# Harvard R6 1AC---Debris // Constellations

#### Incoming mega-constellations of satellites ensure unmanageable space debris, triggering the Kessler Syndrome.

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).

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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.

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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.

#### Debris triggers miscalculated war.

Dockrill 16 [Peter; 2016; Award-winning science & technology journalist. “Space Junk Accidents Could Trigger Armed Conflict, Study Finds.” <https://www.sciencealert.com/space-junk-accidents-could-trigger-armed-conflict-expert-warns>] brett

The increasingly crowded space in Earth's low orbit could set the stage for an international armed conflict, says a new study. Researchers from the Russian Academy of Sciences warn that accidents stemming from the steady rise in space junk floating around the planet could incite political rows and even warfare, with nations potentially mistaking debris-caused incidents as the results of intentional aggressive acts by others. In a paper published in Acta Astronautica, the team suggests that space debris in the form of spent rocket parts and other fragments of hardware hurtling at high speed pose a "special political danger" that could dangerously escalate tensions between nations. According to the study, destructive impacts caused by random space junk cannot easily be told apart from military attacks. "The owner of the impacted and destroyed satellite can hardly quickly determine the real cause of the accident," the authors write. The risks of such an event occurring are compounded by the sheer volume of debris now orbiting Earth. Recent figures from NASA indicate that there are more than 500,000 pieces of space junk currently being tracked in orbit, travelling at speeds up to 28,160 km/h (17,500 mph). The majority of those objects are small – around the size of a marble – but some 20,000 of them are bigger than a softball. In addition to these 500,000 or so fragments – which are big enough for scientists to know about them – NASA estimates that there are millions of undetectable pieces of debris in orbit that are too small to be monitored. But even extremely small fragments such as these pose a threat – in fact, they're considered a greater risk than trackable debris, as their invisible status means spacecraft and satellites can't do anything to avoid them until it's too late. As NASA observed in 2013: "Even tiny paint flecks can damage a spacecraft when travelling at these velocities. In fact a number of space shuttle windows have been replaced because of damage caused by material that was analysed and shown to be paint flecks… With so much orbital debris, there have been surprisingly few disastrous collisions." While we may have been lucky in the past, we can't rely on that to continue. The study by the Russian team cites the repeated sudden failures of defence satellites in past decades that were never explained. The researchers attribute two possible causes: either unrecorded collisions with space junk, or aggressive actions from adversaries. "This is a politically dangerous dilemma," the authors write.

#### **It goes nuclear.**

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).

#### 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.

#### Cascading debris collapses satellites.

Kessler et al., 18 [Donald J. Kessler\* American astrophysicist and former NASA scientist known for his studies regarding space debris. Kessler has received numerous awards for his pioneering work, the most recent being the 2010 Dirk Brower Award for his half-century career in astrodynamics. Dr. Holder Krag\*\* Head of the Space Debris Office at the European Space Agency and has been a Space Debris Analyst in the Space Debris Office since 2006. Asher Isbrucker\*\*\*, Writer & Video Producer; 11-2-2018; "Kessler Syndrome: What Happens When Satellites Collide," Medium, <https://asherkaye.medium.com/kessler-syndrome-what-happens-when-satellites-collide-1b571ca3c47e>] brett

