# 1AC

### 1AC – Plan

#### Plan – The appropriation of outer space through the production of orbital debris by private entities is unjust.

#### Orbital debris is

NASA.gov 21 [NASA – 5/26/21. “Space Debris and Human Spacecraft.” <https://www.nasa.gov/mission_pages/station/news/orbital_debris.html>] Justin

Orbital Debris

Space debris encompasses both natural meteoroid and artificial (human-made) orbital debris. Meteoroids are in orbit about the sun, while most artificial debris is in orbit about the Earth (hence the term “orbital” debris).

Orbital debris is any human-made object in orbit about the Earth that no longer serves a useful function. Such debris includes nonfunctional spacecraft, abandoned launch vehicle stages, mission-related debris, and fragmentation debris.

#### The aff interprets enforcement as an OUF (Orbital Use Fee). Proportionality in relation to the space industry solves best without harming it and any other solution only worsens the threat – models.

Rao et al 20. Akhil, Matthew Burgess, and Daniel Kaffine \*Department of Economics, Middlebury College, Middlebury \*\*Cooperative Institute for Research in Environmental Sciences, University of Colorado, Environmental Studies Program, and Department of Economics \*\*\*Department of Economics. 2020 [PNAS, “Orbital-use fees could more than quadruple the value of the space industry,” <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7293599/>] Justin

The space industry’s rapid recent growth represents the latest tragedy of the commons. Satellites launched into orbit contribute to—and risk damage from—a growing buildup of space debris and other satellites. Collision risk from this orbital congestion is costly to satellite operators. Technological and managerial solutions—such as active debris removal or end-of-life satellite deorbit guidelines—are currently being explored by regulatory authorities. However, none of these approaches address the underlying incentive problem: satellite operators do not account for costs they impose on each other via collision risk. Here, we show that an internationally harmonized orbital-use fee can correct these incentives and substantially increase the value of the space industry. We construct and analyze a coupled physical–economic model of commercial launches and debris accumulation in low-Earth orbit. Similar to carbon taxes, our model projects an optimal fee that rises at a rate of 14% per year, equal to roughly $235,000 per satellite-year in 2040. The long-run value of the satellite industry would more than quadruple by 2040—increasing from around $600 billion under business as usual to around $3 trillion. In contrast, we project that purely technological solutions are unlikely to fully address the problem of orbital congestion. Indeed, we find debris removal sometimes worsens economic damages from congestion by increasing launch incentives. In other sectors, addressing the tragedy of the commons has often been a game of catch-up with substantial social costs. The infant space industry can avert these costs before they escalate.

In 2017, 466 new satellites were launched—more than double the previous year’s launches and more than 20% of all active satellites in orbit in 2017 (1, 2). Rapid space industry growth is projected to continue, driven largely by commercial satellites (Fig. 1). This growth is driving buildup of debris in low-Earth orbit, currently including over 15,000 objects (3). Collision risk from debris is costly; collisions damage or destroy expensive capital assets that are difficult or impossible to repair. Debris buildup could eventually make some low-Earth orbits economically unviable and other orbits difficult or impossible to access (4). In the worst case—although uncertain and occurring over long time sshorizons—debris growth could become self-sustaining due to collisions between debris objects, a tipping point called Kessler Syndrome (4, 5).

Proposed solutions have so far largely been technological and managerial, aimed at mapping, avoiding, and removing debris (6, 7). These include end-of-life deorbit guidelines and “keep out” zones for active satellites and nets, harpoons, and lasers to deorbit debris (6). However, with open access to orbits, reducing debris and collision risk incentivizes additional satellite launches, which eventually restore the debris and risk. For instance, if firms were willing to tolerate a 0.1% annual risk of satellite loss before a technological improvement in debris removal, they will be willing to launch more satellites until the 0.1% annual risk of satellite loss was restored.

Thus, the core of the space debris problem is incentives, not technology. Since satellite operators are unable to secure exclusive property rights to their orbital paths or recover collision-related costs imposed by others, prospective operators face a choice between launching profitable satellites, thereby imposing current and future collision risk on others, or not launching and leaving those profits to competitors. This is a classic tragedy of the commons problem (1, 3, 8, 9). It can be economically efficiently addressed via incentive-based solutions, such as fees or tradable permits per year in orbit, analogous to carbon taxes or cap and trade (8, 10–12). Incentives should target objects in orbit—rather than launches—because orbiting objects are what directly imposes collision risk on other satellites (13). We quantify the economic benefits of implementing such incentives to correct the underlying open-access problem.

We use a coupled physical–economic model combining rich physical dynamics with satellite economics to quantify the benefits of an internationally harmonized “orbital-use fee” (OUF) relative to a business as usual (BAU) open-access scenario and relative to a scenario with active debris removal. An OUF is a type of Pigouvian tax—a well-known economic instrument for addressing externality problems (14). Our model accounts for the effects of each scenario on satellite launch decisions (Materials and Methods and SI Appendix). While we focus on an OUF for analytical convenience, it is conceptually equivalent to other mechanisms for pricing orbits, such as tradable permits.

Our physical model of satellite and debris evolution in orbit obeys relevant accounting identities and utilizes reduced form approximations of physical processes validated in other works (15, 16). We fit and calibrate the model using data on collision risk and orbital debris from the European Space Agency (ESA) (17) and data on active satellites from the Union of Concerned Scientists (UCS) (2) (Materials and Methods and SI Appendix). The ESA dataset covers 1958 to 2017, and the UCS dataset covers 1957 to 2017. Our physical model assumes runaway debris growth (Kessler Syndrome) cannot occur, which likely leads our model to understate the benefits of OUFs (Materials and Methods). Our economic model assumes that satellites are launched and operated to maximize per satellite private profits, net of any fees, subject to collision risk. We calibrate the model by fitting the BAU scenario (no fees or debris removal) to historical industry data and launch trends (1, 2) (Materials and Methods and SI Appendix).

We project future launch rates to 2040 under the BAU scenario using our fitted model and published projections of future growth of the space economy (18). The projections in ref. 18 were developed by projecting how the industries constituting the space sector—telecommunications, imaging, etc.—would grow from 2017 to 2040 under different assumptions on their individual profitability over time, then aggregating up to obtain projections for the space sector. We then calculate launch rates that would maximize the long-run value of the industry, and we calculate the time series of OUFs that would incentivize these optimal launch rates. The industry value is measured as net present value (NPV)—the long-run value of the entire fleet of satellites in orbit, accounting for both the financial costs of replacing satellites due to natural retirement and collisions as well as the opportunity cost of investing funds in satellites rather than capital markets. For instance, an NPV of $1 trillion in 2020 means the sum total of the stream of net benefits, looking from 2020 into the future and accounting for the timing of the net benefits, is $1 trillion.

Although our models are deliberately simplified for tractability, they are based on previously validated approaches to orbital object modeling (15, 16), and our calibrations allow us to reproduce observed trends and magnitudes in the growth of orbital debris and satellite stocks as well as the calculated collision risk (Fig. 3). Nonetheless, our projections should be interpreted as order of magnitude approximations that can be refined as needed by more detailed models. In these respects, our approach mirrors integrated assessment modeling approaches that have been useful in developing solutions to other natural resource management problems (e.g., ref. 19).

RESULTS

We project that shifting from open access to the optimal series of OUFs in 2020 would increase the NPV of the satellite industry from around $600 billion under BAU to around $3 trillion—a more than 4-fold increase (4.18- to 6.49-fold increases in 95% of parameter sets randomly drawn from their calibrated distributions) (Fig. 2D). Assuming a 5% market rate of return, an increase of $2.5 trillion in NPV would be equivalent to annual benefits of approximately $120 billion in perpetuity. The large immediate increase in NPV that we project in each OUF scenario, relative to BAU (Fig. 2A), comes primarily from the immediate effect of reducing launch activity while the satellite and debris stocks are suboptimally high (SI Appendix).

Based on our calculations (Materials and Methods), the optimal OUF starts at roughly $14,900 per satellite-year in 2020 and escalates at roughly 14% per year (aside from some initial transition dynamics) to around $235,000 per satellite-year in 2040. Rising optimal price paths are common in environmental pricing such as carbon taxes (20), although declining optimal price paths are also possible (21). The rising price path in this case partly reflects the rising value of safer orbits (resulting in rising industry NPV) (Fig. 2A) from the OUF. For comparison, the average annual profits of operating a satellite in 2015 were roughly $2.1 million. The 2020 and 2040 OUF values we describe amount to roughly 0.7 and 11% of average annual profits generated by a satellite in 2015.

Forgone NPV from the satellite industry in 2040—which is the cost of inaction under BAU—escalates from around $300 billion if optimal management begins in 2025 to around $700 billion if optimal management begins in 2035. Without OUFs, losses remain substantial even when active debris removal (implemented in the model as removal of 50% of debris objects in orbit each year) is available. In a best-case analysis where we assume debris removal is costless (i.e., it requires no payments nor additional satellites to implement), debris removal can only recover up to 9.5% of the value lost under open access. (The satellite industry’s willingness to pay for debris removal is not easily calculable in our model [SI Appendix, section 1.9.2].) At worst, debris removal can exacerbate orbital congestion via a rebound-type effect, causing additional losses on the order of 3% of the value already lost from open access (Fig. 4 and SI Appendix). The inability of debris removal to induce efficient orbit use is driven by open-access launching behavior and underscores the importance of policies to correct economic incentives to launch satellites.

DISCUSSION

The costly buildup of debris and satellites in low-Earth orbit is fundamentally a problem of incentives—satellite operators currently lack the incentives to factor into their launch decisions the collision risks their satellites impose on other operators. Our analysis suggests that correcting these incentives, via an OUF, could have substantial economic benefits to the satellite industry, and failing to do so could have substantial and escalating economic costs.

