient water is available and climate impacts are mild. Those, however, are very big 'ifs'. In 1995, American environmentalist Lester R. Brown both Eked and aroused the PRC Communist Party bosses with a small, hard-hitting book entitled Who Will Feed China? Wake-Up Call for a Small Planet.57 In it he posited that Chinese population growth was so far out of control that the then-agricultural system could not keep up, and China would be forced to import vast amounts of grain, to the detriment of food prices and availability worldwide. His fears, so far, have not been realised — not because they were unsoundly based, but because China managed — just — to stay abreast of rising food demand by stabilising and subsidising grain prices, restoring degraded lands, boosting agricultural science and technology, piping water from south to north, developing high-intensity urban farms, buying up foreign farmland worldwide and encouraging young Chinese to leave the country. What Brown didn't anticipate was the economic miracle that made China rich enough to afford all this. However, his essential thesis remains valid: China's food supply will remain on a knife-edge for the entire twentyfirst century, vulnerable especially to water scarcity and climate impacts. If the nation outruns its domestic resources yet still has to eat, it may well be at the expense of others globally. Some western commentators were puzzled when China scrapped its 35-year 'One Child Policy' in 2015, but in fact the policy had done its job, shaving around 300 million people off the projected peak of Chinese population. It was also causing serious imbalances, such as China's huge unmarried male sur- plus. Furthermore, rising urbanisation and household incomes meant Chinese parents no longer wanted large families, as in the past. Policy or no policy, China's birthrate has continued to fall and by 2018 was 1.6 babies per woman — well below replacement, lower than the USA and nearly as low as Germany. Its population was 1.4 billion, but this was growing at barely 0.4 per cent a year, with the growth due at least in part to lengthening life expectancy. 58 For China, female fertility is no longer the key issue. The critical issue is water. And the critical region is the north, where 41 per cent of the population reside. Here surface and ground- waters — which support not only the vast grain and vegetable farming industries of the North China Plain but also burgeoning megacities like Beijing, Tianjin and Shenyang — have been vanishing at an alarming rate. 'In the past 25 years, 28,000 rivers have disappeared. Groundwater has fallen by up to 1—3 metres a year. One consequence: parts of Beijing are subsiding by 11 cm a year. The flow of the Yellow River, water supply to millions, is a tenth of what it was in the 1940s; it often fails to reach the sea. Pollution further curtails supply: in 2017 8.8 per cent of water was unfit even for agricultural or industrial use', the Financial Times reported.59 On the North China Plain, annual consump- tion of water for all uses, including food production, is about 27 billion cubic metres a year — compared with an annual water availability of 22 billion cubic metres, a deficit that is made up by the short-term expedient of mining the region's groundwater. 60 To stave off disaster, the PRC has built a prodigious network of canals and pipelines from the Yangtse River in the water-rich south, to Beijing in the water-starved north. Hailed as a 'lifeline', the South—North Water Transfer Project had two drawbacks: first, the fossil energy required to pump millions of tonnes of water over a thousand kilometres and, second, the fact that while the volume was sufficient to satisfy the burgeoning cities for a time, it could not supply and distribute enough clean water to meet the needs of irrigated farming over so vast a region in the long run, nor meet those of its planned industrial growth.61 Oft-mouthed 'solutions' like desalination or the piping of water from Tibet or Russia face similar drawbacks: demand is too great for the potential supply and the costs, both financial and environmental, prohibitive. China is already among the world's most water-stressed nations. The typical Chinese citizen has a 'water footprint' of 1071 cubic metres a year — three quarters of the world average (1385 cubic metres), and scarcely a third that of the average American (2842 cubic metres).62 Of this water, 62 per cent is used to grow food to feed the Chinese population — and 90 per cent is so polluted it is unfit to drink or use in food processing. Despite massive investment in water infrastructure and new technology, many experts doubt that China can keep pace with the growth in its demand for food, at least within its own borders, chiefly because of water scarcity.63 Adding to the pressure is that China's national five-year plans for industrialisation demand massive amounts more water — demands that may confront China with a stark choice between food and economic growth. 'The Chinese government is moving too slowly towards the Camel Economy. It has plans, incentives for officials; it invests in recycling, irrigation, pollution, drought resistant crops; it leads the world in high voltage transmission (to get hydro, wind and solar energy from the west of China). None of this is sufficient or likely to be in time', the Financial Times opined. As the world's leading carbon emitter, China is more responsible for climate change than any other country. It is also, potentially, more at risk. The main reason, quite simply, is the impact of a warming world on China's water supply — in the form of disappearing rivers, lakes, groundwater and mountain glaciers along with rising sea levels. To this is coupled the threat to agriculture from increasing weather disasters and the loss of ecosystem services from a damaged landscape. 65 China is thus impaled on the horns of a classic dilemma. Without more water it cannot grow its economy sufficiently to pay for the water-conserving and food-producing technologies and infrastructure it needs to feed its people. Having inadvertently unleashed a population explosion with its highly successful conversion to modern farming systems, the challenge for China now is to somehow sustain its food supply through the population peak of the mid twentyfirst century, followed by a managed decline to maybe half of today's numbers by the early twentysecond century. It is far from clear whether the present approach — improving market efficiency, continuing to modernise agricultural production systems, pumping water, trying to control soil and water losses and importing more food from overseas will work. 66 China has pinned its main hopes on technology to boost farm yields and improve water distribution and management. Unfortunately, it has selected the unsustainable American industrial farming model to do this — which involves the massive use of water, toxic chemicals, fertilisers, fossil fuels and machines. This in turn is having dreadful consequences for China's soils, waters, landscapes, food supply, air, climate and consumer health. Serious questions are now being asked whether such an approach is not digging the hole China is in, even deeper. Furthermore, some western analysts are sceptical whether the heavy hand of state control is up to the task of generating the levels of innovation required to feed China sustainably.67 Plan B, which is to purchase food from other countries, or import it from Chinese-owned farming and food ventures around the world, faces similar difficulties. Many of the countries where China is investing in food production themselves face a slow-burning crisis of land degradation, water scarcity, surging populations and swelling local food demand. By exporting its own problems, China is adding to their difficulties. While there may be some truth to the claim that China is helping to modernise food systems in Africa, for example, it is equally clear that the export of food at a time of local shortages could have dire consequences for Africans, leading to wars in Africa and elsewhere. How countries will react to Chinese pressure to export food in the face of their own domestic shortages is, as yet, unclear. If they permit exports, it could prove cata- strophic for their own people and governments — but if they cut them off, it could be equally catastrophic for China. Such a situation cannot be regarded as anything other than a menace to world peace. Around 1640, a series of intense droughts caused widespread crop failures in China, leading to unrest and uprisings which, in 1644, brought down the Ming Dynasty. A serious domestic Chinese food and water crisis today — driven by drought, degradation of land and water and climate change in northern China coupled with failure in food imports — could cause a re-run of history: 'The forthcoming water crisis may impact China's social, economic, and political stability to a great extent', a US Intelligence Assessment found. The adverse impacts of climate change will add extra pressure to existing social and resource stresses.' 68 Such events have the potential to precipitate tens, even hundreds, of millions of emigrants and refugees into countries all over the world, with domino consequences for those countries that receive them. Strategic analysts have speculated that tens of millions of desperate Chinese flooding into eastern Russia, or even India, could lead to war, including the risk of international nuclear exchange. 69 Against such a scenario are the plain facts that China is a technologically advanced society, with the foresight, wealth and capacity to plan and implement nationwide changes and the will, if necessary, to enforce them. Its leaders are clearly alert to the food and water challenge — and its resolution may well depend on the extent of water recycling they are able to achieve. As to whether the PRC can afford the cost of transitioning from an unsustainable to a sustainable food system, all countries have a choice between unproductive military spending and feeding their populace. A choice between food or war. It remains to be seen which investment China favours. However, it is vital to understand that the problem of whether China can feed itself through the twentyfirst century is not purely a Chinese problem. It's a problem, both economic and physical, for the entire planet — and it is thus in everyone's best interest to help solve it. For this reason, China is rated number 3 on this list of potential food war hotspots. Africa Food wars — that is, wars in which food, land and water play a significant contributing role — have been a constant in the story of Africa since the mid twentieth century, indeed, far longer. In a sense, the continent is already a microcosm of the world of the twentyfirst century as climate change and resource scarcity com- bine with rapid population growth to ratchet up the tensions that lead competing groups to fight, whether the superficial distinc- Mons between them are ethnic, religious, social or political. We have examined the particular cases of Rwanda, South Sudan and the Horn of Africa — but there are numerous other African conflicts, insurgencies and ongoing disturbances in which food, land and water are primary or secondary triggers and where famine is often the outcome: Nigeria, Congo, Egypt, Tunisia, Libya, Mali, Chad, the Central African Republic, the Maghreb region of the Sahara, Mozambique, Cote d'Ivoire and Zimbabwe have all experienced conflicts in which issues of access to food, land and water were important drivers and consequences. The trajectory of Africa's population in the first two decades of the twentyfirst century implies that the number of its people could quadruple from 1.2 billion in 2017 to 4.5 billion by 2100 (Figure 5.6). If fulfilled, this would make Africans 41 per cent of the world population by the end of the century. The UN Popula- tion Division's nearer projections are for Africans to outnumber Chinese or Indians at 1.7 billion by 2030, and reach 2.5 billion in 2050, which represents a doubling in the continent's inhabitants in barely 30 years. 70 While African fertility rates (babies per woman) remain high by world standards — 4.5 compared with a global average of 2.4 — they have also fallen steeply, from a peak of 8.5 babies in the 1970s. Furthermore, the picture is uneven with birthrates in most Sub-Saharan countries remaining high (around five to six babies/woman), while those of eight, mainly southern, countries have dropped to replace- ment or below (i.e. under 2.1). As has been the case around the world, birth rates tend to drop rapidly with the spread of urban isation, education and economic growth — whereas countries which slide back into poverty tend to experience rising birth- rates. Food access is a vital ingredient in this dynamic: it has been widely observed that better-fed countries tend to have much lower rates of birth and population growth, possibly because people who are food secure lose fewer infants and children in early life and thus are more open to family planning. So, in a real sense, food sufficiency holds one of the keys to limiting the human population to a level sustainable both for Africa and the planet in general. Forecasting the future of Africa is not easy, given the complexity of the interwoven climatic, social, technological and political issues — and many do not attempt it. However, the relentless optimism of the UN and its food agency, the FAO, is probably not justified by the facts as they are known to science — and may have more to do with not wishing to give offence to African governments or discourage donors than with attempting to accurately analyse what may occur. Even the FAO acknowledges however that food insecurity is rising across Sub-Saharan Africa as well as other parts. In 2017, conflict and insecurity were the major drivers of acute food insecurity in 18 countries and territories where almost 74 million food-insecure people were in need of urgent assistance. Eleven of these countries were in Africa and accounted for 37 million acutely food insecure people; the largest numbers were in northern Nigeria, Demo- cratic Republic of Congo, Somalia and South Sudan the agency said in its Global Report on Food Crises 2018.71 The FAO also noted that almost one in four Africans was undernourished in 2016 — a total of nearly a quarter of a billion people. The rise in undernourishment and food insecurity was linked to the effects of climate change, natural disasters and conflict according to Bukar Tijani, the FAO's assistant director general for Africa. 72 Even the comparatively prosperous nation of South Africa sits on a conflict knife-edge, according to a scientific study: 'Results indicate that the country exceeds its environmental boundaries for biodiversity loss, marine harvesting, freshwater use, and climate change, and that social deprivation was most severe in the areas of safety, income, and employment, which are significant factors in conflict risk', Megan Cole and colleagues found. 73 In the Congo, home to the world's second largest tropical forest, 20 years of civil war had not only slain five million civilians but also decimated the forests and their ecological services on which the nation depended. Researchers found evidence that reducing conflict can also help to reduce environ- mental destruction: 'Peace-building can potentially be a win for nature as well, and.. conservation organizations and govern- ments should be ready to seize conservation opportunities'. 74 As the African population doubles toward the mid century, as its water, soils, forests and economic wealth per capita dwindle, as foreign corporations plunder its riches, as a turbulent climate hammers its herders and farmers — both industrial and traditional — the prospect of Africa resolving existing conflicts and avoiding new ones is receding. The mistake most of the world is making is to imagine this only affects the Africans. The consequences will impact everyone on the planet.

## Case

### Advantage 1

#### Private space activities are terminally unsustainable due to debris overshoot – accelerating degredation now prevents colonization.

