### Plan

#### Plan – The appropriation of low Earth orbit by private entities is unjust.

#### We’ll defend an orbital allocation regime operated by a new international regulatory authority operated under the UN. The current “first-come, first-served” model that allows private entities to appropriate low Earth orbit is unsustainable and causes legal uncertainty – careful allocation is key.

Trapp 13 [Timothy; 8-13-2013; JD Candidate @ UIUC Law; University of Illinois Law Review, Vol. 2013 No. 4; “TAKING UP SPACE BY ANY OTHER MEANS: COMING TO TERMS WITH THE NONAPPROPRIATION ARTICLE OF THE OUTER SPACE TREATY” <https://www.illinoislawreview.org/wp-content/ilr-content/articles/2013/4/Trapp.pdf>] brett

Space debris poses a threat to future open access to the space environment. Without some sort of action, the problem will continue to escalate, putting at risk the sustainability of the space around our planet. An international regulatory authority that operated under the U.N. to institute a cap-and-trade regulation system and to allocate LEO orbital trajectories is the best way to curb the space debris problem303 while staying within the mandate of the nonappropriation article of the Outer Space Treaty.304 The allotment of trajectories would ensure that everyone has fair access to the resource, as well as facilitate the reduction of space debris caused by collision.305 A cap-and-trade system would make sure that the proliferation of further debris is curbed, as well as incentivize actors to contribute to cleaning up the space resource.306 Since such an agency would operate under the authority of the U.N., it would be of an international character, similar to the ITU.307 Moreover, since the purpose of the regulation would be to curb the space debris problem, it would fall directly in line with the principle of ensuring continued access to the space resource for all mankind.308 Finally, since the regulation would benefit those nations currently acting in space as well as those who will explore space in the future, without unduly favoring one or the other as some have claimed the ITU allocation procedures have done,309 it is a proportional response to an international concern.310 Thus, the suggested system represents the best way to handle the debris problem without effecting a prohibited appropriation of space.

#### Orbital licensing solves collision risks, debris, and uncertainty far better than private appropriation.

Gangestad 17 [Joseph; March 2017; an expert in orbital mechanics and space-system architectures at The Aerospace Corporation. In addition to publishing several scholarly journal articles in the field of astrodynamics, he authored the articles on “Celestial Mechanics” and “Orbital Motion” for the McGraw-Hill Encyclopedia of Science and Technology. He is also the author of Good Grad! A Practical Guide to Graduate School in the Sciences and Engineering. “ORBITAL SLOTS FOR EVERYONE?” <https://aerospace.org/sites/default/files/2018-05/OrbitalSlots_0.pdf>] brett

Option 3: Orbit Licensing. Just as every operator in space must acquire a license for radio-frequency spectrum, regardless of orbit, it may be necessary to expand the licensing regime to the orbits themselves, whether in LEO, MEO, or GEO. Licensing for orbits, along with the aforementioned disposal requirements, would allow for an enterprise-level assessment of the impact of a proposed satellite or constellation, both on the debris environment as a whole and on the operations of satellites already in orbit. As with spectrum, orbits could be assigned or approved well in advance, and as with flight paths controlled by the FAA, orbits could be managed dynamically at the enterprise level. With active, cross-program flight-safety monitoring of this kind, secondary benefits such as reduced insurance rates may also follow. To make this regulatory regime a reality, the international community would have to come together again, as it did in the 1960s for GEO, and agree on who would manage this licensing, who would perform the enterprise-level analysis, and how it could be realized without strangling the free market. But coordination and management of who goes where in space with what and for how long may be the only sustainable option to ensure reliable access to space in the coming decades.

#### A commons-based approach to orbital licensing is a pre-requisite to effective regulation, ensuring compliance and effective commercialization.

Silverstein & Panda ’21 [Benjamin; a research analyst for the Space Project at the Carnegie Endowment for International Peace; & Ankit; the Stanton Senior Fellow in the Nuclear Policy Program at the Carnegie Endowment for International Peace; 3-9-21; Carnegie Endowment for International Peace; “Space Is a Great Commons. It’s Time to Treat It as Such.” <https://carnegieendowment.org/2021/03/09/space-is-great-commons.-it-s-time-to-treat-it-as-such-pub-84018>] brett

Without new governance agreements, problems related to debris, heavy orbital traffic, and harmful interference will only intensify. Debris in higher orbits can persist for a century or more. The costs of adapting to increasingly polluted orbits would be immense, and the opportunity costs would be even higher. For instance, all else being equal, hardening satellites against collisions increases their mass and volume, in turn raising launch costs per satellite. These costs, rooted in a failure to govern space as a commons, will be borne by all space actors, including emerging states and commercial entities.

EXISTING FORMS OF SPACE GOVERNANCE

A well-designed governance system, founded on a widespread understanding of Earth orbits as a great commons, could temper these risks. Currently, space is not wholly unregulated, but existing regulations are limited both in scope and implementation. Many operators pledge to follow national regulations and international guidelines, but decentralized accountability mechanisms limit enforcement. These guidelines also do not cover the full range of potentially risky behaviors in space. For example, while some space operators can maneuver satellites to avoid collisions, there are no compulsory rules or standards on who has the right of way.

At the interstate level, seminal multilateral agreements provide some more narrow guidance on what is and is not acceptable in space. Most famously, the Outer Space Treaty affirms that outer space “shall be free for exploration and use by all states without discrimination of any kind” and that “there shall be free access to all areas of celestial bodies.” Similar concepts of Earth orbits being a great commons arise in subsequent international texts. Agreements like the Liability Convention impose fault-based liability for debris-related collisions in space, but it is difficult to prove fault in this regime in part because satellite owners and operators have yet to codify a standard of care in space, and thus the regime does not clearly disincentivize debris creation in orbit. Other rules of behavior in Earth orbits have been more successful in reducing harmful interference between satellite operations, but even these efforts are limited in scope.

States have acceded to supranational regulations of the most limited (and thus most valuable) Earth orbits. The International Telecommunication Union (ITU) coordinates, but does not authorize, satellite deployments and operations in geosynchronous orbits and manages radiofrequency spectrum assignments in other regions of space to reduce interference between satellites. These coordination activities are underpinned by the ITU’s constitution, which reminds states “that radio frequencies and any associate orbits . . . are limited natural resources,” indicating a commons-based approach to governing the radiofrequency spectrum. However, the union’s processes are still adapting to new operational realities in low Earth orbit, and these rules were never designed to address issues like debris.

BUILDING ON PRIOR MODELS FOR MANAGING COMMONS

The histories of other great commons provide lessons on how to manage shared space resources meaningfully and effectively. Efforts to minimize damage to other great commons—like the Convention on Long-Range Transboundary Air Pollution and subsequent protocols—offer guidance on how to resolve compliance issues. Notably, the negotiations on the original convention on air pollution involved, among others, the United States and the Soviet Union. This suggests that states can pursue mutual benefits in areas considered great commons even under competitive conditions. More recent negotiations on the convention’s accompanying protocols show that these competing states can even agree on financing a monitoring regime to support progress.

Existing conventions and implementing agreements indicate that states can reach valuable commitments to manage the Earth’s great commons. These governance models protect state interests and preserve the commons themselves. These principles apply to space, but progress on establishing more encompassing space governance principles, enforcement mechanisms, and dispute resolution procedures hinges on states sharing the fundamental view that space is a great commons. Reaching such a consensus is an important first step.

New leadership in prominent spacefaring states can revitalize efforts to recognize space as a commons and can build on established legal standards to pursue commons-related principles for governing Earth orbits. Space actors do not have to resolve all their competing interests based on the debris problem. But negligence, mismanagement, or poorly designed rules may spell disaster for Earth orbits. As a more diverse range of actors with space-based interests emerges, no single actor will be able to unilaterally impose universal rules. States can, however, negotiate agreements to manage commons areas to better pursue national objectives. The only way to effectively govern state and commercial space activities is to settle on and abide by common norms or rules.

New conventions or regulatory mechanisms for governing Earth orbits will not appear overnight, but states can build toward these goals by clarifying their commitments to treat space as a commons and pursuing governance arrangements that reflect this commitment. New policies in the United States should reflect that Earth orbits are a great commons.

However, this is only the beginning of the path toward international governance in space. Developing internal commons-based policies for Earth orbits is only an initial action to create conditions for cooperative regulation of space activities. This domestic policy development effort alone would have limited effect without the necessary next steps: engaging partners and allies to align perspectives and eventually leading negotiations among competitors to mitigate issues like space debris and orbital traffic congestion. Future governance and regulations can leverage commons-based principles to establish accountability mechanisms that preserve the usefulness of Earth orbits for all.

#### No PICs – decks the whole regime.

Hickman 2 [John Hickman and Everett Dolman, \* associate professor in the Department of Government and International Studies at Berry College, “Resurrecting the Space Age: A State-Centered Commentary on the Outer Space Regime,” 2002, *Comparative Strategy*, Vol. 21, Issue 2, https://www.tandfonline.com/doi/abs/10.1080/014959302317350855]

Is the collectivization of all of outer space under international law a permanent disability? Fortunately, the answer is no. Under international law, state parties to a treaty may withdraw from its obligations through negotiation, novation, substitution, cancellation, or, rebus sic stantibus, when events overcome the intent of the original treaty, such as when one or more of the other state parties has ceased to exist. Moreover, Article 17 of the OST articulates a straightforward mechanism for withdrawal:

“Any state party to this treaty may give notice of its withdrawal from the treaty one year after its entry into force by written notification to the Depositary Governments. Such withdrawal shall take effect one year from the date of receipt of this notification.”

Thus a state party need merely announce its intention to withdraw and then wait one year. Withdrawal of a single state party to the treaty, however, would not necessarily terminate the treaty between the other state parties. Yet, the decision of an important state not to be bound by a regime–creating treaty obviously endangers the entire treaty. The decision of the United States or China to withdraw from the OST would have far greater implications for the survival of the international space regime than the same decision by Bangladesh, Burkina Faso, or Papua New Guinea—the equality of states under international law remains nothing more than a useful fiction. For the OST to remain good international law, it must be accepted as such by the major space faring states of the 21st Century: the United States, Russia, the European Union, Japan, and China. One defection from the regime by a member of this group would no doubt lead to its effective collapse, as the remaining space faring states are unlikely to use the kind of coercion necessary to enforce the regime. A more likely response to such a defection is a scramble to make similar claims to sovereignty, based on historical precedent and effective occupation. Similar rushes to stake claims for territory sovereignty in other celestial bodies might follow.

### Advantage

#### Advantage – LEO Appropriation:

#### The “first-come, first-served” approach to usage of low Earth orbit causes unsustainable collisions between mega-constellations and with pre-existing debris.

Runnels ’22 [Michael B.; 1-13-22; an Assistant Professor of Business Law at California State; ABA; “On Clearing Earth’s Orbital Debris & Enforcing the Outer Space Treaty in the U.S.” <https://businesslawtoday.org/2022/01/on-clearing-earths-orbital-debris-enforcing-outer-space-treaty-in-us/>] brett

I. EARTH’S ORBITAL TRAGEDY OF THE COMMONS

Currently, long-dead satellites, spent rocket stages, and other debris from outdated spacecraft remain in Earth orbits, and have been endangering space activities for decades.[34] NASA estimates that there are approximately 27,000 pieces of orbital debris larger than a softball,[35] 500,000 marble-sized pieces of debris, and more than 100 million pieces one millimeter or smaller, orbiting at speeds of up to 17,500 mph.[36] At these speeds, even tiny flecks of paint can damage spacecraft.[37] Much more debris that is too small to track, though large enough to imperil both human spaceflight and robotic missions, also remains in Earth orbits.[38] This untracked debris can lead to potentially dangerous orbital collisions on a regular basis, which is due to the self-generating nature of orbital debris once the amount of debris in orbit reaches a critical mass.[39] Succinctly explaining this phenomena in the New Yorker Magazine, Raffi Khatchadourian writes that:

[e]ven a minuscule shard could smash a satellite to pieces, dispersing more high-velocity debris. If the population of objects became dense enough, collisions would trigger one another in an unstoppable cascade. The fragments would grow smaller, more numerous, more uniform in direction, resembling a maelstrom of sand—a nightmare scenario that became known as the Kessler syndrome. At some point, the process would render all of near-Earth space unusable. Theoretically, Kessler mused, our planet could acquire a ring akin to Saturn’s, but made of garbage.[40]

Simulations of the evolution of orbital debris suggest that LEO is currently in the protracted initial stages of the Kessler syndrome.[41]

Into this debris field, companies are launching satellites at an exponential rate to build mega-constellations of communications satellites.[42] In just two years, the number of active and defunct satellites in LEO has increased by over 50% to roughly 5,000 as of March 30, 2021.[43] SpaceX alone launched 1,740 satellites in construction of its Starlink mega-constellation since 2019,[44] received authorization to launch an additional 30,000 Starlink satellites by the FCC in 2021,[45] now accounts for over half of close encounters between two spacecraft,[46] and is projected to be involved in 90% of all close approaches. Quoting Professor Lewis’s description of the likely scenario of cascading orbital debris created by SpaceX’s Starlink mega-constellation, Pultarova writes that:

[i]n a situation when [satellite operators] are receiving alerts on a daily basis, you can’t maneuver for everything … . The maneuvers use propellant, the satellite cannot provide service. So there must be some threshold. But that means you are accepting a certain amount of risk. The problem is that at some point, you are likely to make a wrong decision.[47]

Other multinational corporations have similar mega-constellation plans, including Amazon,[48] OneWeb,[49] and Telesat.[50]

II. FCC REGULATION OF SATELLITE MEGA-CONSTELLATIONS INCENTIVIZES THE CREATION OF ORBITAL DEBRIS

The international legal regime governing space activities was created at a time when those activities were almost exclusively conducted by government actors.[51] Consequently, the domestic laws implementing these international legal obligations reflect the fact that space was largely the domain of government.[52] With corporate actors increasingly becoming involved in space activities,[53] domestic laws must ensure that corporate space activities are properly authorized and regulated, both for domestic policy purposes and ensuring that such activities comply with international legal obligations.[54] While the domestic legal regime is well-developed regarding established corporate activities (such as the early regulation of telephone and television satellite communications[55]), the current proliferation of satellite mega-constellations[56] exposes a void in this legal regime.[57]

Regarding the allocation of geostationary orbits (“GEO”),[58] FCC regulations implement U.S. obligations as a member of the International Telecommunications Union (“ITU”). The ITU is the United Nations treaty organization responsible for international telecommunications, including the allocation of global radio spectrum and satellite orbits.[59] These coordination activities are underpinned by the ITU’s constitution, which reminds States “that radio frequencies and any associated orbits … are limited natural resources and that they must be used rationally, efficiently and economically … so that countries … may have equitable access to those orbits,”[60] indicating a commons-based approach to governing GEO. However, no corresponding international rules exist for allocating LEO orbits, giving rise to the FCC’s current practice of assigning orbital shells to mega-constellations on a first-come, first-served basis.[61]

Given the exoskeleton-like nature of mega-constellations unfurling around the Earth,[62] and the orbital debris likely to result from their deployment,[63] any further addition of satellites to these orbital shells could become prohibitively dangerous.[64] Such a de facto occupation of orbital shells is arguably in violation of the OST’s language that space be the “province of all mankind,”[65] and there be no “national appropriation” of outer space “by means of use or occupation, or by other means.” [66] Moreover, the FCC assigns LEO orbits without either formally assessing the effects on the use of LEO orbits by other countries[67] or the likely orbital debris-related environmental impacts to LEO orbits resulting from satellite mega-constellations.[68] Under this legal regime, there is neither recognition by the FCC that LEO orbits are a finite resource[69] nor that space and Earth environments are indeed connected.[70] In this regulatory void, multiple tragedies of the commons are likely to occur,[71] particularly tragedies caused by orbital debris.[72]

III. HOW FCC REGULATORY PRACTICES ARGUABLY VIOLATE THE OST

As noted earlier, the OST is the foundation of all international space regulation.[73] Furthermore, the Liability Convention was adopted to clarify the intent of Article VII of the OST.[74] While the Liability Convention does not specifically address orbital debris, as the problem was considered “relatively exotic” at the time of its adoption, it arguably creates a remedial mechanism for orbital debris damage.[75] However, a State is only liable for damage to another State’s space objects if “the damage is due to [the State’s] fault or the fault of persons for whom [the State] is responsible.”[76] Moreover, it is difficult to demonstrate fault with regard to the space environment, as collecting and producing physical evidence is impossible in most instances.[77] As such, neither the OST nor Liability Convention compellingly disincentivize debris creation in orbit.

