### Framework

#### My Value is justice

#### The meta ethic is motivationalism – people need to want to follow a theory of justice any other starting point begs the question of why we follow the framework in the first place.

#### Other frameworks fail. Motivational externalism collapses into internalism.

Joyce Joyce, Richard. “Richard Joyce - The Myth of Morality (Cambridge Studies in Philosophy) (2002).” www.docme.ru/doc/1269345/richard-joyce---the-myth-of-morality--cambridge-studies-i...

Back to the [Suppose] external reason[s]. Suppose it were claimed, instead, that I have a reason to refrain from drinking the coffee because it is tapu and must not be touched. This reason claim will be urged regardless of what I may say about my indifference to tapu, or my citing of nihilistic desires to tempt the hand of fate. [r]egardless of my desires (it is claimed) I ought not drink - l have a reason not to drink. But **how could** that reason ever explain any action of mine? Could the **external reason** even **explain** my **[action]** from drinking**?** Clearly, in order to explain it **the** external **reason must have some causal**ly efficacious **role [in]** among the antecedents of **the action** (in this case, an omission) — l must have. in some manner. "internalized" it. The only possibility, it would seem, consistent with its being an external reason, is that I believe the external reason claim [but] : I believe that the coffee is tapu. There's no doubting that such a belief can play a role in explaining actions - including my refraining from drinking the coffee. The question is whether the **belief alone can[not] produce action**, to which the correct answer is “No.” A very familiar and eminently sensible view says that **in order to explain** an **action** the **belief must couple with desire**s (such that those same desires had in the absence of the belief would not have resulted in the action). And this seems correct: if I believe that the coffee is [bad] tapu but really just don’t care about that, then I will not refrain from drinking it. So in order for the belief to explain action it must couple with [desire] elements - but in that case the putative **external reason collapses into** an **internal** one.3

#### Agents can only be motivated their own desires; not the external desires of another because A) one can’t access the desires of others and B) because there are infinite desires of others that aren’t communicated and thus accounted for.

#### Only contractarianism’s foundation in the empirical fact that individuals have desires provides a non-circular origin for the ability to form a moral obligation.

Gauthier**,** Gauthier, David P. *Morals by Agreement*. Oxford: Clarendon, 1986. Print.

**“A contractarian theory** of morals, developed as part of the theory of rational choice, has evident strengths. It enables us to **demonstrate[s] the rationality of impartial constraints on the pursuit of individual interest to persons who** may **take no interest in others'** interests**.** Morality **is** thus **given a** sure **grounding in a** weak and widely accepted **conception of practical rationality. No alternative account** of morality **accomplishes this. Those who claim that** moral **principles are objects of rational choice in special circumstances fail to establish the rationality of actual compliance** with these principles. Those who claim **to establish the rationality of such compliance appeal[s] to a** strong and controversial **conception of reason that** seems to **incorporate[s] prior** moral **suppositions**. No alternative account generates morals, as a rational constraint on choice and action, from a non-moral, or morally neutral, base.”

#### Thus, the standard is consistency with contractual obligations.

#### This isn’t consequentialist. Contractual obligations are a question of the inherent action not aggregating violations. If you buy a nice car from a store, and a criminal sees you driving and decides to steal it you didn’t break the law even though your action consequentially led to more violations.

#### Prefer additionally

#### A] Prereq: Only contracts dictate action without begging the question of why actors ought to comply since they brought the expectations upon themselves and can’t justify disobeying.

#### B] Topic Lit: space appropriation’s legality is the core of the topic -- most literature is on whether actions follow agreements not whether they cause harms.

#### C] Contracts controls all layers, every ballot claim presumes a contractual expectation between the judge and debater to vote on arguments made in round, otherwise the judge has no motivation to not simply intervene however they wish.

D] Its textually based: just means legally correct

**Merriam Webster** (Merriam Webster, Definition of JUST, No Publication, https://www.merriam-webster.com/dictionary/just, accessed 1-5-2022)//iLake-💣🍔

legally correct: [LAWFUL](https://www.merriam-webster.com/dictionary/lawful) //just title to an estate

#### Just means in accordance with law

**Black’s Law Dictionary** (Black’s Law Dictionary, What is JUST? definition of JUST (Black's Law Dictionary), <https://thelawdictionary.org/just/>, accessed 1-5-2022)//iLake-💣🍔

What is JUST? Right; in accordance with law and justice. “

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

#### Customary law provides a contractual prohibition on space appropriation and the plan clarifies it to ban private satellite mega-constellations that appropriate Low Earth Orbit and solves otherwise detrimental space debris. That’s offense under our framework.