Miraux 22 [Loïs Miraux, Space Engineering / General Engineering dual-degree graduate, specialised in Environmental Management, Politecnico di Milano, “Environmental limits to the space sector's growth,” 2022, *Science of The Total Environment*, Vol. 806, Part 4, https://www.sciencedirect.com/science/article/pii/S0048969721059404, EA]

However, the space sector is undergoing profound transformations, shifting from the “traditional space” driven by government investments to the “NewSpace”, primarily driven by commercial motivations: in 2019, commercial activities represented 79% of the global space economy. This shift has been enabled by technological and business model innovations including advances in manufacturing, miniaturization, and reusable launch systems, leading to a significant reduction in cost and the appearance of new products and services (European Investment Bank, 2019). As a result, the global space economy grew by 6.3% per year on average between 2009 and 2019, reaching a total value of 423.8bn$ in 2019, and is expected to reach 2.7tn$ by 2045 (Merrill Lynch, 2017). Upcoming projects include constellations consisting of thousands of satellites, reusable rockets, space tourism (suborbital flights, space flights, space hotels), but also more ambitious endeavors such as Moon bases, Mars colonization, rocket Earth-to-Earth transportation, asteroid mining, or space-based solar power (Fig. 1). [Figure 1 Omitted] Space activities are, therefore, on the verge of a great increase. But like all human activities, they have impacts on the environment. This paper reviews the most critical impacts of the space sector as well as their potential growth, analyzed together in a comprehensive approach for the first time. Pollution from objects in space (space debris and night sky pollution) is described and the use of a framework based on planetary boundaries is proposed as a way to express its limits. Then, atmospheric impacts and associated regulatory risks are detailed. Limits to the development of space activities emerging from these environmental impacts are outlined, and the relevance of their consideration by actors in the space sector is emphasized. Finally, the future of the environmental, economic, and social sustainability of the space sector in the context of global ecological transition is discussed. 2. Limits due to pollution on orbit 2.1. Space debris Since the beginning of the space age with the launch of the first satellite Sputnik in 1957, there have been 6000 launches placing about 12,000 satellites in orbit (ESA Space Environment Statistics, 2021). Today, among the 29,000 tracked objects in orbit, only 4600 (16%) of these objects are intact, operational satellites. The rest is made up of derelict spacecraft (payload or rocket parts) and fragmentation debris due to explosions, collisions, tiny flecks of paint, etc. Due to this variety, debris is usually classified by size in three categories (ESA, 2021): • large-sized debris (>10 cm), generally possible to trace, with a population of 34,000 objects. • medium-sized debris (between 1 cm and 10 cm), sometimes possible to trace, with a population of 900,000 objects. • small-sized debris (between 1 mm and 1 cm), not traceable, with a population of 128 million objects. Due to their high relative velocity (≈15 km/s), a collision between a spacecraft and debris is likely to be catastrophic. A collision with large debris leads to a complete disintegration of the spacecraft, generating, in turn, thousands of additional debris. Medium-sized debris can either lead to complete disintegration or heavy damage, while small-sized debris cause minor damage that can eventually lead to mission failure. The number of objects in orbit has been steadily increasing, almost doubling over the last decade (Fig. 2). There have been two major events contributing to this continuous increase. In 2007, a Chinese anti-satellite missile test on the satellite Fengyun-1C resulted in the largest debris cloud ever generated by a single event (+25% in debris population) (Weeden, 2007). In 2009, a collision between Iridium-33 and a defunct Russian satellite, Cosmos-2251 generated 2296 catalogued debris and hundreds of thousands of untraceable debris, which became a threat for other satellites within the Iridium constellation potentially orbiting close to the debris cloud (Le May et al., 2018). To avoid such catastrophic events, satellite operators perform collision avoidance maneuvers when passing near a traced debris. However, untraceable objects cannot be avoided by nature, meaning that they cause a permanent risk of potential mission failure (Muelhaupt et al., 2019). [Figure 2 Omitted] In 1978, Kessler and Cour-Palais (1978) theorized that the orbital debris population could reach a critical density above which cascading collisions between debris could self-sustain even without additional launches, eventually making the space environment unusable for hundreds to thousands of years. The concern on this “Kessler Syndrome” was later emphasized by many studies, including D. Kessler discussing “limits of population growth in LEO” (Kessler, 1991) (Low Earth Orbit). Currently, the number of objects is expected to continue to increase, even without additional launches (ESA's Annual Space Environment Report, 2021). Most of the traffic in space is concentrated in the LEO region, at an altitude ranging between 200 km and 2000 km, with about 3300 functioning satellites along with the International Space Station. It is also the most crowded region in terms of debris, hosting 55% of the total catalogued population (ESA's Annual Space Environment Report, 2021). The loss of the LEO region due to debris would impact all the space economy, but more importantly, it would disable essential services upon which society relies such as GPS-based navigation, communications, early warning systems, and meteorological and environmental monitoring services. Efforts have been made by the international community to mitigate space debris with guidelines developed by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). The compliance rate to these guidelines has been increasing in the last 5 years (ESA's Annual Space Environment Report, 2021). In addition, the field of on-orbit servicing is emerging, aiming at expanding spacecraft lifetimes by repairing, refueling, or upgrading them in-situ, thereby delaying debris creation. Remediation measures are also being considered with several missions of debris removal planned in the coming years, but they only target defunct satellites to prevent them from generating additional debris. Their remediating potential is, therefore, significantly limited and making these missions commercially viable will be challenging. On top of this, recent plans of launching constellations of small satellites are raising growing concerns. In 2020, Curzi et al. outlined about one hundred companies or agencies proposing satellite constellations (Curzi et al., 2020). In particular, some commercial companies (such as SpaceX, OneWeb, Amazon, or China Satellite Network Group) have announced plans to launch large constellations – mostly in LEO – representing over 20,000 satellites by 2030, and possibly over 60,000 in the following decade. This is a tremendous increase with respect to the initial population in orbit of about 2000 operational satellites (in 2018) and the 8100 payloads launched since the beginning of the space age (Muelhaupt et al., 2019) before 2019. Most of these large constellations aim at enabling ubiquitous access to high-speed internet services, even in regions lacking the necessary infrastructure. Starting in 2019, SpaceX has already launched 1735 satellites of its Starlink constellation, while OneWeb has launched 146 (as of August 2021). Several studies have investigated the effect of introducing these constellations on the space debris population. They found that collision rate increase is to be expected, showed that high reliability and strong compliance to space debris mitigation guidelines are absolutely necessary, and even argued that these guidelines and current models need to be updated to face this new threat (Le May et al., 2018; Muelhaupt et al., 2019; Bastida Virgili et al., 2016; Diserens et al., 2020; Pardini and Anselmo, 2020). 2.2. Night sky pollution In addition to endangering the sustainable use of the space environment, large constellations can, by reflecting sunlight back to Earth and emitting radio signals, negatively impact the visibility of the night sky and interfere with professional astronomical observations (IAU, 2019). After the launch of the first satellites of SpaceX's Starlink, many astronomers have reported satellite trails, sometimes visible to the naked eye, disturbing their work. The International Astronomical Union (IAU) subsequently presented a report to UNCOPUOS making recommendations to keep “dark and quiet skies for science and society” (UNCOPUOS, 2020). They emphasized that the aggregate effects of constellations have not been properly investigated while reminding that astronomical discoveries can continue only if the night sky remains clear and unpolluted. Along with communication satellites, there have been other concerning propositions (Riesbeck et al., 2020) such as artificial moons to light a Chinese city or orbital billboards to advertise the night sky. In 2018, the launch of an artistic “disco-ball” surprised the astronomical community and was even described by some as “space graffiti” (The Guardian, 2018). The momentary attention created by these sporadic events on this issue is likely to become persistent due to recent findings. Kocifaj et al. (2021) found that artificial space objects including satellites and space debris were responsible for a new skyglow effect increasing the night sky brightness (NSB) already as much as 10% over natural levels. This is above the threshold set by the IAU to define an astronomical site as light polluted. 2.3. New boundaries Breakups or collisions lead to an increased exposure to space debris for other satellites, thereby degrading the orbital resource (Maury et al., 2019). Space debris is, therefore, a major threat to the long-term sustainability of space activities. As the debris population will likely increase even without additional launches, this means that the carrying capacity of the LEO “ecosystem”, defined as the maximum number of orbiting satellites that can be sustained in the long run, may have been overshot (Fig. 3). The pristine night sky is a common heritage of humankind: the discussed changes may have, in addition to impacts on stargazing and scientific inquiry, unforeseen effects on wildlife, human health, and cultural and religious practices. Without further precaution, the unregulated action of private interests in space could lead to the tragedy of two commons — the near-Earth orbital environment and the night sky — which must be avoided. [Figure 3 Omitted] In 2009, Rockström et al. proposed a framework based on planetary boundaries to define preconditions for human development. These boundaries are thresholds associated with Earth system processes that, if crossed, will trigger non-linear, abrupt environmental change (Rockström et al., 2009). The formulation of new boundaries for the proliferation of objects in orbit and night sky brightness (Table 1) would make use of the widely adopted concept of planetary boundaries to encourage sustainable action and avoid or limit their transgression. [Table 1 Omitted] Although the proliferation of the number of objects in LEO is not an Earth system process, an orbital boundary mirroring planetary boundaries could be defined. A reasonable threshold associated with abrupt environmental change in terms of objects in orbit could be the object flux such that the rate of fragment production equals the rate of removal by atmospheric drag (Kessler and Cour-Palais, 1978; Kessler, 1991; Kessler and Anzmeador, 2001). Crossing this threshold would result in the debris population increasing even without additional launches, meaning that, as defined, the orbital boundary has already been transgressed. In addition, light pollution could fit well in the planetary boundaries framework. As the contribution of anthropogenic sources of light to the NSB is rapidly increasing due to space objects, the definition of a specific boundary could prove relevant to anticipate deleterious effects. The relevance of the following discussion goes beyond the space sector since many other anthropogenic activities contribute to night sky pollution. Existing literature on natural and artificial NSB makes the estimation of a pre-industrial and a present value already possible, as was done by Rockström et al. for the Earth system processes they selected. Although the natural NSB is varying widely, a level of 22.0 mag/arcsec2 in the Johnson-Cousins V band has often been reported (Kocifaj et al., 2021; Fryc et al., 2021), corresponding to a visual luminance of 200 μcd/m2 (Masana et al., 2021; Bará et al., 2020). Assuming that the light pollution at pre-industrial times was small, meaning that NSB was close to its natural value, this value could be considered to be the pre-industrial luminance of the night sky. To estimate the present value, global and land averages were approximated using the mapping of artificial NSB of Falchi et al. (2016). The scale was corrected because it is based on a reference value for the luminance of the night sky of 174 μcd/m2, while the previously cited studies revised this estimation to 200 μcd/m2. Present day, global average luminance of the night sky was found to be 256 μcd/m2. As very little light pollution is expected on sea, a land average was also computed, yielding a much higher value of 390 μcd/m2, almost twice the natural luminance. Then, although probably very challenging to evaluate, a boundary for the luminance of the night sky could be based on its proven deleterious effects on wildlife (Bennie et al., 2016; Irwin, 2018; Rich and Longcore, 2013) and human health (Cho et al., 2015; Davies and Smyth, 2018). The definition and calculation of this value are, however, well beyond the scope of this paper. 3. Impacts on the Earth's atmosphere: is the sky the limit? 3.1. The unique nature of rocket emissions The amount of material emitted by the ≈100 rockets launched every year is about 40,000 tons, only 0.01% of the fuel burned by the global aviation sector (Ross and Sheaffer, 2014). However, during their ascent from ground to orbit, they release gases and particles in all the layers of the atmosphere. This is a unique characteristic because rockets are the only anthropogenic source of pollution in the middle and upper atmosphere, that is, above 15 km where airlines emissions stop (Ross and Sheaffer, 2014). Emissions into the troposphere, the lower layer of the atmosphere, are not important besides transient, local pollution. However, emissions in the stratosphere, the layer above the troposphere, are more concerning for two main reasons. First, the stratosphere being dynamically isolated from the troposphere, emissions components of hundreds of launches accumulate for several years (Ross and Vedda, 2018). Then, the stratosphere is the home of the ozone layer, a region of high concentration of ozone at 15–35 km altitudes, absorbing most of the Sun's harmful ultraviolet radiation and thereby protecting living organisms on the ground (Fig. 4). [Figure 4 Omitted] In addition to these particularities, the magnitude of the effects of rocket emissions on the atmosphere varies significantly depending on the type of propellant combination used. Liquid Rocket Engines (LREs) use propellants in the liquid form, such as liquid oxygen combined with liquid hydrogen as a fuel (e.g. Ariane 5) or kerosene (e.g. SpaceX's Falcon 9). This allows thrust variability, but LREs are often coupled with Solid Rocket Motors (SRMs) (e.g. Ariane 5 boosters) because they grant higher energy density for lift-off. SRMs typically use a combination of solid aluminium fuel with ammonium perchlorate as an oxidizer. A third type of rocket is being used more recently: Hybrid Rocket Engines (HREs), using a liquid oxidizer and a solid fuel, often a hydrocarbon. They grant high safety, making them popular for space tourism applications (e.g. Virgin Galactic's SpaceShipTwo). Although there are still many uncertainties and serious knowledge gaps on the effect of launch emissions on the atmosphere (Ross and Vedda, 2018), estimates of orders of magnitude are available in the literature. 3.2. Stratospheric ozone depletion During the lifecycle of complete space missions, the launch event has been reported to contribute to almost 100% of the ozone depletion potential (Chanoine, 2017). Ozone is destructed mostly by highly reactive radicals (oxides of chlorine, nitrogen, bromine, and hydrogen), with a single molecule able to destroy up to 100,000 ozone molecules (Ross et al., 2009). Ozone depletion from SRMs particles has historically been the main concern with the first studies carried out by Cicerone (Cicerone, 1974). LREs exhausts contain less reactive chemicals and particles and are, therefore, responsible for ozone loss one order of magnitude smaller than SRMs (Ross et al., 2009). The ozone loss caused by the global launch fleet has been estimated to be greater than 0.01% and less than 0.1%, with regional effects reaching several percent and with complete destruction in the surroundings of exhaust plumes (Voigt et al., 2013). This is to be compared to the ozone loss caused by ozone-depleting substances (ODSs) banned by the Montreal Protocol of about 3% (Ross and Vedda, 2018) (of the total amount of ozone). As a consequence, the present-day contribution of rockets to ozone loss is small. It represents a few percent of the total anthropogenic contribution to ozone depletion, about the same relative impact that global aviation has on climate radiative forcing (Ross et al., 2009). However, the trends discussed in the introduction make an increase of launch emissions by a factor of 10 credible, which would make the contribution of rockets comparable to that of banned ODSs, as Ross and Vedda warn (Ross and Vedda, 2018). A 2009 study highlighted the limitations to the growth of the space sector due to ozone depletion. It showed that, considering launch rates required by proposed space systems at that time (i.e. to be implemented in the future), global ozone loss could become significant, even using only LREs (Ross et al., 2009). Moreover, a 2010 study found that a fleet of 1000 launches per year of hydrocarbon-based HREs typically used for space tourism would cause ozone loss up to 6% in polar regions (Ross et al., 2010). With the anticipated growth of the space sector, the contribution of rockets to ozone depletion will inevitably increase in the future. As the study warns, there will be a growing risk of regulation of rocket exhaust compounds in the name of ozone protection. Important data uncertainties combined with the fact that the Montreal Protocol lacks adapted metrics to tackle rocket emissions effectively make this risk even more important (Ross and Vedda, 2018). If left unregulated, by 2050 rocket emissions could deplete ozone more than ODSs ever did (Ross et al., 2009; ScienceDaily, 2009). 