Escalating costs of inaction are a common feature of the tragedy of the commons, evident in several other sectors in which it went unaddressed for lengthy periods (22). For example, tens of billions of dollars in net benefits are lost annually from open-access or poorly managed fisheries globally (23). Similarly, open access to oil fields in the United States at the turn of the century drove recovery rates down to 20 to 25% at competitively drilled sites, compared with 85 to 90% potential recovery under optimal management (24). Open access to roadways—somewhat analogous to orbits—is estimated to create traffic congestion costs in excess of $120 billion/y in the United States alone (25). In contrast, there is still time to get out ahead of the tragedy of the commons in the young space industry.

The international and geopolitically complex nature of the space sector poses challenges to implementing orbital-use pricing systems, but these challenges need not be insurmountable. Theory suggests countries could each collect and spend OUF revenues domestically, without losing economic efficiency, as long as the fee’s magnitude was internationally harmonized (20). Engaging in such negotiations would be in the economic interests of all parties involved (26). An example of such a system is the Vessel Day Scheme (VDS) used by the Parties to the Nauru Agreement (PNA) to manage tuna fisheries. Under the VDS, PNA countries each lease fishing rights within their waters, using a common price floor (27). The European Union’s Emissions Trading System provides an example of an internationally coordinated tradable permit system (28). Notably, each of these pricing programs is built on a preexisting international governance institution (the Nauru Agreement and the European Union).

An OUF could also be built within existing space governance institutions, such as the Outer Space Treaty (29). For example, Article VI states that countries supervise their space industries, which provides a framework for OUFs to be administered nationally. Article II prohibits national appropriation of outer space but does not prohibit private property rights, potentially allowing for tradable orbital permitting.

### 1AC – Advantage

#### The private sector locks in the Kessler Syndrome as a structurally inevitability by 2035. The debris threat isn’t internalized, engineering studies, profit-motive AND inefficient guidelines.

Rao and Rondina 2/16/22 [Akhil Rao and Giacomo Rondina. \*Middlebury College in the Department of Economics. \*\*University of California, San Diego. “Open access to orbit and runaway space debris growth.” <https://arxiv.org/pdf/2202.07442.pdf>] Justin

In this paper we present a dynamic physico-economic model of orbit use under rational expectations with endogenous collision probability and Kessler Syndrome. We show how both economic and physical parameters drive equilibrium short- and long-run orbital-use patterns, derive the marginal external cost of a satellite, explore the multiplicity and stability of openaccess steady states, and examine the relationships between open-access orbit use, optimal orbit use, and Kessler Syndrome. We then calibrate the model to an important region of LEO and estimate the likely times when Kessler Syndrome will occur under different patterns of satellite industry economics. We highlight three messages regarding orbital-use management.

First, under open access too many firms will launch satellites because they won’t internalize the risks they impose on other orbit users. Though profit maximizing satellite owners have incentives to reduce launches as the risk of a collision grows, they do not respond to debris growth or collision risk optimally. This inefficiency is independent of whether Kessler Syndrome is possible or not. Unlike many other bioeconomic commons problems, higher discount rates can induce less (rather than more) open-access overexploitation.

Second, Kessler Syndrome is possible as long as debris objects can collide with each other and generate new fragments, i.e the new fragment formation debris coupling exists. Engineering studies indicate that this coupling does in fact exist. Due to open access, even profit maximizing firms with rational expectations may continue to launch satellites despite recognizing their role in causing Kessler Syndrome and even after the Kessler threshold has been crossed.

Third, under open access Kessler Syndrome is more likely as the excess return on a satellite rises, even if firms will respond to orbital congestion by launching fewer satellites. As launch costs fall and new commercial satellite applications become viable, LEO is thus increasingly and inefficiently likely to experience Kessler Syndrome. While it may seem paradoxical that the very changes which make orbit use profitable can also increase the risk of resource collapse, such dynamics occur frequently in bioeconomic commons problems. Calibrated simulations reveal that space economy growth rates projected by investment banks and industry associations are consistent with Kessler Syndrome occurring as early as 2035. Our results suggest that, absent institutional reform, continued growth of the space economy may trigger Kessler Syndrome in the near future. This can occur even in regions perceived to have relatively high rates of natural renewability, providing new evidence that compliance with the 25-year rule is insufficient to ensure sustainable orbit use.

#### Debris is exponentially increasing and current models underestimate the risk – it’s space’s Sword of Damocles.

Shen & Blake 2/24/22 [Zili Shen, Internally citing James Blake \* I am a Ph.D. student in Astronomy at Yale University. My research focuses on ultra-diffuse galaxies and their globular cluster populations. Since I came to Yale, I have worked on two "dark-matter-free" galaxies NGC1052-DF2 and DF4 \*\* Department of Physics and Centre for Space Domain Awareness, University of Warwick, Coventry. “How not to bury ourselves under space trash.” astrobites. <https://astrobites.org/2022/02/24/space-sustainability/>] Justin

What’s wrong with having some stuff orbiting the Earth, you might ask? Like my trash analogy, the problem is that they block our way to space. Fragments as small as 10 cm can kill a satellite mission. Unlike my trash analogy, if enough space junk accumulates, they can produce more fragments on their own. Several bands of LEO are already at risk of what’s called a runaway collisional cascade. This happens when space junk collide with each other and fall apart, their fragments going on to seeding more collisions, generating more debris, and restarting the cycle. On the other hand, space debris in high altitude orbits (like GSO) don’t experience much atmospheric drag, and will stay up there for centuries. From this you probably gathered that most of these debris are either abandoned satellites or their fragments. Even though these objects were originally launched by humans, cataloging and tracking them are a huge challenge.

What’s up there?

Since the first manmade satellite was launched in 1957, space agencies have been keeping track of bodies orbiting the Earth. By mass, 98% of those are satellites and rocket bodies, but we know very little about the remaining 2%, millions of small debris. These small debris elude radars and optical telescopes used in ground-based surveys, but they can still cause mission-fatal damage to a satellite. With limited data, NASA and ESA cannot accurately estimate the risk from orbital debris. Their models don’t even agree on the number of expected debris because there is no good observational constraint for very small fragments.

Fig. 2: Number of tracked objects in Low-Earth Orbit (LEO) and Geo-synchronous orbit (GSO). Modified from Fig.2 of the paper.

Fig. 2 shows a breakdown of what we do know about objects in LEO and GSO. In LEO (left panel) , the most numerous objects are debris. These come from fragmentation events, or “break-ups,” most commonly due to propulsion-related subsystems exploding. In other words, when leftover fuel gets heated up in space, it can blow the satellite to pieces. Other sources of debris include intentional anti-satellite tests (in which countries develop technology to destroy each other’s satellites) and a small number of accidental satellite collisions. In GSO (right panel), a large number of objects are “unknown” because GSO is significantly farther away from Earth and has historically received less attention. To quote Dr. Blake, the author of today’s paper, “monitoring the mess of near-Earth space cannot solve the problem entirely, especially while the bulk of the dangerous debris population remains invisible and uncatalogued.” Now that I’ve alerted you to the grave danger we face, how do we make sure that future humanity can still go to space?

What can be done?

Like any environmental problem, the best solution is prevention. To prevent leftover fuel from exploding, satellite operators are now advised to “passivate” the spacecraft at the end of the mission. That means dumping out residual fuel and discharging batteries while they still control the spacecraft. The other safe disposal measures after the mission ends are to have the satellite re-enter the atmosphere or move into unused high-altitude orbits. Even though these prevention measures are the best way forward, they are (un)surprisingly hard to enforce. The authors says, “despite an apparent consensus that [anti-satellite weapon] tests represent irresponsible and reckless behaviour, legally binding and internationally recognised regulations are still lacking.” The level of adherence to the above safety guidelines remain concerningly low. Given that prevention is a “legal quagmire,” we can also try to remove debris that is already up there. Everything from harpoons to nets and tentacles have been used to collect orbital debris, but there’s no one-size-fits-all solution. Imagine how hard it is to capture metal shards tumbling at high speed without creating more debris.

Looking towards the future

Small satellites have flourished in recent years as LEO satellite constellations proved commercially lucrative. These satellites are not only a problem for astronomers but also a huge issue for the existing surveillance infrastructure. Dr. Blake says, “the problem is one that affects all operators in space, truly global in nature… [and] warrants a cross-sector, cross-disciplinary approach.” As astronomers, we can help society keep a watchful eye and ensure that the future of space flight is sustainable. If you want to learn more about space sustainability, Dr. Blake recommends the GNOSIS project.

#### Fragmentation leads to speedy debris – that’s laws of physics.

Aerospace.org n.d. [As an independent, nonprofit corporation operating the only FFRDC for the space enterprise, The Aerospace Corporation performs objective technical analyses and assessments for a variety of government, civil, and commercial customers. “SPACE DEBRIS 101.” AEROSPACE. <https://aerospace.org/article/space-debris-101>] Justin

Can you see space debris coming at you?

It is very unlikely that you would see space debris. Relative to a person in orbit, space debris is moving about ten times faster than a bullet, and the vast majority of debris is as small as or smaller than a bullet. No one can see a bullet coming, let alone an object moving ten times faster.

What is an on-orbit collision like?

It looks more like an explosion of each object, as if they passed through each other and exploded on the other side. A hyper-velocity collision like those at orbital speed doesn’t behave like collisions that we are used to seeing. The objects are moving so fast that they travel through each other faster than the shock waves can travel. The shock waves in the structures of each object then shatter them into fragments of varying sizes and, in the process, give each fragment a boost in a different direction. Each one of these fragments is then in a different orbit than the original object and will move away according to the laws of orbital motion. With thousands of fragments, each moving in slightly different directions, it looks a lot like an explosion.

Do breakups look like the movies?

For dramatic purposes, movies, TV, and commercials tend to show space breakups at a much slower speed than they would happen at in real life. A breakup in space, especially a collision, can involve a lot of energy, and the pieces are flung away at extremely high speeds. Since there is no air to slow the pieces down the fragments would all fly away from one another and rapidly disappear from view. For many breakups, a softball-sized fragment would fly the length of the space station (a little less than a football field) in less than half a second. If you were watching it from nearby, you would see a flash, and the object that broke up would just disappear and be gone. It would be very unlikely for you to see pieces drifting away. Similarly, a low orbit space collision is unlikely to look much like a car crash — the speeds are much too high. The collisions would look like explosions to a nearby observer.

