## 1AC

### Framework v1 (1:00)

**The standard is maximizing expected wellbeing**

**First, pleasure and pain are intrinsically valuable. People consistently regard pleasure and pain as good reasons for action**

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

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

**Moreover, *only* pleasure and pain are intrinsically valuable. All other values can be explained with reference to pleasure; Occam’s razor requires us to treat these as instrumentally valuable.**

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

I think several things should be said in response to Moore’s challenge to hedonists. First, **I do not think the burden of proof lies on hedonists to explain why the additional values are not intrinsic values. If someone claims that X is intrinsically valuable, this is a substantive, positive claim, and it lies on him or her to explain why we should believe that X is in fact intrinsically valuable.** Possibly, this could be done through thought experiments analogous to those employed in the previous section. Second, **there is something peculiar about the list of additional intrinsic values** that counts in hedonism’s favor**: the listed values have a strong tendency to be well explained as things that help promote pleasure and avert pain.** To go through Frankena’s list, life and consciousness are necessary presuppositions for pleasure; activity, health, and strength bring about pleasure; and happiness, beatitude, and contentment are regarded by Frankena himself as “pleasures and satisfactions.” The same is arguably true of beauty, harmony, and “proportion in objects contemplated,” and also of affection, friendship, harmony, and proportion in life, experiences of achievement, adventure and novelty, self-expression, good reputation, honor and esteem. Other things on Frankena’s list, such as understanding, **wisdom, freedom, peace, and security, although they are perhaps not themselves pleasurable, are important means to achieve a happy life, and as such, they are things that hedonists would value highly.** **Morally good dispositions and virtues, cooperation, and just distribution of goods and evils, moreover, are things that, on a collective level, contribute a happy society, and thus the traits that would be promoted and cultivated if this were something sought after.** To a very large extent, the intrinsic values suggested by pluralists tend to be hedonic instrumental values. Indeed, pluralists’ suggested intrinsic values all point toward pleasure, for while the other values are reasonably explainable as a means toward pleasure, pleasure itself is not reasonably explainable as a means toward the other values. Some have noticed this. Moore himself, for example, writes that though his pluralistic theory of intrinsic value is opposed to hedonism, its application would, in practice, look very much like hedonism’s: “Hedonists,” he writes “do, in general, recommend a course of conduct which is very similar to that which I should recommend.”24 Ross writes that “[i]t is quite certain that by promoting virtue and knowledge we shall inevitably produce much more pleasant consciousness. These are, by general agreement, among the surest sources of happiness for their possessors.”25 Roger Crisp observes that “those goods cited by non-hedonists are goods we often, indeed usually, enjoy.”26 What Moore and Ross do not seem to notice is that their observations give rise to two reasons to reject pluralism and endorse hedonism. The first reason is that if **the suggested non-hedonic intrinsic values are potentially explainable by appeal to just pleasure and pain** (which, following my argument in the previous chapter, we should accept as intrinsically valuable and disvaluable), **then—by appeal to Occam’s razor—we have at least a pro tanto reason to resist the introduction of any further intrinsic values and disvalues. It is ontologically more costly to posit a plurality of intrinsic values and disvalues, so in case all values admit of explanation by reference to a single intrinsic value and a single intrinsic disvalue, we have reason to reject more complicated accounts.** **The fact that suggested non-hedonic intrinsic values tend to be hedonistic instrumental values does not, however, count in favor of hedonism solely in virtue of being most elegantly explained by hedonism; it also does so in virtue of creating an explanatory challenge for pluralists.** The challenge can be phrased as the following question: **If the non-hedonic values suggested by pluralists are truly intrinsic values in their own right, then why do they tend to point toward pleasure and away from pain?**27

**Moral uncertainty means preventing extinction should be our highest priority.  
Bostrom 12** [Nick Bostrom. Faculty of Philosophy & Oxford Martin School University of Oxford. “Existential Risk Prevention as Global Priority.” Global Policy (2012)]  
These reflections on **moral uncertainty suggest** an alternative, complementary way of looking at existential risk; they also suggest a new way of thinking about the ideal of sustainability. Let me elaborate.¶ **Our present understanding of axiology might** well **be confused. We may not** nowknow — at least not in concrete detail — what outcomes would count as a big win for humanity; we might not even yet **be able to imagine the best ends** of our journey. **If we are** indeedprofoundly **uncertain** about our ultimate aims,then we should recognize that **there is a great** option **value in preserving** — and ideally improving — **our ability to recognize value and** to **steer the future accordingly. Ensuring** that **there will be a future** version of **humanity** with great powers and a propensity to use them wisely **is** plausibly **the best way** available to us **to increase the probability that the future will contain** a lot of **value.** To do this, we must prevent any existential catastrophe.

**Reducing the risk of extinction is always priority number one.   
Bostrom 12** [Faculty of Philosophy and Oxford Martin School, University of Oxford.], Existential Risk Prevention as Global Priority.  Forthcoming book (Global Policy). MP. http://www.existenti...org/concept.pdfEven if we use the most conservative of these estimates, which entirely ignores the   possibility of space colonization and software minds, **we find that the expected loss of an existential   catastrophe is greater than the value of 10^16 human lives**.  **This implies that the expected value of   reducing existential risk by a mere one millionth of one percentage point is at least a hundred times the   value of a million human lives.**  The more technologically comprehensive estimate of 10  54 humanbrain-emulation subjective life-years (or 10  52  lives of ordinary length) makes the same point even   more starkly.  Even if we give this allegedly lower bound on the cumulative output potential of a   technologically mature civilization a mere 1% chance of being correct, we find that the expected   value of reducing existential risk by a mere one billionth of one billionth of one percentage point is worth   a hundred billion times as much as a billion human lives. **One might consequently argue that even the tiniest reduction of existential risk has an   expected value greater than that of the definite provision of any ordinary good, such as the direct   benefit of saving 1 billion lives.**  And, further, that the absolute value of the indirect effect of saving 1  billion lives on the total cumulative amount of existential riskâ€”positive or negativeâ€”is almost   certainly larger than the positive value of the direct benefit of such an action.