3.3. Contribution to climate change While the effect of rocket emissions on the ozone layer has been studied for several decades, the concern about their impact on climate is more recent. Available life cycle assessment studies of space missions are scarce and often do not account for emissions occurring during the launch event, or only partially, due to lack of data availability and modeling complexity (Maury et al., 2020a; Chanoine, 2017; Harris and Landis, 2019; Gallice and Maury, 2018). Yet, launch emissions are likely to be the most important contributor to the impact on climate change of the global space sector. Rocket exhausts contain greenhouse gases (e.g. CO2, H2O) but also particles (e.g. alumina, black carbon). The amount of greenhouse gases emitted by rockets is dwarfed by that of other industrial sectors, making their contribution to the problem insignificant. However, the effect of particles is much more concerning. Black carbon particles accumulate in the stratosphere and absorb a fraction of sunlight, resulting in a warming of the stratosphere. Because some rockets can emit about 10,000 times more black carbon than modern turbine engines (Ross and Sheaffer, 2014), the amount of black carbon emitted by rockets in the stratosphere in 2018 was comparable to that emitted by global aviation (Ross and Toohey, 2019). On the other hand, alumina features a more complex behavior by both reflecting incoming radiation into space and absorbing upwelling radiation from the Earth. This also results in a warming of the stratosphere (Ross and Sheaffer, 2014). At the same time, the reduction in solar flux caused by this accumulation of particles in the stratosphere leads to a cooling of the lower atmosphere (the troposphere) and the ground (Fig. 4). In 2014, Ross and Sheaffer estimated that rocket emissions globally contributed to warm the stratosphere by about 16 ± 8 mW/m2, with relative contributions of 70% for black carbon, 28% for alumina, 2% for H2O, and ≈0% for CO2 (Ross and Sheaffer, 2014). This means that hydrocarbon-based rockets emitting black carbon (e.g. kerosene-fueled LREs, or most HREs) and SRMs emitting alumina are responsible for most of rockets' climate impact. As a consequence, studies considering only CO2 emissions to assess the contribution of rockets to climate change underestimate it by several orders of magnitude. Although this value is only an approximation subjected to uncertainties and requiring further confirmation, the study makes an interesting comparison with the contribution of global aviation to radiative forcing, which in 2014 was bigger only by a factor of 4, in absolute values (Ross and Sheaffer, 2014). This means that the magnitude of cooling of the troposphere from rockets could be comparable to the magnitude of warming from aviation. However, this should not be interpreted too quickly as something “positive”. Stratospheric injection of particles has long been discussed by climate scientists as a method of solar geoengineering to counteract the warming of greenhouse gases. But this has always been very controversial and encountered strong opposition. Rocket emissions compounds act as geoengineering agents and, therefore, launchers are already beginning this process in an uncontrolled manner, while black carbon geoengineering — on a much larger scale — has been found to present potentially catastrophic side effects (Kravitz et al., 2012). In addition, since rocket emissions are not distributed homogeneously around the globe, they can cool the troposphere in certain regions but still warm it in other regions because of the complex response of the global climate (Ross et al., 2010). Consequently, Ross and Vedda warn that it is uncertain how policymakers would respond to significant growth in launch activities in a context of growing concerns on climate intervention. Once again, this risk is further increased by the lack of confidence in current radiative forcing estimations (Ross and Vedda, 2018). The projects mentioned in the introduction could fuel such an important growth. For instance, after a decade of launches at a rate of 1000 per year, the fleet of hydrocarbon-based HREs (typical for space tourism applications) would create the same radiative forcing as global aviation (Ross et al., 2010), and could rise polar surface temperatures as much as 1 °C. Interestingly, Ross and Sheaffer estimated that the carbon footprint of a passenger in a typical sub-orbital space tourism flight is comparable to that of a passenger travelling thousands of times in aircraft between Los Angeles and London (Ross and Sheaffer, 2014). This illustrates that, in addition to possible future policy implications, the potential climate impact of space tourism raises important issues related to climate justice in the age of “flygskam”. But space tourism is not the only emerging market with high launch rate potential. The Chinese solar power plant is planned to require more than 100 launches of Long March 9, a heavy rocket fueled by kerosene (SpaceNews, 2021). Current plans of SpaceX for Earth-to-Earth travel and Mars colonization will be based on its Starship that relies on a liquid oxygen/liquid methane combination expected to be less harmful than kerosene, but this may be largely offset by the significant associated increase in launch rate. 3.4. Impacts of reentry Due to natural orbital decay, objects in LEO ultimately fall back down to Earth and burn up when reentering the atmosphere. A common practice in the context of space debris mitigation is to voluntarily deorbit spacecraft by making them reenter Earth's atmosphere when they reach their end-of-life to reduce the population in orbit. However, particles originating from these burning spacecraft (e.g. aluminium) could have detrimental effects on the ozone layer or on climate. Particles of several metals resulting from thousands of large constellations' satellites reentering would exceed by far injection of natural origin such as meteorites, but the resulting effect is yet unknown (Schulz and Glassmeier, 2021). Although purely hypothetical at this stage, it is possible that at a critical rate of reentering objects, the resulting pollution on the atmosphere reaches a level raising regulatory attention from policymakers. This could limit the rate of object disposal in LEO, thereby limiting the rate at which new objects could be launched there because the orbital resource is limited by the risk of space debris (Fig. 5). [Figure 5 Omitted] 4. Environmental sustainability and beyond 4.1. Consideration of environmental limits It is generally assumed that the only limitations to the development of the space sector are either technological or economic. However, the previous discussion shows that there are also environmental limitations that can arise either from (Fig. 5): • Transgression of the boundary of the proliferation of objects in orbit and/or associated regulations •. Transgression of the boundary of light pollution at night and/or associated regulations • Regulations on climate radiative forcing and ozone depletion from launchers emissions • Regulations on climate radiative forcing and ozone depletion from spacecraft reentry emissions These limits are intertwined. A satellite disintegrated into debris is likely to have a higher contribution to NSB than its intact version because of increased reflecting surface area, implying that space debris proliferation could aggravate night sky pollution. In addition, a recent study found that ozone destruction leads to a degradation in plants' capabilities to store carbon because of damages from UV radiation (Young et al., 2021). Impacts of rockets on ozone, therefore, indirectly increase their contribution to climate change. In these cases, this also means that measures to mitigate environmental impacts can have co-benefits. On the contrary, as previously discussed, space debris and the atmospheric impacts of reentry have conflicting mitigation measures. 4.2. Sustainability assessments and ecodesign of space systems The consideration of environmental issues in the space sector is very recent, but there is a growing interest in assessing and mitigating the impacts of space activities. The European Space Agency is leading the development of Life Cycle Assessment (LCA) and ecodesign practices with its Clean Space initiative started in 2012. LCA in space applications presents various specific challenges, such as the difficulty of data collection and the need for specific data sets due to the use of specialty materials, advanced manufacturing processes, and small production volumes (Maury et al., 2020a; Pettersen and Viak, 2015). In addition, space activities can pollute in unique, sector-specific ways requiring extensions of the LCA scope. A framework for assessing impacts on space debris within LCA was recently developed (Maury et al., 2019) and applied on an existing mission (Maury et al., 2020b). Some authors have even considered extensions of the LCA scope for space exploration and space travel (Ko et al., 2017). While this is an interesting exercise, more pressing, new concerns on night sky pollution could make the inclusion of this parameter also relevant, especially for large constellations. A first attempt to assess the sustainability of the global space sector was carried out by A. Wilson in his PhD thesis (Wilson, 2019), using a streamlined Life Cycle Sustainability Assessment evaluating environmental, social, and economic impacts. The approach consists of an approximation of these impacts over one year, which are compared to 2010 worldwide impacts and planetary boundaries. In a future scenario assuming 750 launches per year delivering 5000 spacecraft into orbit, the contribution of the space sector to climate change was found to reach 1.77% of the associated planetary boundary, and 1.54% for ozone depletion. These results are already significant considering the small relative size of the space sector with respect to all human activities. Moreover, it is important to note that despite being a major source of concern, the effects of black carbon and alumina on climate change and ozone depletion were not characterized due to knowledge gaps. Instead, black carbon was not considered in rockets' exhaust compositions and alumina was reported as a flow indicator. In addition, the impacts of other emissions were calculated using characterization factors that were not altitude dependent, again due to knowledge gaps, meaning that emissions in the troposphere and in the stratosphere had the same effects. It is therefore urgent to bridge these gaps to enable sustainability assessments accounting for these most critical impacts. This is a necessary condition to be able to make recommendations to the industry on how to design cleaner launch systems. Ecodesign practices are particularly relevant for the space sector which is characterized by stringent safety and reliability requirements and very long lifecycles from design to exploitation phases. Decisions that can be critical for the environmental performance of a space system are made in the early development phase (Chanoine, 2015) and later changes are often impossible after the qualification of the design. Development cycles of launchers usually vary between 5 and 10 years, while the exploitation time is as long as possible to recover development costs. For instance, Ariane 5 made its maiden flight in 1996 and is still flying today. This means that launchers that are currently under development may still be operating in 2050. This causes several risks for the space sector. In the context of the European REACH regulations (Registration, Evaluation and Authorisation of Chemicals), obsolescence risks were identified for the space industry (ASD Eurospace, 2017), which would undermine the quality, reliability, or even the feasibility of a technology. Regulatory obsolescence can arise from a legal ban on chemical substances, while commercial obsolescence can occur when suppliers change a product used by the space industry because larger sectors stop using it. It was reported that 20% of the materials used in the space industry may be affected in the long term (ASD Eurospace, 2017). These risks related to REACH are insightful for those that can be caused by the environmental limits previously outlined: for instance, a regulation on stratospheric injection of black carbon could make a launch system obsolete way before its planned date of end of exploitation, resulting in significant losses for the operator. 4.3. Space activities in times of environmental breakdown Fast and continuous growth of space activities over the next decades, fueled by the various projects described in the introduction, could pose serious threats to both the space and Earth environments. However, in the same period, the global economy, energy systems, and social structures will undergo profound transformations due to the global environmental threats of climate change, biodiversity loss, freshwater scarcity, resource depletion and various forms of pollution. Responding effectively to these challenges will very likely constrain economic growth, given that the green growth paradigm — the decoupling of economic growth from environmental pressures — lacks empirical evidence, is highly unlikely to be achieved rapidly enough to meet climate targets and is unlikely to happen at all (Parrique et al., 2019; Wiedmann et al., 2020; EEA, 2021). This will also create tensions on some resources, as many studies have reported a dramatic increase in material requirements for a transition to a low-carbon society (Chatterjee and Huang, 2020; Giurco et al., 2019; Moreau et al., 2019; Sovacool et al., 2020; Vidal et al., 2013; Watari et al., 2019; IEA, 2021a), with some materials having high levels of criticality (JRC, 2013; Graedel et al., 2015). In this context, in addition to their potentially severe impacts on the environment, the significant economic, energetic, and material requirements of some proposed space projects like space colonization and Earth-to-Earth transportation could be prohibitive. They could also become increasingly socially unacceptable and ethically questionable. Furthermore, proposed space-based solutions to overcome these energetic and material issues on Earth (e.g. large-scale space-based solar power and asteroid mining) are not relevant in the timescale of the transition to meet climate targets. For instance, the pioneer Chinese space-based solar power plant is planned to reach 1GW by 2050, which over a year would produce only 0.1% of its 2018 electricity needs, expected to grow by 2050 (IEA, 2021b). This will be a meager contribution to China's carbon neutrality planned for 2060, not to mention the plan to phase out coal by 2040 as required for 1.5 °C compatible pathways (Climate Action Tracker, 2021). On the other hand, as the mineral requirements for clean energy technologies would increase by a factor of 6 by 2040 to reach global carbon neutrality by 2050 (IEA, 2021a), space mining is not credible as a potential solution in this context. As a result, the space industry, which relies on high social, industrial, and technological complexity, international supply chains, and critical materials (Pavel and Tzimas, 2016), may see its predicted growth, planned agenda, and established politico-economic support seriously challenged in the next decades. Given the long design and lifecycle timescales of space projects, the space sector's decision-makers should also consider these constraints when making plans for the future, in addition to the environmental limitations previously outlined. Considering the environmental limits to the space sector's growth discussed, the trends of fast growth, commercialization, and search for maximization of profit that are fueling the NewSpace must not undermine space activities that are unambiguously beneficial for mankind. In addition, beyond considerations on the applications of space technologies, the existence of environmental limits constraining the development of space activities has important implications for the future expansion of mankind in space. The visions of space as a new frontier that mankind will inevitably conquer and of a future in which humanity becomes a multi-planetary species are challenged by the physical reality of planetary and orbital boundaries: we may find that shooting for the stars comes at an unbearable cost for the Earth's environment. 5. Conclusion This paper reviews the environmental impacts of the space sector as well as their potential future evolution based on proposed plans, and highlights the existence of environmental limits to the development of space activities, for the first time to the author's knowledge. The space debris situation is identified as critical since, in some orbital regions, the object flux is already so high that the total number of objects in orbit is expected to increase even without additional launches. As the number of satellites in orbit will soar in the coming years with the launch of large constellations, the situation is likely to deteriorate significantly. In this context, the ability of proposed mitigation and remediation measures to reduce the degradation of the orbital environment to sustainable levels — a “green growth” of operational objects in orbit — still remains to be proven. Regarding night sky pollution, recent findings showing that the contribution of space objects is already important combined with plans of large constellations are likely to increase the already growing concerns of the astronomical community and the general public, and result in unknown impacts on natural and human life. The risk of multiple tragedies of the commons from the proliferation of objects in orbit and night sky pollution was emphasized. Then, the definition of an orbital boundary related to the proliferation of the number of objects in orbit mirroring planetary boundaries was proposed, while the inclusion of light pollution as a new planetary boundary was suggested, with a reported pre-industrial level of 200 μcd/m2 and an estimated present level of 256 μcd/m2 (390 μcd/m2 on land). The impacts of the space sector on stratospheric ozone depletion and climate change are likely to be dominated by emissions of launch events. While present-day contributions of space activities to ozone depletion and climate change are small compared to other industrial sectors, proposed plans could lead to much higher levels raising regulatory attention from policymakers. Most concerning rockets are SRMs and hydrocarbon-based HREs and LREs. However, the review showed that even cleaner propellants could create important impacts considering the coming increase in launch rates. In addition, this study highlighted the important knowledge gaps preventing current LCA studies to properly characterize the impacts of the launch event, as well as spacecraft reentry. Putting in perspective these environmental impacts with current trends in the development of space activities, this study outlined several environmental constraints constituting fundamental limits to the space sector's growth. The risks arising from the existence of these limitations for actors of the industry were discussed, and the relevance of the implementation of ecodesign practices was emphasized. Additionally, the relevance and sustainability of some proposed space projects in the context of global ecological transition were analyzed and questioned. Projects featuring large energy and material requirements such as colonization or Earth-to-Earth transportation are likely to meet difficulties and encounter growing opposition from the general public as the global environmental crisis unfolds.