#### Current regulatory guidelines fail – answers neg turns.

Boley and Byers 21. Aaron Boley is at the Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada and Michael Byers is at the Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada. 5/20/21. [Nature, “Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth,” <https://www.nature.com/articles/s41598-021-89909-7>] Justin

Companies are placing satellites into orbit at an unprecedented frequency to build ‘mega-constellations’ of communications satellites in Low Earth Orbit (LEO). In two years, the number of active and defunct satellites in LEO has increased by over 50%, to about 5000 (as of 30 March 2021). SpaceX alone is on track to add 11,000 more as it builds its Starlink mega-constellation and has already fled for permission for another 30,000 satellites with the Federal Communications Commission (FCC)1 . Others have similar plans, including OneWeb, Amazon, Telesat, and GW, which is a Chinese state-owned company2 . Te current governance system for LEO, while slowly changing, is ill-equipped to handle large satellite systems. Here, we outline how applying the consumer electronic model to satellites could lead to multiple tragedies of the commons. Some of these are well known, such as impediments to astronomy and an increased risk of space debris, while others have received insufcient attention, including changes to the chemistry of Earth’s upper atmosphere and increased dangers on Earth’s surface from re-entered debris. Te heavy use of certain orbital regions might also result in a de facto exclusion of other actors from them, violating the 1967 Outer Space Treaty. All of these challenges could be addressed in a coordinated manner through multilateral law-making, whether in the United Nations, the Inter-Agency Debris Committee (IADC), or an ad hoc process, rather than in an uncoordinated manner through diferent national laws. Regardless of the law-making forum, mega-constellations require a shif in perspectives and policies: from looking at single satellites, to evaluating systems of thousands of satellites, and doing so within an understanding of the limitations of Earth’s environment, including its orbits.

Tousands of satellites and 1500 rocket bodies provide considerable mass in LEO, which can break into debris upon collisions, explosions, or degradation in the harsh space environment. Fragmentations increase the cross-section of orbiting material, and with it, the collision probability per time. Eventually, collisions could dominate on-orbit evolution, a situation called the Kessler Syndrome3 . Tere are already over 12,000 trackable debris pieces in LEO, with these being typically 10 cm in diameter or larger. Including sizes down to 1 cm, there are about a million inferred debris pieces, all of which threaten satellites, spacecraf and astronauts due to their orbits crisscrossing at high relative speeds. Simulations of the long-term evolution of debris suggest that LEO is already in the protracted initial stages of the Kessler Syndrome, but that this could be managed through active debris removal4 . Te addition of satellite mega-constellations and the general proliferation of low-cost satellites in LEO stresses the environment further5–8 .

[Omitted Figures 1 and 2]

Results

The overall setting. Te rapid development of the space environment through mega-constellations, predominately by the ongoing construction of Starlink, is shown by the cumulative payload distribution function (Fig. 1). From an environmental perspective, the slope change in the distribution function defnes NewSpace, an era of dominance by commercial actors. Before 2015, changes in the total on-orbit objects came principally from fragmentations, with efects of the 2007 Chinese anti-satellite test and the 2009 Kosmos-2251/Iridium-33 collisions being evident on the graph.

Although the volume of space is large, individual satellites and satellite systems have specifc functions, with associated altitudes and inclinations (Fig. 2). Tis increases congestion and requires active management for station keeping and collision avoidance9 , with automatic collision-avoidance technology still under development. Improved space situational awareness is required, with data from operators as well as ground- and space-based sensors being widely and freely shared10. Improved communications between satellite operators are also necessary: in 2019, the European Space Agency moved an Earth observation satellite to avoid colliding with a Starlink satellite, afer failing to reach SpaceX by e-mail. Internationally adopted ‘right of way’ rules are needed10 to prevent games of ‘chicken’, as companies seek to preserve thruster fuel and avoid service interruptions. SpaceX and NASA recently announced11 a cooperative agreement to help reduce the risk of collisions, but this is only one operator and one agency

When completed, Starlink will include about as many satellites as there are trackable debris pieces today, while its total mass will equal all the mass currently in LEO—over 3000 tonnes. Te satellites will be placed in narrow orbital shells, creating unprecedented congestion, with 1258 already in orbit (as of 30 March 2021). OneWeb has already placed an initial 146 satellites, and Amazon, Telesat, GW and other companies, operating under diferent national regulatory regimes, are soon likely to follow.

Enhanced collision risk. Mega-constellations are composed of mass-produced satellites with few backup systems. Tis consumer electronic model allows for short upgrade cycles and rapid expansions of capabilities, but also considerable discarded equipment. SpaceX will actively de-orbit its satellites at the end of their 5–6-year operational lives. However, this process takes 6 months, so roughly 10% will be de-orbiting at any time. If other companies do likewise, thousands of de-orbiting satellites will be slowly passing through the same congested space, posing collision risks. Failures will increase these numbers, although the long-term failure rate is difcult to project. Figure 3 is similar to the righthand portion of Fig. 2 but includes the Starlink and OneWeb megaconstellations as fled (and amended) with the FCC (see “Methods”). Te large density spikes show that some shells will have satellite number densities in excess of n = 10−6 km−3 .

Deorbiting satellites will be tracked and operational satellites can manoeuvre to avoid close conjunctions. However, this depends on ongoing communication and cooperation between operators, which at present is ad hoc and voluntary. A recent letter12 to the FCC from SpaceX suggests that some companies might be less-thanfully transparent about events13 in LEO.

Despite the congestion and trafc management challenges, FCC flings by SpaceX suggest that collision avoidance manoeuvres can in fact maintain collision-free operations in orbital shells and that the probability of a collision between a non-responsive satellite and tracked debris is negligible. However, the flings do not account for untracked debris6 , including untracked debris decaying through the shells used by Starlink. Using simple estimates (see “Methods”), the probability that a single piece of untracked debris will hit any satellite in the Starlink 550 km shell is about 0.003 afer one year. Tus, if at any time there are 230 pieces of untracked debris decaying through the 550 km orbital shell, there is a 50% chance that there will be one or more collisions between satellites in the shell and the debris. As discussed further in “Methods”, such a situation is plausible. Depending on the balance between the de-orbit and the collision rates, if subsequent fragmentation events lead to similar amounts of debris within that orbital shell, a runaway cascade of collisions could occur.

Fragmentation events are not confned to their local orbits, either. Te India 2019 ASAT test was conducted at an altitude below 300 km in an efort to minimize long-lived debris. Nevertheless, debris was placed on orbits with apogees in excess of 1000 km. As of 30 March 2021, three tracked debris pieces remain in orbit14. Such long-lived debris has high eccentricities, and thus can cross multiple orbital shells twice per orbit. A major fragmentation event from a single satellite could afect all operators in LEO.

#### Rivalrous orbits create space conflict and turn good satellites.

Samson 22 – Victoria Samson is the Washington office director for the Secure World Foundation, an organization that focuses on space sustainability, and she has over 20 years of experience in military space and security issues. Previously, Ms. Samson was a senior analyst for the Center for Defense Information. She also was a senior policy associate at the Coalition to Reduce Nuclear Dangers, a consortium of arms control groups. Earlier, she was a researcher at Riverside Research Institute, where she worked on war-gaming scenarios for the Missile Defense Agency. 1/17/22. [Bulletin of the Atomic Scientists, “The complicating role of the private sector in space,” DOI: 10.1080/00963402.2021.2014229] Justin

At this exact moment, we are seeing the increasing dominance of commercial actors in space – specifically the rise of mega-constellations, or large numbers of small satellites flying in formation to provide global coverage for a variety of governmental and commercial uses, including both communications and Earth observation. Consequently, the fundamental nature of space is changing, to one of a domain dominated by commercial actors. This change will have major consequences for international stability, both in terms of how it demonstrates that the old governance structure for space is being left behind – and how it highlights Russia’s declining rank in global space powers. Certain orbits may be effectively taken over by a handful of entities, and there will be competition for useful portions of the electromagnetic spectrum. With eyes on the sky everywhere, there will be little or no room for state secrets – for better or worse. This is happening at the same time that Russia’s space identity is floundering, which may further upset the stability of the domain of space.

As of November 2021, there are roughly 4,800 active satellites in orbit around Earth, around 1,850 of which belong to just one entity: SpaceX’s Starlink mega-constellation (Thompson 2021). This change has happened very quickly, as Starlink satellites just began to be launched in May 2019 (O’Callaghan 2019). This is only the first wave of the megaconstellations as well. While it is hard to say exactly how many satellites will be launched as part of this new use of space, there are requests or plans for mega-constellations that could mean well over 100,000 new satellites could potentially be in low Earth orbit. While not all of these satellites will be launched, even a small fraction of that proposed number will fundamentally shift the situation so that the major actors in space will no longer be nation-states (as has been the case to date) but the private sector, changing the timbre of the space domain.

This leads to challenges in discussing space security issues: Space is a shared, international domain; if we cannot include all the stakeholders in the discussions, we will not come to complete solutions to the problems. But first, some background.

A little history

The commercial sector is not new to space. Commercial entities have been active in space for decades now; in fact, it was a dispute over what should be the extent of their role in space that shaped part of the 1967 Outer Space Treaty. Article VI of that treaty notes:

States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities . . .. The activities of nongovernmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. (Outer Space Treaty 1967)

This was a compromise between the United States and the USSR, in which the latter argued that there was no such thing as commercial space. Having language requiring state actors to carry out “authorization and continuing supervision” gave the United States the flexibility it wanted to develop a commercial space sector while ensuring that there would still be national oversight.