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.

### Advantage 1 is war

#### 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).

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.

#### Technical solutions to debris and natural disappearance don’t assume increasing atmospheric changes

Benjamin **Schmitt, 21** (Benjamin Schmitt, Earth’s Destructive Tumbling Stars, CEPA, https://cepa.org/earths-destructive-tumbling-stars/, 11-12-2021)//iLake-💣🍔

But while many of these technical solutions involve some variation on forcing debris to lower altitudes for incineration in Earth’s atmosphere, the primary physical mechanism that helps to clear space debris naturally — high-altitude atmospheric drag — in fact may be impeded by climate change itself. According to a [study led](https://www.nytimes.com/2021/05/12/science/space-junk-climate-change.html) by Professor Hugh Lewis of the University of Southampton, the same increases in carbon dioxide levels that are driving climate effects, also reduce the nominal atmospheric density at high altitudes, reducing drag. Lewis has also [recently warned](https://www.space.com/spacex-starlink-satellite-collision-alerts-on-the-rise) of the increased risk of satellite collisions seen in the growing fleet of SpaceX Starlink satellite mega-constellations, and with more of these projects waiting in the wings – including one backed by China – the situation will only become more concerning. The space around our planet is becoming increasingly congested.

#### It collapses satellite networks and kills other space development

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.

#### This causes war 2 scenarios:

#### 1] Debris hits are mistaken for aggression and causes miscalculation.

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.

#### **With no satellites, war 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).

#### Satellite course changes and debris independently trigger missile defense systems.

Hoots 15 (Felix; Fall 2015; Distinguished Engineer in the System Analysis and Simulation Subdivision, Ph.D. in Mathematics from Auburn University, M.S. in Mathematics from Tennessee Tech University; Crosslink, “Keeping Track: Space Surveillance for Operational Support,” <https://aerospace.org/sites/default/files/2019-04/Crosslink%20Fall%202015%20V16N1%20.pdf>)