#### Colonization causes extinction.

Deudney 20 [Daniel Deudney, Associate Professor of Political Science at Johns Hopkins University, “Dark Skies: Space Expansionism, Planetary Geopolitics, and the Ends of Humanity,” 2020, Oxford University Press, pp. 356-362, EA]

Catastrophic and Existential Risks from Solar Space Expansion

This dark scenario of solar space expansion produced by the application of geopolitical theory has profound implications for the argument that colonization of other bodies in the solar system is necessary to alleviate or escape the formidable catastrophic and existential risks facing Earth-bound humanity. Both riskologists and space expansionists strongly believe, with Hawking, that “once we establish independent colonies, our entire future will be safe.”25 If all humanity’s eggs are in one fraying and vulnerable basket, then it stands to reason that spreading viable colonies of humans to other celestial bodies will help ensure the survival of the human species. While the role of existing space capabilities in amplifying the (p.357) dangers of the great technogenic threat of nuclear war belies the astro-optimism of space advocates, what of their cherished larger vision of making humanity a multiworld species? While space advocates propose a variety of ways space expansion might alleviate or escape existing risks, they give almost no attention to whether expansion might generate new risks or help re-activate already regulated ones. The list of major threats facing humanity is dauntingly long, and the expansionist agenda for solar space has many parts, making assessment a complex undertaking. But there are six major ways in which the realization of the space expansionist agenda for solar orbital space is likely to generate or activate catastrophic and existential risks. Taken in combination these arguments provide a strong basis for putting ambitious space expansion on the list of megathreats potentially confronting humanity, and for making every effort to relinquish it. Large-scale space expansion must be viewed as something akin to a full-scale nuclear war and assiduously avoided. Unlike many of the other threats humanity faces, addressing those created by ambitious space expansion is now extremely simple: just say no.

The realization of the space expansionist program for solar orbital space enlarges the probability and scope of catastrophic and existential risks confronting humanity in six ways: malefic geopolitics, natural threat amplification, restraint reversal, hierarchy enablement, alien generation, and monster multiplication (see Table 10.3).

[Table 10.3 Omitted]

First, large-scale solar space expansion will produce a radically novel political and material landscape that is extremely inauspicious for security, freedom, and human survival, a perfect storm of unfavorable possibilities and tendencies. With a new word for a new phenomenon, borrowed from astrology for a conjunction of negatives, solar space patterns can be characterized as geopolitically malefic. Just as the space environment creates terrestrially inconceivable extremes of frigid and torrid temperatures on opposite sides of the same object, so too the prospective solar landscape combines geopolitical extremes in ways unknown to terrestrial experience. Most ominously, solar space geopolitics combines the extreme diversities and high effective distances experienced on Archipelago Earth with system-wide levels of intense violence interdependence found on Planetary Earth. Polities will be extremely different and spatiotemporally remote but will be capable of readily inflicting massive levels of destruction on one another. Add shifting distribution, wide accessibility, and low distinctiveness, and the contours of the violence-material landscape becomes even more prone to large-scale destruction. With system-wide common government and mutual restraints very difficult to create and sustain, solar space comes close to being maximally suboptimal for positive outcomes, a nightmarish worst of all possible worlds in geopolitical conjunction. Extensive mutual restraints will be vitally necessary, but they will be nearly impossible to realize. While humanity’s (p.358) eggs might be scattered among many baskets, egg-smashing with large rocks will be easy—and likely.

Facing this extensive list of major factors disposing the system toward large-scale violent conflict in solar space will require humanity’s transmutation into Tsiolkovskian angels to avoid catastrophic and existentially threatening warfare. Perhaps the only saving grace of this key conclusion of geopolitical analysis is that the demons loosened by opening the Pandora’s box of space colonization might start to wreak their damage early enough to throttle the colonial enterprise before it gets too fatally under way.

A second way in which colonizing solar space poses catastrophic and existential threats is through natural threat amplification. Because asteroids and comets collide with the Earth, and the total energy contained within the population of near-Earth objects vastly exceeds that contained in all nuclear arsenals, they pose the inevitable prospect of terrestrial calamities. The rate at which these objects strike the Earth is now solely a function of natural forces. Space expansionists advance human movement into space to avert this threat and promote their (p.359) solution to this problem as a principal space contribution to reducing catastrophic and existential threats. But because the technologies to divert away from the Earth are essentially identical to those needed to direct objects toward the Earth, the rate at which these objects strike the Earth could increase if they become instruments of interstate rivalry and become weaponized as planetoid bombs. This prospect leads Sagan to recommend delaying the full mapping of asteroid orbits and development of diversion techniques until after some form of effective world government has been established on Earth. But with the spread of colonies across the solar system, the writ of any government on Earth will be severely limited. The same anarchical political configurations that Sagan views as incompatible with security from intentional asteroid bombardment on Earth will almost certainly be reproduced on a vastly larger, and more severe, scale in the Solar Archipelago. If, as seems extremely likely, systemic anarchy returns with the diaspora of humans across the solar system, then militarized rivalries are very likely to ensue, producing asteroidal weaponization. If this happens, a natural threat will have been amplified, enlarging the potential for the occurrence of a catastrophic event.

The third way in which ambitious space expansion could increase the catastrophic and existential risks confronting humanity is through restraint reversal. Barring civilizational collapse, the cornucopia of technological innovation will continue to pour forth its prodigies. If the monstrosities and menaces of the ever-widening technological cone of possibility can be thwarted only by staying within a narrow path of human preservation and enhancement, then space expansion must be assessed for its effects on the reversals, regulations, and relinquishments constituting the barriers of restraint. The record with nuclear weapons demonstrates that institutional architectures of restraint are not easy to erect and sustain on Earth. If space expansion makes the creation and preservation of restraints even more difficult, the probability of otherwise unrelated catastrophic and existential outcomes will rise, making it a potent catalyst for multisided disaster. Instead of mitigating the effects of multiple catastrophic and existential risks, large-scale space expansion promises to multiply them.

There are many reasons to anticipate that restraints established on Earth will be reversed if space colonization occurs. Restraints are unlikely to survive transplantation into diverse and demanding off-world environments. If humans are living on multiple worlds subject to different governments, regulation and relinquishment will be more difficult to establish, there will be more places for potential breakdowns, and verification of compliance will be vastly more difficult. If, as seems extremely likely, the many different worlds in the Solar Archipelago in systemic anarchy have violently hostile relations, establishing and sustaining restraints will become nearly impossible. Surveillance in the vast reaches of solar space will be vastly difficult. And if the human species radiates into multiple (p.360) species, the barriers to regulation and relinquishment will become even more formidable.

A particularly dangerous case of restraint reversal may be technologies leading to artificial superintelligence, a particularly potent technogenic threat. Space activities are already heavily dependent on advanced computing and robotic technologies, and peoples living in space are likely to be far more cyber-dependent than those on Earth. Living in harshly inhospitable environments, spacekind will have strong incentives to push the development of cybernetic capabilities. If a robust regime for the restraint and relinquishment of ASI is not established, human extinction might occur before significant space colonization occurs. If an effective ASI-restraint regime is developed on Earth before extensive space colonization takes place, it seems unlikely that such restraints would survive the expansion of humanity across the solar system.

It might be objected that the breakout of an ASI in some remote world in solar space would not pose a general existential threat to humanity once all of humanity’s eggs are no longer in one basket. If, however, we take seriously the standard scenarios of what an ASI would do once it emerges, the dispersion of humanity across multiple worlds would afford no protection whatsoever because an uncontrolled ASI, it is widely anticipated, will in short order expand not just on the planet of its origins but across the solar system, indeed the galaxy.26 To the extent uncontrolled ASI is deemed something to avoid at all costs, large-scale space expansion must be viewed similarly.