### Plan

#### Mega-constellations being developed now

Boley and Byers 21 Boley, A.C., Byers, M. Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth. Sci Rep 11, 10642 (2021). <https://doi.org/10.1038/s41598-021-89909-7> <https://www.nature.com/articles/s41598-021-89909-7#citeas> Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada Aaron C. Boley Department of Political Science, The University of British Columbia, Vancouver, Canada Michael Byers //avery

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.

#### Current agreements fail

Boley and Byers 21 Boley, A.C., Byers, M. Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth. Sci Rep 11, 10642 (2021). <https://doi.org/10.1038/s41598-021-89909-7> <https://www.nature.com/articles/s41598-021-89909-7#citeas> Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada Aaron C. Boley Department of Political Science, The University of British Columbia, Vancouver, Canada Michael Byers //avery

International Telecommunications Union = ITU

National regulators such as the FCC are assigning orbital shells to mega-constellations on a first come, first served basis, without assessing the effects on other countries. These could include making any addition of further satellites to those shells too dangerous to contemplate. This de facto occupation of orbital shells likely violates Article I of the 1967 Outer Space Treaty, which designates the exploration and use of space as “the province of all mankind” and open to all countries “without discrimination of any kind.” There is also Article II: “Outer space … is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.” Although regulators are not claiming sovereignty over orbital shells, allowing national companies to saturate them with satellites could constitute appropriation by “other means.” Lastly, Article IX requires that space activities be conducted “with due regard to the corresponding interests of other States”. Mega-constellation operators and their regulators could respond that they are exercising the right to explore and use space without discrimination, the use of an orbital shell is time-limited as a result of the license, and the satellites will be actively de-orbited32. They could also reference that countries have been using slots in geostationary orbit for decades, resulting in the de facto exclusion of others from any given slot without this being considered appropriation. However, the use of slots in geostationary orbit is mediated by the International Telecommunications Union (ITU), which does not play the same role in LEO. Another ‘land rush’ is occurring over radio spectrum. The ITU is involved in the allocation of frequencies to communications satellites. Under its binding instruments, countries must treat frequencies as limited resources to which others have equitable access, and therefore limit their own use. But companies are not party to those instruments and do not deal directly with the ITU. They apply for and obtain licenses from their national regulator, which early in the planning process files a general description of the mega-constellation with the ITU, including the frequencies it will use33. A company is required to coordinate with any satellite system that might be affected by its planned mega-constellation, provided the other system was filed before its filing, but there is no requirement to coordinate with those whose filings are made after its own. The ITU recently adopted a tiered management approach, whereby listing a mega-constellation in its ‘Master Register’ depends on certain milestones being met. This deters companies from filing and effectively claiming orbital shells years before they are ready to launch, but thereby disadvantages smaller companies and exacerbates long-term equity concerns for those developing countries that are not yet active in space. No binding international rules exist on other aspects of mega-constellations. In 2007, the Inter-Agency Space Debris Coordination Committee (IADC), currently representing 13 space agencies, indicated that direct re-entry at the end of a satellite’s operational life was preferred but nevertheless only recommended that deorbiting conclude within 25 years. This widely accepted guideline is poorly suited for mega-constellations made up of thousands of satellites with short operational lives. It also overlooks placement, with satellites at higher altitudes producing relatively high collision probabilities when de-orbiting timescales are long34. The IADC also recommended collision avoidance and end-of-life deorbiting technologies. These add costs, and in 2017 the IADC reported that adherence to its guidelines was “insufficient and no apparent trend towards a better implementation is observed”35. More recent analyses indicate that compliance with the end-of-life guidelines is now improving by some metrics36. However, these improvements appear to be driven, at least in part, by SpaceX’s own practices, which may not be followed by other mega-constellation operators. Guidelines allow for ‘free riding’, whereby individual actors can save costs through non-compliance while benefitting from the compliance of others. In the context of any shared resource, free riding can lead to a ‘tragedy of the commons,’ which is exactly what needs to be avoided in LEO. Finally, we would be remiss not to mention the threats posed by mega-constellations to astronomy, although for a detailed discussion we refer to other recent work37,38,39,40,41. Briefly, astronomers pushed for reductions in the number and brightness of Starlink satellites after an image from a telescope in Chile was ruined. SpaceX responded by adding visors to the satellites, which has reduced their naked-eye visibility while still leaving them bright to telescopes39. Next generation sky surveys and observations close to the horizon, especially near sunrise and sunset, are especially vulnerable—and critical for near-Earth object observations for planetary defence. Occultations are another issue: even a satellite that is unilluminated (i.e. passing through the shadow of the Earth) can interfere with rapid time domain astronomy when it passes in front of a star. Radio astronomy is also threatened39, since mega-constellations will require frequencies additional to those traditionally used by land stations. These could encroach on protected spectrum through out-of-band overtone emission. The large number of fast-moving transmitting stations (i.e. satellites) will cause further interference. New analysis methods could mitigate some of these effects, but data loss is inevitable, increasing the time needed for each study and limiting the overall amount of science done. There are reasons for hope. SpaceX is showing some leadership with rapid end-of-life deorbiting, automatic collision avoidance, and visors to reduce light pollution, even if these are not yet sufficient. Spacefaring countries, moreover, recognize that debris threatens all satellites, including military satellites. Some are strengthening their national regulations, including by incorporating non-binding international guidelines into binding national laws. However, there is little recognition that Earth’s orbit is a finite resource, the space and Earth environments are connected, and the actions of one actor can affect everyone. Until that changes, we risk multiple tragedies of the commons in space.

#### I affirm: The appropriation of outer space through mega-constellations by private entities is unjust.

#### Mega constellations overflow LEO and stress the environment

Boley and Byers 21 Boley, A.C., Byers, M. Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth. Sci Rep 11, 10642 (2021). <https://doi.org/10.1038/s41598-021-89909-7> <https://www.nature.com/articles/s41598-021-89909-7#citeas> Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada Aaron C. Boley Department of Political Science, The University of British Columbia, Vancouver, Canada Michael Byers //avery

LEO = Low Earth Orbit

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.