The Space Act, which exempts companies from regulatory oversight until 2023,[78] leaves in place the FCC’s current practice of assigning orbital shells to mega-constellations on a first-come, first-served basis,[79] which is problematic for three reasons. First, due to the exoskeleton-like nature of mega-constellations unfurling around the Earth,[80] and the orbital debris likely to result from their deployment,[81] though FCC regulators are not claiming sovereignty over these orbital shells, allowing national companies to saturate them with satellites could constitute appropriation of outer space by “other means,” which is arguably in violation of Articles I, II, and IX of the OST.[82] Second, unlike the FCC’s allocation of GEO orbits, which is limited by the ITU’s constitutional principle that “any associated orbits … are limited natural resources and that they must be used rationally, efficiently and economical,”[83] no similar commons-based principle limits the FCC’s allocation of LEO orbits.[84] This practice is arguably in violation of NEPA,[85] which “requires federal agencies to take a hard look at the environmental consequences of their projects before taking action.”[86] Third, while the FCC’s 2020 “Mitigation of Orbital Debris in the New Space Age” guidelines[87] may appear to substantively address the cascading problems caused by orbital debris,[88] they only require disclosure of whether mitigation plans exist, not any statement or analysis of whether the plans are effective.[89] Responding to the National Science Foundation and Department of Energy’s request to assess the possible growth and impact of future mega-constellations on orbital debris under the FCC’s enforcement regime, a recent JASON Report found that the FCC’s guidelines:

… fall well short of what the FCC evidently thinks are required for safe traffic management in space, the new constraints on applicants are minimal … are not retroactive for existing licenses … so an applicant could meet these new FCC regulations and still suffer the catastrophic [debris creation] seen in our rate equations.[90]

The toothlessness of these guidelines underwrite the economic incentive for satellite companies to continue viewing their orbital debris as externalities incidental to the costs of doing business.[91]

By way of illustration, the worst known space collision in history occurred when the U.S. telecommunication satellite, Iridium 33, and Russia’s defunct military satellite, Kosmos-2251, collided and spawned over 1,000 pieces of orbital debris larger than 4 inches.[92] Many of these fragments were then involved in further orbital incidents.[93] Of the 95 Iridium satellites launched, 30 malfunctioned and remain stuck in LEO.[94] When Iridium CEO Matt Desch was asked if Iridium would be willing to fund the removal of their debris, he said that it would, “for a low enough cost.”[95] Desch somewhat jokingly floated the idea of paying $10,000[96] per deorbit while acknowledging, “[I] expect the cost is really in the millions or tens of millions, at which price I know it doesn’t make sense,” and argued that there is no financial incentive for removing his company’s orbital debris, explaining that “[i]ncremental ops cost saved is zero. Decreased risk to my network equals zero (all are well below). Decreased regulatory risk is zero (I spend the $$, and someone else runs into something). Removing 1 or 2 things from a catalog of 100,000 is perhaps worth only PR value.”[97]

Professor Hugh Lewis, Head of the Aeronautics Research Group at the University of Southampton, and Europe’s leading expert on space debris, highlights the consequences of such an inadequate orbital debris mitigation regime, arguing that:

[w]e place trust in a single company to do the right thing … [and] are in a situation where most of the maneuvers we see will involve Starlink. [T]hey are the world’s biggest satellite operator, but they have only been doing that for two years so there is a certain amount of inexperience … SpaceX relies on an autonomous collision avoidance system to keep its fleet away from other spacecraft. That, however, could sometimes introduce further problems. The automatic orbital adjustments change the forecasted trajectory and, therefore, make collision predictions more complicated. Starlink doesn’t publicize all the maneuvers that they’re making … [which] causes problems for everybody else because no one knows where the satellite is going to be and what it is going to do in the next few days.[98]

Further echoing the problems of placing singular trust in SpaceX, for example, to do the right thing in this new space age, its terms of service for beta users of its Starlink mega-constellation broadband service are revealing in this regard, as one clause provides that:

[f]or services provided on Mars, or in transit to Mars via Starship or other colonization spacecraft, the parties recognize Mars as a free planet and that no Earth-based government has authority or sovereignty over Martian activities. Accordingly, Disputes will be settled through self-governing principles, established in good faith at the time of the Martian settlement.[99]

As failing to recognize the applicability of the OST to the planet Mars is arguably in violation of the OST,[100] any general expectation that the company now responsible for over half of near collisions in LEO[101] would do the right thing is unrealistic. Accordingly, the FCC’s laissez-faire enforcement regime is in substantive need of reform in a manner that ensures compliance with the OST’s language of prohibiting claims of “national appropriation” of outer space “by other means” and promoting the peaceful use and exploration of space for the “benefit and in the interests of all mankind.”[102]

#### 1 – Uncertainty over ownership and collisions between constellations trigger great power conflict over space.

Goswami 2-20 [Namrata; 2-20-22; an independent scholar on space policy, and an expert on the geopolitics of space; MarshMcLennan; “Low Earth Orbit: The Next Arena of Political Tension” <https://www.brinknews.com/low-earth-orbit-the-next-arena-of-political-tension/>] brett

Low Earth orbit — or LEO — is becoming increasingly commercialized, with large numbers of private satellites being launched or in orbit. However, it is also increasingly seen as a national security realm where tensions are building between the USA, Russia and China.

BRINK spoke to Namrata Goswami, an independent scholar on space policy, and an expert on the geopolitics of space. In 2020, she co-authored the book Scramble for the Skies: The Great Power Competition to Control the Resources of Outer Space.

GOSWAMI: Low Earth orbit has historically been seen as critical for military operations, intelligence gathering and national security purposes. What has changed today is that it is also becoming a very important area for supporting telecommunications, satellite internet, weather forecasting and navigation and global positioning systems.

Government agencies, especially in the U.S, and to an extent in China and India, are starting to support private sector companies in building their commercial space capability, and there has been an exponential rise in the commercialization of LEO. You can see that with companies like SpaceX, OneWeb and China’s private companies that are building small satellites for telecommunication and satellite internet purposes.

NASA Is Starting to Step Back in Favor of the Private Sector

BRINK: Does it mean that NASA is intentionally withdrawing from this area of space?

GOSWAMI: NASA is starting to use its capability, its expertise, its historical legacy to build up the private space sector in the U.S. and actually fund and contract out several different avenues to support that. So, recently, NASA signed agreements with four U.S. companies to build commercial space stations: Blue Origin, Nanoracks, Northrop Grumman and Axiom Space.

There has been a lot of debate in the U.S. as to whether to extend the International Space Station, of which the U.S is the key actor and which is the largest installation in low Earth orbit.

Just recently, the U.S. administration extended the life of the International Space Station to 2030. The original plan was to close the space station and de-orbit it by 2024, but it has now got a new lease of life. So NASA will continue to play a role in supporting the International Space Station, but you will also have private companies like Axiom Space, Nanoracks, Northrop Grumman and Blue Origin developing their own commercial space stations as well. So NASA is not really getting out of the LEO, but it is starting to take a secondary role.

BRINK: What are the main commercial activities in LEO?

GOSWAMI: When we’re talking about LEO, that’s anywhere from about a hundred kilometers above the Earth to about 36,000 kms above Earth.

Everything further than 36,000 kms is seen as cislunar space, i.e., between the Earth and the moon, and that’s where geostationary orbit is, which is basically national security satellites and some commercial satellites. Then, anything beyond the moon, which is about 384,400 kms away, is seen as deep space.

From nothing, China’s commercial space sector has actually been able to register about $3 billion in investment annually since 2016 because of state support.

In the LEO, you have weather satellite services, you have support for navigation, and satellite internet is becoming a very important area of investment. The other important areas that low earth satellite services can also help are agriculture and farming by offering data on weather that can predict where you can actually harvest and also data for fisheries.

LEO is very much connected to the life we live today on Earth, including services such as e-commerce and tele-education. That’s why the low Earth orbit area is getting so critical.

An Absence of Regulation

BRINK: Do you see LEO becoming a venue for political tension?

GOSWAMI: There could be tensions, not just based on the different ideological commitments of different nations, but also in terms of the fact that low Earth orbit is not regulated.

So unlike geostationary orbit, which is regulated by the International Telecommunication Union, in low Earth orbit, all that is required from the different spectrum/orbital slots is a license from national space agencies. If you’re a U.S. company, you apply to the Federal Communications commission, and they will give you a license to basically launch your satellite.

Political tensions can come in regarding these orbital slots — they’re on a first-come, first-serve basis. For example, a Chinese company like GalaxySpace, which wants to launch 142 5G satellites, might want a similar orbital slot to SpaceX, an American company. This could lead to tension, because we do not have a regulatory commission to deal with these issues in low Earth orbit.

It could also happen that you might accidentally run into each other’s satellites because there is no international body that mandates where the satellites are. China’s national space regulatory body has registered about 12,992 satellites to be launched by 2030. India also wants to launch thousands of satellites.

4,550 Satellites Already and Many More to Come

We are talking about a scenario that is very different from the Cold War, when there were not that many satellites. Today, we have about 4,550 satellites in low Earth orbit, according to the Union of Concerned Scientists database, which is one of the most updated. And soon, we could have thousands more.

Companies do not want to spend money on maneuvering their satellites in space because that’s expensive. You have to have fuel. And so it could be that one company might fit its satellites to maneuver, but some other company from another country might not do that. And that could lead to lack of compliance.

There is no common platform where different countries and companies can share data on where their satellites are. This could lead to accidents or even to the deliberate destruction of satellites as well during conflict. In 2019, the European Space Agency had to maneuver one of its satellites because it came very close to a SpaceX satellite and its communication channel to SpaceX was via an email which SpaceX didn’t receive.

#### That escalates to terrestrial war.

Mecklin ’22 [John; 1-17-22; editor in chief of the Bulletin of the Atomic Scientists. “Why the final frontier should not become the final battleground” <https://www.tandfonline.com/doi/full/10.1080/00963402.2021.2020988>] brett

Indeed, the rise of the private sector in space has complicated the security situation for space-faring nations. As Victoria Samson of the Secure World Foundation notes in “The complicating role of the private sector in space,” there are some 4,800 active satellites in orbit around Earth, and 1,850 of them belong to Elon Musk’s SpaceX’s Starlink internet service.

And this is only the first wave; there are, Samson writes, plans for mega-constellations that could wind up putting more than 100,000 new satellites in low Earth orbit. Even a small fraction of that number will force a fundamental shift: Musk and other wealthy private sector space cowboys will become major players in space, and some countries – including, particularly, Russia – may feel threatened by the change. “It is important to work to develop new governance of space to meet the emerging needs of this ecosystem. Otherwise,” Samson writes in understated prose, “we run the risk of inadvertent escalation and even conflict in space that can extend down to Earth.”

As an old television series1 and the exploits of the early human, chimp, and canine astronauts remind us, space can be an inspiring frontier. It has already provided new and almost magical capabilities in communications, navigation, and the monitoring of natural resources and the climate that could expand vastly, for the good of all, if space is managed as a cooperative commons rather than a potential field of battle. “There ought to be some understanding that those things are there for the good of mankind,” Latiff told me. “We’re not talking just about war-fighting and national security here.”

#### **No checks on escalation.**

MacDonald ’18. Bruce W. MacDonald, professor at the Johns Hopkins University School of Advanced International Studies (SAIS), ("Outer Space; Earthly Escalation? Chinese Perspectives on Space Operations and Escalation," August 2018, *NSI* white paper, <https://nsiteam.com/social/wp-content/uploads/2018/08/SMA-White-Paper_Chinese-Persepectives-on-Space_-Aug-2018.pdf>, accessed 7-14-2019) bm

Challenges across all five phases: Another escalation threat is the inexperience that nations share in the space and cyber domains, unlike in conventional domains of conflict and in the nuclear domain to a lesser extent. This inexperience gives rise to a “sorcerer’s apprentice” problem, placing leaders at risk of making potentially unwise judgment calls without a full grasp of their implications. The space and cyber domains are sufficiently new and dynamic that such decisions are highly likely. Adding to this uncertainty is the ever-growing interdependence of infrastructures within and among advanced countries, making the impact of major attacks against a country’s space and/or cyber infrastructures inherently unknowable. In considering all these factors, it is important to keep in mind that events in space do not happen in isolation. Any space conflict would likely be part of a multidimensional field of play, with space being important because of the effects it has on the earth. Significant instability in space is unlikely to lead to war if there is stability in other domains and in the larger geopolitical relationship between participants, while conflict could easily spread to a stable space domain if war in other domains appeared preferable to the alternative. While any use of nuclear weapons would pose a serious threat of escalation to full-scale nuclear war, any use of space or cyber offense would not pose a comparable escalation threat. That said, a series of reciprocal escalations could easily become unstable. No clear-cut escalation barrier exists in the space and cyber domains, and given the short-term tactical benefits of escalating ahead of an adversary, each additional escalation could create incentives for further escalation that an adversary would not always anticipate. Escalation in space, then, is a slippery slope with few off-ramps.