Terrestrial arrangements to restrain nuclear, genetic, and nanotechnologies are also likely to be reversed as humanity expands to other worlds. The prospects of interworld and interspecies wars will provide large incentives for maintaining weaponized nuclear capabilities and for pursuing research into military genetic and nanotechnology applications. Any restraint regime for genetic technologies is unlikely to survive extensive human expansion into space, given the attractiveness of directed and accelerated species alteration in off-worlds. Solar space contains a vast number of islands for potential Doctors Moreau to work their alchemy, as memorably envisioned in Robinson’s 2312. If self-replicating nanomachines are possible and built on Earth, human existence will be threatened. But if a relinquishment regime is established on Earth, it is unlikely to survive in a solar diaspora. While interplanetary distances will afford a buffer from runaway replicators on other celestial bodies, this is unlikely to be permanently effective, thus delaying rather than foreclosing the gray-gooization of the Earth.

Fourth, solar expansion poses catastrophic and existential risks to humanity through hierarchy enablement. The emergence of totalitarian world government, nearly universally viewed as deeply undesirable, is reasonably judged a catastrophic threat to humanity. As we have seen, space expansion is likely to (p.361) produce hierarchies in several significant ways. Many space advocates view large-scale space expansion as freedom insurance and anticipate that various forms of freedom and plurality deemed in jeopardy on Earth can be recovered and preserved in space. But anticipations of a freedom dividend from space expansion are largely illusory because large-scale space expansion into Earth orbital space is very likely to enable the erection of a highly hierarchical world government, either from one-state military dominance of the entire planet or from the control of a major infrastructure for resources or energy. The further large-scale expansion of human activity into solar space is likely to facilitate the emergence of a highly hierarchical world government on Island Earth that could then be prone to become totalitarian.

The fifth way in which ambitious space expansion poses catastrophic and existential risks is through alien generation. The human species radiation anticipated by expansionists will generate significantly different forms of intelligent life suited to other worlds. If these anticipations are realized, there will be multiple intelligent species, all descendants from terrestrial Homo sapiens, in this solar system and eventually across the galaxy. While space expansionists celebrate this as an expansion of life, they rarely dwell on its implications for the future of human life. If ascentionist assumptions about moral improvement resulting from vertical expansion are true, humanity and its descendant species will live in harmony. But if ascentionist assumptions are unfounded, then the generation of alien intelligent species in this solar system should be viewed as a catastrophic and existential threat to humanity. As the cyber visionary Hans Moravec observes, “biological species almost never survive encounters with superior competitors.”27 While habitat space expansionists embrace the Darwinian proposition that life inevitably expands, they do not seem to have thought through the implications of the corollary proposition that life forms often lethally compete.

The mechanisms for the annihilation of humans by advanced forms of extraterrestrial life, long a staple of dystopian SF, are easy enough to imagine. While it might be possible for humanity, mobilized and directed by a centralized world government devoted to planetary and species defense, to survive for a while, eventually the sheer number and variety of alien species with advanced technology is sure to prevail. Fictional accounts of alien threats to humanity are typically about life forms originating on other planets, and their eventual defeat commonly results from improbable expedients and heroics. The more realistic threat is probably from humanity’s descendants, and this threat can simply be prevented from arising by relinquishing space colonization.

The sixth way in which ambitious space expansion is related to catastrophic and existential risk is through monster multiplication. The number of “monsters,” threats that are unknown, has, we are told by riskologists, been steadily growing (p.362) with the development of powerful new technologies. Some monsters are in principle knowable, but others may be unknowable to humans. Ambitious space expansion will clearly entail the development of powerful new technologies, and the actors developing these technologies will be spread in multiple worlds across the solar system. Therefore it stands to reason that the number of monsters posing potential terminal threats will inevitably increase as ambitious space expansionist projects are realized.

Taken together, these six ways in which the realization of the space expansionist program for solar space pose catastrophic and existential threats demolish the core proposition of space advocates that large-scale expansion is desirable. Space expansionists start with the persuasive proposition that technological capabilities for destruction are rapidly enlarging, while the Earth remains spatially finite. They then reason that expanding the spatial range of human activities through expansion into outer space will dilute dangers and bring the ratios between the powers of destruction and the spatial domain of human activity into safer proportions. But they fail to recognize or acknowledge that the potency of the destructive potentials inherent in space expansion also increases, and these capabilities can potentially be brought to bear on the finite and fragile Earth and its human populations, thus making the survival problem, at least for the Earth and humanity, much greater. If humans, or their alien progeny, occupying this vaster spatial realm behave in the same manner as they have on Earth, all that will have changed is that the magnitude of the threats will have been enlarged. For large-scale space expansion, there is no plausible human path of preservation bypassing its many very likely menaces and monstrosities. For humanity in space, there is only darkness at the end of the tunnel.

#### Independently, creates massive suffering risks that outweigh extinction.

Kovic 21 [Marko Kovic, co-founder of the Zurich Institute of Public Affairs Research, “Risks of space colonization,” 2021, *Futures*, Vol. 126, https://doi.org/10.1016/j.futures.2020.102638, EA]

4.1. Unhappy future generations

The moral impetus of colonizing space is to increase the probability that all the potential future humans that could live do come into existence. But we do not only want future generations to exist but to live lives that are actually worth living. However, the moral landscape of the far future might turn out to be much blurrier.

Imagine, for example, a scenario in which 10 billion people live on Earth, and another 2 billion people live on a terraformed Venus. The people on Earth are living roughly as good lives as we are today, but the Venusians are all categorically suffering: Because the terraforming was not entirely successful, some of the original toxic Venusian atmosphere remained, leading to mild respiratory issues in most of the population. Is this state of affairs preferable to there not being any Venusians at all? On the face of it, yes. After all, the total wellbeing of humankind is much greater with the 2 billion Venusians than without them. Mild respiratory issues in 2 billion people are a nontrivial amount of disvalue, but their existence still seems preferable to their non-existence.

Let us imagine a second scenario. There are 10 billion people on Earth living lives that are roughly as good as the lives we are currently living, there are 2 billion people on Venus with chronic respiratory issues, and there are 500 million people on Mars. Unfortunately, given Mars’ inexistent atmosphere and magnetosphere, cosmic radiation is battering the surface, including human habitats. This has led to permanent damage in the Martians’ DNA, resulting in chronic muscular and skeletal disease. As a result, the whole Martian population is collectively suffering from a hereditary and incurable congenital disease. Is this scenario preferable to there being no Mars colony or to there being no colonization at all? On the face of it, the answer is again yes: Even though the lives of the Martians are much less pleasant than the lives of the Earthlings and the Venusians, the Martians are still living lives that are worth living to them. The total amount of wellbeing and happiness of humankind is greater than if there were no Martians at all.

In these hypothetical scenarios, we are confronted with two classic problems from population ethics: The so-called repugnant conclusion (Parfit, 2004) and the non-identity problem (Parfit, 2017). The repugnant conclusion is the observation that our intuitive judgement of moral desirability, the increase of total happiness or welfare, is flawed. In our second scenario, the Martians are living fairly terrible lives that might barely be worth living because they are full of suffering. Just because the total amount of happiness or welfare is greater with the Martians than without them does not mean that a world with the chronically suffering Martians is morally desirable. The repugnant conclusion is relevant in the context of space colonization both because of its existential scope as well as its empirical plausibility. Creating habitats that are able to permanently sustain human life is an immense technological challenge, and it is not unrealistic to expect that life beyond Earth will be miserable for quite some time.

The non-identity problem is the observation that something is wrong with another common moral intuition. Our Martians live miserable lives, but from their own subjective point of view, that reality is preferable to the alternative of not existing at all. In a sense, no matter how terrible life for the Martians is, no moral harm seems to be done because no person was actively harmed by there being Martians — the Martians are not suffering because someone actively and malevolently hurt them or made them sick; they simply come into existence in their frail, sickly state. This means that if a Martian could choose between existing the way she does and not existing at all, she would almost certainly pick the former. But something is wrong with this conclusion. The Martians are living lives full of suffering, and clearly, this state of affairs is morally undesirable.

The concrete problems within scenarios in which the repugnant conclusion and the non-identity problem apply can be described in several ways. For example, if we put moral emphasis on average wellbeing rather than just total wellbeing, we see that the growth of total wellbeing can go hand in hand with a decrease of average wellbeing. This would indicate that something has gone wrong. However, average wellbeing alone might not be a good enough indicator. For example, in an Omelas-like configuration (Le Guin, 1991), it is conceivable that average wellbeing would increase while a small subset of people endures hellish suffering. That is why another approach to understand these problems of population ethics is to not only focus on happiness and wellbeing, but also on the negative side of the utilitarian coin, suffering: If some situation or decision produces a disproportionate amount of suffering compared to wellbeing, that situation is undesirable.7

The repugnant conclusion and the non-identity problem are examples of how many billions of future humans could live considerably worse lives than we do today. That would constitute a moral failure on an existential or near-existential level — humankind would still exist, but the primary result of our expansion beyond Earth would be a gradual erosion of happiness and a gradual accumulation of suffering.

4.2. Eliminating future extraterrestrial value

The discussion so far has mostly centered around the moral value of humankind. But in the context of space colonization, the moral reference group is not just humankind. Given the vastness of our galaxy alone, let alone the entire observable universe, the risks of space colonization for beings other than humankind need to be also taken into consideration. This starts with microbial life: Endangering primitive extraterrestrial life through space colonization could destroy immense future moral value.

We do not currently know whether life exists (or has ever existed) beyond Earth. But there is some plausibility to the assumption that the development of life is not a once-in-a-universe event. The conditions that presumably gave rise to life on Earth are almost certainly abundant throughout our galaxy, which means that, statistically speaking, primitive microbial life could come into existence relatively often (Chyba & Hand, 2005). If humans engage in space colonization, and if humans come into contact with extraterrestrial life, the extraterrestrial life in question will most likely be microbial in nature. What moral obligations do future human colonizers have towards microbial extraterrestrial life? To make this question more concrete, imagine a colonization scenario in the near future: Humans decide to terraform Mars in order to make it habitable for humans, but doing so would kill all existing species of Martian microbes that were discovered not long before the decision to terraform Mars. Would terraforming Mars be morally acceptable?

Microbial life on Earth is non-sentient, and the microbial life on Mars would also, in all likelihood, be non-sentient. If the Martian microbes neither feel anything like happiness nor experience anything like suffering, there are no utilitarian considerations of wellbeing or happiness to be made — humans could neither affect their level of wellbeing nor could they rob them of their capacity for happiness since microbial life forms lack both. However, there is a counterargument to this position: The Martian microbes have the potential to evolve into more complex, sentient and possibly even intelligent life forms. Eradicating them would therefore represent an existential damage, because all the potential future moral value would be lost. If this argument seems abstract, consider the scenario if the microbial life in question was Earth-based: If some extraterrestrial intelligence had eradicated our primitive microbial ancestors, humankind (as well as all other sentient Earth-based life) would never have come to be.

A second moral argument in favor of preserving the Martian microbes in our scenario is the argument of intrinsic value (Cockrell & Center for Environmental Philosophy, 2005). According to this position, the moral obligation towards extraterrestrial microbial life is not contingent on its sentience, but on its mere existence: Life in and of itself has a moral value, and by virtue of existing, our Martian microbes have a kind of right to their existence. In addition, and perhaps crucially, we have an obligation to respect that right. This deontological, Kantian view is not concerned with wellbeing and suffering, but instead with rights of and duties towards life. I find the utilitarian view of potential future moral value more useful than the intrinsic value argument, but it is worth mentioning the latter for the sake of completeness.

In any case, both moral arguments, the utilitarian view of potential future moral value as well as the deontological intrinsic value argument, suggest that endangering microbial life could be devastatingly wrong. A logical consequence of such considerations would be to adopt a strongly conservationist stance whereby humans refrain from colonizing a potentially large number of viable celestial bodies lest they threaten the microbes that have evolved there (Smith, 2016). Such an approach could limit human expansion to entirely artificial habitats and to biologically completely barren moons and planets.

4.3. Astronomical suffering

Space colonization means that humans and human actions will spread beyond Earth and possibly cover, relatively speaking, vast areas of the reachable universe. This will potentially create immense positive value, but it also makes possible a form of existential risks that are astronomical in scope and hellish in severity — that are, in other words, orders of magnitude worse than anything humankind has caused or encountered so far. This subset of extreme existential risks is referred to as suffering risks (Tomasik, 2015a).