### Adv 1 – Collisions

#### Causes chain reaction collisions that spill out

Boley and Byers 21 Boley, A.C., Byers, M. Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth. Sci Rep 11, 10642 (2021). <https://doi.org/10.1038/s41598-021-89909-7> <https://www.nature.com/articles/s41598-021-89909-7#citeas> Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada Aaron C. Boley Department of Political Science, The University of British Columbia, Vancouver, Canada Michael Byers //avery

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

Chart, histogram

Description automatically generated

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. 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.

#### Risk will only increase

Pultarova 21 SpaceX Starlink satellites responsible for over half of close encounters in orbit, scientist says By Tereza Pultarova published August 18, 2021 Starlink satellites might soon be involved in 90% of close encounters between two spacecraft in low Earth orbit. <https://www.space.com/spacex-starlink-satellite-collision-alerts-on-the-rise> Tereza is a London-based science and technology journalist, aspiring fiction writer and amateur gymnast. Originally from Prague, the Czech Republic, she spent the first seven years of her career working as a reporter, script-writer and presenter for various TV programmes of the Czech Public Service Television. She later took a career break to pursue further education and added a Master's in Science from the International Space University, France, to her Bachelor's in Journalism and Master's in Cultural Anthropology from Prague's Charles University. She worked as a reporter at the Engineering and Technology magazine, freelanced for a range of publications including Live Science, Space.com, Professional Engineering, Via Satellite and Space News and served as a maternity cover science editor at the European Space Agency. //avery

Operators of satellite constellations are constantly forced to move their satellites because of encounters with other spacecraft and pieces of space junk. And, thanks to [SpaceX's](https://www.space.com/18853-spacex.html) Starlink satellites, the number of such dangerous approaches will continue to grow, according to estimates based on available data. SpaceX's [Starlink](https://www.space.com/spacex-starlink-satellites.html) satellites alone are involved in about 1,600 close encounters between two spacecraft every week, that's about 50 % of all such incidents, according to Hugh Lewis, the head of the Astronautics Research Group at the University of Southampton, U.K. These encounters include situations when two spacecraft pass within a distance of 0.6 miles (1 kilometer) from each other. Lewis, Europe's leading expert on space debris, makes regular estimates of the situation in orbit based on data from the Socrates (Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space ) database. This tool, managed by Celestrack, provides information about satellite orbits and models their trajectories into the future to assess collision risk. Lewis publishes regular updates on Twitter and has seen a worrying trend in the data that reflects the fast deployment of the Starlink constellation. "I have looked at the data going back to May 2019 when Starlink was first launched to understand the burden of these megaconstellations," Lewis told Space.com. "Since then, the number of encounters picked up by the Socrates database has more than doubled and now we are in a situation where Starlink accounts for half of all encounters." The current 1,600 close passes include those between two Starlink satellites. Excluding these encounters, Starlink satellites approach other operators’ spacecraft 500 times every week.

Chart, line chart, scatter chart

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In comparison, Starlink's competitor OneWeb, currently flying over 250 satellites, is involved in 80 close passes with other operators' satellites every week, according to Lewis' data. And the situation is bound to get worse. Only 1,700 satellites of an expected constellation of tens of thousands have been placed into orbit so far. Once SpaceX launches all 12,000 satellites of its first generation constellation, Starlink satellites will be involved in 90% of all close approaches, Lewis’ calculations suggest.

Chart

Description automatically generated

#### Companies don’t share data and rely on autonomous systems – high risk

Pultarova 21 SpaceX Starlink satellites responsible for over half of close encounters in orbit, scientist says By Tereza Pultarova published August 18, 2021 Starlink satellites might soon be involved in 90% of close encounters between two spacecraft in low Earth orbit. <https://www.space.com/spacex-starlink-satellite-collision-alerts-on-the-rise> Tereza is a London-based science and technology journalist, aspiring fiction writer and amateur gymnast. Originally from Prague, the Czech Republic, she spent the first seven years of her career working as a reporter, script-writer and presenter for various TV programmes of the Czech Public Service Television. She later took a career break to pursue further education and added a Master's in Science from the International Space University, France, to her Bachelor's in Journalism and Master's in Cultural Anthropology from Prague's Charles University. She worked as a reporter at the Engineering and Technology magazine, freelanced for a range of publications including Live Science, Space.com, Professional Engineering, Via Satellite and Space News and served as a maternity cover science editor at the European Space Agency. //avery

Lewis is concerned about the growing influence of a single actor — Starlink — on the safety of orbital operations. Especially, he says, as the spaceflight company has entered the satellite operations world only recently. "We place trust in a single company, to do the right thing," Lewis said. "We are in a situation where most of the maneuvers we see will involve Starlink. They were a launch provider before, now they are the world's biggest satellite operator, but they have only been doing that for two years so there is a certain amount of inexperience." SpaceX relies on an autonomous collision avoidance system to keep its fleet away from other spacecraft. That, however, could sometimes introduce further problems. The automatic orbital adjustments change the forecasted trajectory and therefore make collision predictions more complicated, according to Lewis. "Starlink doesn't publicize all the maneuvers that they're making, but it is believed that they are making a lot of small corrections and adjustments all the time," Lewis said. "But that causes problems for everybody else because no one knows where the satellite is going to be and what it is going to do in the next few days."