#### Nuclear war causes extinction.

Trevithick and Rogoway ’19 [Joseph and Tyler; February 27; Military Analyst, M.A. in Conflict Resolution from Georgetown University, B.A. in the History and Policy of International Relations at Carnegie-Mellon University; Defense Journalist; The Drive, “Yes, India And Pakistan Could End The World As We Know It Through A Nuclear Exchange,” <https://www.thedrive.com/the-war-zone/26674/yes-india-and-pakistan-could-end-the-world-as-we-know-it-through-a-nuclear-exchange>] brett

A global threat

India and Pakistan's nuclear arsenals are tiny compared to those of the [United States and Russia](http://thedrive.com/the-war-zone/26013/russia-says-its-own-new-weapons-are-exempt-after-accusing-u-s-of-violating-nuclear-arms-deal), and these weapons are focused primarily on deterring each other, but that does not mean they're purely regional threats. Unlike conventional weapons, nuclear weapons create lasting and far-reaching effects that scientists have posited could upend life on Earth if warring parties were to use them in sufficient numbers.

[In 2012](http://climate.envsci.rutgers.edu/pdf/RobockToonSAD.pdf), Alan Robock, a distinguished professor in the Department of Environmental  Sciences and Associate Director of the Center for Environmental Prediction at Rutgers University, and Owen Brian Toon, a professor in the Department of Atmospheric and Oceanic Sciences and a research associate at  the Laboratory for Atmospheric and Space Physics at the University of Colorado, Boulder, argued that it might not take a large amount of nuclear weapons to create a scenario commonly known as "[Nuclear Winter](https://en.wikipedia.org/wiki/Nuclear_winter)."

In general, this hypothesized event occurs when smoke and soot from nuclear explosions block significant amounts of sunlight from reaching the earth's surface, leading to a precipitous drop in temperatures that results in mass crop failure and widespread famine.

Robcock and Toon summarized their findings, which were based in part on their previous work, in an article in the Bulletin of The Atomic Scientists, [writing](http://climate.envsci.rutgers.edu/pdf/RobockToonSAD.pdf):

"Even a 'small' nuclear war between India and Pakistan, with each country detonating 50 Hiroshima-size atom bombs – only about 0.03 percent of the global nuclear arsenal's explosive power – as airbursts in urban areas, could produce so much smoke that temperatures would fall below those of the [Little Ice Age](https://en.wikipedia.org/wiki/Little_Ice_Age) of the fourteenth to nineteenth centuries, shortening the growing season around the world and threatening the global food supply. Furthermore, there would be massive ozone depletion, allowing more ultraviolet radiation to reach Earth's surface. Recent studies predict that agricultural production in parts of the United States and China would decline by about 20 percent for four years, and by 10 percent for a decade.

The bomb the United States dropped on Hiroshima Japan, known as [Little Boy](https://en.wikipedia.org/wiki/Little_Boy), was an inefficient and essentially experimental design with a yield of around 15 kilotons. The reported results from [Indian](https://en.wikipedia.org/wiki/List_of_nuclear_weapons_tests_of_India) and Pakistani nuclear testing indicate that both countries can meet this threshold and both countries' weapons programs have almost certainly matured in the decades since.

In previous studies, Robcock, working with others, postulated that temperature changes could begin within 10 days of a limited nuclear exchange and the effects from the detonations of 100 nuclear weapons in the 15-kiloton class would directly result in the deaths of [at least 20 million people](http://www.nucleardarkness.org/warconsequences/fivemilliontonsofsmoke/). The second order impacts would be even worse in the years that followed.

In 2014, Michael Mills and Julia Lee-Taylor, both then working at the federally-funded National Center for Atmospheric Research's (NCAR) Earth System Laboratory, authored another paper with Robcock and Toon. This [study concluded](https://web.archive.org/web/20140308191334/http:/acd.ucar.edu/~mmills/pubs/2014_EarthsFuture_Mills_et_al.pdf) again that detonation of 100 15-kiloton yield bombs in a purely regional conflict would result in "multi-decadal global cooling" and "would put significant pressures on global food supplies and could trigger a global nuclear famine."

It is important to note that[critics have questioned](https://en.wikipedia.org/wiki/Nuclear_winter#Critical_response_to_the_more_modern_papers) whether the Nuclear Winter concept relies on too many assumptions and would ever actually occur. At the center of many of these rebuttals are debates about whether the nuclear explosions would truly create the amount of smoke and soot necessary for major climate change, as well as the specific conditions for those particles to remain in the atmosphere for a prolonged period of time.

The studies here do indicate significant impacts based on a relatively limited number of nuclear detonations of smaller yield devices, though. But even if the impacts are less pronounced than projected in this particular scenario, they could be far more severe if India and Pakistan were to use a larger number weapons and/or ones of higher yields, which both belligerents readily have.

In addition, Nuclear Winter is just one of the potential things that might happen following a nuclear exchange between the longtime foes. A detonation of dozens of nuclear weapons, even small ones, would throw hazardous nuclear fallout [into the air](http://thedrive.com/the-war-zone/19450/u-s-training-for-arctic-nuclear-satellite-disaster-amid-russian-weapons-developments) that, depending on the weather pattern, could carry that material [far and wide](https://futureoflife.org/background/us-nuclear-targets/?cn-reloaded=1#nukemap), causing both near- and short-term health impacts. The various [ground zeroes](https://nuclearsecrecy.com/nukemap/) themselves would be irritated and potentially hazardous for many years to come.

Depending on where the detonations occur, a nuclear exchange could potentially cut people off from critical water and food supplies, putting increased and potentially unsustainable strains on uncontaminated areas.  After the Chernobyl nuclear power plant, situated in Ukraine, [melted down and exploded](https://en.wikipedia.org/wiki/Chernobyl_disaster) in 1986, authorities established a 1,000 square mile restricted access "[exclusion zone](https://en.wikipedia.org/wiki/Chernobyl_Exclusion_Zone)" that remains in place today.

There would also be a major danger of second-order "spillover" effects, as individuals fled affected areas, putting economic and political strains on neighboring regions. This could inflame existing tensions not directly related to the inter-state conflict between India or Pakistan or lead to all new and potentially violent competition for what might already be limited resources. India has already threatened to [weaponize water access](https://www.nytimes.com/2019/02/21/world/asia/india-pakistan-water-kashmir.html) in its latest spat with the Pakistanis.

Any serious impacts on food and water supplies, or other economic upheavals as a direct or indirect result of the conflict, would have cascading impact across South Asia and beyond, as well. The very threat of a potential India-Pakistan war of any kind already caused [some negative reactions](https://www.cnbc.com/2019/02/27/indian-air-force-plane-crashes-in-kashmir-says-indian-police-official.html) in regional financial markets. Those markets would certainly collapse after an unprecedented nuclear exchange actually occurred, and that is before the long-term physical impacts of such an event would even manifest themselves.

Overall, we are talking about a sudden and dramatic geopolitical, financial, and environmental shift that would change our reality in a matter of hours. Even then, the darkness, both figuratively and literally, that could propagate over the weeks, months, and years would be far more damaging.

How great is the risk?

So far, India and Pakistan have not made any clear indications that the fighting is close to crossing their nuclear thresholds. Pakistan's warnings about the [risks of escalation](http://thedrive.com/the-war-zone/26642/pakistan-promises-retaliation-makes-nuclear-threats-after-indian-jets-bomb-its-territory) seem more calculated to try and prompt India to back down.

India itself has a so-called "no first use" policy, which means it has publicly pledged to use its nuclear weapons only in retaliation to a nuclear strike. However, experts have increasingly called into question whether this is truly the case and whether India might be developing delivery systems more suited to a first strike should there be a need to shift policies.

Pakistan, however, does not have a no first use policy and has insisted on its right to employ nuclear weapons to defend itself even in the face of purely conventional threat. Pakistani officials have, in the past, [specifically cited this policy](https://www.cfr.org/event/promoting-us-pakistan-relations-future-challenges-and-opportunities) as way of deterring India, which has a much larger and in some cases more advanced conventional force, and preventing larger wars.

The concern, then, is that this policy appears to have failed, at least to some degree, with India's strike on undisputed Pakistani territory on Feb. 26, 2019. India, however, did not target Pakistani forces in that instance and exchanges between the two countries have been limited, at least so far, to the disputed Jammu and Kashmir region, where violent skirmishes occur semi-regularly without precipitating a larger confrontation.

We can only hope that the two countries will find a diplomatic solution to this latest conflict and avoid any further escalation. If things were to spiral out of control and lead to the use of nuclear weapons, it would be something that would threaten all of humanity.

#### 2 – Ineffective governance causes unmanageable debris – that cascades and renders existing and future satellites unusable.

Boley & Byers ’21 [Aaron C., Department of Physics and Astronomy @ The University of British Columbia\*, and Michael, Department of Political Science @ The University of British Columbia; Published: 20 May 2021; Scientific Reports; “Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth,” <https://www.nature.com/articles/s41598-021-89909-7>] brett

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 filed 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. The 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 insufficient attention, including changes to the chemistry of Earth’s upper atmosphere and increased dangers on Earth’s surface from re-entered debris. The 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 different national laws. Regardless of the law-making forum, mega-constellations require a shift 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.

Thousands 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. There 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, spacecraft 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. The addition of satellite mega-constellations and the general proliferation of low-cost satellites in LEO stresses the environment further5,6,7,8.

Results

The overall setting

The 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 defines NewSpace, an era of dominance by commercial actors. Before 2015, changes in the total on-orbit objects came principally from fragmentations, with effects of the 2007 Chinese anti-satellite test and the 2009 Kosmos-2251/Iridium-33 collisions being evident on the graph.

Figure 1

[Figure 1 omitted]

Cumulative on-orbit distribution functions (all orbits). Deorbited objects are not included. The 2007 and 2009 spikes are a Chinese anti-satellite test and the Iridium 33-Kosmos 2251 collision, respectively. The recent, rapid rise of the orange curve represents NewSpace (see "Methods").

Full size image

Although the volume of space is large, individual satellites and satellite systems have specific functions, with associated altitudes and inclinations (Fig. 2). This 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, after 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.

Figure 2

[Figure 2 omitted]

Orbital distribution and density information for objects in Low Earth Orbit (LEO). (Left) Distribution of payloads (active and defunct satellites), binned to the nearest 1 km in altitude and 1° in orbital inclination. The centre of each circle represents the position on the diagram, and the size of the circle is proportional to the number of satellites within the given parameter space. (Right) Number density of different space resident objects (SROs) based on 1 km radial bins, averaged over the entire sky. Because SRO objects are on elliptical orbits, the contribution of a given object to an orbital shell is weighted by the time that object spends in the shell. Despite significant parameter space, satellites are clustered in their orbits due to mission requirements. The emerging Starlink cluster at 550 km and 55° inclination is already evident in both plots (Left and Right).

Full size image

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. The 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 different national regulatory regimes, are soon likely to follow.

Enhanced collision risk

Mega-constellations are composed of mass-produced satellites with few backup systems. This 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 difficult to project. Figure 3 is similar to the righthand portion of Fig. 2 but includes the Starlink and OneWeb mega-constellations as filed (and amended) with the FCC (see “Methods”). The large density spikes show that some shells will have satellite number densities in excess of n=10−6 km−3.

Figure 3

[Figure 3 omitted]

Satellite density distribution in LEO with the Starlink and OneWeb mega-constellations as filed (and amended) with the FCC. Provided that the orbits are nearly circular, the number densities in those shells will exceed 10–6 km−3. Because the collisional cross-section in those shells is also high, they represent regions that have a high collision risk whenever debris is too small to be tracked or collision avoidance manoeuvres are impossible for other reasons.

Full size image

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-than-fully transparent about events13 in LEO.

Despite the congestion and traffic management challenges, FCC filings 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 filings 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 after one year. Thus, 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 confined to their local orbits, either. The India 2019 ASAT test was conducted at an altitude below 300 km in an effort 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 affect all operators in LEO.

Even if debris collisions were avoidable, meteoroids are always a threat. The cumulative meteoroid flux15 for masses m > 10–2 g is about 1.2 × 10–4 meteoroids m−2 year−1 (see “Methods”). Such masses could cause non-negligible damage to satellites16. Assuming a Starlink constellation of 12,000 satellites (i.e. the initial phase), there is about a 50% chance of 15 or more meteoroid impacts per year at m > 10–2 g. Satellites will have shielding, but events that might be rare to a single satellite could become common across the constellation.

One partial response to these congestion and collision concerns is for operators to construct mega-constellations out of a smaller number of satellites. But this does not, individually or collectively, eliminate the need for an all-of-LEO approach to evaluating the effects of the construction and maintenance of any one constellation.

#### **Satellites secure MAD – solves nuke war.**

Johnson ’14 [Les, Baen science fiction author, popular science writer, and NASA technologist. “Living without satellites”. <https://www.baen.com/living_without_satellites>.] brett

Satellite imagery is used by the military and our political leaders to maintain the peace. When your potential adversaries can’t hide what they’re doing, where their armies are moving and what they are doing with their civilian and military infrastructure, then the danger of surprise attack is diminished. In our nuclear age with instant death only minutes away by missile attack, the doctrine of Mutual Assured Destruction (MAD) only works if both sides know whether or not they are being attacked. The launch of missiles or a bomber fleet can easily be seen from space far in advance of either reaching their potential targets halfway around the globe. The danger of surprise attack is therefore small, making an accidental war far less likely. So what does all this mean? And what do we do about it? First of all, it means that the advocates of space development, exploration and commercialization have succeeded far beyond their initial expectations and dreams. The economies and security of countries in the developed world are now dependent on space satellites. We space advocates should celebrate our success and be terrified of it at the same time. Should we lose these fragile assets in space, our economy would experience a disruption like no other: ship, air and train travel would stop and only restart/operate in a much-reduced capacity for years (GPS loss). Many banking and retail transactions would cease (VSAT loss). Distribution of news and vital national information would be crippled (communications satellite loss). Lives would be put at risk and the productivity of our farming would dramatically decrease (weather satellite loss). The risk of war, including nuclear war, would increase (loss of spy satellites) and our military’s ability to react to crises would be significantly reduced (loss of military logistics and intelligence gathering satellites).

#### Satellites solves the grid and every extinction scenario.

Pellegrino & Stang ’16. Massimo Pellegrino, Master’s Degree in Space Studies from ISU, with Gerald Stang, Senior Associate Analyst at the EUISS, holds BSc and MSc degrees in chemical engineering from the University of Saskatchewan and an MA in international affairs from the School of International and Public Affairs at Columbia University (“Space Security for Europe”, *EU Institute for Security Studies*, published July 2016, <https://www.iss.europa.eu/content/space-security-europe>, accessed 7-10-2019) bm

Modern societies are highly dependent on the continuous operation of critical infrastructure to ensure the provision of basic goods and services. They consist of assets, systems or parts thereof which are so vital, that their disruption would significantly impact the economy, national security, public health, safety, or social well-being. Examples of critical infrastructure include energy, water, food supply, communication, transportation, and waste processing systems. Space assets are so deeply embedded in developed economies that a day without fully functioning space capabilities would severely restrict or even endanger our lives.

Space systems are critical for running energy grids and telecommunication networks, border and maritime surveillance, crisis management and humanitarian operations, environmental and climate monitoring, verification of international treaties and arms control agreements, and the fight against organised crime and terrorism. Space assets also provide the technological backbone for other critical infrastructures. The synchronisation of power grids and telecommunication networks, for example, is heavily dependent on GNSS timing signals and any disruption would create a domino effect on other critical infrastructures (see Figure 5).