Suffering risks are risks that are far worse than humankind going extinct or entering permanent moral stagnation because they mean that the suffering that is created through these risks is far greater than all suffering that has existed on Earth so far. There are different vectors of potential astronomical suffering. For example, it is conceivable that future human generations will spread wildlife throughout the colonized space, either inadvertently or actively. Wild animals on Earth generally lead short, miserable lives full of sometimes the most brutal suffering (Tomasik, 2015b). In in the history of Earth, wildlife suffering has not really improved at all, so astronomical wildlife suffering would likely represent a constant source of disvalue.

Another vector for suffering risks are sentient simulations. Given growing computational power, it is conceivable that we will eventually be able to simulate sentience, and as soon as simulated sentience is possible, simulated suffering will be as well. This technological path is not necessarily dependent on space colonization, but a colonizing humankind might have greater capabilities for running such simulations, for example by tapping into the power of stars in different Solar systems. Instances of simulated suffering could create more suffering than has ever occurred in the biological universe, within fractions of a second.

The risk of astronomical suffering is more uncertain than other existential risks, but it is at the same time more severe. At stake is not just humankind's total potential positive future moral value, but disvalue that is decoupled from humankind and is potentially many orders of magnitude greater than all the happiness and wellbeing that could be created by human colonization of space.

#### Colonization doesn’t reduce existential risk – Earth-bound threats outweigh even in long term risk management

* Short- and long-term risk assessment should focus on protecting earth
* Earth gets riskier as tech advances which raises the risk that our impact happens before colonization
* Even if tech gets there, future social and economic context prevents missions
* Risk Dynamics Paradox – existential risks are rooted in human psychology, so they’ll follow us to space – Bostrom agrees!

Szocik 19 [Konrad Szocik, Assistant Professor of Philosophy at the University of Information Technology and Management in Rzeszow, “Should and could humans go to Mars? Yes, but not now and not in the near future,” 2019, *Futures*, Vol. 105, pp. 54-66, https://doi.org/10.1016/j.futures.2018.08.004, EA]

I argue, following other authors (Baum, 2009; Baum, Denkenberger, & Haqq-Misra, 2015; Jebari, 2015; Sandberg, Matheny, & Ćirković, 2008; Turchin & Green, 2017) that human space settlement is not able to reduce and/or to exclude the risk of human extinction. For this reason, it should not be perceived in terms of space refuge. In terms of both short-term and long-term perspectives of risk assessment, it would be better to protect humans on Earth.5 I reject the supportive role which could be played by human space settlement after a catastrophe on Earth, i.e., a recovery coordination mission. Due to so-called the paradox of technological progress discussed in the last section, further putative progress in space technology will be counterbalanced by increasing anthropogenic risks including, among others, overpopulation and limited resources (these anthropogenic threats are unavoidable in near future, in contrast to other risks that are only more or less probable but not unavoidable). Permanent lack of strong rationale for human mission to Mars – both now and in the near future – leads to paradoxical situation. Even if in some point in the future the minimum level of advancement in human deep-space technologies will be achieved, social, political, and economic contexts will gradually decrease the chances for real preparation of this mission. Another paradox, let’s call it the risk dynamics paradox, is that the most probable threats in the near future are, as Bostrom and Cirkovic (2008) argue, anthropogenic threats caused by civilizational and technological progress. The paradox lies in the fact that humans are not able to run from these kinds of risks that are rooted in their way of thinking, style of life, and population dynamics, risks implied by Malthus’ law. The human species can try to protect against natural disaster but not against deleterious effects of its own technological progress. In regard to possible future existential risks, I assume that their deleterious power is a little bit exaggerated, and, in any event, human space settlement is not a right way to cope with them. However, in any case, it is hard to speculate if any human space settlement must repeat the same path of human expansion as it was the case on Earth. It is unclear if human technological expansion and exploration must always lead to deleterious and self-destructive effects. In this paper, I do not discuss ethical and moral concerns which are traditionally considered when discussing the human place in space. They include such topics as the human right to explore space (it means both right to intervene in any extraterrestrial object, and human duty and rationale for space expansionism, mostly in the context of the idea of space refuge and possible catastrophic scenarios on Earth), or the value of human life and space objects.

#### Nuclear war doesn’t cause extinction – that’s all their impacts.

Ladish 20 [Jeffrey Ladish, security researcher and risk consultant focused on global catastrophic threats; citing Reisner et al., Luke Oman, atmospheric scientist at NASA, “Nuclear war is unlikely to cause human extinction,” 11/06/20, *Effective Altruism Forum*, https://forum.effectivealtruism.org/posts/mxKwP2PFtg8ABwzug/nuclear-war-is-unlikely-to-cause-human-extinction, Accessed: 09/25/21, EA]

A number of people have claimed that a full-scale nuclear war is likely to cause human extinction. I have investigated this issue in depth and concluded that even a full scale nuclear exchange is unlikely (<1%) to cause human extinction.

By a full-scale war, I mean a nuclear exchange between major world powers, such as the US, Russia, and China, using the complete arsenals of each country. The total number of warheads today (14,000) is significantly smaller than during the height of the cold war (70,000). While extinction from nuclear war is unlikely today, it may become more likely if significantly more warheads are deployed or if designs of weapons change significantly.

There are three potential mechanisms of human extinction from nuclear war:

1) Kinetic destruction

2) Radiation

3) Climate alteration

Only 3) is remotely plausible with existing weapons, but let's go through them all.

1) Kinetic destruction

There simply aren't enough nuclear warheads to kill everyone directly with kinetic force, and there likely never will be. There are ~14,000 nuclear weapons in the world, and let’s suppose they have an average yield of something like 1 megaton. This is a conservative guess, the actual average is probably closer to 100 kilotons. With a 1 megaton warhead, you can create a fireball covering 3 km², and a moderate pressure wave that knocks down most residential houses covering 155 km². The former kills nearly everyone and the latter kills a decent percentage of people but not everyone. Let's be conservative and assume the pressure wave kills everyone in its radius. 14,000 \* 155 = 2.17 million km². The New York Metro area is 8,683 km². So all the nuclear weapons in the world could destroy about 250 New York Metro areas. This is a lot! But not near enough, even if someone intentionally tried to hit all the populations at once. Total land surface of earth is: 510.1 million km². Urban area, by one estimate, is about 2%, or 10.2 million km.² Since the total possible area destroyed from nuclear weapons is ~2.17 million km² is considerably less than a lower bound on the area of human habitation, 10.2 million km², there should be basically no risk of human extinction from kinetic destruction.

If you want to check my work there, I was using nuke map.

The even more obvious reason why kinetic damage wouldn't lead to human extinction is that nuclear states only threaten one or several countries at a time, and never the population centers of the entire world. Even if NATO countries and Russia and China all went to war at the same time, Africa, South America, and other neutral regions would be spared any kinetic damage.

2) Radiation

Radiation won't kill everyone because there aren't enough weapons, and radiation from them would be concentrated in some areas and wholly absent from other areas. Even in the worst affected areas, lethal radiation from fallout would drop to survivable levels within weeks.

Here it's worth noting that there is an inherent tradeoff between length of halflife and energy released by radionuclides. The shorter the half life the more energy will be released, and the longer the half life the less energy. The fallout products from modern nuclear weapons are very lethal, but only for days to several weeks.

Let's try the same calculation we used with kinetic damage, and see if an attack aimed at optimizing fallout for killing everyone could succeed. Using Nukemap again, I'll go with the fallout contour for 100 rads per hour. 400 rads is thought too be enough to kill 50% of people, so 100 rads per hour is likely to kill most all people not in some kind of shelter. We need to switch to using a groundburst detonation rather than an airburst detonation, because groundbursts create far more fallout. A 1mt ground burst would create an area of about 8,000 km² of >100 rads per hour. Okay, multiple that by 14,000 warheads, and we get 112 million km². That's a lot! It's still less than the 510.1 million km² of earth's land mass, but it's a lot more than the ~10.2 million km² of urban space. Presumably this is enough to cover every human habitation, so in principle, it might be possible to kill everyone with radiation from existing nuclear weapons.

In practice, it would be almost impossible to kill every human via radiation with the existing nuclear arsenals, even if they were targeted explicitly for this purpose. The first reason is that fallout patterns are very uneven. After a ground burst, fallout is carried by the wind. Some areas will be hit bad and some areas will be hardly affected by fallout. Even if most human population centers were covered, a few areas would almost certainly escape.

Two other things make extinction by radiation unlikely. Many countries, especially in the southern hemisphere, are unlikely to be affected by fallout much at all. Since most of these countries are likely to be neutral in a conflict, and not near combatant countries, they should be relatively safe from fallout. While fallout might travel hundreds of kms, it still won't reach places separated by greater distances. Fallout that reaches the upper atmosphere will eventually fall back down, but usually after the period of lethal radioactivity. The other mitigating factor is that in typical nuclear war plans, ground bursts are usually restricted to hardened targets, and air bursts are favored for population and industry centers. This is because air bursts maximize the size of the destructive pressure wave. Air burst detonations result in little lethal fallout reaching the ground, so populations not downwind of military targets would likely be safe from the worst of the radiological effects in a war scenario.

The final protection from extinction by radiation is simply large amounts of mass between people and the radiation source, in other words, fallout shelters. After several weeks, the radionuclides in fallout from ground burst detonations will have decayed to the point where humans can survive outside of shelters. Many fallout shelters exist in the world, and many more could be made easily in a day or two with a shovel, some ground, and some boards. Even if lethally radioactive fallout from ground bursts covered all population centers, many humans would still survive in shelters.

The risks of extinction from nuclear-weapon-induced-radiation wouldn't be complete without discussing two factors: nuclear power plants and radiological weapons. I'm only going to cover these briefly, but they both don't change the conclusions much.

Nuclear power plants could be targeted by nuclear weapons to create large amounts of fallout with a longer half-life but less energy per unit time. The main concern here is that nuclear power plants and spent fuel sites contain a much greater \*mass\* of radioactive material than nuclear missiles can carry. The danger comes primarily from spreading the already very radiative spent or unspent nuclear fuel. The risk this poses requires a longer analysis, but the short version is that while nuking a nuclear power plant or stored fuel site would indeed create some pretty long-lived fallout it would still be concentrated in a relatively small area. Fortunately, even a nuclear detonation wouldn't spread the nuclear fuel more than several hundred km at most. Having regions of countries covered in spent nuclear fuel would be awful, but it doesn't much raise the risk of extinction.

Radiological weapons are nuclear weapons designed to maximize the spread of lethal fallout rather than destructive yield. The particular concern from the extinction perspective is that they can be designed to create fallout that continues to emit levels of radiation that can make an area uninhabitable for months to years. These kind of radiological weapons kill more slowly, but they still kill. In principle, radiological weapons could be used to kill everyone on earth. However, in practice, the same constraints that apply to standard nuclear weapons apply to weapons optimized for long-lasting fallout, as well as some additional constraints.

Radiological weapons wouldn't produce more fallout than standard warheads, they would just produce fallout with different characteristics. As a result the amount of radiological weapons required to cover every part of earth's surface would be massively expensive (likely as expensive as the largest existing nuclear arsenals), and serve no military purpose. Their inefficiency in destruction and death compared to standard nuclear weapons is probably why radiological weapons have never been developed or deployed in large numbers. This makes them an ongoing theoretical concern, but not an existential risk in the immediate future. A concerning development is Russia's claim to have developed a large-yield (100mt) submersible nuclear weapon with the suggestion that it could be used as a radiological weapon, but even if this is true, it's unlikely to be deployed in large numbers.

3) Climate alteration

The bulk of the risk of human extinction from nuclear weapons come from risks of catastrophic climate change, nuclear winter, due to secondary effects from nuclear detonations. However, even in most full-scale nuclear exchange scenarios, the resulting climate effects are unlikely to cause human extinction.

Reasons for this:

a) Under scenarios where a severe nuclear winter occurs as described by Robock et al, some human populations would likely survive.

b) The Robock group’s models are probably overestimating the risk

c) Nuclear war planners are aware of nuclear winter risks and can incorporate these risks into their targeting plans

Before diving into each subject, it’s worth understanding the background of nuclear winter research. In the 1980s a group of atmospheric scientists proposed the hypothesis that a nuclear war would result in massive firestorms in burning cities, which would loft particles high into the atmosphere and cause catastrophic cooling that would last for years. Many found it alarming that such an effect could be possible and go unnoticed for decades while the risk existed. Some scientists also thought the proposed effect was too strong, or unlikely to occur at all. Until a few years ago, if you looked only at peer reviewed literature you would only find papers forecasting severe nuclear winter effects in the event of a nuclear war. Understandably, many people assumed that this was the scientific consensus. Unfortunately, this misrepresented the scientific community’s state of uncertainty about the risks of nuclear war. There have only ever been a small numbers of papers published about this topic (<15 probably), mostly from one group of researchers, despite the topic being one of existential importance.