Donald Kessler: The worst case scenario is that you end up creating enough debris that it’s not cost-effective to depend on space. Now, that may take a long time, but because it’s a non-reversible process, once you’ve reached a certain threshold where you’re generating debris from these collisions faster than it can be cleaned out, it’ll just continually get worse unless you can do something drastic. Holger Krag: If we continue operating the way we do today, we will have a disaster in 50 years, in 100 years. It compares quite nicely to the CO2 issue, and the climate on ground, so it’s not our generation suffering from all the CO2 released into the atmosphere, it is future generations, but it is our generation that has to take the action. And the space debris problem is quite similar. DK: My name’s Don Kessler, I worked for NASA till 1996 as the senior researcher for orbital debris. I started the program back in 1979, and the program is still very active today. In the 1960s my main job was to define the interplanetary meteoroid environment. At the time, the only space debris NASA had to be concerned about were meteoroids, many of which are generated from collisions in the asteroid belt. These asteroid collisions are a cascading phenomenon, meaning every collision creates more ammunition for future collisions. It’s a positive feedback loop. Don was studying this phenomenon when he started to consider an interesting question: DK: When will the same phenomenon start happening in the Earth’s orbit? When will this same kind of cascading occur with satellites? And it was just a matter of curiosity as to what that number may be, and actually when I did the calculations, I was really shocked at the answer that it would happen so soon. Don published a paper in 1978 proposing this scenario, predicting that we’d start to see satellite collisions in Earth orbit by the year 2000. Just like in the asteroid belt, these satellite collisions would trigger a domino effect: creating a whole bunch of debris which causes more collisions, creating more debris, and so on. His main point: once the process starts, it’ll be nearly impossible to stop. This self-perpetuating phenomenon, this domino effect, became known as Kessler Syndrome. The first accidental collision occurred in 1996, when a French satellite was struck by a piece of a rocket thruster that had exploded ten years earlier, severing its stabilization boom and, for the first time, demonstrating how entangled the orbital environment has become. HK: In 2009 a collision happened that was by far more dramatic. The event he’s referring to was the first collision between two intact satellites: the Russian satellite Kosmos and an American Iridium. And that was the first catastrophic accidental collision that got everybody’s attention because not only did they realize how much debris is generated when something like that occurs but that we are now entering this phase of what we’re calling the Kessler Syndrome. Just two years earlier the Chinese military conducted a controversial anti-satellite test, intercepting one of their own defunct weather satellites with a kinetic kill vehicle — a non-explosive missile which relies on sheer speed of impact to destroy its target. It blew the satellite to smithereens and created just a huge mess, it was really bad. DK: And unfortunately it was something they should have known not to do. Yeah, that’s because the US did the same thing back in 1985 — the first anti-satellite test, with more or less the same results. DK: We at NASA tried to delay that or stop that because, we said it’s going to create enough debris that we’ll have to add more shielding to the space station which was planned to be launched a few years later. And nobody believed it would make that much debris, but it did. All of these collisions, accidental or otherwise, make a big mess of junk zipping around the Earth called space debris. It accounts for 95% of the objects in Low Earth orbit, and comes in all shapes and sizes. It’s technically defined as any nonfunctional object in orbit, so there’s big stuff like rocket thrusters and defunct satellites, but the vast majority are little bits and pieces called fragmentation debris. Many of these fragments come from explosions caused by residual fuel and other explosive energy sources self-igniting under the extreme conditions of space. These explosions happen more often than you might think, and as catastrophic and messy as these explosions are, collisions are even worse due to the incredible amount of kinetic energy involved. At the velocities objects travel in Lower Earth Orbit (speeds known as hypervelocity) even an object as tiny as a screw can deliver an incapacitating strike to a satellite. In fact, NASA has repeatedly had to replace shuttle windows due to hypervelocity impacts by flecks of paint. HK: These are velocities, we have no example nor anything that compares to that on ground. So the energy involved in these collisions is extremely high. A 1 cm object that size like a cherry hitting a satellite with 10 km/s, the energy released by this corresponds roughly to an exploding grenade. You can imagine what the satellite looks like after that. DK: Yes, let me know show you something. This is something that was shot in the lab, it’s a projectile about the size of a BB, and it makes a crater into, this is solid aluminum, and this was only going about 5 km/s, about half the speed of what you would expect in space. Most of this is happening in Low Earth Orbit, the 2000 km strip of space above our heads where we’ve packed the vast majority of our satellites, including the International Space Station and the Hubble Space Telescope. The most crowded section is between 500 and 1000 km up. It’s the densest region, it’s the Highway 401 of space. DK: And that’s what’s creating the problem because we’ve crowded so much stuff in that small region. And the probability of collision goes as the square of the spatial density. So you double the number of satellites, you get four times as many collisions. Now, the space station usually flies around 300 km but the debris that’s generated at that higher altitude is being thrown down and drifting down to the lower altitudes. HK: If you look at the space station surface you will find craters everywhere, impact craters caused by debris everywhere. Whenever you bring hardware down and inspect it on ground you find craters of all sizes. What do we do with this? How do you protect the life of the astronauts? The only thing you can do is shielding. And to protect against a hypervelocity impact you need a special type of lightweight shielding, called Whipple shielding. DK: Let me show you something else. The same particle that caused this kind of damage [image below, left] only caused this kind of damage [image below, right]on a surface with a very minor amount of shielding on it. And that’s, it’s almost a liquid splattered onto that. Most spacecraft utilize this type of shielding, which can withstand impacts from objects up to about one centimeter. Objects larger than a softball are catalogued and tracked by the US Space Surveillance Network. Tracking is imprecise, but allows spacecraft to dodge some of the debris that comes too close. This only works for objects larger than 10 cm or so. Anything smaller can’t be reliably tracked. For that reason, the most concerning objects are those between 1 and 10 cm; too large for shielding to withstand and too small to be tracked. These objects could incapacitate any spacecraft in their path, or worse. And with every future explosion and collision there will be more and more of these invisible projectiles going around. The problem gets worse when you consider how long objects can remain in orbit. Depending on altitude, debris in Low Earth Orbit may remain there for years, decades, or centuries before their orbit naturally decays enough to re-enter the Earth’s atmosphere. For example, look no further than ENVISAT; a defunct 8-tonne satellite operated by the European Space Agency until it lost contact in 2012, becoming a massive piece of space junk in the densest region of Earth orbit. ENVISAT will remain in orbit for 200 years if not removed. Experts hope to avoid an encore of ENVISAT and to mitigate Kessler Syndrome through the international adoption of two clean space policies. The first will prevent explosions by requiring so-called passivation of onboard energy sources. HK: Meaning, residual fuel must be either depleted, burned, released through a valve, whatever. That’s number one: no more explosions. DK: And the other is what we call a 25 year rule. Once you put something in orbit, after you finish using it you have 25 years to get it out. Either by moving up to a designated “graveyard orbit” where it will pose minimal risk to active spacecraft or more ideally, lowering its altitude so it will burn up in the atmosphere sooner. These policies aren’t difficult to follow and are beginning to be adopted internationally. HK: When we do these two things that would already make space flight pretty safe for the future. It would mean, if we do this systematically, the risk in the future would be almost the same as it is today. The mitigation measures they help to dampen the effect of the Kessler Syndrome, we are not talking about stopping it, we are talking about maintaining it on an acceptable level, the growth. But it will grow, even if we implement these two measures strictly. If we want to even prevent this growth, then we need to do active removal. DK: We’ve already concluded that it’s going to take something like removing 500 intact objects over the next 100 years in order to stabilize the Low Earth Orbit environment again. That works out to five objects per year for the next century, which at least seems achievable, right? The challenge though is that there’s no easy way to remove space debris. HK: We need to approach the object that are not under control anymore, and attach to them, dock with them, rendezvous them, capture them somehow, and then get rid of them in a controlled way. You can imagine this is not so easy. Experts are working on ways to remove debris, and there are several promising ideas in early development. There are reusable concepts like tethers and space tugs which can grab multiple objects per launch, which saves money. There are ground- or space-based lasers which can deorbit objects by kind of shooting them down, but these face political challenges. There are actually active satellites in space right now, the University of Surrey is controlling a spacecraft called RemoveDEBRIS which will use a harpoon to grab on to debris, that’s promising. And there’s another single-use option like ESA’s e.Deorbit, currently planned to retrieve and deorbit ENVISAT in 2023. Many of these ideas aren’t scalable, though, that’s the problem, they’re expensive and complicated, and missions like these are almost completely unprecedented. The pressure is on, though, because Kessler Syndrome isn’t waiting, and the consequences for space infrastructure are dire. HK: Today only half of the satellites actually disappear from space within the 25 years that are recommended as the maximum on orbit time. We still have five explosions every year. If we continue and not improve the way we do spaceflight, then in a few decades some regions of space might not be useable anymore for spaceflight, or it might be much too risky to go there. And that might mean that we either lose services from space that we rely on today, or they get more expensive. AI: Do you think something like Kessler Syndrome is inevitable? Are you optimistic that this can be managed properly, or do you think this is an inevitable issue for a spacefaring society? HK: I think it can be managed, it can be managed. I do believe it’s time for young people to take charge and there’s a lot of work to be done, and there’s enough people involved today that I’m confident that it’s going to be done. Much like other environmental and generational problems, Kessler Syndrome is invisible to us. When you look up at the night sky, you don’t see collisions and explosions and fragments of debris. If you’re lucky and the conditions are right, you might see one white speck drifting across the sky, a tiny testament to humankind’s highest collective ambitions. But that speck is at risk, along with all it represents, if we don’t address this invisible problem — because Kessler Syndrome isn’t waiting.