Satellites also play a central role in supporting defence systems and military operations. They are force multipliers that provide intelligence, surveillance, and reconnaissance (ISR) capabilities, as well as communication, navigation, positioning and timing signals. Armed forces do not only use their own space systems, but are also significant consumers of space services provided by private operators. In fact, about 90% of US military communications traffic passes through civilian satellites, many of which privately owned, rather than through dedicated systems designed to withstand attempted interruptions.1 The reliance of both civilian and military users on space systems therefore places them firmly in the area of critical infrastructure. Some critical space systems, such as the American GPS, are under foreign control, and the governments controlling those systems retain the authority to disrupt services, even for allies, in case of a national emergency. While the United States announced that it has no intention of ever intentionally degrading public GPS signals (also known as ‘Selective Availability’) and that the next generation of GPS satellites will not include this feature, other governments might still do so.2

These dependences engender new and growing vulnerabilities. Reliance on space is likely to increase further as space capabilities and services improve in diversity, quality and affordability. Close to 1,500 satellites with a launch mass of over 50 kg are expected to be launched over the next decade; an increase of 50% compared to 2005-2014. This estimate excludes both the expected proliferation of smaller satellites (such as CubeSats), but also the planned OneWeb and Steam mega-constellations for global internet broadband service. Advances in small satellite capabilities and in launch technology (e.g. SpaceX’s Falcon rocket family) have already lowered the cost of access to space. About 45% more CubeSats were launched in 2014 than in 2013 (130 vs. 91), accounting for 63% of all satellites launched3 . However, just as the reliance on space increases, so too do threats and vulnerabilities. Therefore, in order to realise the full potential of investments in space, critical space systems need to be adequately protected and the space environment properly managed.

#### 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.

#### Independent of Kessler syndrome, congestion de-rails effective commercial use of outer space – rules of the road are key.

Taverny ’20 [Thomas; 3-5-20; a retired U.S. Air Force major general and former vice DARPA commander of Air Force Space Command; SPACENEWS; “Op-ed | Proliferated LEO is risky but necessary,” <https://spacenews.com/op-ed-proliferated-leo-is-risky-but-necessary/>] brett

CURRENT APPROACHES ARE NOT CAPABLE OF HANDLING THE PROLIFERATION PROBLEM

Every time we conduct a space launch, we have to de-conflict based on potential interference from LEO objects. If low Earth orbit becomes too crowded for new launches, then active space junk removal missions — no matter how far-fetched they may sound — could become the only option. But these would come at an opportunity cost for other science, civil and defense missions. If we do not pay attention and set up some rules of the road, especially for Proliferated LEO, we run the risk of cascading collisions rendering LEO unusable, and creating so much debris that we also cannot safely launch through it.

There are currently limited actions on best practices for deorbit. The real issue is the current commercial “Gold Rush” approach to pLEO, with ventures vying to be the first and build the most in order to drive competitors out of the marketplace. A possible result of this rush could be an overpopulation of pLEO space. There are guidelines, but no real rules, for eliminating space debris and removing defunct satellites from orbit. For the expanding field of cubesat and smaller satellites, we lack even clear guidelines. These tiny satellites, some weighing less than a kilogram, can’t be easily deorbited as a result of their low fuel reserves. And because they’re so small, it takes a long time for drag to pull them out of low Earth orbit. Because deorbit time is proportional to ballistic coefficient (effective drag area/ mass), small, dense objects linger in orbit longer than large light objects.

Some of the commercial companies pursuing big LEO constellations populated with mass-produced satellites are assuming 10-15% of the spacecraft they launch could die on orbit.

Consider an historical example: Iridium, which launched its first 95 satellites between 1997 and 2002, still has 30 of those satellites in orbit because the malfunctioned before they could be brought down. Up to 23 of those defunct satellites are expected to remain there for 100 years or more.

If something similar happens with today’s planned mega-constellations, and we end up with 20,000 commercial satellites in LEO, we could also end up with 2,000 rocks orbiting with the potential to cause a collision cascade. The scenario looks even worse if we assume that some of these constellations go bankrupt, leaving space cluttered with abandoned assets waiting years or decades to decay and deorbit. Who has the responsibility to ensure the satellites from these bankrupt companies are disposed of properly? The biggest issue is that once the damage is done, it is a long wait for the problem to self-correct.

Another question that should be asked of these owner-operators of proliferated, low-cost satellite constellations is this: What assumptions have you made with regard to the ability of your “disposal” approach to handle radiation environments more hostile than are currently present? Are your satellite avionics capable of surviving a significant solar flare or coronal mass ejection event? Do you even know at what point your avionics suffer a catastrophic latch-up that leaves your satellite deaf to commands? Traditional national security space missions have, for decades, required worst-case analysis to be performed to understand how failures can occur and what to do to mitigate them. The commercial, proliferated constellation operators should have to demonstrate a similar level of understanding of their constellations and prove that their disposal approach will function in the most challenging of space environments.

WHAT NEEDS TO BE DONE?

“Not everything that is faced can be changed. But nothing can be changed until it is faced.” — James Baldwin

Many ideas are being floated for how to address the problem of actively removing space junk. However, it is probably cheaper to prevent the space debris from accumulating in the first place to than to remove it once it is there. Who is going to spend millions of dollars to build and launch a satellite that collects a couple of pieces of debris? It does not currently appear financially feasible.

Currently, the U.S. Space Force — via its absorption of Air Force Space Command — provides space object and debris tracking and provides potential collision warnings. In the past, this has not been a huge job. But that’s changing with the growing number of shrinking satellites being built and launched. Appropriately, there is an ongoing transition — per the Trump administration’s Space Policy Directive-3 (SPD-3) — of this responsibility to the Federal Aviation Administration and the Federal Communications Commission.

SPD-3 also represents the definitive U.S. government position for space traffic management. Per the White House directive, space traffic management (which is similar to “Basic Space Situational Awareness Services” provided by the18th Space Control Squadron at Vandenberg Air Force Base) will transition to the Department of Commerce. Overall, the impact of constellations on the LEO environment are currently managed as part of the launch licensing process. Given the potential issues, we need to explicitly include best practices for failure rates and de-orbit guidelines for LEO smallsat constellations. As we move to FAA and FCC as the responsible U.S. government entities, they will have to develop policies and practices to deal with these challenges. Under Space Policy Directives 2 and 3, the FAA and FCC both solicited industry input to new launch licensing and orbital debris guidelines. These flight risk and orbital safety issues need to be part of this process.

For the junk that has been already created in space, the current mitigation approach entails using ground-based systems to map it, sending out collision avoidance messages, and maneuvering to avoid it. For now, we will have to rely on these tracking systems to keep low Earth orbit safe, and also work to prevent new missions from making the problem worse. Though tracking space junk is easier and cheaper than collecting and getting rid of debris, it is not without challenges. The Space Fence and other space junk-tracking telescopes need to be funded, built and deployed.

As we build thousands of new satellites bound for LEO, we need to build in the requirements for keeping LEO viable. This will cost money, but if satellite makers don’t take the necessary steps to ensure their products won’t contribute to space junk, the increasing odds of a collision and the risk of starting a collision cascade will increase. Late last year, a newly established group of space industry leaders called the Space Safety Coalition published a list of best practices for spacecraft operators, including guidelines for limiting the impact of new satellites and preventing the growth of space debris. The guidelines call on spacecraft operators to create improved deorbiting plans and for engineers to prioritize collision-avoidance capabilities. Spacecraft owners, operators and stakeholders should exchange information relevant to safety-of-flight and collision avoidance. Both SpaceX and OneWeb have submitted plans, but no one has assessed the adequacy in the new pLEO world.

KEEPING LEO LIVABLE

“Running away from a problem only increases the distance from the solution.” — Anonymous

Proliferated LEO is necessary for contending with the new world realities in space. As you move to LEO to take advantage of shorter distances and lower latency, you clearly need more satellites to provide the coverage you need vs. higher altitudes. Additionally, the military also proliferates for resiliency so they can absorb the loss of satellites and have the mission continue.

We can overpopulate any orbit, but it is in LEO where we face the most significant challenges. The shift to pLEO is moving fast from both government and commercial points of view. Being in a place where we can now build and launch systems that make this feasible is a good thing. The concern is that the commercial rush could over-clutter space and prevent an effective, defensive national security use of space. The evolution of all classes of smallsats, increasing launch competition, and the move to smaller lower cost launch are allowing this to happen.

So, yes, we must move to proliferated constellations, but we must do it with intelligence and care. Now is the time to make sure that this will not turn into a nightmare. We need to plan and have rules, and these rules need to be internationally accepted. We need an international organization that protects space similar to spectrum allocation. There is an urgent need to tell operators that if you put it up, you have to bring it down — or fund some kind of independent remediation fund for space similar to the federal Superfund program the United States established in the 1980s to clean up toxic waste sites. Maybe operators should be required to put up bonds based on the number of satellites they put into space.

The affordability and shorter lifetimes of proliferated LEO systems will allow the United States to effectively counter its adversaries through rapid insertion of new technology. As we move to LEO to take advantage of shorter distances and lower latency, we need more satellites to provide the same coverage as small numbers of satellites in higher altitudes. Additionally, proliferation provides resiliency, allowing the military — not to mention commercial operators — to absorb the loss of satellites and have the mission continue.

We should celebrate industry advances, but we should not deploy them without the consideration and mitigation of their corresponding risks.

#### That’s key to ecological sustainability, including warming – extinction.

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Low launch costs will continue to dramatically change the economics of many space business models, enabling a new era of capabilities once thought prohibitively expensive.

One reason for this recent explosion in space-related activity is the plunging cost of launch to low Earth orbit (LEO). Launching to LEO in the past has been among the most expensive element of any space endeavor. Historically, costs have averaged more than $10,000 per kilogram of launched mass. Recently, however, space companies including SpaceX, Blue Origin, and United Launch Alliance (ULA) have been successfully pursuing reusable launch vehicle technology that promises to significantly reduce the launch cost to LEO. SpaceX’s Falcon Heavy now boasts the lowest cost in the industry, with a base price of $1,655 per kilogram to LEO.[1] SpaceX’s long-term ambitions, as well as that of many others, are to lower this cost to $100 per kilogram or less.[2] Such low launch costs will continue to dramatically change the economics of many space business models, enabling a new era of capabilities once thought prohibitively expensive.

Other technologies, such as manufacturing materials in space from resources found on the Moon, Mars, or asteroids, could further improve the economics of space activities by dramatically reducing the amount, and hence cost, of material launched from Earth. A prime example is sourcing rocket propellant in space from water-rich regions of the Moon or asteroids, which could lower transportation costs to locations beyond LEO.

Space activities with positive impacts today

1. Earth observation for weather prediction and climate monitoring: Accurate weather prediction enabled by space systems has become a critically important element in our daily lives, impacting government, industry, and personal decision making. Satellites used for weather prediction almost certainly save thousands of lives each year by giving the public storm warnings. Although no one can say exactly how many lives are saved every year, it is worthwhile to note that, in 1900, a hurricane hit Galveston, Texas, killing 6,000 to 12,000 people because they had no warning. Earth observing satellites also monitor greenhouse gases and other crucial climate indicators, as well as overall Earth ecosystem health. Without this kind of environmental information coming from satellites, plans for dealing with climate change would have less scientific basis.

2. Earth resources observation: Earth observation provides information and support for agricultural production, fisheries management, freshwater management, and forestry management, as well as monitoring for harmful activities, such as illegal logging, animal poaching, fires, and environmentally pernicious mining.

3. Space-based communication services: Space communication capabilities positively impact almost every aspect of human civilization. Satellite technologies have already revolutionized banking and finance, navigation, and everyday communications, allowing international and long-distance national phone calls, video feeds, streaming media, and satellite TV and radio to become completely routine. (See point 1 in the next subheading for where we are headed in this area.)

4. Space-based Positioning, Navigation, and Timing (PNT) services: Global PNT satellite systems, which can pinpoint a location to within a few meters (or much better) anywhere on the Earth’s surface, have enhanced land and sea navigation, logistics (including ride-hailing services that are transforming personal transportation), precision agriculture, military operations, electrical grids, and many other industrial and societal aspects of Earth life. Space-based location services built into mobile phones and used by applications on mobile phones ranging from maps to dating services have become so intertwined with modern life that their abrupt cessation would be viewed as catastrophic.

5. Increasing economic opportunities in expanding commercial space and non-space sectors: Aside from long-standing commercial satellite services, our expanding space industry, in the process of moving beyond exclusive dependence on limited government budgets and cost-plus contracting, brings with it economic opportunities, not only to those working directly in the space sector but also to non-space actors, including many small businesses. Put another way, an expanding commercial space industry will not only result in high-tech jobs, but also everyday jobs connected to construction, food service, wholesale and retail, finance, and more throughout the communities hosting commercial space companies.

6. Inspiration for STEAM education: Beyond economics, a healthy space sector will continue to inspire people young and old about new frontiers, discoveries, and technologies, and foster interest in STEAM (science, technology, engineering, art, and math) disciplines, which helps create a scientifically literate society able to participate in an increasingly technology-driven world.

7. International space cooperation countering geopolitical tensions: Joint space projects among nations are sometimes the only positive force countering mutual suspicion and geopolitical rivalries. The ISS is a prime example of such a project, a source of pride to all the nations involved. Cross-border business-to-business relationships also serve the same purpose. We are a global community and space endeavors, public and private, are making us more interdependent and interconnected.

Simply affording people the opportunity to experience the Overview Effect firsthand could lead to powerful shifts in attitudes toward the environment and social welfare, and could become an important “side benefit” of a growing space tourism industry.

8. Space spinoffs for Earth: Since the dawn of the space program, there have been more than 2,000 examples of space-developed technologies that have since found beneficial uses on Earth, including cordless power tools, freeze-dried food, flame-resistant firefighter gear, the integrated circuit, lightweight insulation, improvements to kidney dialysis, lightning detection, and automated credit card transactions. NASA tracks spinoffs each year across a wide range of topics spanning transportation, public safety, consumer goods, energy and environment, information technology, industrial productivity, and health and medicine. Future health-related spinoffs will foreseeably come from the dealing with the medical issues of isolated populations in deep space.

Space activities with the potential for positive impact in the next 5 to 20 years

1. Megaconstellations: This is an emerging business with huge potential, which will possibly enhance the efficiency, capacity, and security of a variety of services to Earth-based business customers by drastically cutting communications latency, while increasing throughput and global coverage. Data satellite constellations, which are planned for launching mostly to LEO, will benefit the business end-users of services in the banking, maritime, energy, Internet, cellular, and government sectors. A related aspect of this service business is focused on everyday Internet end-users and will provide high-speed, high-bandwidth coverage globally, benefitting billions of people. Thousands of LEO satellites are being planned by SpaceX, OneWeb, Telesat, Amazon, Samsung, and others. Such constellations, though, will require orbital debris mitigation and remediation services, as discussed below.