I’m very glad Robock, Toon, and others have spent much of their careers studying nuclear winter effects, and their models are useful in estimating potential climate change caused by nuclear war. However, I’ve become less convinced over time the Robock model is largely correct. See section B below for why I’ve changed my mind. However, I’m quite uncertain about the probability of strong cooling effects from nuclear war, and am still quite concerned about the potential for severe cooling, even if the risk of extinction from such events is small.

A: Under scenarios where a severe nuclear winter occurs as described by Robock et al, some human populations would likely survive.

The latest and most detailed model of potential cooling effects from a fullscale nuclear exchange comes from, Robock et al., “Nuclear winter revisited with a modern climate model and current nuclear arsenals: Still catastrophic consequences” found here.

The effects from this model are severe. In the 150Tg case, after a year, summer temperatures in the Northern hemisphere are 10-30 degrees C cooler. The effects are less severe at the equator (5 degrees C), but basically all places in the world are affected. The most likely outcome is that most people starve to death. Many would freeze too, but starvation is likely the greatest risk. Even in this model, it appears that in equatorial regions, some farming would still be possible, enough for some populations to survive. After a 10-15 years, agriculture in most of the world would be possible at reduced capacity.

Carl Shulman asked one of the authors of this paper, Luke Oman, his probability that the 150Tg nuclear winter scenario discussed in the paper would result in human extinction, the answer he gave was “in the range of 1 in 10,000 to 1 in 100,000.” This strikes me as quite plausible, though one expert opinion is no substitute for a deep analysis. The Q&A with Oman contains his reasoning for this assessment.

Two different analyses are required to calculate the chances of human extinction from nuclear winter. The first is the analysis of the climate change that could result from a nuclear war, and the second is the adaptive capacity of human groups to these climate changes. I have not seen an in depth analysis of the latter, but I believe such an assessment would be worthwhile.

My own guess is that humans are capable of surviving far more severe climate shifts than those projected in nuclear winter scenarios. Humans are more robust than most any other mammal to drastic changes in temperature, as evidenced by our global range, even in pre-historic times. While a loss of most agriculture would likely kill most people on earth, modern technology would enable some populations to survive. Great stores of food currently exist in the world, and it is l likely that some of these would be seized and protected by small groups, providing enough food to last for years. While even such populations with food stores wouldn’t have enough to survive for 10-15 years, such food stores would give groups time to adapt to new food sources. The organization ALLFED has explored a number of alternative food sources that could keep populations alive in the event of a nuclear war or other large solar disruption, and I expect great necessity to drive the discovery of even more in the event of such a disaster.

B: The Robock group’s models are probably overestimating the risk

The nuclear winter model at its simplest: Nuclear detonations → Fires in cities → Firestorms in cities → Lofted black carbon into the upper atmosphere → black carbon persists in upper atmosphere, reflecting sunlight and causes massive cooling

Each step is required in order for the effect to occur. If nuclear war causes massive fires in cities but does not lead to firestorms that loft particles, then no long term cooling is going to occur. Some of these steps are easier to model than others. Based on my reading of the literature, the greatest uncertainties involve the dynamics of cities burning after a nuclear attack, and whether the conditions would produce firestorms sufficient to loft large numbers of particles high enough in the atmosphere to persist for years.

We’re finally beginning to see some healthy debate about some of these questions in the scientific literature. Alan Robock’s group published a paper in 2007 that found significant cooling effects even from a relatively limited regional war. A group from Los Alamos, Reisner et al, published a paper in 2018 that reexamined some of the assumptions that went into Robock et al’s model, and concluded that global cooling was unlikely in such a scenario. Robock et al. responded, and Reisner et al responded to the response. Both authors bring up good points, but I find Reisner’s position more compelling. This back and forth is worth reading for those who want to investigate deeper. Unfortunately Reisner’s group has not published an analysis on potential cooling effects from a modern full scale nuclear exchange, rather than a limited regional exchange. Even so, it’s not hard to extrapolate that Reisner’s model would result in far less cooling than Robock’s model in the equivalent situation.

C: Nuclear war planners are aware of nuclear winter risks and can incorporate these risks into their targeting plans

A very simple way to reduce risks from nuclear winter is to refrain from targeting cities with nuclear weapons. The proposed mechanism behind nuclear winter results from cities burning, not ground bursts on military targets. I’ve spoken with some of the officials in the US defense establishment responsible for nuclear war planning, and they’re well aware of the potential risks from nuclear winter. Of course, being aware of the risks does not guarantee they will have reasoned about the risks well, or have engaged in good risk management practices. However, the fact that this risk is well publicized makes it more likely that nuclear war planners will take steps to minimize blowback risk from climate effects.

It’s hard to know to what extent this has been done. Nuclear war plans are classified, and as far as we know current US nuclear war plans do target cities under some circumstances but not under others. However, the defense establishment has access to classified information and models that we civilians do not have, in addition to all the public material. I’m confident that nuclear war planners have thought deeply about the risks of climate change from nuclear war, even though I don’t know their conclusions or bureaucratic constraints. All else being equal, the knowledge of these risks makes military planners less likely to accidentally cause human extinction.

#### Space war is impossible – limited access, attribution, and interdependence.

James Pavur 19, Professor of Computer Science Department of Computer Science at Oxford University and Ivan Martinovic, DPhil Researcher Cybersecurity Centre for Doctoral Training at Oxford University, “The Cyber-ASAT: On the Impact of Cyber Weapons in Outer Space”, 2019 11th International Conference on Cyber Conflict: Silent Battle T. Minárik, S. Alatalu, S. Biondi, M. Signoretti, I. Tolga, G. Visky (Eds.), <https://ccdcoe.org/uploads/2019/06/Art_12_The-Cyber-ASAT.pdf>

A. Limited Accessibility Space is difficult. Over 60 years have passed since the first Sputnik launch and only nine countries (ten including the EU) have orbital launch capabilities. Moreover, a launch programme alone does not guarantee the resources and precision required to operate a meaningful ASAT capability. Given this, one possible reason why space wars have not broken out is simply because only the US has ever had the ability to fight one [21, p. 402], [22, pp. 419–420]. Although launch technology may become cheaper and easier, it is unclear to what extent these advances will be distributed among presently non-spacefaring nations. Limited access to orbit necessarily reduces the scenarios which could plausibly escalate to ASAT usage. Only major conflicts between the handful of states with ‘space club’ membership could be considered possible flashpoints. Even then, the fragility of an attacker’s own space assets creates de-escalatory pressures due to the deterrent effect of retaliation. Since the earliest days of the space race, dominant powers have recognized this dynamic and demonstrated an inclination towards de-escalatory space strategies [23]. B. Attributable Norms There also exists a long-standing normative framework favouring the peaceful use of space. The effectiveness of this regime, centred around the Outer Space Treaty (OST), is highly contentious and many have pointed out its serious legal and political shortcomings [24]–[26]. Nevertheless, this status quo framework has somehow supported over six decades of relative peace in orbit. Over these six decades, norms have become deeply ingrained into the way states describe and perceive space weaponization. This de facto codification was dramatically demonstrated in 2005 when the US found itself on the short end of a 160-1 UN vote after opposing a non-binding resolution on space weaponization. Although states have occasionally pushed the boundaries of these norms, this has typically occurred through incremental legal re-interpretation rather than outright opposition [27]. Even the most notable incidents, such as the 2007-2008 US and Chinese ASAT demonstrations, were couched in rhetoric from both the norm violators and defenders, depicting space as a peaceful global commons [27, p. 56]. Altogether, this suggests that states perceive real costs to breaking this normative tradition and may even moderate their behaviours accordingly. One further factor supporting this norms regime is the high degree of attributability surrounding ASAT weapons. For kinetic ASAT technology, plausible deniability and stealth are essentially impossible. The literally explosive act of launching a rocket cannot evade detection and, if used offensively, retaliation. This imposes high diplomatic costs on ASAT usage and testing, particularly during peacetime. C. Environmental Interdependence A third stabilizing force relates to the orbital debris consequences of ASATs. China’s 2007 ASAT demonstration was the largest debris-generating event in history, as the targeted satellite dissipated into thousands of dangerous debris particles [28, p. 4]. Since debris particles are indiscriminate and unpredictable, they often threaten the attacker’s own space assets [22, p. 420]. This is compounded by Kessler syndrome, a phenomenon whereby orbital debris ‘breeds’ as large pieces of debris collide and disintegrate. As space debris remains in orbit for hundreds of years, the cascade effect of an ASAT attack can constrain the attacker’s long-term use of space [29, pp. 295– 296]. Any state with kinetic ASAT capabilities will likely also operate satellites of its own, and they are necessarily exposed to this collateral damage threat. Space debris thus acts as a strong strategic deterrent to ASAT usage.

#### No one’s going to war over a downed satellite

Bowen 18 [Bleddyn Bowen, Lecturer in International Relations at the University of Leicester. The Art of Space Deterrence. February 20, 2018. https://www.europeanleadershipnetwork.org/commentary/the-art-of-space-deterrence/]

Space is often an afterthought or a miscellaneous ancillary in the grand strategic views of top-level decision-makers. A president may not care that one satellite may be lost or go dark; it may cause panic and Twitter-based hysteria for the space community, of course. But the terrestrial context and consequences, as well as the political stakes and symbolism of any exchange of hostilities in space matters more. The political and media dimension can magnify or minimise the perceived consequences of losing specific satellites out of all proportion to their actual strategic effect.

#### Megaconstellations solves satellite hacking – multiple warrants. Commercial Satellites are key due to production capacity.

Hallex and Cottom 20 Hallex, Matthew, and Travis Cottom. "Proliferated commercial satellite constellations: Implications for national security." Joint Forces Quarterly 97.July (2020): 20-29. (Matthew A. Hallex is a Research Staff Member at the Institute for Defense Analyses. Travis S. Cottom is a Research Associate at the Institute for Defense Analyses.)//Re-cut by Elmer

While potentially threatening the sustainability of safe orbital operations, new proliferated constellations also offer opportunities for the United States to increase the resilience of its national security space architectures. Increasing the resilience of U.S. national security space architectures has strategic implications beyond the space domain. Adversaries such as China and Russia see U.S. dependence on space as a key vulnerability to exploit during a conflict. Resilient, proliferated satellite constellations support deterrence by denying adversaries the space superiority they believe is necessary to initiate and win a war against the United States.28 Should deterrence fail, these constellations could provide assured space support to U.S. forces in the face of adversary counterspace threats while imposing costs on competitors by rendering their investments in counterspace systems irrelevant. Proliferated constellations can support these goals in four main ways. First, the extreme degree of disaggregation inherent in government and commercial proliferated constellations could make them more resilient to attacks by many adversary counterspace systems. A constellation composed of hundreds or thousands of satellites could withstand losing a relatively large number of them before losing significant capability. Conducting such an attack with kinetic antisatellite weapons—like those China and Russia are developing—would require hundreds of costly weapons to destroy satellites that would be relatively inexpensive to replace. Second, proliferated constellations would be more resilient to adversary electronic warfare. Satellites in LEO can emit signals 1,280 times more powerful than signals from satellites in GEO.29 They also are faster in the sky than satellites in more distant orbits, which, combined with the planned use of small spot beams for communications proliferated constellations, would shrink the geographic area in which an adversary ground-based jammer could effectively operate, making jammers less effective and easier to geolocate and eliminate.30 Third, even if the United States chooses not to deploy national security proliferated constellations during peacetime, industrial capacity for mass-producing proliferated constellation satellites could be repurposed during a conflict. Just as Ford production lines shifted from automobiles to tanks and aircraft during World War II, one can easily imagine commercial satellite factories building military reconnaissance or communications satellites during a conflict. Fourth, deploying and maintaining constellations of hundreds or thousands of satellites will drive the development of low-cost launches to a much higher rate than is available today. Inexpensive, high-cadence space launch could provide a commercial solution to operationally responsive launch needs of the U.S. Government. In a future where space launches occur weekly or less, the launch capacity needed to augment national security space systems during a crisis or to replace systems lost during a conflict in space would be readily available.31

#### No independent terminal impact to hacks – 1AR is too late.

#### Empirically no retaliation or escalation from satellite attacks

Eric J. Zarybnisky 18, MA in National Security Studies from the Naval War College, PhD in Operations Research from the MIT Sloan School of Management, Lt Col, USAF, “Celestial Deterrence: Deterring Aggression in the Global Commons of Space”, 3/28/2018, <https://apps.dtic.mil/dtic/tr/fulltext/u2/1062004.pdf>

PREVENTING AGGRESSION IN SPACE While deterrence and the Cold War are strongly linked in the public’s mind through the nuclear standoff between the United States and the Soviet Union, the fundamentals of deterrence date back millennia and deterrence remains relevant. Thucydides alludes to the concept of deterrence in his telling of the Peloponnesian War when he describes rivals seeking advantages, such as recruiting allies, to dissuade an adversary from starting or expanding a conflict.6F6 Aggression in space was successfully avoided during the Cold War because both sides viewed an attack on military satellites as highly escalatory, and such an action would likely result in general nuclear war.7F7 In today’s more nuanced world, attacking satellites, including military satellites, does not necessarily result in nuclear war. For instance, foreign countries have used high-powered lasers against American intelligence-gathering satellites8F8 and the United States has been reluctant to respond, let alone retaliate with nuclear weapons. This shift in policy is a result of the broader use of gray zone operations, to which countries struggle to respond while limiting escalation. Beginning with the fundamentals of deterrence illuminates how it applies to prevention of aggression in space.