The launch of Sputnik on October 4, 1957, marked the beginning of the Space Age. It also marked the beginning of an intense space race that brought a remarkable rate of rocket launches. In a very short time, the number of objects in orbit grew dramatically. This created a host of strategic challenges, including the need for space surveillance. In particular, the Air Force needed a way to prevent false alarms as satellites came within view of missile-warning radars, while the Navy needed a way to alert deployed units of possible reconnaissance by satellites overhead. These needs led to the establishment of a military mission to maintain a catalog of all Earth-orbiting objects—active payloads, rocket bodies, and debris—along with detailed information about trajectory and point of origin. Such a catalog could be used to filter normal orbital passages from potential incoming missiles and predict the passage of suspected spy satellites. The first catalog was relatively small in comparison with today’s version, which lists more than 22,000 items (as of May 2015). Also, the current version supports much more than the original military mission—and Aerospace is helping to extend its utility even further. The Space Catalog The Space Catalog is maintained by the Joint Space Operations Center (JSpOC) at Vandenberg Air Force Base, part of U.S. Strategic Command. One of the missions of JSpOC is to detect, track, and identify all artificial objects in Earth orbit. A key component of this mission is the Space Surveillance Network, a worldwide system of ground-based radars along with ground-based and orbital telescopes. The radars are used primarily for tracking near-Earth satellites with orbital period of 225 minutes or less, as well as some eccentric orbits that come down to near-Earth altitudes as they go towards their perigee. Ground-based telescopes are used for tracking more distant satellites, with orbital period greater than 225 minutes, and space-based sensors are used to track both near and distant satellites. The JSpOC tasks these sensors to track specific satellites and to record data such as time, azimuth, elevation, and range. This data is used to create orbital element sets or state vectors that represent the observed position of the satellite. The observed position can then be compared with the predicted position. The dynamic models used for predicting satellite motion are not perfect; factors such as atmospheric density variation caused by unmodeled solar activity can cause the predicted position to gradually stray from the true position. The observations are used to correct the predicted trajectory so the network can continue to track the satellite. This process of using observations to correct and refine an orbit in an ongoing feedback loop is called catalog maintenance, and it continues as long as the satellite remains in orbit. Ideally, the process is automatic, with manual inter vention only required when satellites maneuver or get near to reentry due to atmospheric drag. Sometimes, however, more effort is required. For example, a sensor may encounter a satellite trajectory that does not correspond well to anything in the catalog. Such observations are known as partially correlated observations if they are somewhat close to a known orbit or uncorrelated observations (or uncorrelated tracks) if they are far from any known orbit. Also, if a satellite is not tracked for five days, it is placed on an attention list for manual intervention. In that case, an analyst will attempt to match the wayward satellite to one of these partially correlated or uncorrelated tracks. If that effort succeeds, then the element sets are updated, and the object is returned to automatic catalog maintenance. On the other hand, if the satellite cannot be matched to a partially correlated or uncorrelated track, the satellite information continues to age. If it reaches 30 days without a match, the satellite is placed on the lost list. Risk Prediction One of the most visible uses of the catalog is to warn about collision risks for active payloads. This function predicts potential close approaches three to five days in advance to allow time to plan avoidance maneuvers, if necessary. Unplanned maneuvers may disturb normal operations and deplete resources for future maneuvers, so one would like to have high confidence in the collision-risk predictions. The reliability of the predictions depends directly on the accuracy of the orbit calculation, which in turn depends on the quality and quantity of the tracking data, which is limited by the capability of the Space Surveillance Network. Simply put, there are not enough tracking resources in the network to achieve high-quality orbits for every object in the catalog. Furthermore, many smaller objects can only be tracked by the most sensitive radars, and this tracking is infrequent. Most objects in the catalog are considered debris, which can neither maneuver nor broadcast telemetry. On the other hand, some satellite operators depend exclusively on the satellite catalog to know where their satellites are, and users of the satellite orbital data depend on the catalog to know when the satellites will be within view. This situation creates a challenging problem in balancing Space Surveillance Network resources to support the collision-warning task (tracking as many potential hazards as possible) while also providing highly accurate support to operational satellites (tracking the spacecraft as precisely as possible). The practical solution is to perform collision risk assessment using a large screening radius to ensure no close approaches are missed despite lower-quality predictions. Once an object is identified as having a potentially close approach, then the tasking level is raised, with the expectation that more tracking data will be obtained to refine the collision risk calculations. When the danger has passed, the object reverts to a normal tracking level. Collisions and spontaneous breakups do happen. The first satellite breakup occurred on June 29, 1961, when residual fuel in an Ablestar rocket body exploded, creating 296 trackable pieces of debris. Since that time, there have been more than 200 satellite breakups, the most notable being the missile intercept of the Fengyun-1C satellite, which created more than 3300 trackable fragments. In most cases, these breakups are first detected by the phased-array radars in the Space Surveillance Network. When multiple objects are observed where only one was expected, the downstream sensors are alerted, but no tasking is issued because specific debris orbits are not yet established. Tracks are taken and tagged as uncorrelated. Analysts at JSpOC then attempt to link uncorrelated tracks from different sensors to form a candidate orbit. Subsequent tracking improves the orbit to the point that the object can be named and numbered and moved into the catalog for automatic maintenance.

#### Activating early warning systems leads to nuclear launches

Rogoway 15 (Tyler; November 12; Defense Journalist and Editor of Time Inc’s The War Zone; Jalopnik, “These Are The Doomsday Satellites That Detected The Explosion Of Metrojet 9268,” <https://foxtrotalpha.jalopnik.com/these-are-the-doomsday-satellites-that-detected-the-exp-1737434876>)