#### The modern food system relies on satellites. Collapse triggers global shocks to supply.

Tompkins 19 [Steven, Inmarsat’s Director of Sector Development for Agriculture. Head of Resilient and Sustainable Supply Chains Team at ADAS. Entrepreneurial manager with a sustained track record of building new profitable business streams for science-based organizations in the agri-food sector.; 3-18-2019; "Enabling the connected farm – the importance of satellite communications," Inmarsat, <https://www.inmarsat.com/blog/enabling-the-connected-farm-the-importance-of-satellite-communications/>] brett

The Agri-Tech Revolution, Agriculture 4.0, the smart and connected farm. There is no shortage of buzzwords hinting at a digitalised future, or solutions being touted as game-changing for the global agricultural industry. Commonly claimed benefits include increasing crop yields, and a reduction in input costs and the reliance on manual labour. Many of these solutions rely on reliable internet connectivity in the field to push data from one place to another, but there are still vast swathes of agricultural land that suffer from unreliable or non-existent connectivity, either lacking cellular or broadband connectivity. If we are to take advantage of the huge possibilities available to us, overcoming our connectivity challenges will be crucial. This is where satellite communications can help. When I tell people that I am an agriculturalist working for a satellite company, almost always the response is related to an experience of using space imagery (known as Earth Observation) to help automate processes such as crop scouting. But there is another breed of satellites that don’t produce images but do provide fast and reliable internet and voice communications across the world in areas that cellular and fibre connectivity cannot reach. Ubiquitous connectivity from satellites opens up huge possibilities for farmers in remote areas to take advantage of the Agri-Tech Revolution. In some cases, this is as simple as connecting frontline worker teams in large plantations to operations centres to prioritise workload and create efficiencies. Taking it one step further, satellite communications can be a bridge to enable farmers to connect data producing devices in the field (such as weather stations, sensors, data from farm machinery) to business applications. Known by the tech world as the ‘Internet of Things’ or IoT, this approach collects data from the field and harnesses it to support intelligent decision-making. For instance: obtaining real-time data on nutrient status in the field from NPK (Nitrogen Phosphorous and Potassium) sensors, alongside crop monitoring data and hyper-local weather that would allow you to make completely objective risk-based decisions on when and where to apply fertiliser. We know the industry is taking this proposition seriously – our own research told us that on average agriculture respondents expect to spend close to $1million on IoT solutions in the next three years and 72% of respondents would use satellite technology to support their projects. Of course, satellite isn’t the answer to everything and should be used in tandem with other connectivity types, and the good news is it’s easy to integrate with other connectivity technologies. With increasing demand to connect the physical world to the digital world, in some of the world’s remotest locations think of satellite not just as a series of images taken from space but an enabler to the Agri-Tech Revolution.