A lack of coordination

One way in which the rise of these mega-constellations may complicate international security in space is through concerns about these satellites hampering access to certain orbits. While slots in geosynchronous Earth orbit are set by the International Telecommunication Union, there is no international entity coordinating orbital slots at low Earth orbit. This means that, given the potentially tens of thousands of satellites that could be launched given company plans, certain orbits could be de facto ceded to a handful of entities – in defiance of Article II of the Outer Space Treaty, which says that space “is not subject to national appropriation.” Consequently, this could lead to strife or competition over certain orbits.

It is possible that, given the number of satellites that companies are asking the United States’ Federal Communications Commission for broadcasting rights to, certain orbits may reach their carrying capacities – meaning that they are at the maximum number of satellites that can be operated, as defined by physical and radiofrequency interference aspects. This could lead to disputes over which country has the right to use certain orbits, or, alternatively, resentment when one country’s commercial sector essentially takes over a particular orbit

Competition over parts of the electromagnetic spectrum is another possible path for international security issues to arise from mega-constellations. Satellites are only as good as their ability to receive and communicate information, which requires spectrum; if one or a few entities from one country use up all the readily accessible spectrum for specific capabilities at certain orbits, that could possibly lead to confrontation as well. For the most part, the companies launching mega-constellations are largely based in the West, which can shape the global perception of their effects and intent – although there have been some plans for at least one Chinese company to launch a mega-constellation of potentially 13,000 satellites, and the South Koreans have expressed interest in their own mega-constellation.

#### Triggers space escalation and nuclear war.

Perez 21 – Veronica Delgado-Perez is a Staff Writer at The International Scholar. 12/14/21 – Note, doesn’t say date but most recent cited event is 2021, correct if I’m wrong. [The International Scholar, “Argument | The Commercialization of Space Risks Launching a Militarized Space Race,” <https://www.theintlscholar.com/periodical/12/14/2020/analysis-commercialization-space-risk-international-law-military-space-race>] Justin

With new actors on the game stage, conflicts of interest may arise. There is a risk that each actor adopts a kind of short-term Realist approach to space policy — one which is driven by self-interest in reaping the greatest benefits of extraterrestrial exploration and commercialization while controlling access to others. If unmitigated, states may choose to militarize outer space to gain a strategic edge over competitors and adversaries.

This process has already begun. Under the Trump administration, the Pentagon established the U.S. Space Force as a new branch of the Armed Forces to protect the country and allied interests in space. Already, Delta 4 — one of the U.S. Space Force’s missions — conducts strategic and theater missile warnings, manages weapon systems, and provides information to missile defense forces. The measure shows that for the U.S., outer space is not only a domain of scientific exploration but has the potential to become increasingly securitized.

With the impending expiration of the Strategic Arms Reduction Treaty (START) between the U.S. and Russia on February 5, 2021, a number of security dilemmas could arise. If the world’s two largest nuclear powers do not edge toward extending the treaty, Washington and Moscow risk returning to the era of unrestricted expansion of launch platforms and strategically-deployed nuclear warheads — potentially with the aid of military infrastructure in space.

Although President-elect Biden has expressed his interest in negotiating an extension of New START, how Moscow and Washington might proceed remains an open question. Bilateral progress towards a new arms-control regime would require establishing limits on the number and range of long- and mid-range missiles, establishing measures to limit the expansion of traditional missile deployment to space, and banning the deployment of nuclear weapons and weapons of mass destruction in outer space.

#### Debris shreds ozone.

Josy O’Donnell 18, creator of Conservation Institute, “WHAT HAPPENS TO THE “SPACE JUNK” THAT FALLS BACK TO EARTH?,” https://ourplnt.com/space-junk-earth/#axzz5xRXia1uD

Second, as the orbits of man-made debris degrade, and they re-enter the earth’s atmosphere, a shock wave occurs in the upper reaches of the layer of ozone. This physical stress on the area can be damaging to the protective buffer. Researchers have discovered that the impact of objects entering the atmosphere at high speed can produce nitric oxide during the rapid cooling that follows the splitting of oxygen and nitrogen. Nitric oxide is very destructive to the ozone layer. Finally, though most of the debris that re-enters the earth’s atmosphere is vaporized due to the build- up of intense heat, the chemical residue of this material can also react with the ozone and deplete it. Some scientists fear that erosion of the ozone layer may cause global climate change. They predict that these altered weather patterns could transform fertile farmland into deserts and threaten human life on the planet. Thus, the environmental effect of space debris upon the ozone is of great concern to these experts.

#### **Ozone collapse causes extinction.**

Simmons 20 [Carla Simmons,, The Science Times, "A Repeat of One of the Biggest Extinctions Caused by Ozone Layer Erosion 359M Years Ago Possible, Warn Scientists | Science Times", May 27, 2020, https://www.sciencetimes.com/articles/25838/20200527/repeat-one-biggest-extinctions-caused-ozone-layer-erosion-359m-years.htm] BD

University of Southampton researchers have delved deeper into an extinction event that occurred about 360 million years ago. According to their research, the ozone layer's breakdown caused by ultraviolet (UV) radiation vanquished much of the Earth's marine life and greenery. Moreover, their discovery led to weighty indications for today's continually warming Earth.

Numerous episodes of mass extinction occurred in the geological past. One of the most notorious ones caused the extinction of dinosaurs about 66 million years ago. Their destruction was believed to have been caused by an asteroid hitting the Earth.

Additionally, two chapters were caused by large-scale volcanic eruptions that created the imbalance of oceans and atmospheres in the planets. Another one happened during the end of Permian Great Dying, which, according to Stanford, wiped out 96% of the Earth's aquatic species.

Scientists have discovered evidence pointing to high levels of UV radiation responsible for collapsing forest ecosystems and killing off water animal species during the Devonian geological period about 359 million years ago.

Their research revealed that warming temperatures after an intense ice age could have caused the ozone to collapse. The researchers suggest that the Earth might possibly reach comparable temperatures, thus might face the same consequences that occurred in the past.

The findings of their study are published in the journal Science Advances. Additionally, the research was partly funded by a grant from the National Geographic Society. It was also regulated in collaboration with The Sedgwick Museum of Earth Sciences at the University of Cambridge.

The team collected various rock samples during expeditions in locations in South America. They formed clues as to what was happening at the edge of the melting Devonian ice sheet, which allowed them to compare between the extinction event close to the pole and near the equator.

The rocks were then dissolved in hydrofluoric acid back in the laboratory. The dissolved rocks released microscopic plant spores, which were preserved for hundreds of millions of years. On microscopic examination, the scientists found many of the spores had bizarrely formed spines on their surface.

According to the researchers, the spikes were due to UV radiation damaging their DNA. Furthermore, they found that many spores had dark pigmented walls. These walls were thought to be a protective 'shield' against the increasing and damaging UV levels.

From their findings, the scientists have concluded that during a time of expeditious global warming, the ozone layer collapsed for a short while. Moreover, the ozone collapse exposed life on Earth to harmful UV radiation levels and, therefore, triggered a mass extinction event. This affected life on land and in shallow water at the Devonian-Carboniferous boundary.

From Climate Change to Climate Emergency

Professor John Marshall, the lead researcher from the University of Southampton's School of Ocean and Earth Science, said that our ozone layer is currently in a state of alteration. He adds that they have seen this pattern in the past, where a stimulant or impetus was unnecessary for the phenomenon to kick in.

He also says that current approximate calculations suggest that the Earth will reach similar global temperatures to those of 360 million years ago. Furthermore, they say it is possible that a similar collapse of the ozone layer could occur again, dangerously exposing surface and shallow sea life to harmful radiation.

#### Satellites revolutionize acidification response.

Newton 20 – A freelance writer originally hailing from England, he moved to Berlin in 2012 and hasn’t looked back. Prior to this, he gained a MScEcon in Strategic Studies from Aberystywth, specialising in information strategy and military-media relations. He also finds it awkward to write about himself in the third person. 8/12/20. [Reset, “Satellite Technology Could Hold the Key to Measuring the Ocean’s Increasing Acidification,” <https://en.reset.org/satellite-technology-could-hold-key-measuring-oceans-increasing-acidification-08112020/>] Justin

Advanced satellite technology has the potential to revolutionise the way we see our planet. Satellites equipped with high-tech camera equipment can provide never-seen-before views of Earth and allow researchers to observe vast areas in an instant. Combine this with machine learning algorithms and we’re able to track and discover information about challenging environmental issues – such as deforestation or plastic pollution – using satellite photography.

And some satellites are able to go even further than that. Using specialised camera equipment, satellites can now also be used to measure things generally invisible to the human eye, such as air and sea pollution.

For example, the European Space Agency’s Sentinel-5P satellite, which was launched in 2017, has an advanced suite of tools which can be used to measure various pollutants in the Earth’s atmosphere. Of particular note is the Tropomi (TROPOspheric Monitoring Instrument), a spectrometer capable of scanning the Earth’s atmosphere through ultraviolet (UV), visible (VIS), near (NIR) and short-wavelength infrared (SWIR) spectrums. By detecting fluctuations in these various wave-lengths, the satellite can detect the presence of compounds such as sulphur dioxide and nitrogen dioxide.

However, air pollution isn’t limited to our atmosphere – it’s increasingly making its way into our seas and oceans, where it’s absorbed by seawater and causes ocean acidification.

Examining Our Oceans From Space

Both NASA and ESA are exploring the issue of measuring ocean acidification from space, with their Soil Moisture and Ocean Salinity (SMOS) and Aquarius programmes respectively. The Earth’s oceans have been instrumental in containing climate change, as they can absorb vast amounts of carbon, reducing the global temperature. But, this effect takes its toll. In recent years the ocean’s chemical balance has been shifting with seawater becoming less alkaline and more acidic.

This process has the potential to greatly affect the biodiversity of the ocean, especially in regards to smaller creatures such as pteropods. Increased ocean acidification can act to disrupt the growth of pteropods’ shells, affecting their chances of survival. This is especially important as pteropods form the basis of many ocean food chains.