#### Collisions destabilize and risk global conflict – misallocation

Breen 18 CAN THE OUTER SPACE TREATY PREVENT CONFLICTS IN ORBIT IN THE 21ST CENTURY? Nicole M. Breen Lieutenant, United States Navy BS, U.S. Naval Academy, 2013 Submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN SPACE SYSTEMS OPERATIONS from the NAVAL POSTGRADUATE SCHOOL June 2018 <https://apps.dtic.mil/dtic/tr/fulltext/u2/1059769.pdf> //avery

One of the more dangerous concerns is the idea that the world will reach “a point of no return in space” 431 meaning there will be so much space junk that the ability to operate ceases to exist.432 In Marshall Kaplan’s view, “space-faring nations have already passed the point of no return, with the accumulation of debris objects in LEO steadily building over the past 50 years.” 433 As discussed earlier, NASA’s Kessler, established a similar concept called the Kessler Syndrome, which stated “when debris reaches a critical density in particular orbit, it can set off a chain reaction of collisions that create more debris, eventually making the orbit unusable.” 434 The importance of this statement is with the word “eventually,” because Kessler understood that this process could take decades.435 But, he wanted the world, especially the U.S., “to understand that if we don’t actively start removing five to ten objects per year for the next 100 years, we’ll have an unstable environment.” 436 Unstable environments have the potential to lead to political and military crisis. For example, imagine a hypothetical future scenario where LEO has been banned for satellite usage due to the immense amount of traffic, which no longer allows satellites to orbit safely without being hit by debris. Also, the satellites left in LEO are colliding with one another, creating even more debris and, additionally, making it difficult to launch satellites into higher orbits. This becomes a global conflict; militaries lose capabilities, and civilians lose basic luxuries that commercial space offers such as Internet connectivity, satellite television broadcasts, and other communications. The scenario presented above could result in an international crisis, creating the potential for more dangerous political and military disputes and disagreements. If space were unusable, the world might then become unstable, since we now depend on a variety of data from space for society, national militaries, and the international economy to function. The loss of satellites, specifically military assets, to space debris could incite armed conflict between space-faring nations.437 Armed conflict or even war in space would be the most dangerous possibility resulting from space debris collisions. Vitaly Adushkin,from the Russian Academy of Sciences, says that there can only be two likelihoods when a military defense satellite suddenly fails: “an unregistered collision with space debris or an aggressive action by an adversary.” 438 Both of those possibilities deal with a sensitivity that has the potential to become a politically or militarily dangerous conflict.439

#### Goes nuclear

Johnson-Freese 17 Joan Johnson-Freese is a Professor and former Chair of National Security Affairs at the US Naval War College, Newport, Rhode Island, and author of several books. Pg 18-19 SPACE WARFARE IN THE 21ST CENTURY https://www.routledge.com/Space-Warfare-in-the-21st-Century-Arming-the-Heavens/Johnson-Freese/p/book/9781138693883 //avery,

Space warfare runs two untenable risks: the creation of destructive debris and escalation to terrestrial, even nuclear, warfare. Kinetic warfare in space creates debris traveling at a speed of more than 17,000 miles per hour, which then in itself becomes a destructive weapon if it hits another object—even potentially triggering the so-called Kessler Syndrome,86 exaggerated for dramatic effect in the movie Gravity. Ironically, both China and the United States learned the negative lessons of debris creation the hard way. In 1985, the United States tested a miniature homing vehicle (MHV) ASAT launched from an F-15 aircraft. The MHV intercepted and destroyed a defunct US satellite at an altitude of approximately 250 miles. It took almost 17 years for the debris resulting from that test to be fully eliminated by conflagration re-entering the Earth’s atmosphere or being consumed by frictional forces, though no fragment had any adverse consequences to another satellite—in particular, no collisions. China irresponsibly tested a direct-ascent ASAT in 2007, destroying one if its defunct satellites. That test was at an altitude almost twice that of the 1985 US test. The debris created by the impact added 25 percent to the debris total in low Earth orbit87 and will dissipate through the low Earth orbit, heavily populated with satellites, for decades, perhaps centuries, to come. Perhaps most ironically, because of superior US debris-tracking capabilities, the United States—even though not required to do so—has on more than one occasion warned China that it needed to maneuver one of its satellites to avoid a collision with debris China itself had likely created.88 In 2013, a piece of Chinese space junk from the 2007 ASAT test collided with a Russian laser ranging nanosatellite called BLITS, creating still more debris.89 The broader point is that all nations have a compelling common interest in avoiding the massive increase in space debris that would be created by a substantial ASAT conflict. Gen. Hyten has said that not creating debris is “the one limiting factor” to space war. “Whatever you do,” he warns, “don’t create debris.”90 While that might appear an obvious “limiting factor,” preparing to fight its way through a debris cloud had been a Pentagon consideration in the past. Now, however, sustaining the space environment has been incorporated into Pentagon space goals. Beyond debris creation, MacDonald points out that as China becomes more militarily capable in space and there is more symmetry between the countries, other risks are created – specifically, escalation. That is, the United States could threaten to attack not just Chinese space assets, but also ground-based assets, including ASAT command-and-control centers and other military capabilities. But such actions, which would involve attacking Chinese soil and likely causing substantial direct casualties, would politically weigh much heavier than the U.S. loss of space hardware, and Protecting space assets 19 thus might climb the escalatory ladder to a more damaging war that both sides would probably want to avoid.91 MacDonald isn’t alone in concerns about escalation. Secure World Foundation analyst Victoria Samson has also voiced apprehension regarding US rhetoric that does not distinguish between actions against unclassified and classified US satellites, stating that “things can escalate pretty quickly should we come into a time of hostility.”92 Theresa Hitchens explained the most frightening, but not implausible, risk of space war escalation in a 2012 Time magazine interview. Say you have a crisis between two nuclear-armed, space-faring countries, Nation A and Nation B, which have a long-standing border dispute. Nation A, with its satellite capability, sees that Nation B is mobilizing troops and opening up military depots in a region where things are very tense already, on the tipping point. Nation A thinks: “That’s it, they’re going to attack.” So it might decide to pre-emptively strike the communications satellite used by Nation B to slow down its ability to move toward the border and give itself time to fortify. Say this happens and Nation B has no use of satellites for 12 hours, the time it takes it to get another satellite into position. What does Nation B do? It’s blind, it’s deaf, it’s thinking all this time that it’s about to be overwhelmed by an invasion or even nuked. This is possibly a real crisis escalation situation; something similar has been played out in U.S. Air Force war games, a scenario-planning exercise practiced by the U.S. military. The first game involving anti-satellite weapons stopped in five minutes because it went nuclear – bam. Nation B nuked Nation A. This is not a far-out, “The sky’s falling in!” concern, it is something that has been played out over and over again in the gaming of these things, and I have real fears about it.93 While escalation to a nuclear exchange may seem unthinkable, in war games conducted by the military, nuclear weapons are treated as just another warfighting weapon. Morgan also voiced concerns about escalation generally and nuclear escalation specifically in the 2010 RAND report, stating: The adversary would also likely be deterred from damaging U.S. satellite early-warning system (SEWS) assets to avoid risking inadvertent escalation to the nuclear threshold, but that firebreak would almost certainly collapse with the conclusion that such escalation is inevitable and that it is in the adversary’s interest to launch a preemptive nuclear strike.