#### Food shortages go nuclear.

FDI 12 [FDI; a Research institute providing strategic analysis of Australia’s global interests; citing Lindsay Falvery, PhD in Agricultural Science and former Professor at the University of Melbourne’s Institute of Land and Environment (Future Directions International, , “Food and Water Insecurity: International Conflict Triggers & Potential Conflict Points,” <http://www.futuredirections.org.au/workshop-papers/537-international-conflict-triggers-and-potential-conflict-points-resulting-from-food-and-water-insecurity.html>] brett

There is a growing appreciation that the conflicts in the next century will most likely be fought over a lack of resources. Yet, in a sense, this is not new. Researchers point to the French and Russian revolutions as conflicts induced by a lack of food. More recently, Germany’s World War Two efforts are said to have been inspired, at least in part, by its perceived need to gain access to more food. Yet the general sense among those that attended FDI’s recent workshops, was that the scale of the problem in the future could be significantly greater as a result of population pressures, changing weather, urbanisation, migration, loss of arable land and other farm inputs, and increased affluence in the developing world. In his book, Small Farmers Secure Food, Lindsay Falvey, a participant in FDI’s March 2012 workshop on the issue of food and conflict, clearly expresses the problem and why countries across the globe are starting to take note. . He writes (p.36), “…if people are hungry, especially in cities, the state is not stable – riots, violence, breakdown of law and order and migration result.” “Hunger feeds anarchy.” This view is also shared by Julian Cribb, who in his book, The Coming Famine, writes that if “large regions of the world run short of food, land or water in the decades that lie ahead, then wholesale, bloody wars are liable to follow.” He continues: “An increasingly credible scenario for World War 3 is not so much a confrontation of super powers and their allies, as a festering, self-perpetuating chain of resource conflicts.” He also says: “The wars of the 21st Century are less likely to be global conflicts with sharply defined sides and huge armies, than a scrappy mass of failed states, rebellions, civil strife, insurgencies, terrorism and genocides, sparked by bloody competition over dwindling resources.” As another workshop participant put it, people do not go to war to kill; they go to war over resources, either to protect or to gain the resources for themselves. Another observed that hunger results in passivity not conflict. Conflict is over resources, not because people are going hungry. A study by the International Peace Research Institute indicates that where food security is an issue, it is more likely to result in some form of conflict. Darfur, Rwanda, Eritrea andthe Balkans experienced such wars. Governments, especially in developed countries, are increasingly aware of this phenomenon. The UK Ministry of Defence, the CIA, the US Center for Strategic and International Studies and the Oslo Peace Research Institute, all identify famine as a potential trigger for conflicts and possibly even nuclear war.

### Plan

#### Resolved: States ought to prohibit the appropriation of Low Earth Orbit by private entities.

#### The plan clarifies customary law to ban private satellite mega-constellations that appropriate Low Earth Orbit and solves otherwise detrimental space debris.

Johnson 20 [Chris, Space Law Advisor for Secure World Foundation, 9 years of professional experience in international space law and policy. J.D. from New York Law School; 2020; “The Legal Status of MegaLEO Constellations and Concerns About Appropriation of Large Swaths of Earth Orbit,” <https://swfound.org/media/206951/johnson2020_referenceworkentry_thelegalstatusofmegaleoconstel.pdf>] brett

Yes, This Is Impermissible Appropriation

Article II of the Outer Space Treaty, discussed above, is clear on the point that the appropriation of outer space, including the appropriation of either void space or of celestial bodies, is an impermissible and prohibited action under international law. No means or methods of possession of outer space will legitimize the appropriation or ownership of outer space, or subsections thereof.

Excludes Others

The constellations above, because they seem to so overwhelmingly possess particular orbits through the use of multiple satellites to occupy orbital planes, and in a manner that precludes other actors from using those exact planes, constitute an appropriation of those orbits. While the access to outer space is nonrivalrous – in the sense that anyone with the technological capacity to launch space objects can therefore explore space – it is also true that orbits closer to Earth are unique, and when any actor utilizes that orbit to such an extent to these proposed constellations will, it means that other actors simply cannot go there.

To allow SpaceX, for example, to so overwhelmingly occupy a number of altitudes with so many of their spacecraft, essentially means that SpaceX will henceforth be the sole owner and user of that orbit (at least until their satellites are removed). No other actors can realistically expect to operate there until that time. No other operator would dare run the risk of possible collision with so many other spacecraft in that orbit. Consequently, the sole occupant will be SpaceX, and if “possession is 9/10th of the law,” then SpaceX appears to be the owner of that orbit.