For over 50 years the Pentagon has had early warning satellites in orbit aimed at spotting launches of ballistic missiles, especially the big intercontinental kind that can fly around the globe in less than 30 minutes and bring about nuclear Armageddon. Recently, these satellites have made news for their “secondary capabilities,” spotting the downing of Metrojet Flight 9268 and Malaysian Airlines Flight 17. These are the shadowy satellites that are capable of such amazing feats, and an idea of how they work. In 1960, at the height of the Cold War and at the dawn of the space age, the first Missile Defense Alarm System (MiDAS) satellite was launched into low earth orbit. Six years later there was a constellation of nine of these satellites roaming the heavens, each scanning the Soviet Union for large infrared plumes, the tell-tale sign of a ballistic missile or rocket launch. These fairly crude, low-earth orbit satellites, along with the radar-based Ballistic Missile Early Warning System, would be the basis for a Cold War ballistic missile surveillance system that would become ever more complex and capable as the years went by. If ballistic missile launches were detected and deemed a threat, the decision to retaliate would mean the National Command Authority making the call to do so within half an hour, an act that could bring an the end of humanity’s reign on Earth, permanently. The first really reliable and full coverage space-based ballistic missile early warning capability came with the launch of the first Defense Support Program (DSP) satellite in 1970. These new satellites were much more capable than their MiDAS predecessors. Early DSP satellite design was relatively straight forward, with the satellites’ spinning around their center axis while in geosynchronous orbit. This allows their telescopic infrared sensor to continuously sweep an area of the planet in a relatively brief amount of time, around six times in one minute. If something were detected, the information would immediately be data-linked to controllers on the ground at the 460th Space Wing located at Buckley AFB in in Colorado. A total of 23 of these satellites have been launched over the program’s life, with constant upgrades made along the way. A DSP satellite was launched by the Space Shuttle on STS-44 in 1991, and the last one was launched by a Delta IV Heavy in 2007. Most famously, the Defense Support Program constellation of satellites were used to detect launches of SCUD missiles during Operation Desert Storm.

#### 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] 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.

### Advantage 2 is climate

#### Space debris jeopardizes government satellites which are necessary to stop climate change and natural disasters

Jonathan **O’Callaghan, 21** (Jonathan O’Callaghan, What if Space Junk and Climate Change Become the Same Problem?, No Publication, https://www.nytimes.com/2021/05/12/science/space-junk-climate-change.html, 5-12-2021)//iLake-💣🍔