#### Extinction

Starr 15 Nuclear War, Nuclear Winter, and Human Extinction By Federation of American Scientists • October 14, 2015 by Steven Starr Steven Starr is the director of the University of Missouri’s Clinical Laboratory Science Program, as well as a senior scientist at the Physicians for Social Responsibility. He has been published in the Bulletin of the Atomic Scientists and the Strategic Arms Reduction (STAR) website of the Moscow Institute of Physics and Technology; he also maintains the website Nuclear Darkness. Starr also teaches a class on the Environmental, Health and Social Effects of nuclear weapons at the University of Missouri. <https://fas.org/pir-pubs/nuclear-war-nuclear-winter-and-human-extinction/> //avery

While it is impossible to precisely predict all the human impacts that would result from a nuclear winter, it is relatively simple to predict those which would be most profound. That is, a nuclear winter would cause most humans and large animals to die from nuclear famine in a mass extinction event similar to the one that wiped out the dinosaurs. Following the detonation (in conflict) of US and/or Russian launch-ready strategic nuclear weapons, nuclear firestorms would burn simultaneously over a total land surface area of many thousands or tens of thousands of square miles. These mass fires, many of which would rage over large cities and industrial areas, would release many tens of millions of tons of black carbon soot and smoke (up to 180 million tons, according to peer-reviewed studies), which would rise rapidly above cloud level and into the stratosphere. [For an explanation of the calculation of smoke emissions, see Atmospheric effects & societal consequences of regional scale nuclear conflicts.] The scientists who completed the most recent peer-reviewed studies on nuclear winter discovered that the sunlight would heat the smoke, producing a self-lofting effect that would not only aid the rise of the smoke into the stratosphere (above cloud level, where it could not be rained out), but act to keep the smoke in the stratosphere for 10 years or more. The longevity of the smoke layer would act to greatly increase the severity of its effects upon the biosphere. Once in the stratosphere, the smoke (predicted to be produced by a range of strategic nuclear wars) would rapidly engulf the Earth and form a dense stratospheric smoke layer. The smoke from a war fought with strategic nuclear weapons would quickly prevent up to 70% of sunlight from reaching the surface of the Northern Hemisphere and 35% of sunlight from reaching the surface of the Southern Hemisphere. Such an enormous loss of warming sunlight would produce Ice Age weather conditions on Earth in a matter of weeks. For a period of 1-3 years following the war, temperatures would fall below freezing every day in the central agricultural zones of North America and Eurasia. [For an explanation of nuclear winter, see Nuclear winter revisited with a modern climate model and current nuclear arsenals: Still catastrophic consequences.] Nuclear winter would cause average global surface temperatures to become colder than they were at the height of the last Ice Age. Such extreme cold would eliminate growing seasons for many years, probably for a decade or longer. Can you imagine a winter that lasts for ten years? The results of such a scenario are obvious. Temperatures would be much too cold to grow food, and they would remain this way long enough to cause most humans and animals to starve to death. Global nuclear famine would ensue in a setting in which the infrastructure of the combatant nations has been totally destroyed, resulting in massive amounts of chemical and radioactive toxins being released into the biosphere. We don’t need a sophisticated study to tell us that no food and Ice Age temperatures for a decade would kill most people and animals on the planet. Would the few remaining survivors be able to survive in a radioactive, toxic environment? It is, of course, debatable whether or not nuclear winter could cause human extinction. There is essentially no way to truly “know” without fighting a strategic nuclear war. Yet while it is crucial that we all understand the mortal peril that we face, it is not necessary to engage in an unwinnable academic debate as to whether any humans will survive. What is of the utmost importance is that this entire subject –the catastrophic environmental consequences of nuclear war – has been effectively dropped from the global discussion of nuclear weaponry. The focus is instead upon “nuclear terrorism”, a subject that fits official narratives and centers upon the danger of one nuclear weapon being detonated – yet the scientifically predicted consequences of nuclear war are never publically acknowledged or discussed. Why has the existential threat of nuclear war been effectively omitted from public debate? Perhaps the leaders of the nuclear weapon states do not want the public to understand that their nuclear arsenals represent a self-destruct mechanism for the human race? Such an understanding could lead to a demand that nuclear weapons be banned and abolished. Consequently, the nuclear weapon states continue to maintain and modernize their nuclear arsenals, as their leaders remain silent about the ultimate threat that nuclear war poses to the human species.

### Adv 2 – Environment

#### The entire process of mega constellation development is environmentally disastrous

Boley and Byers 21 Boley, A.C., Byers, M. Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth. Sci Rep 11, 10642 (2021). <https://doi.org/10.1038/s41598-021-89909-7> <https://www.nature.com/articles/s41598-021-89909-7#citeas> Department of Physics and Astronomy, The University of British Columbia, Vancouver, Canada Aaron C. Boley Department of Political Science, The University of British Columbia, Vancouver, Canada Michael Byers //avery