New research has recently been concluded which looked into the feasibility of measuring ocean acidification from space. Although satellites would be unable to measure the ocean’s pH level – the clearest indication of ocean acidification – it can measure ocean salinity, the amount of salt in the seawater.

For example, NASA’s Aquarius satellite is equipped with devices which can detect and measure the microwaves by blackbody radiation coming from the ocean’s surface. With this information, it can estimate the salinity of the top 2 centimetres of the ocean’s surface. It is possible this information can then be extrapolated and combined with carbon measurements to come to an accurate prediction of ocean acidification. A large international team headed up by the Plymouth Marine Laboratory is currently looking into the feasibility of this model. The project’s lead, Dr Peter Land told RESET:

“The main advantage satellites confer is regular coverage of the entire globe, giving us a far more detailed, synoptic view than is possible with in situ data, especially in regions that are hard to access. The main challenge is whether satellite measurements can estimate ocean acidification parameters with sufficient accuracy to be useful. In this respect, satellites have had a big boost in the last few years with the advent of satellites that measure salinity.”

Are Satellites Up to the Task?

If satellites can perform this role, it could greatly increase the efficiency of ocean acidification studies as well as decrease their costs. Plymouth Laboratory’s Helen Findlay explained that, previously, ocean acidification was measured in situ from ships or moorings which could take water samples and return them to a lab for analysis.

#### Extinction – empirics.

Carrington 19 – Damian is an Environmental Editor for the Guardian. 10/21/19. [Guardian, “Ocean acidification can cause mass extinctions, fossils reveal,” <https://www.theguardian.com/environment/2019/oct/21/ocean-acidification-can-cause-mass-extinctions-fossils-reveal#:~:text=Ocean%20acidification%20can%20cause%20the,66m%20years%20ago%20has%20revealed.&text=This%20spike%20demonstrated%20it%20was,chalky%20shells%20of%20many%20species>.] Justin

Ocean acidification can cause the mass extinction of marine life, fossil evidence from 66m years ago has revealed.

A key impact of today’s climate crisis is that seas are again getting more acidic, as they absorb carbon emissions from the burning of coal, oil and gas. Scientists said the latest research is a warning that humanity is risking potential “ecological collapse” in the oceans, which produce half the oxygen we breathe.

The researchers analysed small seashells in sediment laid down shortly after a giant meteorite hit the Earth, wiping out the dinosaurs and three-quarters of marine species. Chemical analysis of the shells showed a sharp drop in the pH of the ocean in the century to the millennium after the strike.

This spike demonstrated it was the meteorite impact that made the ocean more acidic, effectively dissolving the chalky shells of many species. Large-scale volcanic activity was also considered a possible culprit, but this occurred over a much longer period.

The oceans acidified because the meteorite impact vaporised rocks containing sulphates and carbonates, causing sulphuric acid and carbonic acid to rain down. The mass die-off of plants on land after the strike also increased CO2 in the atmosphere.

“We show ocean acidification can precipitate ecological collapse,” said Michael Henehan at the GFZ German research centre for geosciences in Potsdam, who led the study. “Before we had the idea, but we did not have the empirical proof.”

The researchers found that the pH dropped by 0.25 pH units in the 100-1,000 years after the strike. It is possible that there was an even bigger drop in pH in the decade or two after the strike and the scientists are examining other sediments in even finer detail.

Henehan said: “If 0.25 was enough to precipitate a mass extinction, we should be worried.” Researchers estimate that the pH of the ocean will drop by 0.4 pH units by the end of this century if carbon emissions are not stopped, or by 0.15 units if global temperature rise is limited to 2C.

Henehan said: “We may think of [acidification] as something to worry about for our grandchildren. But if it truly does get to the same acidification as at the [meteorite strike] boundary, then you are talking about effects that will last for the lifetime of our species. It was hundreds of thousands of years before carbon cycling returned to normal.”

The research, published in the journal Proceedings of the National Academy of Sciences, analysed sediments that Henehan encountered by chance, during a conference field trip in the Netherlands. The sediments, which straddle the moment of the impact, lie in caves that were used by people hiding from the Nazis during the second world war. “It was so lucky,” said Henehan.

The rocks contained foraminifera, small-shelled marine organisms. “In the boundary clay, we managed to capture them just limping on past the asteroid impact. But you can see their shell walls were much thinner and poorly calcified after the impact,” he said.

It was the knock-on effects of acidification and other stresses, such as the “nuclear winter” that followed the impact, that finally drove these foraminifera to extinction, he said: “You have the complete breakdown of the whole food chain.” He said oceans also faced additional stresses today, from global heating to widespread pollution, overfishing and invasive alien species.

Phil Williamson, at the University of East Anglia, who was not involved in the research, said: “It is relatively easy to identify mass extinction events in the fossil record, but much harder to know exactly what caused them. Evidence for the role of ocean acidification has generally been weak, until now.”

He said caution was needed in making the comparison between the acidification spike 66m years ago and today: “When the asteroid struck, atmospheric CO2 was naturally already much higher than today, and the pH much lower. Furthermore, large asteroid impacts cause prolonged darkness.”

Williamson added: “Nevertheless, this study provides further warning that the global changes in ocean chemistry that we are currently driving have the potential to cause highly undesirable and effectively irreversible damage to ocean biology.”

Henehan said the generally lower ocean pH 66m years ago might have made shelled organisms more resilient to acidification. “Who knows if our current [marine] system is as well set up to cope with sudden acidification?”

#### Debris cascades triggers global grid shutdown---generator dispersion is dependent on satellites.

Silberg 1/26/14 [Bob Silberg, NASA’s Jet Propulsion Laboratory. “Satellites help power grid keep its balance.” Climate.NASA.Gov. <https://climate.nasa.gov/news/1027/satellites-help-power-grid-keep-its-balance/>] Justin

Imagine a generator pumping more electricity than a nuclear power plant into the grid, but inconsistently and without the grid’s caretakers being able to see what it was doing. How could they maintain the critical balance between generation and consumption that the grid requires? A key to the answer hovers some 22,000 miles overhead.

The amount of electricity fed into an electrical grid at any given moment must equal the amount that is being used at that moment. Too much or too little could damage the millions of electrical devices connected to the grid or even trigger a power outage. Nine of North America’s largest grids have special independent organizations charged with maintaining that balance.

California Independent Service Operator (ISO) manages the grid that serves most of California and a chunk of Nevada. They rebalance the grid’s intake and output every four seconds, using sophisticated algorithms to forecast demand and a variety of ways to adjust the wattage they introduce into the system throughout the day. But they can only manage what they can see: the big power plants that produce the bulk of the system’s electricity. “We can’t see the solar panels on the rooftop of your house,” said Jim Blatchford, the ISO’s short-term forecasting manager. “We don’t know how much they are reducing your demand or feeding back into the grid.” And that’s a significant challenge.

More electricity than a power plant

The nearly 200,000 solar installations on private homes and businesses in California, taken together, generate more electricity than any power plant in the state. Clearly, grid managers need to take them into account to calculate accurately how much electricity the grid should carry.

But this multitude of small solar setups is scattered over a vast area with a wide range of highly variable weather conditions that affect how much sunlight each one receives—and therefore how much electricity it produces—at any given moment. The sun may shine brightly on a rooftop in Bakersfield while a bungalow in Santa Monica is shrouded in fog. When the fog lifts and those panels begin to produce, a morning shower may dampen productivity in San Francisco while a giant cloud bank plays peekaboo with the sun over Sacramento.

Tracking all those solar panels and their ever-changing environments may seem like herding cats, but a company called Clean Power Research (CPR) has developed a solution that the California ISO is currently testing. CPR accumulated information about the state’s small solar installations by playing a role in registering them for rebates. So they know where the solar panels are and the size, angle and shading characteristics of each group.

What remains is to determine how much sunlight reaches each set of solar panels at any given time, and that’s where the Geostationary Operational Environmental Satellite (GOES) system comes in.

CPR uses a stream of data from GOES in real time to characterize how much sunlight each relevant square kilometer of California is receiving and to forecast how the picture is going to change over the course of a week. “If you look at a series of those GOES images, you can track the motion of the clouds,” said Adam Kankiewicz, Solar Research Specialist at CPR. “You can say if it’s gone from here to here in the last hour, we predict that it’s going to go, say, 10 kilometers in that direction in two hours. For short-term forecasting, that's the most accurate method out there.”

Hour by hour

“We model each of those nearly 200,000 systems individually,” said Mark Liffmann, who is Vice President of Business Development, Sales and Marketing at CPR. “We use the irradiance (the measurement of sunlight intensity) to determine how much electricity each system is likely to produce each hour for the next seven days, and then we aggregate those forecasts and feed that into the ISO’s software so they can determine how much generation they’ll need to meet the net load.”

CPR’s software and the ISO’s software engage in an ongoing dialogue to keep the balancing authority up to date. “It needs to happen quickly in real time,” Liffmann said. “You need the ongoing forecast continuously to be able to accurately calculate what solar panels are going to provide and therefore what traditional resources you are going to need to turn on and off.”

California ISO’s Blatchford points out that the monitoring and forecasting that GOES enables can also help his organization determine what to expect from the large, commercial solar stations in its system. Their output is just as dependent on weather conditions as a small rooftop system.

“The sun angle plays a big part in it, too,” he said. “A cloud 10 miles away from the plant could be in between the plant and the sun.”

Despite the challenges they present, having California’s single largest generator in the form of 200,000 widely dispersed solar-panel setups has a big potential upside. “It gives you two advantages,” Liffmann said. “One, you don’t have a single point of failure. If one system goes down, it’s a small percentage of the total generation. The other is that it smooths out a lot of the weather variation. As long as you can forecast it well, it’s a great benefit.”

And the view from 22,000 miles up is indispensible to making those forecasts. “GOES satellites are the only available source for the images we need over North America,” Kankiewicz said.