The explosion of Earth observation satellites may be the key to getting control of the crisis — if the data is shared and the capacity is built to utilize it. The battle against climate change — and to mitigate some of its most deadly effects — is increasingly being waged from space. Satellites are measuring the rate of icebergs calving into the Arctic Ocean and outbreaks of phytoplankton from rising water temperatures and pollution. Soon, they will be used to “persistently pinpoint” the amount of methane and carbon dioxide spewing from factories and power plants most responsible for supercharging the planet. As President Joe Biden and other world leaders gather in Scotland this week for the [United Nations’ annual climate change conference](https://ukcop26.org/), the new space age has armed them with some of the best tools yet to diagnose climate change and gauge whether their policies to reverse it are working. “Satellites were absolutely key in understanding we had a climate crisis,” said Krystal Azelton, director of space applications programs at the Secure World Foundation, a nonprofit Washington, D.C., think tank. “We are seeing vast improvements … in data sharing and access” and “the push to have open access to government data around the world is huge.” The surge in new constellations of optical and radar satellites are also now making it possible to limit some of the damage of climate change — by predicting the trajectories of forest fires, measuring soil saturation to reduce flooding and detecting radio signals in remote regions to uncover illicit deforestation or mining. A top priority Biden, who arrives Monday in Glasgow, has made greater reliance on space technologies **a major pillar** of his ambitious agenda to tackle the climate crisis. One new effort is NASA’s [Earth System Observatory](https://www.nasa.gov/press-release/new-nasa-earth-system-observatory-to-help-address-mitigate-climate-change) program to “create a 3D, holistic view of Earth, from bedrock to atmosphere.” Biden’s first annual budget request for NASA also sought $24.8 billion, including a $2.25 billion for the Earth Science Division, a 12.5 percent boost. And he requested $6.98 billion, or a 22 percent increase, for the National Oceanic and Atmospheric Administration, which operates an extensive constellation of weather satellites. That includes a proposed 25 percent increase for NOAA’s National Environmental Satellite, Data, and Information Service. Biden’s budget proposals have been moving slowly through Congress since they were introduced in May. The NASA budget proposal [has been approved](https://spacepolicyonline.com/news/senate-appropriators-increase-nasas-budget-a-tad/) by the House Science subcommittee and Senate appropriators, with increases of $240 million and $35.8 million, respectively. NOAA [would get nearly $6.3 billion](https://www.eenews.net/articles/inside-the-senates-new-fiscal-2022-spending-bills/) under the Senate appropriations bill and the House Appropriations committee approved a $6.46 billion budget. Rep. Eddie Bernice Johnson (D-Texas), chair of the House Science Committee, backed strong investments in space and Earth observation, while leaving the door open for federal government and private sector collaboration. “The challenge of the climate crisis certainly requires that we examine every opportunity to leverage capabilities and build or enhance partnerships across the government and private sectors,” Johnson said. “One area we are continuing to consider is how to ensure open public access for any commercially provided data by our federal science agencies.” Meanwhile, the National Space Council, the Cabinet-level body headed by Vice President Kamala Harris, has also made improving “our indications and warning of climate change” a priority for the nation’s space agenda. Using satellites to understand changes in the environment is not new; NASA’s first effort to gather facts about natural resources from orbit, as opposed to measuring the weather in the atmosphere, was the launch of the first Landsat satellite in 1972. Now, there are a variety of space-based means available on the commercial market to do it with far more accuracy and frequency. A climate census From September 2011 to August 2020, the number of commercial satellites designed to capture high-resolution images or detect heat or other invisible signatures jumped from 10 to 338, according to the Union of Concerned Scientists, which updates its list several times a year. POLITICO used the final update of each year for the tally. In the most recent update released in May, there were [450 commercial satellites used for earth observation](https://www.ucsusa.org/resources/satellite-database). “The only way to really get a global view is from satellites,” said Walter Scott, chief technology officer at space technology company Maxar Technologies. “You need to be able to make observations over a longer period of time, to be able to see trends that are in fact climate as opposed to local variations in weather.” The tools now available, however, are akin to being able to analyze census data by neighborhood instead of just at the regional or national levels. One class of targets is what climate scientists call “heat islands,” or urbanized areas that experience higher temperatures than outlying areas, which can be better analyzed with higher resolution imaging. “There are things that are happening on very small scales, urban scales,” said Vernon Morris, an atmospheric and climate scientist at Arizona State University. “The ability to gather this granularity of data, so often, is probably the biggest difference,” agreed Matt Tirman, head of Satellogic North America, a division of the Argentine company founded in 2010 that operates a constellation of satellites that can also capture live-motion video. “I do think it is a game changer,” added Morris. Planet, an Earth observation company founded in 2010, recently partnered with NASA’s Jet Propulsion Lab, the state of California and a group of nonprofits to [create the Carbon Mapper](https://carbonmapper.org/), which will use its satellites to scan the globe daily for emissions of damaging substances like methane — an invisible, odorless and powerful greenhouse gas. “It will be able to see that it's that building, and that oil pad, and that landfill that are responsible for methane leaks,” said Andrew Zolli, Planet’s chief impact officer. “This is the incredibly sensitive — what we call point source emissions detector.” Another similar effort is [Climate TRACE](https://www.climatetrace.org/), a collection of scientific institutions that is using Earth observation data to monitor coal-fired power plants. “They are looking at the coal plant and the coal that is flowing through the plant to determine if it is operating,” Zolli said. Another new set of tools is radar satellites that can monitor environmental changes in the Arctic or mountainous regions that are often obscured by clouds and darkness, major limitations for optical satellites. For instance, ICEYE, a Finnish company founded in 2014, is monitoring [floating ice in the Nares Strait](https://twitter.com/iceyefi/status/1385246590219296770) near Greenland