Although failures do occur, first stages of SpaceX rockets are usually landed and re-used, while second stages are usually controlled through re-entry and deposited in remote areas of ocean. This best practice might not be followed by others. For example, the first stages of the Soyuz rockets employed by OneWeb are not reusable, nor are the second stage re-entries controllable. The Long March rockets that will likely be employed by GW are similar. Uncontrolled re-entries do not always meet safety standards17, a situation that may be exacerbated by mega-constellations. Moreover, the cumulative impact of thousands of rocket stages on the ocean environment could be significant should those stages contain hazardous materials, such as unspent hydrazine fuels17,18,19. In the 1990s, Pacific island countries opposed the Sea Launch project because of environmental concerns, including from discarded rocket stages20. In 2016, Inuit in the Canadian Arctic protested the Russian practice of disposing rocket stages in the North Water Polynya, a biologically rich area of year-round open water21. The first Starlink satellites contained some components that survive re-entry, with the highest human casualty risk for a single satellite calculated to be 1:17,40022, below NASA’s recommended 1:10,000 threshold. However, the initial approval process did not account for the cumulative casualty risk, and if all the then-planned 12,000 sate\llites had contained the same components, a continuous 5-year replacement cycle would have seen a 45% probability of one or more casualties per cycle. When the subsequent FCC petition process identified the problem, SpaceX reportedly replaced some materials with a view to having all of the satellite components now demise in the atmosphere23. Other companies, based in other countries, might not follow this best practice or be required to do so. The demise of satellite components during re-entry introduces a different problem, since none of that material actually disappears. Starlink satellites have a dry mass of about 260 kg; 12,000 satellites will total 3100 tonnes. A 5-year cycle would see on average almost 2 tonnes re-entering Earth’s atmosphere daily. While small compared to the 54 daily tonnes of meteoroid mass24, the satellites are mostly aluminum; most meteoroids, in contrast, contain less than 1% Al by mass25. Thus, depending on the atmospheric residence time of material from re-entered satellites, each mega-constellation will produce fine particulates that could greatly exceed natural forms of high-altitude atmospheric aluminum deposition, particularly if the full numbers of envisaged satellites are launched. Anthropogenic deposition of aluminum in the atmosphere has long been proposed in the context of geoengineering as a way to alter Earth’s albedo26. These proposals have been scientifically controversial and controlled experiments encountered substantial opposition27. Mega-constellations will begin this process as an uncontrolled experiment28. Rocket launches themselves affect the atmosphere. While cumulative CO2 emissions are small compared to other sources, CO2 is not the relevant metric. Black carbon produced by kerosene-fueled rockets such as SpaceX’s Falcon 9 and alumina particles produced by solid-fueled rockets lead to instantaneous radiative forcing. Modelling of the cumulative effect of emissions from 1000 annual launches of hydrocarbon-fuelled rockets found that, after one decade, the black carbon would result in radiative forcing comparable to that resulting from sub-sonic aviation29. Although 1000 launches annually is 10 times the current rate, the construction and renewal of multiple mega-constellations will require dramatic increases in launches. Current launches likely cause non-negligible radiative forcing already30. Rockets fueled with liquid hydrogen do not produce black carbon but require larger tanks and therefore larger rockets, with solid-fueled boosters often being used to increase payload capacity. SpaceX’s new Starship, which the company plans to use to launch 400 Starlink satellites at a time, will be fueled by methane, the combustion of which produces soot that may, like black carbon, contribute to radiative forcing. All liquid fuels will affect mesospheric cloud formation31, with potential climate consequences. Rockets even threaten the ozone layer by depositing radicals directly into the stratosphere29, with solid-fueled rockets causing the most damage because of the hydrogen chloride and alumina they contain29.

#### Megaconstellations restart and spiral the ozone crisis

Pultarova 21 Air pollution from reentering megaconstellation satellites could cause ozone hole 2.0 By Tereza Pultarova published June 07, 2021 Tereza is a London-based science and technology journalist, aspiring fiction writer and amateur gymnast. Originally from Prague, the Czech Republic, she spent the first seven years of her career working as a reporter, script-writer and presenter for various TV programmes of the Czech Public Service Television. She later took a career break to pursue further education and added a Master's in Science from the International Space University, France, to her Bachelor's in Journalism and Master's in Cultural Anthropology from Prague's Charles University. She worked as a reporter at the Engineering and Technology magazine, freelanced for a range of publications including Live Science, Space.com, Professional Engineering, Via Satellite and Space News and served as a maternity cover science editor at the European Space Agency. <https://www.space.com/starlink-satellite-reentry-ozone-depletion-atmosphere> //arjun!

The aluminum from re-entering satellites also has a potential to damage the ozone layer, a problem well known to humanity, which has been successfully solved by widespread bans on the use of chlorofluorocarbons, chemicals used in the past in aerosol sprays and refrigerators. In their paper, Boley and his colleague Michael Byers cite research by their counterparts from the Aerospace Corporation, a U.S. non-profit research organization, which identified local damage to the planet's ozone layer triggered by the passage of polluting rockets through the atmosphere. "We know that alumina does deplete ozone just from rocket launches themselves because a lot of solid-fuel rockets use, or have, alumina as a byproduct," Boley said. "That creates these little temporary holes in the stratospheric ozone layer. That's one of the biggest concerns about compositional changes to the atmosphere that spaceflight can cause." The ozone layer protects life on Earth from harmful UV radiation. The depletion of ozone in the stratosphere, the second lowest layer of the atmosphere extending between altitudes of approximately 7 to 40 miles (10 to 60 kilometers), led to an increased risk of cancer and eye damage for humans on Earth. Gerhard Drolshagen, of the University of Oldenburg, Germany, who has published papers about the effects of meteoroid material on Earth, told Space.com that reentering satellites usually evaporate at altitudes between 55 and 30 miles (90 and 50 km), just above the ozone-rich stratosphere. However, he added, the particles created as a result of the satellites' burning will eventually sink to the lower layers. Boley said that as the alumina sinks into the stratosphere, it will cause chemical reactions, which, based on existing knowledge, will likely trigger ozone destruction. Drolshagen, who wasn't involved in the recent study, agreed that because "satellites are mostly made of aluminum, the amount of aluminum deposited in the atmosphere will certainly increase." Concerns about the effects of aluminium oxides on the atmosphere have been cited by U.S. telecommunications operator Viasat in its request to the US Federal Communications Commision to suspend launches of SpaceX's Starlink megaconstellation until a proper environmental review of its possible impacts is conducted. In their study, Boley and his colleagues looked only at the effects of the first generation of the Starlink megaconstellation, which is expected to consist of 12,000 satellites. [More than 1,700 of these](https://www.space.com/spacex-starlink-28-rocket-launch-and-landing-success) have already been launched. As a result of SpaceX's activities (and to a lesser extent those of other constellation operators), the number of active and defunct satellites in low Earth orbit, the region of space below the altitude of 620 miles (1,000 km), has increased by 50% over the past two years, according to the paper.  "The problem is that there are now plans to launch about 55,000 satellites," Boley said. "Starlink second generation could consist of up to 30,000 satellites, then you have Starnet, which is China's response to Starlink, Amazon's Kuiper, OneWeb. That could lead to unprecedented changes to the Earth’s upper atmosphere." Megaconstellation operators, inspired by the consumer technology model, expect fast development of new satellites and frequent replacement, thus the high amount of satellites expected to be burning in the atmosphere on a daily basis.  "Humans are exceptionally good at underestimating our ability to change the environment," said Boley. "There is this perception that there is no way that we can dump enough plastic into the ocean to make a difference. There is no way we can dump enough carbon into the atmosphere to make a difference. But here we are. We have a plastic pollution problem with the ocean, we have climate change ongoing as a result of our actions and our changing of the composition of the atmosphere and we are poised to make the same type of mistake by our use of space."