#### Grid security is an impact filter.

Denkenberger 21 [David Denkenberger, Anders Sandberg, Ross John Tieman, and Joshua M. Pearce, \* assistant professor of mechanical engineering at University of Alaska Fairbanks, “Long-term cost-effectiveness of interventions for loss of electricity/industry compared to artificial general intelligence safety,” 2021, *European Journal of Futures Research*, Vol. 9, Issue 1, https://doi.org/10.1186/s40309-021-00178-z, EA]

Civilization relies on a network of highly interdependent critical infrastructure (CI) to provide basic necessities (water, food, shelter, basic goods), as well as complex items (computers, cars, space shuttles) and services (the internet, cloud computing, global supply chains), henceforth referred to as industry. Electricity and the electrical infrastructure that distributes it plays an important role within industry, providing a convenient means to distribute energy able to be converted into various forms of useful work. Electricity is one component of industry albeit a critical one. Industry provides the means to sustain advanced civilization structures and the citizens that inhabit them. These structures play a critical role in realizing various futures by allowing humanity to discover and utilize new resources, adapt to various environments, and resist natural stressors.

Though industry is capable of resisting small stressors, a sufficiently large event can precipitate cascading failure of CI systems, resulting in a collapse of industry. If one does not temporally discount the value of future people, the long-term future (thousands, millions, or even billions of years) could contain an astronomically large amount of value [18]. Events capable of curtailing the potential of civilization (existential risks, such as human extinction or an unrecoverable collapse) would prevent such futures from being achieved, implying reducing the likelihood of such events is of the utmost importance [100]. Reducing the prevalence of existential risks factors; events, systemic structures, or biases which increase the likelihood of extinction but do not cause extinction by themselves is also highly valuable. Complete collapse or degraded function of industry would drastically reduce humanity’s capacity to coordinate and deploy technology to prevent existential risks, representing an existential risk factor. Consequently, interventions preventing loss of industry, reducing the magnitude of impacts, or increasing speed of recovery could be extremely valuable.

Existential risk research is, by nature, future focused, requiring the investigation of events that have not yet occurred. Futures studies methodologies are often applied to uncover salient trends or events, and explore potential causal structures [54, 123]. Probabilistic modeling techniques can then be used to determine the likelihood of such events occurring, including adequate treatment of uncertainty [101]. The cost-effectiveness modeling approach outlined in this paper is an example of this, attempting to assess the marginal utility of losing industry interventions on improving the long-term future. This approach could guide future efforts to assess the relative cost-effectiveness of interventions for different risks, existential or otherwise. More practically, this research can inform prioritization efforts of industrialized countries by providing estimates of the cost of global industrial collapse, and the utility of resilience interventions. This is relevant to the European Union which has a highly industrialized economy, providing $2.3 Trillion USD of the $13.7 Trillion USD global total of value add manufacturing [122]. The EU has shifted toward a more proactive foresight approach about natural and man-made disasters, noting the importance of rare high-impact events, systemic risks, and converging trends requiring better data and forecasting to drive a more ambitious crisis management system [47]. Still, it is clear that most academic and institutional emphasis has been on “ordinary” rather than extreme disasters, and risks from industry to the public and environment rather than widespread failures of industrial services causing harm.

The integrated nature of the electric grid, which is based on centralized generation makes the entire system vulnerable to disruption.1 There are a number of anthropogenic and natural catastrophes that could result in regional-scale electrical grid failure, which would be expected to halt the majority of industries and machines in that area. A high-altitude electromagnetic pulse (HEMP) caused by a nuclear weapon could disable electricity over part of a continent [16, 48, 66, 93]. This could destroy the majority of electrical grid infrastructure, and as fossil fuel extraction and industry is reliant on electricity [49], industry would be disabled. Similarly, solar storms have destroyed electrical transformers connected to long transmission lines in the past [117]. The Carrington event in 1859 damaged telegraph lines, which was the only electrical infrastructure in existence at the time. It also caused Aurora Borealis that was visible in Cuba and Jamaica [70]. This could potentially disable electrical systems at high latitudes, which could represent 10% of electricity/industry globally. Though solar storms may last less than the 12 h that would be required to expose the entire earth with direct line of sight, the earth’s magnetic field lines redirect the storm to affect the opposite side of the earth [117].

Lastly, both physical [6, 8, 69, 89, 111] and cyber attacks [3, 63, 90, 96, 118, 128, 130] could also compromise electric grids. Physical attacks include traditional acts of terrorism such as bombing or sabotage [130] in addition to EMP attacks. Significant actors could scale up physical attacks, for example by using drones. A scenario could include terrorist groups hindering individual power plants [126], while a large adversary could undertake a similar operation physically to all plants and electrical grids in a region.

Unfortunately, the traditional power grid infrastructure is simply incapable of withstanding intentional physical attacks [91]. Damage to the electric grid resulting in physical attack could be long lasting, as most traditional power plants operate with large transformers that are difficult to move and source. Custom rebuilt transformers require time for replacement ranging from months and even up to years [91]. For example, a relatively mild 2013 sniper attack on California’s Pacific Gas and Electric (PG&E) substation, which injured no one directly, was able to disable 17 transformers supplying power to Silicon Valley. Repairs and improvements cost PG&E roughly $100 million and lasted about a month [10, 102]. A coordinated attack with relatively simple technology (e.g., guns) could cause a regional electricity disruption.

However, a high-tech attack could be even further widespread. The Pentagon reports spending roughly $100 million to repair cyber-related damages to the electric grid in 2009 [57]. There is also evidence that a computer virus caused an electrical outage in the Ukraine [56]. Unlike simplistic physical attacks, cyber attackers are capable of penetrating critical electric infrastructure from remote regions of the world, needing only communication pathways (e.g., the Internet or infected memory sticks) to install malware into the control systems of the electric power grid. For example, Stuxnet was a computer worm that destroyed Iranian centrifuges [73] to disable their nuclear industry. Many efforts are underway to harden the grid from such attacks [51, 63]. The U.S. Department of Homeland Security responded to ~ 200 cyber incidents in 2012 and 41% involved the electrical grid [103]. Nations routinely have made attempts to map current critical infrastructure for future navigation and control of the U.S. electrical system [57].

The electric grid in general is growing increasingly dependent upon the Internet and other network connections for data communication and monitoring systems [17, 112, 118, 127, 135]. Although this conveniently allows electrical suppliers management of systems, it increases the susceptibility of the grid to cyber-attack, through denial of webpage services to consumers, disruption to supervisory control and data acquisition (SCADA) operating systems, or sustained widespread power outages [3, 72, 118, 120]. Thus global or regional loss of the Internet could have similar implications.

A less obvious potential cause is a pandemic that disrupts global trade. Countries may ban trade for fear of the disease entering their country, but many countries are dependent on imports for the functioning of their industry. If the region over which electricity is disrupted had significant agricultural production, the catastrophe could be accompanied by a ~ 10% food production shortfall as well. It is uncertain whether countries outside the affected region would help the affected countries, do nothing, or conquer the affected countries. Larger versions of these catastrophes could disrupt electricity/industry globally. For instance, it is possible that multiple HEMPs could be detonated around the world, due to a world nuclear war [105] or due to terrorists gaining control of nuclear weapons. There is evidence that, in the last 2000 years, two solar storms occurred that were much stronger than the Carrington event [85]. Therefore, it is possible that an extreme solar storm could disable electricity and therefore industry globally. It is conceivable that a coordinated cyber or physical attack (or a combination) on many electric grids could also disrupt industry globally. Many of the techniques to harden the electric grid could help with this vulnerability as well as moving to more distributed generation and microgrids [23, 29, 75, 76, 103, 114]. An extreme pandemic could cause enough people to not show up to work such that industrial functioning could not be maintained. Though this could be mitigated by directing military personnel to fill vacant positions, if the pandemic were severe enough, it could be rational to retreat from high human contact industrial civilization in order to limit disease mortality. The global loss of electricity could even be self-inflicted as a way of stopping rogue artificial general intelligence (AGI) [124]. As the current high agricultural productivity depends on industry (e.g., for fertilizers), it has been assumed that there would be mass starvation in these scenarios [107].

Repairing these systems and re-establishing electrical infrastructure would be a goal of the long term and work should ideally start on it immediately after a catastrophe. However, human needs would need to be met immediately (and continually) and since there is only a few months of stored food, it would likely run out before industry is restored with the current state of preparedness. In some of the less challenging scenarios, it may be possible to continue running some machines on the fossil fuels that had previously been brought to the surface or from the use microgrids or shielded electrical systems. In addition, it may be feasible to run some machines on gasified wood [31]. However, in the worst-case scenario, all unshielded electronics would be destroyed.

#### Debris triggers miscalculated war.

Robert Farley 22, Now a 1945 Contributing Editor, Dr. Robert Farley is a Senior Lecturer at the Patterson School at the University of Kentucky. Dr. Farley is the author of Grounded: The Case for Abolishing the United States Air Force (University Press of Kentucky, 2014), the Battleship Book (Wildside, 2016), and Patents for Power: Intellectual Property Law and the Diffusion of Military Technology (University of Chicago, 2020). 1/9/22. [19 Fourty Five, “Does A Space War Mean A Nuclear War?,” <https://www.19fortyfive.com/2022/01/does-a-space-war-mean-a-nuclear-war/>] Justin

The recent Russian anti-satellite test didn’t tell the world anything new, but it did reaffirm the peril posed by warfare in space. Debris from explosions could make some earth orbits remarkably risky to use for both civilian and military purposes. But the test also highlighted a less visible danger; attacks on nuclear command and control satellites could rapidly produce an extremely dangerous escalatory situation in a war between nuclear powers. James Acton and Thomas Macdonald drew attention to this problem in a recent article at Inside Defense. As Acton and MacDonald point out, nuclear command and control satellites are the connective tissue of nuclear deterrence, assuring countries that they’re not being attacked and that they’ll be able to respond quickly if they are.