Done Without Coordination

Additionally, SpaceX and other operators of megaconstellations are doing so without any real international conversation or agreement, which is especially egregious and transgressive of the norms of outer space. Compared to the regime for GSO, as administered by the ITU and national frequency administrators, Low Earth Orbit is essentially ungoverned, and SpaceX and others are attempting to seize this lack of authority to claim entire portions of LEO for itself; and before any international agreement, consensus, or even discussion is had. They are operating on a purely “first come, first served” basis that smacks of unilateralism, if not colonialism.

Governments Are Ultimately Implicated

As we know, under international space law, what a nongovernmental entity does, a State is responsible for. Article VI of the Outer Space Treaty requires that at least one State authorize and supervise its nongovernmental entities and assure their continuing compliance with international law. As such, the prohibition on nonappropriation imposed upon States under Article II of the Outer Space Treaty applies equally to nongovernmental private entities such as SpaceX.

Nevertheless, through the launching and bringing into use of the Starlink constellation, SpaceX will be the sole occupant, and thereby, possessor, both fact and in law, of 550 km, 1100 km, 1130 km, 1275 km, and 1325 km above our planet (or whatever orbits they finally come to occupy). The same is true for the other operators of these large constellations which will be solely occupying entire orbits.

Long-Term Occupation Constitutes Appropriation

These altitudes are additionally significant, as nonfunctional spacecraft in orbits lower than around 500 km will re-enter the Earth’s atmosphere in months or a few years, but the altitudes selected for the Starlink constellation, while technologically desirable for their purposes, also mean that any spacecraft which are not de-orbited from these regions may be there for decades, or possibly even hundreds of years. By comparison, the granting of rights for orbital slots at GSO is in 15-year increments, a length of time much less than what the altitudes of the megaconstellations threaten. Such long spans of time at these altitudes by these megaconstellations further bolster the contention that this occupation rises to the level of appropriation of these orbits.

Prevents Others from Using Space

Article I of the Outer Space Treaty establishes that the exploration and use of outer space is “the province of all mankind.” It further requires that this exploration and use shall be by all States “without discrimination of any kind, on a basis of equality and in accordance with international law...” However, when one private corporation so overwhelmingly possesses entire portions of outer space, their use is discriminatory to other potential users and interferes with their freedom to access, explore, and use outer space. So long as these actors are so dominantly possessing and occupying those orbits, their actions exclude others from using them. What other operator would dare use orbits where there are already hundreds of satellites operating as part of a constellation? It would be an extremely unwise and risky decision to try to share these orbits with a mega constellation, so they will likely choose other altitudes and orbits. This massive occupation of particular orbits effectively defeats others from enjoying the use of outer space. While a State can issue permits for one of its corporations allowing them to launch and operate satellites to this extent, that does not automatically mean that their activities in outer space, an area beyond national sovereignty, are therefore in perfect accordance with the strictures of international law. Indeed, national permissions offer no such guarantee.

No Due Regard for Others

That these megaconstellations violate the prohibition on appropriation in Article II is additionally supported by Article IX of the Outer Space Treaty. Article IX requires that in the exploration and use of outer space, States “shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space... with due regard to the corresponding interests of other States...” There is hardly any way to view this deployment of megaconstellations as showing any type of due regard to the corresponding interests of others. This lack of regard further supports the notion of their unilateral transgressive violations of the purposes of space law norms.

Harmful Contamination

The impacts of the spacecraft on the pressing issue of space debris need not be gone into detail here. Suffice it to say, megaconstellations threaten mega-debris. The failure rate of these comparatively cheap satellites should give pause, because if 5% of a constellation of 100 satellites fails, this is 5 guaranteed new pieces of debris intentionally introduced to the fragile space domain. Article IX of the Outer Space Treaty warns of harmful contamination of the space environment and requires States to take appropriate measures to prevent this harmful contamination. A responsible government could not, in all seriousness, permit the intentional release of such amounts of space debris, especially in the already fraught orbits that many megaconstellations are headed towards. While the threat of space debris is not directly relevant to the accusation of appropriation of outer space, it goes towards the argument that these actors are conducting activities in a manner lacking in regard to others, and in fact, amounts to excluding others from using the space domain. By excluding others, this has the effect of taking orbits for themselves, which IS occupation.