### Advantage 2

#### Earth-based observatories obviously check asteroid detection.

#### No asteroids impact – too unlikely, and adaptation solves

Young 20 [Chris Young, tech writer at Bourbon Creative, citing NASA data and experts including Heidi Hammel, who led the observations of the comet with NASA's Hubble Space Telescope, “What is the Probability of a Huge Civilization-Ending Asteroid Impact?” 1-24-20, https://interestingengineering.com/what-is-the-probability-of-a-huge-civilization-ending-asteroid-impact]

Thankfully, based on current calculations, **the probability of a civilization-ending asteroid impact**, like the one that killed off the dinosaurs 66 million years ago, **is very low within our lifetimes**. But how do we know this and what is the probability that we will see a large meteor impact? What is the actual probability of a huge asteroid impact? Space debris burns up in our atmosphere every day. Any space rock with a diameter of about 10-meters (33 feet), will be destroyed in the Earth's atmosphere during thermal explosions. However, some of these space fragments do hit the ground. According to NASA, a meteor punched a hole in the rear end of an automobile in 1992, while a Connecticut dining room and an Alabama bedroom were also damaged by falling space debris in this century. And yet, there is no record of a human being having been killed by a small space rock in the last thousand years. But what of the big ones? Some scientists claim we are overdue for an asteroid impact of the scale that took out the dinosaurs — as these happen approximately once every 50 to 60 million years. The assertion, however, is highly debatable. First off, when we're talking in a scale of probabilities based on tens of millions of years, a tiny fraction in either direction is still a difference of hundreds of thousands, even millions, of years. Secondly, the solar system is showing signs of relative tranquility. As the universe expands, stars move farther apart meaning fewer interactions between distant stars and space rocks, and less of a chance that a huge asteroid will have its trajectory altered to come hurtling in our direction. According to NASA, the probability of an asteroid capable of destroying a city striking Earth is 0.1% every year. If one of these does hit Earth, there is a 70% chance it will land in the ocean, and a 25% chance it will land over a relatively unpopulated area. This is what happened with the Tunguska impact in Russia just over a hundred years ago. The odds of a 5-10 kilometer wide asteroid, the likes of which made the dinosaurs go extinct, hitting Earth is almost negligible at 0.000001%. Monitoring the skies NASA's Near Earth Object program monitors space rocks in our neck of the universe. It has compiled a risk table for all known Near-Earth Objects (NEOs). For each of these, NASA calculates the likelihood of an impact with Earth for the next 100 years. The brains behind the operation? The calculations are made by Sentry, a highly automated collision monitoring computer system that scans the most up-to-date list of asteroids near Earth. The Torino Scale, which runs from 1 to 10, is used to assess the danger we face from any individual asteroid. At the moment, nothing on the table is rated above 1 on the Torino Scale, meaning that impacts are calculated as being extremely unlikely. What's more, as Wired points out, new private endeavors like the B612 Foundation are aiming to launch dedicated telescopes to analyze 90 percent of all asteroids that are more than 30-meters in diameter, as these are capable of leveling large areas. As a reference, the meteor that impacted Chelyabinsk, Russia (video above) in 2013 causing millions of dollars of property damage and injuring over a thousand, was a relatively small meteor at 15 meters in diameter. Readings will become more and more accurate the more funds are invested in building monitoring systems. Planetary defense is still important All of this isn't to say that investment in planetary defense systems is not important. While NASA, and other organizations, are keeping an eye on the skies, asteroids are understandably difficult to spot. In fact, just last year a large asteroid, called '2019 OK', was spotted just a day before flying between the Earth and the Moon. Even scarier than the size and proximity of the asteroid — it was the size of a football field and came within 65,000 km of Earth's surface — is the fact that it caught researchers off guard. According to internal NASA documents obtained by Buzzfeed News, a NASA scientist said: "this one did sneak up on us." If the asteroid had hit Earth, "the blast wave could have created localized devastation to an area roughly 50 miles across,” NASA said in a statement. Worryingly, some researchers have claimed that planetary defense measures are underfunded. NASA chief Jim Bridenstine has said that we need to get serious about asteroid threats, while MIT planetary scientist Richard Binzel told BuzzFeed News that “it's no surprise an object like [2019 OK] would take us by surprise. Our current asteroid search capabilities are not up to the level they should be.” While we have mentioned that we are living through a relatively calm period when it comes to asteroid impacts, there is still the occasional reminder that big impacts are still possible in our solar system. For example, in 1992 a huge asteroid impact did occur and was observed on Jupiter. If the asteroid, called Shoemaker-Levy 9, had hit Earth, it would have created a global atmospheric disaster similar to the one that wiped out the dinosaurs 65 million years ago. "Shoemaker-Levy 9 was a sort of punch in the gut," Heidi Hammel, who led the observations of the comet with NASA's Hubble Space Telescope, said in a NASA blog post. "It really invigorated our understanding of how important it is to monitor our local neighborhood, and to understand what the potential is for impacts on Earth in the future." Then there's 99942 Apophis, a huge asteroid that will fly so close to Earth in 2029 that our planet's gravitational pull will alter its trajectory. What can we do if a large asteroid is headed our way? As the European Space Agency, ESA, which is a part of the International Asteroid Warning Network, points out, there is a range of options available in the unlikely event that we do detect an asteroid on a collision course with Earth. The most important factor would be how early the asteroid would be detected. While there is the very small, yet frightening, possibility that one could catch us unaware, like '2019 OK's' close flyby, which was spotted only 24 hours before occurring, current technology allows us to detect the trajectories of NEOs years in advance. Options include reconnaissance missions in space to gather information, while nuclear impactors can also be used to try to break up or deflect the course of an asteroid into a safe trajectory. Preparations on the ground, meanwhile, would potentially involve evacuations of entire cities.

#### They won’t hit us

Ord 20 [Toby Ord, Senior Research Fellow in Philosophy at Oxford University, “The Precipice: Existential Risk and the Future of Humanity,” 2020, Hachette Books, EA]

But what about our century? By analyzing the exact trajectories of the known asteroids, astronomers can determine whether there is any real chance that they will hit the Earth within the next hundred years. At the time of writing, 95 percent of asteroids bigger than one kilometer have been found and none have an appreciable chance of collision with the Earth. So almost all the remaining risk is from the 5 percent we haven’t yet tracked.15 We have even better news with asteroids greater than ten kilometers, as astronomers are almost certain that they have found them all, and that they pose no immediate danger. 16 Taking this trajectory information into account, the probability of an Earth-impact in the next hundred years falls to about one in 120,000 for asteroids between one and ten kilometers, and about one in 150 million for those above ten kilometers.17

These probabilities are immensely reassuring. While there is still real risk, it has been studied in great detail and shown to be vanishingly low. It is a famous risk, but a small one. If humanity were to go extinct in the next century, it would almost certainly be from something other than an asteroid or comet impact.

#### Coop checks

Ord 20 [Toby Ord, Senior Research Fellow in Philosophy at Oxford University, “The Precipice: Existential Risk and the Future of Humanity,” 2020, Hachette Books, EA]

While uncertainties remain, the overall story here is one of humanity having its act together. It was just 12 years from the first scientific realization of the risk of global catastrophe to the point where government started taking it seriously. And now, 28 years later, almost all the large asteroids have been tracked. There is international cooperation, with a United Nations–sanctioned organization and an international alliance of spaceguard programs.19 The work is well managed and NASA funding has increased more than tenfold between 2010 and 2016.20 In my view, no other existential risk is as well handled as that of asteroids and comets.

### Advantage 3

#### DebrisDev takes out ozone – their card is about launches more broadly, which Kessler would stop.

#### No ozone impact

**Ridley 14** -- Matthew White Ridley, 5th Viscount Ridley DL FRSL FMedSci, known commonly as Matt Ridley, is a British journalist, businessman and author of popular science books. Since 2013 Ridley has been a Conservative hereditary peer in the House of Lords. “THE OZONE HOLE WAS EXAGGERATED AS A PROBLEM” http://www.rationaloptimist.com/blog/the-ozone-hole-was-exaggerated-as-a-problem.aspx

Serial hyperbole does the environmental movement no favours My recent Times column argued that the alleged healing of the ozone layer is exaggerated, but so was the impact of the ozone hole over Antarctica: The ozone layer is healing. Or so said the news last week. Thanks to a treaty signed in Montreal in 1989 to get rid of refrigerant chemicals called chlorofluorocarbons (CFCs), the planet’s stratospheric sunscreen has at last begun thickening again. Planetary disaster has been averted by politics. For reasons I will explain, this news deserves to be taken with a large pinch of salt. You do not have to dig far to find evidence that the ozone hole was never nearly as dangerous as some people said, that it is not necessarily healing yet and that it might not have been caused mainly by CFCs anyway. The timing of the announcement was plainly political: it came on the 25th anniversary of the treaty, and just before a big United Nations climate conference in New York, the aim of which is to push for a climate treaty modelled on the ozone one. Here’s what was actually announced last week, in the words of a Nasa scientist, Paul Newman: “From 2000 to 2013, ozone levels climbed 4 per cent in the key mid-northern latitudes.” That’s a pretty small change and it is in the wrong place. The ozone thinning that worried everybody in the 1980s was over Antarctica. Over northern latitudes, ozone concentration has been falling by about 4 per cent each March before recovering. Over Antarctica, since 1980, the ozone concentration has fallen by 40 or 50 per cent each September before the sun rebuilds it. So what’s happening to the Antarctic ozone hole? Thanks to a diligent blogger named Anthony Watts, I came across a press release also from Nasa about nine months ago, which said: “ Two new studies show that signs of recovery are not yet present, and that temperature and winds are still driving any annual changes in ozone hole size.” As recently as 2006, Nasa announced, quoting Paul Newman again, that the Antarctic ozone hole that year was “the largest ever recorded”. The following year a paper in Nature magazine from Markus Rex, a German scientist, presented new evidence that suggested CFCs may be responsible for less than 40 per cent of ozone destruction anyway. Besides, nobody knows for sure how big the ozone hole was each spring before CFCs were invented. All we know is that it varies from year to year. How much damage did the ozone hole ever threaten to do anyway? It is fascinating to go back and read what the usual hyperventilating eco-exaggerators said about ozone thinning in the 1980s. As a result of the extra ultraviolet light coming through the Antarctic ozone hole, southernmost parts of Patagonia and New Zealand see about 12 per cent more UV light than expected. This means that the weak September sunshine, though it feels much the same, has the power to cause sunburn more like that of latitudes a few hundred miles north. Hardly Armageddon. The New York Times reported “an increase in Twilight Zone-type reports of sheep and rabbits with cataracts” in southern Chile. Not to be outdone, Al Gore wrote that “hunters now report finding blind rabbits; fisherman catch blind salmon”. Zoologists briefly blamed the near extinction of many amphibian species on thin ozone. Melanoma in people was also said to be on the rise as a result. This was nonsense. Frogs were dying out because of a fungal disease spread from Africa — nothing to do with ozone. Rabbits and fish blinded by a little extra sunlight proved to be as mythical as unicorns. An eye disease in Chilean sheep was happening outside the ozone-depleted zone and was caused by an infection called pinkeye — nothing to do with UV light. And melanoma incidence in people actually levelled out during the period when the ozone got thinner. Then remember that the ozone hole appears when the sky is dark all day, and over an uninhabited continent. Even if it persists into the Antarctic spring and spills north briefly, the hole allows 50 times less ultraviolet light through than would hit your skin at the equator at sea level (let alone at a high altitude) in the tropics. So it would be bonkers to worry about UV as you sailed round Cape Horn in spring, say, but not when you stopped at the Galapagos: the skin cancer risk is 50 times higher in the latter place. This kind of eco-exaggeration has been going on for 50 years. In the 1960s Rachel Carson said there was an epidemic of childhood cancer caused by DDT; it was not true — DDT had environmental effects but did not cause human cancers.