and the [Thwaites Glacier in Antarctica](https://www.iceye.com/hubfs/Thwaites-Glacier-26996-26998_20200419-0503-BLUE.gif). The new tools are “of great importance especially for small-scale glacier monitoring,” said Eric Jensen, president of ICEYE US, its American subsidiary, Satellites outfitted with synthetic aperture and hyperspectral radars, meanwhile, have “an influence on our ability to better understand wildfires and what causes them and how they can be addressed,” said Azelton. Minimizing the damage Indeed, the growth of satellite imagery and data is providing new means to head off some of the more calamitous effects of climate change. “The ability to observe, which can ultimately lead to the ability to predict, is really what prepares us for hazards and helps us mitigate the disasters that they can lead to,” said Karen St. Germain, director of NASA’s Earth Science division. She noted that satellites can examine the trajectory of forest fires in real time and identify burn scars that cause landslides. “Vegetation is what holds the soil together,” she explained. “So, if the area’s burned and then the precipitation comes, that's when you can get landslides and cascading effects.” ICEYE’s radar satellites can also be used to quickly identify downed or damaged power lines, responsible for starting thousands of forest fires, so that crews can respond before it’s too late. Satellites are also assisting in the aftermath of climate-related natural disasters. Maxar [aided several nongovernmental organizations](https://blog.maxar.com/for-a-better-world/2018/satellite-imagery-helps-indonesian-earthquake-victims) in identifying safe sources of drinking water, accessible transportation routes, and even potentially trapped families after a destructive 2018 earthquake in Indonesia. California’s Dixie forest fire earlier this year burned across five counties and grew into the single largest forest fire in the state’s history. | Courtesy of Planet The satellite data of Spire Global, which describes itself as a “space-to-cloud data and analytics company,” boosted the accuracy of climate models and [predicted a wildfire](https://spire.com/blog/weather/spires-weather-data-helped-predict-californias-caldor-fire/) south of Lake Tahoe in Northern California 45 days before the inferno. It also forecast where winds would drive the flames. New satellites and sensors are also being used to track human activity that might be taking advantage of environmental calamity. One example is in the Arctic, where melting ice has led to a steady rise in commercial and military activity, particularly in the summer months. “It's really opened up that whole region,” said Adam Bennett, a senior director at HawkEye 360, which operates satellites that can detect radio frequency signals. “People don’t always know what's happening up there. So we did some sweeps and it was interesting to see here how we detected all kinds of additional RF activity in some cases in places we never would have expected.” “We were detecting things even all over the sea ice,” he added. “You know different concentrations of VHF communication. We saw a lot of additional maritime activity. You could even see vessels taking these pathways around the sea ice. You would not even know they were there.” Detections can also be made in real-time when responding to major disasters. Satellites from Maxar, NOAA and the Bureau of Ocean Energy Management [were used to map](https://www.nytimes.com/interactive/2021/10/05/climate/california-oil-spill-map.html) the early October oil spill off California’s Pacific coast. Unleashing the potential There are, of course, limitations to space-based technology, most notably in ocean environments. Satellites can capture sea surface temperatures and measure coral reefs — and they can even gauge the thickness of the oil on the surface of the water to direct cleanup crews after a spill. But they can only see a few meters deep. According to NOAA’s National Ocean Service, more than 80 percent of the world’s oceans [remain unmapped, unobserved and unexplored](https://oceanservice.noaa.gov/facts/exploration.html). “That's why we need to rely on ocean technologies and ocean exploration, and a lot of the marine sensor technologies that are coming online, to understand what's going on in the deeper ocean, both in terms of biodiversity, as well as energy changes,” Morris said. Yet, the game-changing potential of satellite data can make a huge difference if it is matched with the capacity on the ground to analyze, share and apply it. And large swaths of the globe where the effects of climate change are most pronounced are not connected. In West Africa, for example, “people don't know when the big flood is coming because there's no one to really take the satellite data and make it applicable on the ground,” said Gregory Jenkins, a professor of atmospheric science and African studies at Pennsylvania State University, noting that satellite data hasn’t even been fully integrated into weather forecasting on most of the continent. “We need to do much more in terms of assimilating satellite data into the weather forecast to improve them,” Jenkins said. “But we also need ground information to evaluate whatever the forecasts or the satellites are saying.” Finding more ways to share the data needs to be the priority of global leaders, numerous experts and executives say. Jasmine Sanders, a climate scientist and marine biologist who is executive director of [climate youth advocacy organization Our Climate](https://ourclimate.us/), said there remains too wide a gap between satellite companies and the advocacy groups, the scientific community and the government agencies who can make the most of it. “There's no one in between or no entity or organization that is showing how these groups could be connected,” she said. Bureaucratic stumbling blocks in industrialized nations like the United States are also stymying efforts to share more climate data gleaned from satellites across government agencies, said Mark Mozena, senior director of government affairs at Planet. “Getting data should not be an issue when you're dealing with an emergency like a hurricane,” he said. “It should not be an issue when you're trying to prepare for next year's fires.” Johnson said one of her priorities is “how to ensure open public access for any commercially provided data by our federal science agencies.” But ultimately applying all this new, increasingly more detailed data is about far more than just diagnosing the extent of climate change and singling out the leading causes. “It's not just about naming and shaming,” said Zolli. “It's about creating the feedback loop so that we know whether we're making progress or not.”

#### Warming leads to extinction---it’s a conflict-multiplier and defense doesn’t assume non-linearity

Kareiva 18, Ph.D. in ecology and applied mathematics from Cornell University, director of the Institute of the Environment and Sustainability at UCLA, Pritzker Distinguished Professor in Environment & Sustainability at UCLA, et al. (Peter, “Existential risk due to ecosystem collapse: Nature strikes back,” *Futures*, 102)

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