If This Isn’t Appropriation, Then What Is?

Arguing in the alternative, if these megaconstellations — in their dominant occupation of entire orbits in orbital planes with numerous satellites — could be considered (merely for the sake of argument) to not be appropriation, we must therefore ask: what would be appropriation? What use of void space, including orbits of the Earth, would constitute actual appropriation? What further, additional fact of these uses of space, if added to the scenario, would cause that constellation to cross over the line into clearly prohibited appropriation? Perhaps the exact same scenario, but supplemented with an actual, formal claim of sovereignty, issued by a government, is the only element which could be added to megaconstellations which would then cross the threshold into appropriation. However, a formal claim of sovereignty would be merely an act occurring on Earth and would not change any actual facts in the space domain. Consequently, the lack of a formal claim of sovereignty should not be the deciding criteria in arriving at the conclusion that megaconstellations constitute appropriation of orbits.

Conclusion

In conclusion, these megaconstellations effectively occupy entire orbital regions with their vast fleet of spacecraft and in so doing effectively preclude other actors from sharing those domains. They have done so, or are attempting to do so, without any international consensus or discussion, which is most egregious for a domain outside of State sovereignty and which no State can own. Governments will ultimately be responsible for this appropriation, and both are prohibited from appropriating space. In distinction to GSO, their permission to go there means that they could occupy these regions for incredibly long periods — which again shows their appropriation. These constellations significantly prevent others from using those regions, which therefore interferes with others’ right to explore and use space. And ultimately, this reckless ambition shows absolutely no due regard (as per Article IX) for the corresponding rights of others. As such, these megaconstellations constitute an impermissible appropriation of particular regions of outer space, regardless of any formal, official claim of such by a responsible, authorizing government.

#### No circumvention. Authorization, supervision, and liability ensure compliance -- potential for liability causes self-regulation.

Johnson 20 [Chris, Space Law Advisor for Secure World Foundation, 9 years of professional experience in international space law and policy. J.D. from New York Law School; 2020; “The Legal Status of MegaLEO Constellations and Concerns About Appropriation of Large Swaths of Earth Orbit,” <https://swfound.org/media/206951/johnson2020_referenceworkentry_thelegalstatusofmegaleoconstel.pdf>] brett

Authorization and Continuing Supervision

The second sentence of Article VI then gives States a positive obligation to undertake authorization and continuing supervision of nongovernmental entities.

The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty.

Consequently, it is not merely sufficient that governments allow private actors to access and explore space. States have a duty to authorize and supervise them. Looking again at the first sentence of Article VI, above, gives some indication as to what standard this supervision must meet. The first sentence of Article VI ends with “... and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty.” Consequently, States must authorize and supervise private entities to make sure that these private entities conform with the Outer Space Treaty.

Additionally, Article III of the Outer Space Treaty creates a link between the treaty and the rest of international law, including the UN Charter. Therefore, and to the extent that other sources of international law create norms applicable for private entities in outer space, all national activities – including private, nongovernmental activities – must conform with said laws. Some of these other sources include the other UN treaties on outer space, such as the 1968 Astronaut Rescue and Return Agreement, the 1972 Liability Convention, and the 1975 Registration Convention. Other specialized treaties on outer space, like the international telecommunications regime of the International Telecommunications Union Convention and Constitution, international enviromental law, international humanitiarian law, and other special regimes also form the rest of the normative order for outer space.

Potential Liability

Supplemental to international responsibility for acts in space committed by private entities is the potential for liability for damage resulting from their activities. Article VIII of the Outer Space Treaty establishes a liability provision, and the 1972 Liability Convention expands the mechanisms for dealing with liability claims. Liability is a requirement to pay compensation to an injured party for the damage or suffering that has been caused to them. In space law, liability is for physical damage to a space object by another space object. These provisions on liability have not yet been enforced relating to any actual claims of damage in space. However, and just like the obligation to be internationally responsible for private actors mentioned in Article VI, the potential for liability serves as a strong motivator and incentive for States to oversee, monitor, and regulate what private actors are doing in space.