2. Space manufacturing of materials hard to make on Earth: At this time there are only a few materials that can only be made in the microgravity environment of space and have sufficient value back on Earth to justify its manufacture even at today’s high launch costs. The hallmark example is ZBLAN, a fiber optic material that may lead to much lower signal losses per length of fiber than anything that can be made on Earth. This material is being made experimentally on the ISS by Made In Space, Inc., with two competitors working on similar products. Other on-orbit manufacturing projects underway on the ISS include bio-printing, industrial crystallization, super alloy casting, growing human stem cells, and ceramic stereolithography.[3]

3. Fast point-to-point suborbital transport: Supersonic air transport dates back to the Concorde in the 1970s and, more recently, several companies have begun exploring technologies for even faster transport using so-called “hypersonic” airplanes. SpaceX has announced its intentions to utilize its Starship/Super Heavy rocket system currently in development to leapfrog these companies and provide point-to-point (P2P) “suborbital” travel that temporarily leaves Earth’s atmosphere only to reenter a short time later somewhere else on the planet. The potential travel time savings using this technology is enormous, allowing access to anywhere on Earth in less than one hour. While current technologies continue to rely on fossil fuels for propellant, it is possible to substitute those with hydrogen/oxygen propellant electrolyzed from water. Such technology would not emit carbon dioxide, and could thus provide a “green” alternative to long-distance air travel while simultaneously shortening travel times tremendously.

4. Space tourism: There are now several start-up companies whose sole mission is to provide low-cost access to the edge of space. Some are using suborbital rocket technology that affords a few minutes of weightlessness about 100 kilometers above the surface, while others use high-altitude balloons to more inexpensively provide access to high altitudes without becoming weightless. The desire among ordinary people to travel into space is strong. A recent survey indicated that more than 60 percent of Americans would do so, if they could afford a ticket.[4] Space tourism, including Earth and Moon orbiting hotels, sports arenas, yacht cruises, and the like could soon become open to millions of people with the falling cost of space access.

5. The Overview Effect: A well-known phenomenon experienced by virtually every person who has traveled into space and gazed back on our world from above is the “Overview Effect,”[5] usually described as a sudden but lasting feeling of human unity and concern for the fragility of our planet.[6] Therefore, simply affording people the opportunity to experience the Overview Effect firsthand could lead to powerful shifts in attitudes toward the environment and social welfare, and could become an important “side benefit” of a growing space tourism industry.

6. Asteroid impact prevention: With increasing knowledge of the space environment, humanity has become aware that asteroids with the potential to do great harm will sporadically enter Earth’s atmosphere and reach the surface. While an early-warning system is an obvious first response to this threat (even this capability is nowhere near operational), some asteroids may pose so deadly a threat that deflection is the only way to avoid devastating loss of life on Earth. Several technologies to accomplish this task have been studied, but the capability is still in its infancy. A side benefit of investing in such a capability is that the more we learn about such “killer” asteroids the better we can identify valuable asteroids for asteroid mining.

7. Space solar power: In space, sunlight is unfiltered by Earth’s atmosphere and, at orbits of sufficiently high altitude, sunlight can shine more than 99 percent of the year.[7] The principle of space solar power (SSP) is to capture this abundant sunlight and then, after conversion into microwaves or laser light, beam it to the Earth’s surface where ground-based receivers re-convert the energy into electricity.

Such a system can provide electricity much of the day. Moreover, due to its vantage point in space, power can be beamed to virtually any location on Earth within line-of-sight of the satellite, and can be directed at a moment’s notice to locations thousands of kilometers apart, or even to multiple locations simultaneously through the use of phased array technology. An early application could focus on supplying power to isolated communities or for disaster relief.

It is possible that space-based data centers could eventually become cost effective, resulting in lower electricity demand and carbon emissions on Earth.

With reductions in launch cost and mass production of SSP modules, SSP has the potential to eventually become less expensive than wind or solar electricity is today, i.e., a few cents per kilowatt-hour.[8] As it matures and especially as units in modular SSP systems begin to be mass produced from in-situ space resources, it will be able to replace much of baseload electricity as well as peak electricity generation, due to its ability for power to be sent wherever it is desired on demand. Moreover, with SSP providing baseload power, there will be less need for energy storage using batteries or other systems that could negatively impact the environment.

8. Space-based data centers: Together with the communications network itself, data centers are the beating heart of the Internet that drives much of today’s economy, but they consume vast and increasing amounts of electricity. Today, data centers are often being located in cold climates to take advantage of lower operating temperatures and cooling loads, and there have been serious discussions of locating data centers underwater for similar reasons.

Another option could be to place servers and their power supplies directly in space, using the virtually unlimited solar energy (see earlier discussion on SSP) there to remove the burden of Earth-based electricity systems to power them. While cooling may be more challenging (the vacuum of space is a very good thermal insulator), there are several advantages, including increased physical security, decreased signal transmission times, and superior performance of spinning disk drives in microgravity. It is possible that space-based data centers could eventually become cost effective, resulting in lower electricity demand and carbon emissions on Earth.

9. Space mining of high-value elements: The focus of most space mining companies today is targeting water that will provide rocket propellant in Earth orbit, helping lower the cost of deep space operations. Other plentiful materials such as iron and other metals will be valuable for in-space construction, avoiding the expense of launching structures from Earth. However, space mining could eventually mature to the point that other valuable elements could be obtained as a natural byproduct of the large amounts of processed material, justifying the high cost of producing them in space. Prime examples are the platinum group metals (platinum, palladium, rhodium, rhenium, osmium and iridium, collectively called PGMs) and gold, which can fetch prices of $30,000 or more per kilogram today. It is possible that some other elements, such as “critical materials” listed by the US Department of Energy, may reach similar price levels in the next two decades, and become amenable to space mining. Delivering large amounts of material from space can be inexpensive if they are returned using space-manufactured ablative heat shields that can be recovered from controlled landings in shallow water. Space mining techniques will be also different from water-based approaches frequently used on Earth, and instead would mainly rely on thermal separation and multistep processes to aggregate small percentages of metal typically found in terrestrial ores into higher and higher concentrations. For example, some asteroids may contain high concentrations of high value metals amenable to mechanical separation.

10. Closed-loop ecosystems, material recycling, and in situ resource utilization: Limited physical resources and the inherently high cost of operating in space naturally pushes system designs toward efficient utilization and recycling of gases, water, nutrients, and other materials, both for life support and other uses. Efficient re-use and/or recycling of plastics, aluminum, steel, and other structural materials confer great benefit as well. Once these systems have been matured for space applications, the potential to apply these technology solutions on Earth is enormous, saving energy and material resources, and shifting people’s outlook from once-through to circular economic thinking. Moreover, there is a need for large-scale space operations to rely as much as possible on in situ resources, literally using the rocks and regolith around which the rockets land as the raw materials for construction, life support, and other needs. If such processes can be developed in space with a high degree of efficiency and reliability, there is also potential for them to be customized for use on Earth for construction and processed goods.

11. Intensive organic agricultural techniques: As the size of crews in space increases, and especially as bases are constructed on distant worlds such as Mars, it will be impractical to sustain these populations using imported food. This will require the development of high-density, water-efficient, low-energy, fully organic agricultural methods that operate on a closed cycle. Such techniques can be anticipated to have widespread application back on Earth to increase food production.

12.Science projects and programs that can only be (or better be) done in space: Beyond the science and technology projects and programs listed above, there are others that can only be carried out in space. For instance, the Earth’s atmosphere filters out some wavelengths of light, so telescopes seeking to observe in those bands can only be placed in space. The lunar farside is protected by the Moon from electromagnetic emissions coming from the Earth. For that reason, with the proper precautions and infrastructure in place, it could be an ideal location to monitor low-frequency radio waves from space. Many other kinds of telescopes benefit from being located beyond the Earth’s atmosphere. Freed from Earth’s gravity, extremely large on-orbit structures could also be assembled, such as modular arrays for radio and optical interferometry telescopes and other types of receivers or transmitters. Finally, risky biological experiments could be carried out in isolated laboratories in deep space or on the Moon, protecting Earth populations with a vast expanse of hard vacuum.

13. Orbital debris management: While not a technology of direct benefit to Earth, the removal of debris from spent rocket stages, defunct satellites, and all other manner of space junk in Earth orbits poses an increasing hazard to space operations and must eventually be dealt with. The worst-case scenario is that a series of accidental or deliberate collisions in orbit produces an exponential increase in debris, leading to an inability to operate in space—the so-called “Kessler Syndrome.” Technologies are being explored to deal with this problem in various ways, but it is currently very expensive. With lower launch costs and space infrastructure investments, it may become feasible to manage debris cost-effectively (at least one company, Cislunar Industries, plans to melt down and refine orbital debris into useful materials for use in space.) Another company, Star Technology and Research Corporation, is developing a non-fuel consuming, electrodynamic debris eliminator (EDDE), which can also be useful for monitoring debris in orbit.

Space activities with potential for positive impact in the more distant future

1. Widespread space manufacturing and industrialization: Eventually, the falling cost of space-based manufacturing, and the rising cost of Earth-based manufacturing (due to increased scarcity, environmental impacts, labor standards, etc.) may cause many, if not virtually all, extractive industries and their downstream manufacturing processes to move into space. The impact of such a change would be profound, as it would shift the side effects of these activities to locations in space without biological ecosystems, endangered species, or human populations to negatively impact. The vastly larger domain of outer space would provide virtually unlimited space, energy and materials with which to operate. Provided that such industrial activities are done responsibly so as not to pollute or otherwise compromise the ability of future generations to use space resources (an example of which is described above under orbital debris removal), this could be critical to permanently preserving and restoring the health of the Earth.

2. Waste disposal in space: As the reliability of space launch improves, it will be possible to dispose of toxic substances away from Earth. For example, in a century or so, space launch should be very reliable, making it possible to dispose of nuclear waste materials in an orbit permanently out of harm’s way, yet providing access for future generations to mine it for valuable materials. Storing nuclear waste on Earth for hundreds of years is a much simpler problem than the current much greater challenge of storing them for tens of thousands of years. This change in perspective could make the cleanup of nuclear debris much more tractable.

3. Construction of a space-based “sunshade” to reduce global warming: The severity of climate change may necessitate radical approaches, such as the reduction of sunlight reaching the Earth’s surface in conjunction with greatly reduced greenhouse emissions. Known in climate change circles as “solar geoengineering” or “solar radiation management” (SRM), most approaches rely on injection of aerosol particles into the stratosphere, though others increase cloud reflectance, or directly block sunlight in space. First suggested three decades ago,[9] the concept of placing a fleet of spacecraft in orbit near Earth to reduce incident solar radiation and thereby lower surface temperatures received increased attention after Roger Angel published an influential paper in 2006.[10] Placing asteroid dust with similar effects in Earth orbit has also been explored.[11] While no identified SRM method can perfectly cancel the effects of climate change (and can do nothing to halt ocean acidification), SRM may be the only way to quickly lower global temperatures. The advantages of space-based approaches include the absence of unwanted chemical interactions in Earth’s atmosphere and the ability to be quickly “turned off” if unforeseen consequences were detected. Launching trillions of tiny spacecraft to form a vast “sunshade” over the planet is not feasible today, but could become possible with decreased launch costs, development of ultra-lightweight “solar sail” materials, and mass production of spacecraft.

4. Physical benefits of low gravity: While currently very speculative, a number of physical maladies that could be described as “aggravated by Earth gravity” (including obesity, joint pain, and osteoporosis) might be partially or completely eliminated in a lower gravity environment such as found on the Moon, Mars, or in artificial gravity environments (a rotating habitat) in Earth orbit. Low gravity is to be distinguished from zero gravity (technically, “microgravity”) such as found on board the ISS, which has been shown to almost universally result in negative health effects. Research in this area is still in its infancy, due to the almost complete lack of funding for artificial gravity centrifuges in orbit to study these effects in humans. If funding materializes and positive outcomes are found, spending time in low gravity could become highly desirable, driving significant numbers of people to visit or even live in space.

5. Food production in space for people on Earth: Once space technology advances to the point where self-sustaining space settlements of many millions of people are possible, the vastly larger resources of space could be used to grow food for people on Earth as well. Indeed, the current tension among the uses of land on Earth for human habitation, agriculture, industrial activities, and preservation of nature could be broken, providing ample room for all these competing needs. Initially only small amounts of food, or specialty items deemed too expensive or taxing on Earth’s ecosystems, would be shipped to Earth, but eventually, large portions of the world might be fed from space.

6. Migration of the human population into space: One of the main drivers of space development is provide new locations for people to live, work, and explore. While currently only very few people have been able visit space, the space community today is on a clear path to grow a commercial space tourism industry and establish small but permanent human bases on the Moon and Mars. Very large space hotels would be similar to small space settlements in Equatorial LEO (close to Earth and near the equator) where radiation levels are very low by space standards. The biggest difference could be the rotation rate, as hotels guests may want just a little “gravity” to keep the silverware in place, whereas settlements will want full Earth gravity so children grow up strong. Such small habitats may lead to very large space settlements (e.g., “O’Neill cylinders”) built with space resources, each capable of hosting populations in the millions. Eventually, such settlements could allow the human population to grow to fill the much larger region of the Solar System, reducing pressure on Earth’s finite land and resources.

#### Ecological degradation and ensuing resource pressures go nuclear.

Klare 20 [Dr. Michael T.; 1-13-20; Five Colleges Professor of Peace and World Security Studies at Hampshire College, Ph.D. from the Graduate School of the Union Institute, BA and MA from Columbia University, Member of the Board of Director at the Arms Control Association, Defense Correspondent for The Nation, “How Rising Temperatures Increase the Likelihood of Nuclear War”, The Nation, https://www.thenation.com/article/archive/nuclear-defense-climate-change/]

Climbing world temperatures and rising sea levels will diminish the supply of food and water in many resource-deprived areas, increasing the risk of widespread starvation, social unrest, and human flight. Global corn production, for example, is projected to fall by as much as 14 percent in a 2°C warmer world, according to research cited in a 2018 special report by the UN’s Intergovernmental Panel on Climate Change (IPCC). Food scarcity and crop failures risk pushing hundreds of millions of people into overcrowded cities, where the likelihood of pandemics, ethnic strife, and severe storm damage is bound to increase. All of this will impose an immense burden on human institutions. Some states may collapse or break up into a collection of warring chiefdoms—all fighting over sources of water and other vital resources.

A similar momentum is now evident in the emerging nuclear arms race, with all three major powers—China, Russia, and the United States—rushing to deploy a host of new munitions. This dangerous process commenced a decade ago, when Russian and Chinese leaders sought improvements to their nuclear arsenals and President Barack Obama, in order to secure Senate approval of the New Strategic Arms Reduction Treaty of 2010, agreed to initial funding for the modernization of all three legs of America’s strategic triad, which encompasses submarines, intercontinental ballistic missiles, and bombers. (New START, which mandated significant reductions in US and Russian arsenals, will expire in February 2021 unless renewed by the two countries.) Although Obama initiated the modernization of the nuclear triad, the Trump administration has sought funds to proceed with their full-scale production, at an estimated initial installment of $500 billion over 10 years.