#### Mass satellites risk destroying the magnetosphere

Coma 21 Satellite mega-constellations’ mega-threats The rise of space junk and the fall of reason 23 JULY 2021, MIGUEL COMA Miguel Coma is an engineer in telecommunications and an Information Technology architect. After over two decades of professional activity in various industries, he began to write, speak and consult about our digital environmental footprint. He believes in peoples' potential to use technology wisely and create sustainable progress. <https://wsimag.com/science-and-technology/66440-satellite-mega-constellations-mega-threats> //avery

Deploying 5G networks that use millimetre wave frequencies on the Earth’s surface could significantly jam satellite weather and climate observations8. Besides Earth-based 5G radio-frequencies, even higher frequencies used by future satellite constellations could interfere with weather observations. Facebook’s constellation is still experimental, but it might use frequencies near 88.2 gigahertz, which weather-observing satellites9 currently use. Space launches have significant global warming effects1. Some satellite-launching rockets such as SpaceX’s Falcon 9 consume liquid kerosene and release black carbon. Solid-fuelled rockets produce alumina particles. All of these increase the greenhouse effect. Global warming from kerosene rockets has been modelled for 1,000 annual rocket launches during one decade. Scientists find that these kerosene rockets’ greenhouse effects are comparable to pre-Covid emissions from aviation. SpaceX’s Starship, the most powerful rocket ever built, fuelled by liquid methane, can launch 400 Starlink satellites at one time. Methane combustion produces soot that increases global warming. Liquid rocket fuels can also impact cloud formations—and the Earth’s climate. Radiation all over (and above) the Earth’s surface The magnetosphere (the magnetic envelope surrounding the Earth) shields our planet from solar and cosmic particle radiation. How/does microwave radiation emitted by satellites impact it? The Van Allen belts surround and protect the Earth with electric charges. Could satellites’ microwave radiation emission drain the belts’ electrons into the atmosphere, and change its electric properties? How are the Schumann resonances, the electromagnetic “heartbeat” of the atmosphere to which living beings on Earth are attuned, affected by satellites’ emissions? Satellites beam massive amounts of microwave radiation day and night from within the magnetosphere and through the atmosphere. What effect does this have on the magnetosphere and the electromagnetic balance of all life? Should subject matter experts study this before we deploy any more satellites? There are very few studies of millimetre waves’ impacts on plants and animals10. Consequently, predicting the effects of tens of thousands of satellites beaming millimetre waves on biodiversity is nearly impossible. As long as we fail to limit deployments, we risk increasing loss of biodiversity. Unlike Earth-based networks, satellite constellations will virtually radiate even areas with low population density. There will be no place for humans and wildlife to escape microwave radiation—or its potentially harmful effects. The Earth’s gigantic electric circuit allows a permanent flow of electrons from the ionosphere to the planet’s surface, and back to the ionosphere when lightning strikes. According to Eastern medicine, this electric current flows supportively through our chakras and meridians. The potential health effects of satellites beaming radiation from the ionosphere—and interfering with the Earth’s natural electromagnetic fields—have not been studied.

#### Ozone destruction causes extinction

University of Southampton 20 University of Southampton. "Erosion of ozone layer responsible for mass extinction event." ScienceDaily. ScienceDaily, 27 May 2020. <www.sciencedaily.com/releases/2020/05/200527150158.htm>. https://www.sciencedaily.com/releases/2020/05/200527150158.htm //avery