#### LEO is in outer space. Outerspace is defined in the card.

DoC 16 [Department of Commerce; February 22, 2016; National Oceanic & Atmospheric Administration, “Where is Space?”, <https://www.nesdis.noaa.gov/news/where-space>] brett

But where is “space” exactly? This may seem like a simple question, but any answer beyond “up” may be more complicated than you think. Although most people are generally in agreement that space begins when Earth’s atmosphere ends— where exactly that is depends on who you ask.

International law states that outer space shall be free for exploration and use by all, but there is no definitive law stating where national air space actually ends and outer space begins. This leaves the door open for a variety of interpretations.

A common definition of space is known as the Kármán Line, an imaginary boundary 100 kilometers (62 miles) above mean sea level. In theory, once this 100 km line is crossed, the atmosphere becomes too thin to provide enough lift for conventional aircraft to maintain flight. At this altitude, a conventional plane would need to reach orbital velocity or risk falling back to Earth.

The world governing body for aeronautic and astronautic records, the Fédération Aéronautique Internationale (FAI), and many other organizations use the Kármán Line as a way of determining when space flight has been achieved.

### Framing

**The value is morality and the criterion is utilitarianism**

#### **Moen 16** [Ole Martin Moen, Research Fellow in Philosophy at University of Oslo “An Argument for Hedonism” Journal of Value Inquiry (Springer), 50 (2) 2016: 267–281] SJDI // RCT by JPark

Let us start by observing, empirically, that a widely shared judgment about intrinsic value and disvalue is that pleasure is intrinsically valuable and pain is intrinsically disvaluable. On virtually any proposed list of intrinsic values and disvalues (we will look at some of them below), pleasure is included among the intrinsic values and pain among the intrinsic disvalues. This inclusion makes intuitive sense, moreover, for there is something undeniably good about the way pleasure feels and something undeniably bad about the way pain feels, and neither the goodness of pleasure nor the badness of pain seems to be exhausted by the further effects that these experiences might have. “Pleasure” and “pain” are here understood inclusively, as encompassing anything hedonically positive and anything hedonically negative.2 The special value statuses of pleasure and pain are manifested in how we treat these experiences in our everyday reasoning about values. If you tell me that you are heading for the convenience store, I might ask: “What for?” This is a reasonable question, for when you go to the convenience store you usually do so, not merely for the sake of going to the convenience store, but for the sake of achieving something further that you deem to be valuable. You might answer, for example: “To buy soda.” This answer makes sense, for soda is a nice thing and you can get it at the convenience store. I might further inquire, however: “What is buying the soda good for?” This further question can also be a reasonable one, for it need not be obvious why you want the soda. You might answer: “Well, I want it for the pleasure of drinking it.” If I then proceed by asking “But what is the pleasure of drinking the soda good for?” the discussion is likely to reach an awkward end. The reason is that the pleasure is not good for anything further; it is simply that for which going to the convenience store and buying the soda is good.3 As Aristotle observes: “We never ask [a man] what his end is in being pleased, because we assume that pleasure is choice worthy in itself.”4 Presumably, a similar story can be told in the case of pains, for if someone says “This is painful!” we never respond by asking: “And why is that a problem?” We take for granted that if something is painful, we have a sufficient explanation of why it is bad. If we are onto something in our everyday reasoning about values, it seems that pleasure and pain are both places where we reach the end of the line in matters of value.

#### 1] Bindingness-- I could put my hand on a hot stove and I’d automatically pull it back before a signal is sent to my brain—

#### 2] Actor spec—governments must use util because they don’t have intentions and are constantly dealing with tradeoffs—outweighs since different agents have different obligations

#### 3] Extinction first under any framework

#### A] Future lives -- trillions of future lives are lost. They are just as valuable as current ones – anything else says some lives are worth less than others which is a slippery slope to genocide

#### B] Reversibility -- extinction forecloses future improvement; prefer moral uncertainty -- if we’re unsure about which interpretation of the world is true, we should preserve it to figure things out.