Even during the initial modernization program of the Obama era, Russian and Chinese leaders were sufficiently alarmed to hasten their own nuclear acquisitions. Both countries were already in the process of modernizing their stockpiles—Russia to replace Cold War–era systems that had become unreliable, China to provide its relatively small arsenal with enhanced capabilities. Trump’s decision to acquire a whole new suite of ICBMs, nuclear-armed submarines, and bombers has added momentum to these efforts. And with all three major powers upgrading their arsenals, the other nuclear-weapon states—led by India, Pakistan, and North Korea—have been expanding their stockpiles as well. Moreover, with Trump’s recent decision to abandon the Intermediate-Range Nuclear Forces (INF) Treaty, all major powers are developing missile delivery systems for a regional nuclear war such as might erupt in Europe, South Asia, or the western Pacific.

### Framing

#### The standard is maximizing expected wellbeing. Pleasure and pain are intrinsic value and disvalue – everything else regresses – robust neuroscience.

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**Pleasure** is not only one of the three primary reward functions but it also **defines reward.** As homeostasis explains the functions of only a limited number of rewards, the principal reason why particular stimuli, objects, events, situations, and activities are rewarding may be due to pleasure. This applies first of all to sex and to the primary homeostatic rewards of food and liquid and extends to money, taste, beauty, social encounters and nonmaterial, internally set, and intrinsic rewards. Pleasure, as the primary effect of rewards, drives the prime reward functions of learning, approach behavior, and decision making and provides the basis **for hedonic** theories of reward function. We are attracted by most rewards and exert intense efforts to obtain them, just because they are enjoyable [10]. Pleasure is a passive reaction that derives from the experience or prediction of reward and may lead to a long-lasting state of happiness. The word happiness is difficult to define. In fact, just obtaining physical pleasure may not be enough. One key to happiness involves a network of good friends. However, it is not obvious how the higher forms of satisfaction and pleasure are related to an ice cream cone, or to your team winning a sporting event. Recent multidisciplinary research, using both humans and detailed invasive brain analysis of animals has discovered some critical ways that the brain processes pleasure [14]. Pleasure as a hallmark of reward is sufficient for defining a reward, but it may not be necessary. A reward may generate positive learning and approach behavior simply because it contains substances that are essential for body function. When we are hungry, we may eat bad and unpleasant meals. A monkey who receives hundreds of small drops of water every morning in the laboratory is unlikely to feel a rush of pleasure every time it gets the 0.1 ml. Nevertheless, with these precautions in mind, we may define any stimulus, object, event, activity, or situation that has the potential to produce pleasure as a reward. In the context of reward deficiency or for disorders of addiction, homeostasis pursues pharmacological treatments: drugs to treat drug addiction, obesity, and other compulsive behaviors. The theory of allostasis suggests broader approaches - such as re-expanding the range of possible pleasures and providing opportunities to expend effort in their pursuit. [15]. It is noteworthy, the first animal studies eliciting approach behavior by electrical brain stimulation interpreted their findings as a discovery of the brain’s pleasure centers [16] which were later partly associated with midbrain dopamine neurons [17–19] despite the notorious difficulties of identifying emotions in animals. Evolutionary theories of pleasure: The love connection BO:D Charles Darwin and other biological scientists that have examined the biological evolution and its basic principles found various mechanisms that steer behavior and biological development. Besides their theory on natural selection, it was particularly the sexual selection process that gained significance in the latter context over the last century, especially when it comes to the question of what makes us “what we are,” i.e., human. However, the capacity to sexually select and evolve is not at all a human accomplishment alone or a sign of our uniqueness; yet, we humans, as it seems, are ingenious in fooling ourselves and others–when we are in love or desperately search for it. It is well established that modern biological theory conjectures that **organisms are** the **result of evolutionary competition.** In fact, Richard Dawkins stresses gene survival and propagation as the basic mechanism of life [20]. Only genes that lead to the fittest phenotype will make it. It is noteworthy that the phenotype is selected based on behavior that maximizes gene propagation. To do so, the phenotype must survive and generate offspring, and be better at it than its competitors. Thus, the ultimate, distal function of rewards is to increase evolutionary fitness by ensuring the survival of the organism and reproduction. It is agreed that learning, approach, economic decisions, and positive emotions are the proximal functions through which phenotypes obtain other necessary nutrients for survival, mating, and care for offspring. Behavioral reward functions have evolved to help individuals to survive and propagate their genes. Apparently, people need to live well and long enough to reproduce. Most would agree that homo-sapiens do so by ingesting the substances that make their bodies function properly. For this reason, foods and drinks are rewards. Additional rewards, including those used for economic exchanges, ensure sufficient palatable food and drink supply. Mating and gene propagation is supported by powerful sexual attraction. Additional properties, like body form, augment the chance to mate and nourish and defend offspring and are therefore also rewards. Care for offspring until they can reproduce themselves helps gene propagation and is rewarding; otherwise, many believe mating is useless. According to David E Comings, as any small edge will ultimately result in evolutionary advantage [21], additional reward mechanisms like novelty seeking and exploration widen the spectrum of available rewards and thus enhance the chance for survival, reproduction, and ultimate gene propagation. These functions may help us to obtain the benefits of distant rewards that are determined by our own interests and not immediately available in the environment. Thus the distal reward function in gene propagation and evolutionary fitness defines the proximal reward functions that we see in everyday behavior. That is why foods, drinks, mates, and offspring are rewarding. There have been theories linking pleasure as a required component of health benefits salutogenesis, (salugenesis). In essence, under these terms, pleasure is described as a state or feeling of happiness and satisfaction resulting from an experience that one enjoys. Regarding pleasure, it is a double-edged sword, on the one hand, it promotes positive feelings (like mindfulness) and even better cognition, possibly through the release of dopamine [22]. But on the other hand, pleasure simultaneously encourages addiction and other negative behaviors, i.e., motivational toxicity. It is a complex neurobiological phenomenon, relying on reward circuitry or limbic activity. It is important to realize that through the “Brain Reward Cascade” (BRC) endorphin and endogenous morphinergic mechanisms may play a role [23]. While natural rewards are essential for survival and appetitive motivation leading to beneficial biological behaviors like eating, sex, and reproduction, crucial social interactions seem to further facilitate the positive effects exerted by pleasurable experiences. Indeed, experimentation with addictive drugs is capable of directly acting on reward pathways and causing deterioration of these systems promoting hypodopaminergia [24]. Most would agree that pleasurable activities can stimulate personal growth and may help to induce healthy behavioral changes, including stress management [25]. The work of Esch and Stefano [26] concerning the link between compassion and love implicate the brain reward system, and pleasure induction suggests that social contact in general, i.e., love, attachment, and compassion, can be highly effective in stress reduction, survival, and overall health. Understanding the role of neurotransmission and pleasurable states both positive and negative have been adequately studied over many decades [26–37], but comparative anatomical and neurobiological function between animals and homo sapiens appear to be required and seem to be in an infancy stage. Finding happiness is different between apes and humans As stated earlier in this expert opinion one key to happiness involves a network of good friends [38]. However, it is not entirely clear exactly how the higher forms of satisfaction and pleasure are related to a sugar rush, winning a sports event or even sky diving, all of which augment dopamine release at the reward brain site. Recent multidisciplinary research, using both humans and detailed invasive brain analysis of animals has discovered some critical ways that the brain processes pleasure. Remarkably, there are pathways for ordinary liking and pleasure, which are limited in scope as described above in this commentary. However, there are **many brain regions**, often termed hot and cold spots, that significantly **modulate** (increase or decrease) our **pleasure or** even produce the opposite of pleasure— that is disgust and fear [39]. One specific region of the nucleus accumbens is organized like a computer keyboard, with particular stimulus triggers in rows— producing an increase and decrease of pleasure and disgust. Moreover, the cortex has unique roles in the cognitive evaluation of our feelings of pleasure [40]. Importantly, the interplay of these multiple triggers and the higher brain centers in the prefrontal cortex are very intricate and are just being uncovered. Desire and reward centers It is surprising that many different sources of pleasure activate the same circuits between the mesocorticolimbic regions (Figure 1). Reward and desire are two aspects pleasure induction and have a very widespread, large circuit. Some part of this circuit distinguishes between desire and dread. The so-called pleasure circuitry called “REWARD” involves a well-known dopamine pathway in the mesolimbic system that can influence both pleasure and motivation. In simplest terms, the well-established mesolimbic system is a dopamine circuit for reward. It starts in the ventral tegmental area (VTA) of the midbrain and travels to the nucleus accumbens (Figure 2). It is the cornerstone target to all addictions. The VTA is encompassed with neurons using glutamate, GABA, and dopamine. The nucleus accumbens (NAc) is located within the ventral striatum and is divided into two sub-regions—the motor and limbic regions associated with its core and shell, respectively. The NAc has spiny neurons that receive dopamine from the VTA and glutamate (a dopamine driver) from the hippocampus, amygdala and medial prefrontal cortex. Subsequently, the NAc projects GABA signals to an area termed the ventral pallidum (VP). The region is a relay station in the limbic loop of the basal ganglia, critical for motivation, behavior, emotions and the “Feel Good” response. This defined system of the brain is involved in all addictions –substance, and non –substance related. In 1995, our laboratory coined the term “Reward Deficiency Syndrome” (RDS) to describe genetic and epigenetic induced hypodopaminergia in the “Brain Reward Cascade” that contribute to addiction and compulsive behaviors [3,6,41]. Furthermore, ordinary “liking” of something, or pure pleasure, is represented by small regions mainly in the limbic system (old reptilian part of the brain). These may be part of larger neural circuits. In Latin, hedus is the term for “sweet”; and in Greek, hodone is the term for “pleasure.” Thus, the word Hedonic is now referring to various subcomponents of pleasure: some associated with purely sensory and others with more complex emotions involving morals, aesthetics, and social interactions. The capacity to have pleasure is part of being healthy and may even extend life, especially if linked to optimism as a dopaminergic response [42]. Psychiatric illness often includes symptoms of an abnormal inability to experience pleasure, referred to as anhedonia. A negative feeling state is called dysphoria, which can consist of many emotions such as pain, depression, anxiety, fear, and disgust. Previously many scientists used animal research to uncover the complex mechanisms of pleasure, liking, motivation and even emotions like panic and fear, as discussed above [43]. However, as a significant amount of related research about the specific brain regions of pleasure/reward circuitry has been derived from invasive studies of animals, these cannot be directly compared with subjective states experienced by humans. In an attempt to resolve the controversy regarding the causal contributions of mesolimbic dopamine systems to reward, we have previously evaluated the three-main competing explanatory categories: “liking,” “learning,” and “wanting” [3]. That is, dopamine may mediate (a) liking: the hedonic impact of reward, (b) learning: learned predictions about rewarding effects, or (c) wanting: the pursuit of rewards by attributing incentive salience to reward-related stimuli [44]. We have evaluated these hypotheses, especially as they relate to the RDS, and we find that the incentive salience or “wanting” hypothesis of dopaminergic functioning is supported by a majority of the scientific evidence. Various neuroimaging studies have shown that anticipated behaviors such as sex and gaming, delicious foods and drugs of abuse all affect brain regions associated with reward networks, and may not be unidirectional. Drugs of abuse enhance dopamine signaling which sensitizes mesolimbic brain mechanisms that apparently evolved explicitly to attribute incentive salience to various rewards [45]. Addictive substances are voluntarily self-administered, and they enhance (directly or indirectly) dopaminergic synaptic function in the NAc. This activation of the brain reward networks (producing the ecstatic “high” that users seek). Although these circuits were initially thought to encode a set point of hedonic tone, it is now being considered to be far more complicated in function, also encoding attention, reward expectancy, disconfirmation of reward expectancy, and incentive motivation [46]. The argument about addiction as a disease may be confused with a predisposition to substance and nonsubstance rewards relative to the extreme effect of drugs of abuse on brain neurochemistry. The former sets up an individual to be at high risk through both genetic polymorphisms in reward genes as well as harmful epigenetic insult. Some Psychologists, even with all the data, still infer that addiction is not a disease [47]. Elevated stress levels, together with polymorphisms (genetic variations) of various dopaminergic genes and the genes related to other neurotransmitters (and their genetic variants), and may have an additive effect on vulnerability to various addictions [48]. In this regard, Vanyukov, et al. [48] suggested based on review that whereas the gateway hypothesis does not specify mechanistic connections between “stages,” and does not extend to the risks for addictions the concept of common liability to addictions may be more parsimonious. The latter theory is grounded in genetic theory and supported by data identifying common sources of variation in the risk for specific addictions (e.g., RDS). This commonality has identifiable neurobiological substrate and plausible evolutionary explanations. Over many years the controversy of dopamine involvement in especially “pleasure” has led to confusion concerning separating motivation from actual pleasure (wanting versus liking) [49]. We take the position that animal studies cannot provide real clinical information as described by self-reports in humans. As mentioned earlier and in the abstract, on November 23rd, 2017, evidence for our concerns was discovered [50] In essence, although nonhuman primate brains are similar to our own, the disparity between other primates and those of human cognitive abilities tells us that surface similarity is not the whole story. Sousa et al. [50] small case found various differentially expressed genes, to associate with pleasure related systems. Furthermore, the dopaminergic interneurons located in the human neocortex were absent from the neocortex of nonhuman African apes. Such differences in neuronal transcriptional programs may underlie a variety of neurodevelopmental disorders. In simpler terms, the system controls the production of dopamine, a chemical messenger that plays a significant role in pleasure and rewards. The senior author, Dr. Nenad Sestan from Yale, stated: “Humans have evolved a dopamine system that is different than the one in chimpanzees.” This may explain why the behavior of humans is so unique from that of non-human primates, even though our brains are so surprisingly similar, Sestan said: “It might also shed light on why people are vulnerable to mental disorders such as autism (possibly even addiction).” Remarkably, this research finding emerged from an extensive, multicenter collaboration to compare the brains across several species. These researchers examined 247 specimens of neural tissue from six humans, five chimpanzees, and five macaque monkeys. Moreover, these investigators analyzed which genes were turned on or off in 16 regions of the brain. While the differences among species were subtle, **there was** a **remarkable contrast in** theneocortices, specifically in an area of the brain that is much more developed in humans than in chimpanzees. In fact, these researchers found that a gene called tyrosine hydroxylase (TH) for the enzyme, responsible for the production of dopamine, was expressed in the neocortex of humans, but not chimpanzees. As discussed earlier, dopamine is best known for its essential role within the brain’s reward system; the very system that responds to everything from sex, to gambling, to food, and to addictive drugs. However, dopamine also assists in regulating emotional responses, memory, and movement. Notably, abnormal dopamine levels have been linked to disorders including Parkinson’s, schizophrenia and spectrum disorders such as autism and addiction or RDS. Nora Volkow, the director of NIDA, pointed out that one alluring possibility is that the neurotransmitter dopamine plays a substantial role in humans’ ability to pursue various rewards that are perhaps months or even years away in the future. This same idea has been suggested by Dr. Robert Sapolsky, a professor of biology and neurology at Stanford University. Dr. Sapolsky cited evidence that dopamine levels rise dramatically in humans when we anticipate potential rewards that are uncertain and even far off in our futures, such as retirement or even the possible alterlife. This may explain what often motivates people to work for things that have no apparent short-term benefit [51]. In similar work, Volkow and Bale [52] proposed a model in which dopamine can favor NOW processes through phasic signaling in reward circuits or LATER processes through tonic signaling in control circuits. Specifically, they suggest that through its modulation of the orbitofrontal cortex, which processes salience attribution, dopamine also enables shilting from NOW to LATER, while its modulation of the insula, which processes interoceptive information, influences the probability of selecting NOW versus LATER actions based on an individual’s physiological state. This hypothesis further supports the concept that disruptions along these circuits contribute to diverse pathologies, including obesity and addiction or RDS.