For a long time, these strategic early-warning satellites were akin to a center of gravity in ICBM warfare. Nuclear deterrence requires awareness that an attack is underway. Attacks on the monitoring system could easily be read as an attempt to ~~blind~~ an opponent in preparation for general war, and could themselves incur nuclear retaliation. Thus, the nuclear command and control satellites are critical to the maintenance of nuclear deterrence. They make it possible to distribute an order from the chief of government to the nuclear delivery systems themselves. Consequently, their destruction might lead to hesitation or delay in performing a nuclear launch order.

It was only later that the relevance of satellites for conventional warfare became clear. Satellites could reconnoiter enemy positions and, more importantly, provide communications for friendly forces. Indeed, the expansion of the role of satellites in conventional warfare has complicated the prospect of space warfare. States have a clear reason for targeting enemy satellites which support conventional warfare, as those satellites enable the most lethal part of the kill chain, the communications and recon networks that link targets with shooters. Thus, we now have a situation in which space military assets have both nuclear and conventional roles. In a conflict confusion and misperception could rapidly become lethal. If one combatant views an attack against nuclear command and control as a prelude to a general nuclear attack, it might choose to pre-empt.

Nuclear powers have dealt with problems in this general category for a good long while; would a conventional attack against tactical nuclear staging areas represent an escalation, for example? Would the use of ballistic missiles that can carry either conventional or nuclear weapons trigger a nuclear response? Do attacks against air defense networks that have both strategic and tactical responsibilities run the risk of triggering a nuclear response? There’s also the danger that damage to communications networks designated for conventional combat could force traffic onto the nuclear control systems, further confusing the issue.

#### No limited nuclear wars – extinction.

Webber 19 – Dr Philip Webber has written widely on nuclear issues and is Chair of Scientists for Global Responsibility (SGR) – a membership organisation promoting responsible science and technology. We will all end up killing each other and one nuclear blast could do it. 5/18/19. [METRO.UK “We will all end up killing each other and one nuclear blast could do it,” <https://metro.co.uk/2019/05/18/we-will-all-end-up-killing-each-other-and-one-nuclear-blast-could-do-it-9370115/>] Recut Justin

The nuclear armed nations have inadvertently created a global Doomsday machine, built with 15,000 nuclear weapons.

Most (93%) have been built by Russia and in the US, 3,100 of them are ready to fire within hours.

Pre-programmed targets include main cities as well as a range of military and civilian targets across the world primarily in the UK, Europe, US, Russia and China but also in Japan, Australia and South America.

One nuclear blast, one mistake, one cyber attack could trigger it.

But first a reminder about the incredible destructive power of a nuclear weapon. Modern nuclear warheads are typically 20 times larger than either of the two bombs that obliterated Hiroshima and Nagasaki at the end of the Second World War. What just one nuclear warhead can do is unimaginable. We’ve drawn some of the key features to scale against cityscapes in the UK for a Russian SS-18 RS 20V (NATO designation ‘Satan’) 500kT warhead. US submarines deploy a similar weapon – the Trident II Mk5, 475kT warhead. A deafening, terrifying noise will be created, like an intense thunder that lasts for 10 seconds or longer.

After a blinding flash of light bright destroying the retina of anyone looking, and a violent electromagnetic pulse (EMP) knocking out electrical equipment several miles away, a bomb of this size quickly forms an incandescent fireball 850 metres across.

This is about the same height as the world’s tallest building, the Burj Khalifa. Drawn against the London Canary Wharf financial district or the Manchester skyline, the huge fireball dwarfs one Canary Sq. (240m), the South Tower Deansgate (201m) and the Beetham Tower Hilton, (170m). The fireball engulfs both city centres completely, melting glass and steel and forms an intensely radioactive 60m deep crater zone of molten earth and debris. A devastating supersonic blast wave flattens everything within a radius of two to three km, the entire Manchester centre, an area larger than the City of London, with lighter damage out to eight km. Most people in these areas would be killed or very seriously injured.

The fireball quickly rises forming an enormous characteristic mushroom shaped cloud raining highly radioactive particles (fallout). It rises to 60,000 ft (18,000m) – twice the altitude of Everest – and is 15 miles, 24km across.

This is one warhead. There are 10 such warheads on each of Russia’s 46 missiles (460 in total) and 48 on each of eight US Trident submarines (384 in total). In reality, in a nuclear conflict all of these warheads and a further 956 ready-to-fire are likely to be launched.

Whilst this scale of destruction is horrific and hundreds of millions of people would be killed in a few hours from a combination of blast, radiation and huge fires, there are also terrible longer-term effects.

Scientists predict that huge city-wide firestorms combined with very the high-altitude debris clouds would severely reduce sunlight levels and disrupt the world’s climate for a decade causing drought, a prolonged winter, global famine and catastrophic impacts for all life on earth and in the seas due to intense levels of UV with the destruction of the ozone layer.

But even at the level of a few hundred nuclear warheads, the consequences of a nuclear war would be extremely severe across the world far beyond the areas hit directly. A nuclear conflict between India and Pakistan with ‘only’ 100 small warheads would kill hundreds of millions and cause climate damage leading to a global famine. The sheer destructive nature of nuclear explosions combined with long lasting radiation, means that nuclear weapons are of no military use. ‘Enemy’ territory would be unusable for years because of intense radiation – especially when nuclear power stations and reprocessing plants are hit.

Even if your own country is not hit, radiation and climate damage will spread across the globe. No one escapes the consequences.

But the nuclear nations argue that they build and keep nuclear weapons to make sure that they are never used. After all no one would be stupid enough to actually launch a nuclear weapon facing such terrible retaliation? It sounds obvious. If you threaten any attacker with terrible nuclear devastation of course they won’t attack you. That might be true most of the time. It is very unlikely that any country would launch a nuclear attack deliberately. But there are two very major problems. First, a terrorist organisation with a nuclear weapon cannot be deterred in this way. Secondly, there are several ways in which a nuclear war can start by mistake. A report by the prestigious Chatham House in 2014 documents 30 instances between 1962 and 2002 when nuclear weapons came within minutes of being launched due to miscalculation, miscommunication, or technical errors. What prevented their use on many of these occasions was the intervention of individuals who, against military orders, either refused to authorise a nuclear strike or relay information that would have led to launch. Examples include a weather rocket launch mistaken for an attack on Russia, a US satellite misinterpreting sunlight reflecting off clouds as multiple missiles firings, a 42c chip fault creating a false warning of 220 missiles launched at the United States. Such risks are heightened during political crises.

The risk of mistake is very high because, in a hangover from the Cold War, the USA and Russia each keep 900 warheads ready to fire in a few minutes, in a ‘launch on warning’ status, should a warning of nuclear attack come in.

These nuclear weapons form a dangerous nuclear stand-off – rather like two people holding guns to each other’s heads.

With only a few minutes to evaluate a warning of nuclear attack before warheads would strike, one mistake can trigger disaster. A similar nuclear stand-off exists between India and Pakistan.

#### Satellites enable digitalized agriculture – solves food insecurity.

Prof. Dr. Nevin Demirbaş 18 – Professor, Department of Agricultural Economics, Ege University, “Precision Agriculture in Terms of Food Security : Needs for The Future,” [https://www.researchgate.net/publication/328655146\_Precision\_Agriculture\_in\_Terms\_of\_Food\_Security\_Needs\_for\_The\_Future](https://www.researchgate.net/publication/328655146_Precision_Agriculture_in_Terms_of_Food_Security_Needs_for_The_Future,)

The current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to United Nations (UN). With roughly 83 million people being added to the world’s population every year, the upward trend in population size is expected to continue, even assuming that fertility levels will continue to decline (UN, 2017). This means there will be an extra billion people to feed within the next decade. Continuing population and consumption growth will mean that the global demand for food will increase for at least another 50 years. A major correlate of this deceleration in population growth is increased wealth, and with higher purchasing power comes higher consumption and a greater demand for food, all of which add pressure to the food supply system (Godfray et al., 2010; FAO, 2017). At the same time, farmers are experiencing greater competition for land, water, and energy, and the need to curb the many negative effects of food production on the environmentis becoming increasingly clear. The effects of climate change are a further threat. But the world can produce more food and can ensure that it is used more efficiently and equitably (Thornton et al., 2009; Godfray and Garnett, 2014). There is a need for multi-faceted and linked strategies in which different components are explored to ensure sustainable and equitable food security at the global, regional and national level. At the same time, future’s food systems need to be resource efficient and sustainable. Efficient use of water, reduction of soil erosion and degradation to the minimum, minimization of energy input and maximization of yields under uncertain natural conditions are the goal (Hakkim et al., 2016). They pose highest requirements on the underlying information and knowledge infrastructure and make future farming a knowledge business and a very sophisticated management task (Bach and Mauser, 2018). Digitization has increased in importance for the agricultural sector and is described through concepts like Smart Farming (SF), Precision Farming (PF) and Precision Agriculture (PA). These type practices are sciences that is intertwined with several other emerging areas of research and practice (Zhou et al., 2017) such as digital agriculture, decision agriculture, smart agriculture, virtual agriculture, ‘Big-Data’ in agriculture, sustainable agriculture, agriculture 4.0, prescription farming and others (Yost et al., 2018). Technology like GPS, and, in particular, sensors are being used in field cultivation and livestock farming to undertake automatized agricultural management activities. PA or PF is generally defined as information and technology based farm management system to identify, analyse and manage spatial and temporal variability within fields for optimum productivity and profitability, sustainability and protection of the land resource by minimizing the production costs. Increasing environmental consciousness of the general public is necessitating us to modify agricultural management practices for sustainable conservation of natural resources such as water, air and soil quality, while staying economically profitable (Sonka and Cheng, 2015; Webber et al., 2017). Stakeholders, such as farmers, seed producers, machinery manufacturers, and agricultural service providers are trying to influence this process (Schönfeld et al., 2018). These practices are facilitating long-term improvements in order to achieve effective environmental protection. Despite all the positive contributions, the use of such technologies brings with it some controversial issues, particularly data protection.