There have been a number of mass extinction in the geological past. Only one was caused by an asteroid hitting the Earth, which was 66 million years ago when the dinosaurs became extinct. Three of the others, including the end Permian Great Dying, 252 million years ago, were caused by huge continental scale volcanic eruptions that destabilised the Earth's atmospheres and oceans. Now, scientists have found evidence showing it was high levels of UV radiation which collapsed forest ecosystems and killed off many species of fish and tetrapods (our four limbed ancestors) at the end of the Devonian geological period, 359 million years ago. This damaging burst of UV radiation occurred as part of one of the Earth's climate cycles, rather than being caused by a huge volcanic eruption. The ozone collapse occurred as the climate rapidly warmed following an intense ice age and the researchers suggest that the Earth today could reach comparable temperatures, possibly triggering a similar event. Their findings are published in the journal Science Advances. The team collected rock samples during expeditions to mountainous polar-regions in East Greenland, which once formed a huge ancient lake bed in the arid interior of the Old Red Sandstone Continent, made up of Europe and North America. This lake was situated in the Earth's southern hemisphere and would have been similar in nature to modern day Lake Chad on the edge of the Sahara Desert. Other rocks were collected from the Andean Mountains above Lake Titicaca in Bolivia. These South American samples were from the southern continent of Gondwana, which was closer to the Devonian South Pole. They held clues as to what was happening at the edge of the melting Devonian ice sheet, allowing a comparison between the extinction event close to the pole and close to the equator. Back in the lab, the rocks were dissolved in hydrofluoric acid, releasing microscopic plant spores (like pollen, but from fern like plants that didn't have seeds or flowers) which had lain preserved for hundreds of millions of years. On microscopic examination, the scientists found many of the spores had bizarrely formed spines on their surface -- a response to UV radiation damaging their DNA. Also, many spores had dark pigmented walls, thought to be a kind of protective 'tan', due to increased and damaging UV levels. The scientists concluded that, during a time of rapid global warming, the ozone layer collapsed for a short period, exposing life on Earth to harmful levels of UV radiation and triggering a mass extinction event on land and in shallow water at the Devonian-Carboniferous boundary. Following melting of the ice sheets, the climate was very warm, with the increased heat above continents pushing more naturally generated ozone destroying chemicals into the upper atmosphere. This let in high levels of UV-B radiation for several thousand years. Lead researcher Professor John Marshall, of the University of Southampton's School of Ocean and Earth Science, who is a National Geographic Explorer, comments: "Our ozone shield vanished for a short time in this ancient period, coinciding with a brief and quick warming of the Earth. Our ozone layer is naturally in a state of flux -- constantly being created and lost -- and we have shown this happened in the past too, without a catalyst such as a continental scale volcanic eruption." During the extinction, plants selectively survived, but were enormously disrupted as the forest ecosystem collapsed. The dominant group of armoured fish became extinct. Those that survived -- sharks and bony fish -- remain to this day the dominant fish in our ecosystems. These extinctions came at a key time for the evolution of our own ancestors, the tetrapods. These early tetrapods are fish that evolved to have limbs rather than fins, but still mostly lived in water. Their limbs possessed many fingers and toes. The extinction reset the direction of their evolution with the post-extinction survivors being terrestrial and with the number of fingers and toes reduced to five. Professor Marshall says his team's findings have startling implications for life on Earth today: "Current estimates suggest we will reach similar global temperatures to those of 360 million years ago, with the possibility that a similar collapse of the ozone layer could occur again, exposing surface and shallow sea life to deadly radiation. This would move us from the current state of climate change, to a climate emergency." The remote locations visited in East Greenland are very difficult to access, with travel involving light aircraft capable of landing directly on the tundra. Transport within the vast field area was by inflatable boats equipped with outboard motors, all of which had to fit in the small aircraft. All field logistics was organised by CASP, an independent charitable trust based in Cambridge specialising in remote geological fieldwork. Mike Curtis, Managing Director of CASP says: "We have a history of assisting research geologists such as John Marshall and colleagues to access remote field areas and we are particularly pleased that their research has proved to have such potentially profound implications."

#### Magnetic field collapse causes extinction

Osborne 19 Earth's Magnetic Field Was on the Brink of Collapse 565 Million Years Ago BY HANNAH OSBORNE ON 1/28/19 AT 11:37 AM EST Education Goldsmiths College, U. of LondonGoldsmiths College, U. of London Graphic Goldsmiths College, U. of London MAJournalism 2011 - 2012 King's College LondonKing's College London Graphic King's College London BA 2.1English Literature and Film Studies 2004 – 2007 Science Editor at Newsweek <https://www.newsweek.com/earth-magnetic-field-collapse-inner-core-solid-geodynamo-solar-wind-1307659> //avery

About 565 million years ago, the strength of Earth's magnetic field dipped to its lowest point and almost collapsed completely, scientists have discovered. However, at this point, the planet's inner core started to solidify, providing a new energy source to drive the magnetic shield "just in the nick of time." The discovery, published in Nature Geoscience, provides a new insight into the formation of Earth's core—a subject that has been debated for over 80 years. Earth's magnetic field is thought to be generated deep down in the planet's core. This consists of a solid ball of iron surrounded by a liquid metal. As the planet rotates, the liquid iron moves, forming electric currents that produce the magnetic field. Without a magnetic field, the planet would have had no protection from the solar wind—charged particles that flow from the sun and travel through the solar system at around a million miles per hour. These particles could have the interacted with Earth's atmosphere and slowly stripped it away, leaving the planet a barren landscape like the one we see on Mars today. In the latest paper, a team of researchers led by Richard Bono of the University of Rochester in New York, were looking to find out when Earth's core solidified by analyzing rocks that carry information about the geomagnetic field. "Unknowns in Earth's thermal evolution have led to a wide range of potential ages for the solid inner core," study co-author John Tarduno told Newsweek. "This range spans more than 2 billion years of Precambrian history. "Numerical models predict that the magnetic field would be unstable at the onset of inner core growth. But the paleomagnetic record is relatively sparse, so this has led to debate," he said. The solidification of Earth's core would have provided a boost of energy to the planet's geodynamo—the formation of the magnetic field in the liquid outer core. "Liquid iron in the outer core convects, carrying with it magnetic field lines that twist, continuously regenerating the field. Without the convection there would be no core magnetic field," Tarduno explained. This boost should have left a mark in the rock record. After taking measurements from rock samples taken from Sept-Îles in Quebec, Canada, researchers found a prolonged period where Earth's magnetic field was very weak—about 10 times less intense than it is today. This period of weakness lasted for about 75,000 years—far longer than any changes that occur when the field flips or changes direction. The authors say the magnetic field intensity was so low that the geodynamo was on the verge of collapse. "As Earth evolved, the energy to drive convection gradually decreased, until a critical point 565 million years ago marked by the extremely low magnetic field intensity," Tarduno said. "The growth on the inner core provided a new source to drive convection and the geodynamo." Essentially, a big boost of energy was needed to drive the geodynamo and stop the magnetic field from collapsing—and the solidification of Earth's core would have done just that. Tarduno continued: "If the geodynamo had collapsed entirely, Earth would not have been protected from the solar wind, which can erode the atmosphere and eventually rob water from the planet." In an accompanying article, Peter Driscoll of the Carnegie Institution for Science said scientists had previously interpreted the weak magnetic field 565 million years ago as being the result of "rapid tectonic motion, hyper-frequent polarity reversals, and even an equatorial dipole." However, he said that if the latest research is right, "the nucleation of the inner core may have occurred right in the nick of time to recharge the geodynamo and save Earth's magnetic shield."