#### Prioritize utilitarianism with a focus on existential risk in the context of debates about outer space.

Baum 16 [Seth, @ Global Catastrophic Risk Institute, In “The Ethics of Space Exploration”, ed. James S.J. Schwartz & Tony Milligan, Springer, 2016, pages 109-123. This version 29 July 2016. <https://sethbaum.com/ac/2016_SpaceEthics.pdf>] brett

A basic conclusion of this paper is that consequentialists should pay attention to outer space. This is because outer space can be the location of immense consequences (via space colonization) and because outer space scenarios can force us to rethink our consequentialist ethics (via ETI encounter).

Attention to outer space prompts us to recognize the big picture. This holds for consequentialist ethics as much as it does for anything else. Only by thinking through the possibilities of outer space can we understand how our lives could matter in the grand scheme of things. And the fact of the matter is that our lives can matter immensely. We can set the pieces in motion for an immense cosmic civilization. We can help prevent civilization-ending global catastrophe so as to enable future space colonization. And we can determine whether or not to try messaging to ETI.

Should we do these things? Answering this all-important question requires ethics. Therefore, just as consequentialists should pay attention to outer space, so too should outer space analysts pay attention to consequentialism, and indeed to ethics in general. Defensible forms of consequentialism will generally conclude that (1) humanity today should focus on avoiding global catastrophe, (2) space colonization should proceed with caution, but ultimately should proceed at immense scale, and (3) high-power/long-duration METI should not be conducted until more effort is put to assessing whether the consequences are likely to be good.

The ethical arguments and empirical analyses in this paper are quite brief and are not the final word on the subject. I have said little in defense of consequentialism and my preferred form of it. The analyses of space colonization and ETI encounter are likewise at best only approximate and leaving much for future work. Some of it is due to space constraints in this paper, but much of it is due to the fact that the research simply has not yet been performed. Outer space consequentialism could make for a fruitful line of inquiry.

The merits of this line of inquiry are diminished by the conclusion to focus on avoiding global catastrophe. Any global catastrophe would preclude the possibility of future research on all topics, including outer space consequentialism. Likewise, any hopes of resolving the ethical dilemmas and empirical uncertainties depend on us surviving long enough to do the research. An argument can thus be made against any work on outer space in favor of work on the global catastrophic risks. My own view is that work on outer space should be pursued mainly to the extent that it is instrumentally valuable towards reducing the global catastrophic risks. To that end it can be quite instrumentally valuable. Outer space can offer great motivation due to its immense opportunities, and it can be deeply inspirational due to its beauty and wonder and the big-picture perspective it offers. While attention to outer space should not distract humanity from the urgent threats that it faces, some attention is very much worthwhile.

#### That outweighs -- 1] Fairness, as it’s most predictable to topic-oriented prep, so any alternative framework throws away the hard work of novices and well-prepared debaters, 2] Education, absent an incentive to go deep into the topic literature we lose out on research skills that we take out of this space and benefit us for our entire lives.

#### Extinction must outweigh – moral uncertainty demands we preserve the conditions for life, even a tiny risk outweighs, and future gains in quality of life ensure it’s a prior question

Todd 17 [Ben has a 1st from Oxford in Physics and Philosophy, has published in Climate Physics, once kick-boxed for Oxford, and speaks Chinese, badly. "The case for reducing extinction risk." <https://80000hours.org/articles/extinction-risk/>] brett