#### It’s an impact multiplier – causes extinction.

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Extinction and Ecological Collapse More than half of the large animals that once inhabited the Earth have been wiped from it by human action since 1970, according to the Worldwide Fund for Nature’s Living Planet Index.3 So, too, have half the fish in the sea on which humans rely for food.4 Humans are, in the words of the great biologist E. O. Wilson, ‘tearing down the biosphere’, demolishing the very home that keeps us alive.5 Extinction, it should be noted, is a part of life: 99.9 per cent of all species ever to evolve on this planet have disappeared, and new ones like ourselves have arisen to replace them. But extinction rates like today’s – a hundred to a thousand times faster than normal – are a freak occurrence that usually takes tens of millions of years, not mere decades. Animal, plant and marine species are presently vanishing so fast that scientists have dubbed our time “the Sixth Extinction” – the sixth such megadeath in the geological history of the Earth.6 By the end of the present century, Wilson says, it is possible that up to half of the eight million species thought to exist here will be gone. Furthermore, in all previous extinctions, natural events like asteroid strikes and vast volcanic outbursts have been to blame. This will be the only time in the Earth’s history when the wipe-out was caused by a single species. Us.7 [Ommited 178-180] Oxfam, illustrates how just one tenth of humanity consumes five times as much in the way of material resources (expressed here in the form of their carbon footprint) as the poorest half of the world population. The affluent are chiefly responsible for the destruction taking place on a global scale as they seek to sustain lifestyles that the planet can no longer afford or support. The significance of this blind spot around consumption for global food security is very great. As described in earlier chapters, the world food system depends critically on soil, water, nutrients and a stable climate, to supply humanity’s daily need for nutriment – and all of these essential resources are in increasingly short supply, chiefly because of our own mismanagement of them and our collective failure to appreciate that they are finite. On current trends, the existing food system will tend to break down, first regionally and then globally, owing to resource scarcity from the 2020s onward, and especially towards the mid century – unless there is radical change in the world diet and the means by which we feed ourselves. This will lead to increasing outbreaks of violence and war. Nobody, neither rich nor poor, will escape the consequences. It remains an open question whether panicking regimes in Russia, the USA or even France would be ruthless enough to deploy atomic weapons in an attempt to quell invasion by tens of millions of desperate refugees, fleeing famine and climate chaos in their own homelands – but the possibility ought not to be ignored. That nuclear war is at least a possible outcome of food and climate crises was first flagged in the report The Age of Consequences by Kurt Campbell and the US-based Centre for Strategic and International Studies, which stated ‘it is clear that even nuclear war cannot be excluded as a political consequence of global warming’. 15 Food insecurity is therefore a driver in the preconditions for the use of nuclear weapons, whether limited or unlimited. A global famine is a likely outcome of limited use of nuclear weapons by any country or countries – and would be unavoidable in the event of an unlimited nuclear war between America and Russia, making it unwinnable for either. And that, as the mute hands of the ‘Doomsday Clock’ so eloquently admonish, is also the most likely scenario for the premature termination of the human species. Such a grim scenario can be alleviated by two measures: the voluntary banning by the whole of humanity of nuclear weapons, their technology, materials and stocks – and by a global effort to secure food against future insecurity by diverting the funds now wasted on nuclear armaments into building the sustainable food and water systems of the future (see Chapters 8 and 9). Food Security Our demand for food is set to double by the 2060s – potentially the decade of ‘peak people’, the moment in history when the irresistible human population surge may top out at around 10 billion. However, as we have seen, many of the resources needed to supply it agriculturally could halve and the climate for the growing of food outdoors become far more hostile. Why food insecurity is an existential threat to humanity should, by now, be abundantly clear from the earlier chapters of this book: present systems are unsustainable and, as they fail, will pose risks both to civilization and, should these spiral into nuclear conflict, to the future of the human species. The important thing to note in this chapter is that food insecurity plays into many, if not all, of the other existential threats facing humanity. The food sector’s role in extinction, resource scarcity, global toxicity and potential nuclear war has already been explained. Its role in the suppression of conflict is discussed in the next chapter. Its role in securing the future of the megacities, and of a largely urbanised humanity, is covered in Chapter 8. And its role in sustaining humanity through the peak in population and into a sustainable world beyond is covered in Chapter 9. Food clearly has a pivotal role in the future of human population – both as a driver of population growth when supplies are abundant and as a potential driver of population decline, should food chains collapse. It is no exaggeration to state that the fate of civilisation depends on it. Food insecurity affects the progression of pandemic diseases, often in ways that are not entirely obvious. First, new pandemics of infectious disease tend to originate in developing regions where nutritional levels are poor or agricultural practices favour the evolution of novel pathogens such as, for example, the new flu strains seen every year – which arise mainly from places where people, pigs and poultry live side-by-side and shuffle viruses between them – and also novel diseases like SARS and MERS. Second, because totally unknown diseases tend to arise first in places where rainforests are being cut down for farming and viruses hitherto confined to wild animals and birds make an enforced transition into humans. Examples of novel human diseases escaping from the rainforest and tropical savannah in recent times include HIV/AIDS, Hendra, Nipah, Ebola, Marburg, Lassa and Hanta, Lujo, Junin, Machupo, Rift Valley, Congo and Zika.29 And thirdly, because the loss of vital micronutrients from heavily farmed soils and from food itself predisposes many populations to various deficiency diseases – for example, a lack of selenium in the diet has been linked with increased risk from both HIV/AIDS and bowel cancer.30 A key synergy is the way **hunger** and **malnourishment** **exacerbate** the **spread** **of** **disease**, classic examples being the 1918 Global Flu Pandemic which spread rapidly among war-starved populations, or the more recent cholera outbreak in war-torn Yemen. In a fresh twist, Dr Melinda Beck of North Carolina University has demonstrated that obesity – itself a form of malnutrition – may cause increased deaths from influenza by both aiding the virus and suppressing the patient’s immune response.31

### 1AC – Framing

#### Extinction outweighs:

#### A] Structural violence- death causes suffering because people can’t get access to resources and basic necessities

#### B] Mathematically outweighs.

MacAskill 14 [William, Oxford Philosopher and youngest tenured philosopher in the world, Normative Uncertainty, 2014]

The human race might go extinct from a number of causes: asteroids, supervolcanoes, runaway climate change, pandemics, nuclear war, and the development and use of dangerous new technologies such as synthetic biology, all pose risks (even if very small) to the continued survival of the human race.184 And different moral views give opposing answers to question of whether this would be a good or a bad thing. It might seem obvious that human extinction would be a very bad thing, both because of the loss of potential future lives, and because of the loss of the scientific and artistic progress that we would make in the future. But the issue is at least unclear. The continuation of the human race would be a mixed bag: inevitably, it would involve both upsides and downsides. And if one regards it as much more important to avoid bad things happening than to promote good things happening then one could plausibly regard human extinction as a good thing.For example, one might regard the prevention of bads as being in general more important that the promotion of goods, as defended historically by G. E. Moore,185 and more recently by Thomas Hurka.186 One could weight the prevention of suffering as being much more important that the promotion of happiness. Or one could weight the prevention of objective bads, such as war and genocide, as being much more important than the promotion of objective goods, such as scientific and artistic progress. If the human race continues its future will inevitably involve suffering as well as happiness, and objective bads as well as objective goods. So, if one weights the bads sufficiently heavily against the goods, or if one is sufficiently pessimistic about humanity’s ability to achieve good outcomes, then one will regard human extinction as a good thing.187 However, even if we believe in a moral view according to which human extinction would be a good thing, we still have strong reason to prevent near-term human extinction. To see this, we must note three points. First, we should note that the extinction of the human race is an extremely high stakes moral issue. Humanity could be around for a very long time: if humans survive as long as the median mammal species, we will last another two million years. On this estimate, the number of humans in existence in the The future, given that we don’t go extinct any time soon, would be 2×10^14. So if it is good to bring new people into existence, then it’s very good to prevent human extinction. Second, human extinction is by its nature an irreversible scenario. If we continue to exist, then we always have the option of letting ourselves go extinct in the future (or, perhaps more realistically, of considerably reducing population size). But if we go extinct, then we can’t magically bring ourselves back into existence at a later date. Third, we should expect ourselves to progress, morally, over the next few centuries, as we have progressed in the past. So we should expect that in a few centuries’ time we will have better evidence about how to evaluate human extinction than we currently have. Given these three factors, it would be better to prevent the near-term extinction of the human race, even if we thought that the extinction of the human race would actually be a very good thing. To make this concrete, I’ll give the following simple but illustrative model. Suppose that we have 0.8 credence that it is a bad thing to produce new people, and 0.2 certain that it’s a good thing to produce new people; and the degree to which it is good to produce new people, if it is good, is the same as the degree to which it is bad to produce new people, if it is bad. That is, I’m supposing, for simplicity, that we know that one new life has one unit of value; we just don’t know whether that unit is positive or negative. And let’s use our estimate of 2×10^14 people who would exist in the future, if we avoid near-term human extinction. Given our stipulated credences, the expected benefit of letting the human race go extinct now would be (.8-.2)×(2×10^14) = 1.2×(10^14). Suppose that, if we let the human race continue and did research for 300 years, we would know for certain whether or not additional people are of positive or negative value. If so, then with the credences above we should think it 80% likely that we will find out that it is a bad thing to produce new people, and 20% likely that we will find out that it’s a good thing to produce new people. So there’s an 80% chance of a loss of 3×(10^10) (because of the delay of letting the human race go extinct), the expected value of which is 2.4×(10^10). But there’s also a 20% chance of a gain of 2×(10^14), the expected value of which is 4×(10^13). That is, in expected value terms, the cost of waiting for a few hundred years is vanishingly small compared with the benefit of keeping one’s options open while one gains new information.

### 1AC – Underview

#### 1] 1AR theory is legit – anything else means infinite abuse – drop the debater, competing interps, and the highest layer – 1AR are too short to make up for the time trade-off – no RVIs – 6 min 2NR means they can brute force me every time.