In this new age, what should be our biggest priority as a civilisation? Improving technology? Helping the poor? Changing the political system? Here’s a suggestion that’s not so often discussed: our first priority should be to survive. So long as civilisation continues to exist, we’ll have the chance to solve all our other problems, and have a far better future. But if we go extinct, that’s it. Why isn’t this priority more discussed? Here’s one reason: many people don’t yet appreciate the change in situation, and so don’t think our future is at risk. Social science researcher Spencer Greenberg surveyed Americans on their estimate of the chances of human extinction within 50 years. The results found that many think the chances are extremely low, with over 30% guessing they’re under one in ten million.3 We used to think the risks were extremely low as well, but when we looked into it, we changed our minds. As we’ll see, researchers who study these issues think the risks are over one thousand times higher, and are probably increasing. These concerns have started a new movement working to safeguard civilisation, which has been joined by Stephen Hawking, Max Tegmark, and new institutes founded by researchers at Cambridge, MIT, Oxford, and elsewhere. In the rest of this article, we cover the greatest risks to civilisation, including some that might be bigger than nuclear war and climate change. We then make the case that reducing these risks could be the most important thing you do with your life, and explain exactly what you can do to help. If you would like to use your career to work on these issues, we can also give one-on-one support. Reading time: 25 minutes How likely are you to be killed by an asteroid? An overview of naturally occurring existential risks A one in ten million chance of extinction in the next 50 years — what many people think the risk is — must be an underestimate. Naturally occurring existential risks can be estimated pretty accurately from history, and are much higher. If Earth was hit by a 1km-wide asteroid, there’s a chance that civilisation would be destroyed. By looking at the historical record, and tracking the objects in the sky, astronomers can estimate the risk of an asteroid this size hitting Earth as about 1 in 5000 per century.4 That’s higher than most people’s chances of being in a plane crash (about one in five million per flight), and already about 1000-times higher than the one in ten million risk that some people estimated.5 Some argue that although a 1km-sized object would be a disaster, it wouldn’t be enough to cause extinction, so this is a high estimate of the risk. But on the other hand, there are other naturally occurring risks, such as supervolcanoes.6 All this said, natural risks are still quite small in absolute terms. An upcoming paper by Dr. Toby Ord estimated that if we sum all the natural risks together, they’re very unlikely to add up to more than a 1 in 300 chance of extinction per century.7 Unfortunately, as we’ll now show, the natural risks are dwarfed by the human-caused ones. And this is why the risk of extinction has become an especially urgent issue. A history of progress, leading to the start of the most dangerous epoch in human history If you look at history over millennia, the basic message is that for a long-time almost everyone was poor, and then in the 18th century, that changed.8 Large economic growth created the conditions in which now face anthropogenic existential risks This was caused by the industrial revolution — perhaps the most important event in history. It wasn’t just wealth that grew. The following chart shows that over the long-term, life expectancy, energy use and democracy have all grown rapidly, while the percentage living in poverty has dramatically decreased.9 Chart prepared by Luke Muehlhauser in 2017. Literacy and education levels have also dramatically increased: Image source. People also seem to become happier as they get wealthier. In The Better Angels of Our Nature, Steven Pinker argues that violence is going down.10 Individual freedom has increased, while racism, sexism and homophobia have decreased. Many people think the world is getting worse,11 and it’s true that modern civilisation does some terrible things, such as factory farming. But as you can see in the data, many important measures of progress have improved dramatically. More to the point, no matter what you think has happened in the past, if we look forward, improving technology, political organisation and freedom gives our descendants the potential to solve our current problems, and have vastly better lives.12 It is possible to end poverty, prevent climate change, alleviate suffering, and more. But also notice the purple line on the second chart: war-making capacity. It’s based on estimates of global military power by the historian Ian Morris, and it has also increased dramatically. Here’s the issue: improving technology holds the possibility of enormous gains, but also enormous risks. Each time we discover a new technology, most of the time it yields huge benefits. But there’s also a chance we discover a technology with more destructive power than we have the ability to wisely use. And so, although the present generation lives in the most prosperous period in human history, it’s plausibly also the most dangerous. The first destructive technology of this kind was nuclear weapons. Nuclear weapons: a history of near-misses Today we all have North Korea’s nuclear programme on our minds, but current events are just one chapter in a long saga of near misses. We came near to nuclear war several times during the Cuban Missile crisis alone.13 In one incident, the Americans resolved that if one of their spy planes were shot down, they would immediately invade Cuba without a further War Council meeting. The next day, a spy plane was shot down. JFK called the council anyway, and decided against invading. An invasion of Cuba might well have triggered nuclear war; it later emerged that Castro was in favour of nuclear retaliation even if “it would’ve led to the complete annihilation of Cuba”. Some of the launch commanders in Cuba also had independent authority to target American forces with tactical nuclear weapons in the event of an invasion. In another incident, a Russian nuclear submarine was trying to smuggle materials into Cuba when they were discovered by the American fleet. The fleet began to drop dummy depth charges to force the submarine to surface. The Russian captain thought they were real depth charges and that, while out of radio communication, the third world war had started. He ordered a nuclear strike on the American fleet with one of their nuclear torpedoes. Fortunately, he needed the approval of other senior officers. One, Vasili Arkhipov, disagreed, preventing war. Thanks to Vasili Arkhipov, we narrowly averted a global catastrophic risk from nuclear weapons Thank you Vasili Arkhipov. Putting all these events together, JFK later estimated that the chances of nuclear war were “between one in three and even”.14 There have been plenty of other close calls with Russia, even after the Cold War, as listed on this nice Wikipedia page. And those are just the ones we know about. Nuclear experts today are just as concerned about tensions between India and Pakistan, which both possess nuclear weapons, as North Korea.15 The key problem is that several countries maintain large nuclear arsenals that are ready to be deployed in minutes. This means that a false alarm or accident can rapidly escalate into a full-blown nuclear war, especially in times of tense foreign relations. Would a nuclear war end civilisation? It was initially thought that a nuclear blast might be so hot that it would ignite the atmosphere and make the Earth uninhabitable. Scientists estimated this was sufficiently unlikely that the weapons could be “safely” tested, and we now know this won’t happen. In the 1980s, the concern was that ash from burning buildings would plunge the Earth into a long-term winter that would make it impossible to grow crops for decades.16 Modern climate models suggest that a nuclear winter severe enough to kill everyone is very unlikely, though it’s hard to be confident due to model uncertainty.17 Even a “mild” nuclear winter, however, could still cause mass starvation.18 For this and other reasons, a nuclear war would be extremely destabilising, and it’s unclear whether civilisation could recover. How likely is a nuclear war to permanently end civilisation? It’s very hard to estimate, but it seems hard to conclude that the chance of a civilisation-ending nuclear war in the next century isn’t over 0.3%. That would mean the risks from nuclear weapons are greater than all the natural risks put together. (Read more about nuclear risks.) This is why the 1950s marked the start of a new age for humanity. For the first time in history, it became possible for a small number of decision-makers to wreak havoc on the whole world. We now pose the greatest threat to our own survival — that makes today the most dangerous point in human history. And nuclear weapons aren’t the only way we could end civilisation. How big is the risk of run-away climate change? In 2015, President Obama said in his State of the Union address that:19 “No challenge  poses a greater threat to future generations than climate change” Climate change is certainly a major risk to civilisation. The graph below shows estimates of climate sensitivity. Climate sensitivity is how much warming to expect in the long-term if CO2 concentrations double, which is roughly what’s expected within the century. Does climate change pose an existential risk? Wagner and Weitzman predict a greater than 10% chance of greater than 6 degrees celsius of warming. Image source The most likely outcome is 2-4 degrees of warming, which would be bad, but survivable. However, these estimates give a 10% chance of warming over 6 degrees, and perhaps a 1% chance of warming of 9 degrees. That would render large fractions of the Earth functionally uninhabitable, requiring at least a massive reorganisation of society. It would also probably increase conflict, and make us more vulnerable to other risks. (If you’re sceptical of climate models, then you should increase your uncertainty, which makes the situation more worrying.) So, it seems like the chance of a massive climate disaster created by CO2 is perhaps similar to the chance of a nuclear war. Researchers who study these issues think nuclear war seems more likely to result in outright extinction, due to the possibility of nuclear winter, which is why we think nuclear weapons pose an even greater risk than climate change. That said, climate change is certainly a major problem, which should raise our estimate of the risks even higher. (Read more about run-away climate change.) What new technologies might be as dangerous as nuclear weapons? The invention of nuclear weapons led to the anti-nuclear movement just a decade later in the 1960s, and the environmentalist movement soon adopted the cause of fighting climate change. What’s less appreciated is that new technologies will present further catastrophic risks. This is why we need a movement that is concerned with safeguarding civilisation in general. Predicting the future of technology is difficult, but because we only have one civilisation, we need to try our best. Here are some candidates for the next technology that’s as dangerous as nuclear weapons. In 1918-1919, over 3% of the world’s population died of the Spanish Flu.20 If such a pandemic arose today, it might be even harder to contain due to rapid global transport. What’s more concerning, though, is that it may soon be possible to genetically engineer a virus that’s as contagious as the Spanish Flu, but also deadlier, and which could spread for years undetected. That would be a weapon with the destructive power of nuclear weapons, but far harder to prevent from being used. Nuclear weapons require huge factories and rare materials to make, which makes them relatively easy to control. Designer viruses might be possible to create in a lab with a couple of biology PhDs. In fact, in 2006, The Guardian was able to receive segments of the extinct smallpox virus by mail order.21 Some terrorist groups have expressed interest in using indiscriminate weapons like these. (Read more about pandemic risks.) In fact, in 2006, The Guardian was able to receive segments of the extinct smallpox virus by mail order. Relevant experts suggest synthetic pathogens could potentially pose a global catastrophic risk. Who ordered the smallpox? Credit: The Guardian Another new technology with huge potential power is artificial intelligence. The reason that humans are in charge and not chimps is purely a matter of intelligence. Our large and powerful brains give us incredible control of the world, despite the fact that we are so much physically weaker than chimpanzees. So then what would happen if one day we created something much more intelligent than ourselves? In 2017, 350 researchers who have published peer-reviewed research into artificial intelligence at top conferences were polled about when they believe that we will develop computers with human-level intelligence: that is, a machine that is capable of carrying out all work tasks better than humans. The median estimate was that there is a 50% chance we will develop high-level machine intelligence in 45 years, and 75% by the end of the century.22 Graph of expert prediction from Grace et al: The median estimate was that there is a 50% chance we will develop high-level machine intelligence in 45 years These probabilities are hard to estimate, and the researchers gave very different figures depending on precisely how you ask the question.23 Nevertheless, it seems there is at least a reasonable chance that some kind of transformative machine intelligence is invented in the next century. Moreover, greater uncertainty means that it might come sooner than people think rather than later. What risks might this development pose? The original pioneers in computing, like Alan Turing and Marvin Minsky, raised concerns about the risks of powerful computer systems,24 and these risks are still around today. We’re not talking about computers “turning evil”. Rather, one concern is that a powerful AI system could be used by one group to gain control of the world, or otherwise be mis-used. If the USSR had developed nuclear weapons 10 years before the USA, the USSR might have become the dominant global power. Powerful computer technology might pose similar risks. Another concern is that deploying the system could have unintended consequences, since it would be difficult to predict what something smarter than us would do. A sufficiently powerful system might also be difficult to control, and so be hard to reverse once implemented. These concerns have been documented by Oxford Professor Nick Bostrom in Superintelligence and by AI pioneer Stuart Russell. Most experts think that better AI will be a hugely positive development, but they also agree there are risks. In the survey we just mentioned, AI experts estimated that the development of high-level machine intelligence has a 10% chance of a “bad outcome” and a 5% chance of an “extremely bad” outcome, such as human extinction.22 And we should probably expect this group to be positively biased, since, after all, they make their living from the technology. Putting the estimates together, if there’s a 75% chance that high-level machine intelligence is developed in the next century, then this means that the chance of a major AI disaster is 5% of 75%, which is about 4%. (Read more about risks from artificial intelligence.) People have raised concern about other new technologies, such as other forms of geo-engineering and atomic manufacturing, but they seem significantly less imminent, so are widely seen as less dangerous than the other technologies we’ve covered. You can see a longer list of existential risks here. What’s probably more concerning is the risks we haven’t thought of yet. If you had asked people in 1900 what the greatest risks to civilisation were, they probably wouldn’t have suggested nuclear weapons, genetic engineering or artificial intelligence, since none of these were yet invented. It’s possible we’re in the same situation looking forward to the next century. Future “unknown unknowns” might pose a greater risk than the risks we know today. Each time we discover a new technology, it’s a little like betting against a single number on a roulette wheel. Most of the time we win, and the technology is overall good. But each time there’s also a small chance the technology gives us more destructive power than we can handle, and we lose everything. Each new technology we develop has both unprecedented potential and perils. Image source. What’s the total risk of human extinction if we add everything together? Many experts who study these issues estimate that the total chance of human extinction in the next century is between 1 and 20%. For instance, an informal poll in 2008 at a conference on catastrophic risks found they believe it’s pretty likely we’ll face a catastrophe that kills over a billion people, and estimate a 19% chance of extinction before 2100.25 Risk At least 1 billion dead Human extinction Number killed by molecular nanotech weapons. 10% 5% Total killed by superintelligent AI. 5% 5% Total killed in all wars (including civil wars). 30% 4% Number killed in the single biggest engineered pandemic. 10% 2% Total killed in all nuclear wars. 10% 1% Number killed in the single biggest nanotech accident. 1% 0.5% Number killed in the single biggest natural pandemic. 5% 0.05% Total killed in all acts of nuclear terrorism. 1% 0.03% Overall risk of extinction prior to 2100 n/a 19% These figures are about one million times higher than what people normally think. In our podcast episode with Will MacAskill we discuss why he puts the risk of extinction this century at around 1%. In his his book The Precipice: Existential Risk and the Future of Humanity, Dr Toby Ord gives his guess at our total existential risk this century as 1 in 6 — a roll of the dice. Listen to our episode with Toby. What should we make of these estimates? Presumably, the researchers only work on these issues because they think they’re so important, so we should expect their estimates to be high (“selection bias”). But does that mean we can dismiss their concerns entirely? Given this, what’s our personal best guess? It’s very hard to say, but we find it hard to confidently ignore the risks. Overall, we guess the risk is likely over 3%. Why helping to safeguard the future could be the most important thing you can do with your life How much should we prioritise working to reduce these risks compared to other issues, like global poverty, ending cancer or political change? At 80,000 Hours, we do research to help people find careers with positive social impact. As part of this, we try to find the most urgent problems in the world to work on. We evaluate different global problems using our problem framework, which compares problems in terms of: Scale – how many are affected by the problem Neglectedness -how many people are working on it already Solvability – how easy it is to make progress If you apply this framework, we think that safeguarding the future comes out as the world’s biggest priority. And so, if you want to have a big positive impact with your career, this is the top area to focus on. In the next few sections, we’ll evaluate this issue on scale, neglectedness and solvability, drawing heavily on Existential Risk Prevention as a Global Priority by Nick Bostrom and unpublished work by Toby Ord, as well as our own research. First, let’s start with the scale of the issue. We’ve argued there’s likely over a 3% chance of extinction in the next century. How big an issue is this? One figure we can look at is how many people might die in such a catastrophe. The population of the Earth in the middle of the century will be about 10 billion, so a 3% chance of everyone dying means the expected number of deaths is about 300 million. This is probably more deaths than we can expect over the next century due to the diseases of poverty, like malaria.26 Many of the risks we’ve covered could also cause a “medium” catastrophe rather than one that ends civilisation, and this is presumably significantly more likely. The survey we covered earlier suggested over a 10% chance of a catastrophe that kills over 1 billion people in the next century, which would be at least another 100 million deaths in expectation, along with far more suffering among those who survive. So, even if we only focus on the impact on the present generation, these catastrophic risks are one of the most serious issues facing humanity. But this is a huge underestimate of the scale of the problem, because if civilisation ends, then we give up our entire future too. Most people want to leave a better world for their grandchildren, and most also think we should have some concern for future generations more broadly. There could be many more people having great lives in the future than there are people alive today, and we should have some concern for their interests. There’s a possibility that human civilization could last for millions of years, so when we consider the impact of the risks on future generations, the stakes are millions of times higher — for good or evil. As Carl Sagan wrote on the costs of nuclear war in Foreign Affairs: A nuclear war imperils all of our descendants, for as long as there will be humans. Even if the population remains static, with an average lifetime of the order of 100 years, over a typical time period for the biological evolution of a successful species (roughly ten million years), we are talking about some 500 trillion people yet to come. By this criterion, the stakes are one million times greater for extinction than for the more modest nuclear wars that kill “only” hundreds of millions of people. There are many other possible measures of the potential loss–including culture and science, the evolutionary history of the planet, and the significance of the lives of all of our ancestors who contributed to the future of their descendants. Extinction is the undoing of the human enterprise. We’re glad the Romans didn’t let humanity go extinct, since it means that all of modern civilisation has been able to exist. We think we owe a similar responsibility to the people who will come after us, assuming (as we believe) that they are likely to lead fulfilling lives. It would be reckless and unjust to endanger their existence just to make ourselves better off in the short-term. It’s not just that there might be more people in the future. As Sagan also pointed out, no matter what you think is of value, there is potentially a lot more of it in the future. Future civilisation could create a world without need or want, and make mindblowing intellectual and artistic achievements. We could build a far more just and virtuous society. And there’s no in-principle reason why civilisation couldn’t reach other planets, of which there are some 100 billion in our galaxy.27 If we let civilisation end, then none of this can ever happen. We’re unsure whether this great future will really happen, but that’s all the more reason to keep civilisation going so we have a chance to find out. Failing to pass on the torch to the next generation might be the worst thing we could ever do. So, a couple of percent risk that civilisation ends seems likely to be the biggest issue facing the world today. What’s also striking is just how neglected these risks are. Why these risks are some of the most neglected global issues Here is how much money per year goes into some important causes:28 Cause Annual targeted spending from all sources (highly approximate) Global R&D $1.5 trillion Luxury goods $1.3 trillion US social welfare $900 billion Climate change >$300 billion To the global poor >$250 billion Nuclear security $1-10 billion Extreme pandemic prevention $1 billion AI safety research $10 million As you can see, we spend a vast amount of resources on R&D to develop even more powerful technology. We also expend a lot in a (possibly misguided) attempt to improve our lives by buying luxury goods. Far less is spent mitigating catastrophic risks from climate change. Welfare spending in the US alone dwarfs global spending on climate change. But climate change still receives enormous amounts of money compared to some of these other risks we’ve covered. We roughly estimate that the prevention of extreme global pandemics receives under 300 times less, even though the size of the risk seems about the same. Research to avoid accidents from AI systems is the most neglected of all, perhaps receiving 100-times fewer resources again, at around only $10m per year. You’d find a similar picture if you looked at the number of people working on these risks rather than money spent, but it’s easier to get figures for money. If we look at scientific attention instead, we see a similar picture of neglect (though, some of the individual risks receive significant attention, such as climate change): Existential risk research receives less funding than dung beetle research. Credit: Nick Bostrom Our impression is that if you look at political attention, you’d find a similar picture to the funding figures. An overwhelming amount of political attention goes on concrete issues that help the present generation in the short-term, since that’s what gets votes. Catastrophic risks are far more neglected. Then, among the catastrophic risks, climate change gets the most attention, while issues like pandemics and AI are the most neglected. This neglect in resources, scientific study and political attention is exactly what you’d expect to happen from the underlying economics, and are why the area presents an opportunity for people who want to make the world a better place. First, these risks aren’t the responsibility of any single nation. Suppose the US invested heavily to prevent climate change. This benefits everyone in the world, but only about 5% of the world’s population lives in the US, so US citizens would only receive 5% of the benefits of this spending. This means the US will dramatically underinvest in these efforts compared to how much they’re worth to the world. And the same is true of every other country. This could be solved if we could all coordinate — if every nation agreed to contribute its fair share to reducing climate change, then all nations would benefit by avoiding its worst effects. Unfortunately, from the perspective of each individual nation, it’s better if every other country reduces their emissions, while leaving their own economy unhampered. So, there’s an incentive for each nation to defect from climate agreements, and this is why so little progress gets made (it’s a prisoner’s dilemma). And in fact, this dramatically understates the problem. The greatest beneficiaries of efforts to reduce catastrophic risks are future generations. They have no way to stand up for their interests, whether economically or politically. If future generations could vote in our elections, then they’d vote overwhelmingly in favour of safer policies. Likewise, if future generations could send money back in time, they’d be willing to pay us huge amounts of money to reduce these risks. (Technically, reducing these risks creates a trans-generational, global public good, which should make them among the most neglected ways to do good.) Our current system does a poor job of protecting future generations. We know people who have spoken to top government officials in the UK, and many want to do something about these risks, but they say the pressures of the news and election cycle make it hard to focus on them. In most countries, there is no government agency that naturally has mitigation of these risks in its remit. This is a depressing situation, but it’s also an opportunity. For people who do want to make the world a better place, this lack of attention means there are lots high-impact ways to help. What can be done about these risks? We’ve covered the scale and neglectedness of these issues, but what about the third element of our framework, solvability? It’s less certain that we can make progress on these issues than more conventional areas like global health. It’s much easier to measure our impact on health (at least in the short-run) and we have decades of evidence on what works. This means working to reduce catastrophic risks looks worse on solvability. However, there is still much we can do, and given the huge scale and neglectedness of these risks, they still seem like the most urgent issues. We’ll sketch out some ways to reduce these risks, divided into three broad categories: 1. Targeted efforts to reduce specific risks One approach is to address each risk directly. There are many concrete proposals for dealing with each, such as the following: Many experts agree that better disease surveillance would reduce the risk of pandemics. This could involve improved technology or better collection and aggregation of existing data, to help us spot new pandemics faster. And the faster you can spot a new pandemic, the easier it is to manage. There are many ways to reduce climate change, such as helping to develop better solar panels, or introducing a carbon tax. With AI, we can do research into the “control problem” within computer science, to reduce the chance of unintended damage from powerful AI systems. A recent paper, Concrete problems in AI safety, outlines some specific topics, but only about 20 people work full-time on similar research today. In nuclear security, many experts think that the deterrence benefits of nuclear weapons could be maintained with far smaller stockpiles. But, lower stockpiles would also reduce the risks of accidents, as well as the chance that a nuclear war, if it occurred, would end civilisation. We go into more depth on what you can do to tackle each risk within our problem profiles: AI safety Pandemic prevention Nuclear security Run-away climate change We don’t focus on naturally caused risks in this section, because they’re much less likely and we’re already doing a lot to deal with some of them. Improved wealth and technology makes us more resilient to natural risks, and a huge amount of effort already goes into getting more of these. 2. Broad efforts to reduce risks Rather than try to reduce each risk individually, we can try to make civilisation generally better at managing them. The “broad” efforts help to reduce all the threats at once, even those we haven’t thought of yet. For instance, there are key decision-makers, often in government, who will need to manage these risks as they arise. If we could improve the decision-making ability of these people and institutions, then it would help to make society in general more resilient, and solve many other problems. Recent research has uncovered lots of ways to improve decision-making, but most of it hasn’t yet been implemented. At the same time, few people are working on the issue. We go into more depth in our write-up of improving institutional decision-making. Another example is that we could try to make it easier for civilisation to rebound from a catastrophe. The Global Seed Vault is a frozen vault in the Arctic, which contains the seeds of many important crop varieties, reducing the chance we lose an important species. Melting water recently entered the tunnel leading to the vault due, ironically, to climate change, so could probably use more funding. There are lots of other projects like this we could do to preserve knowledge. Similarly, we could create better disaster shelters, which would reduce the chance of extinction from pandemics, nuclear winter and asteroids (though not AI), while also increasing the chance of a recovery after a disaster. Right now, these measures don’t seem as effective as reducing the risks in the first place, but they still help. A more neglected, and perhaps much cheaper option is to create alternative food sources, such as those that be produced without light, and could be quickly scaled up in a prolonged winter. Since broad efforts help even if we’re not sure about the details of the risks, they’re more attractive the more uncertain you are. As you get closer to the risks, you should gradually reallocate resources from broad to targeted efforts (read more). We expect there are many more promising broad interventions, but it’s an area where little research has been done. For instance, another approach could involve improving international coordination. Since these risks are caused by humanity, they can be prevented by humanity, but what stops us is the difficulty of coordination. For instance, Russia doesn’t want to disarm because it would put it at a disadvantage compared to the US, and vice versa, even though both countries would be better off if there were no possibility of nuclear war. However, it might be possible to improve our ability to coordinate as a civilisation, such as by improving foreign relations or developing better international institutions. We’re keen to see more research into these kinds of proposals. Mainstream efforts to do good like improving education and international development can also help to make society more resilient and wise, and so also contribute to reducing catastrophic risks. For instance, a better educated population would probably elect more enlightened leaders (cough), and richer countries are, all else equal, better able to prevent pandemics — it’s no accident that Ebola took hold in some of the poorest parts of West Africa. But, we don’t see education and health as the best areas to focus on for two reasons. First, these areas are far less neglected than the more unconventional approaches we’ve covered. In fact, improving education is perhaps the most popular cause for people who want to do good, and in the US alone, receives 800 billion dollars of government funding, and another trillion dollars of private funding. Second, these approaches have much more diffuse effects on reducing these risks — you’d have to improve education on a very large scale to have any noticeable effect. We prefer to focus on more targeted and neglected solutions.