# Framework

#### My value is justice.

#### My value criterion is maximizing expected well-being

#### Prefer this value criterion to all others

#### 1 – Tradeoffs are inevitable, so governments need to make policies that best benefit the people

**Woller 97**  [Gary Woller, BYU Prof., “An Overview by Gary Woller”, A Forum on the Role of Environmental Ethics, June 1997, pg. 10]

Moreover, virtually all public policies entail some redistribution of economic or political resources, such that one group's gains must come at another group's expense. Consequently, public policies in a democracy must be justified to the public, and especially to those who pay the costs of those policies. Such justification cannot simply be assumed a priori by invoking some higher-order moral principle. Appeals to a priori moral principles, such as environmental preservation, also often fail to acknowledge that public policies inevitably entail trade-offs among competing values. Thus since policymakers cannot justify inherent value conflicts to the public in any philosophical sense, and since public policies inherently imply winners and losers, the policymakers' duty to the public interest requires them to demonstrate that the redistributive effects and value trade-offs implied by their policies are somehow to the overall advantage of society. At the same time, deontologically based ethical systems have severe practical limitations as a basis for public policy. At best, a priori moral principles provide only general guidance to ethical dilemmas in public affairs and do not themselves suggest appropriate public policies, and at worst, they create a regimen of regulatory unreasonableness while failing to adequately address the problem or actually making it worse.

#### 2 - Only acting through maximizing well-being can we best account for the value of human life

Cummiskey 90

[Cummiskey, David. Associate professor of philosophy at the University of Chicago. “Kantian Consequentiaism.” Ethics 100 (April 1990), University of Chicago. <http://www.jstor.org/stable/2381810>]

We must not obscure the issue by characterizing this type of case as the sacrifice of individuals for some abstract “social entity.” It is not a question of some persons having to bear the cost for some elusive “overall social good.” Instead, the question is whether some persons must bear the inescapable cost for the sake of other persons. Robert Nozick, for example, argues that “to use a person in this way does not sufficiently respect and take account of the fact that he is a separate person, that his is the only life he has.” But why is this not equally true of all those whom we do not save through our failure to act? By emphasizing solely the one who must bear the cost if we act, we fail to sufficiently respect and take account of the many other separate persons, each with only one life, who will bear the cost of our inaction. In such a situation, what would a conscientious Kantian agent, an agent motivated by the unconditional value of rational beings, choose? A morally good agent recognizes that the basis of all particular duties is the principle that “rational nature exists as an end in itself”. Rational nature as such is the supreme objective end of all conduct. If one truly believes that all rational beings have an equal value, then the rational solution to such a dilemma involves maximally promoting the lives and liberties of as many rational beings as possible. In order to avoid this conclusion, the non-consequentialist Kantian needs to justify agent-centered constraints. As we saw in chapter 1, however, even most Kantian deontologists recognize that agent-centered constraints require a non- value-based rationale. But we have seen that Kant’s normative theory is based on an unconditionally valuable end. How can a concern for the value of rational beings lead to a refusal to sacrifice rational beings even when this would prevent other more extensive losses of rational beings? If the moral law is based on the value of rational beings and their ends, then what is the rationale for prohibiting a moral agent from maximally promoting these two tiers of value? If I sacrifice some for the sake of others, I do not use them arbitrarily, and I do not deny the unconditional value of rational beings. Persons may have “dignity, that is, an unconditional and incomparable worth” that transcends any market value, but persons also have a fundamental equality that dictates that some must sometimes give way for the sake of others. The concept of the end-in-itself does not support the view that we may never force another to bear some cost in order to benefit others.

Thus, I affirm: the appropriation of outer space by private entities is unjust.

# Contention: The Environment

**More private actors will be going to space – a new space race has begun.**

**Grady 17** [Monica Grady. Professor of Planetary and Space Sciences at the Open University. “Private companies are launching a new space race –  here's what to expect”. 10-3-2017. Conversation. <https://theconversation.com/private-companies-are-launching-a-new-space-race-heres-what-to-expect-80697>] //ab sp

The space race between the USA and Russia started with a beep from the Sputnik satellite exactly 60 years ago (October 4, 1957) and ended with a [handshake in space](https://theconversation.com/a-handshake-in-space-changed-us-russia-relations-how-long-will-it-last-44846) just 18 years later. The handshake was the start of many decades of international collaboration in space. But over the past decade there has been a huge change.

The space environment is no longer the sole preserve of government agencies. Private companies have entered the exploration domain and are propelling the sector forward more vigorously and swiftly than would be the case if left to governments alone.

It could be argued that a new space race has begun, in which private companies are competing against each other and against government organisations. But this time it is driven by a competition for customers rather than the urge to show dominance by being first to achieve a certain goal. So who are the main players and how will they change the science, technology and politics of space exploration?

Put the phrase “private space exploration” into a search engine and a wealth of links emerges. Several have titles such as: “[Six private companies that could launch humans into space](https://www.space.com/8541-6-private-companies-launch-humans-space.html)”, “[The world’s top 10 most innovative companies in space](https://www.fastcompany.com/3026685/the-worlds-top-10-most-innovative-companies-in-space)” or “10 major players in the private sector space race”. What is immediately apparent is that practically all these companies are based in the US.

There is a big difference between building and launching satellites into low Earth orbit for telecommunications and sending crew and cargo to the International Space Station (ISS) and beyond. Private companies in several nations have been engaged in the satellite market for many years. Their contributions to the development of non-governmental space exploration has helped to lay the trail for entrepreneurs with the vision and resources to develop their own pathways to space.

Today, several companies in the US are looking very specifically at human spaceflight. The three that are perhaps furthest down the road are [SpaceX](http://www.spacex.com/about), [Blue Origin](https://www.blueorigin.com/) and [Virgin Galactic](http://www.virgingalactic.com/). The main goals of all three companies is to reduce the cost of access to space – mainly through reuse of launchers and spacecraft – making space accessible to people who are not specially trained astronauts. One thing these companies have in common is the private passion of their chief executives.

SpaceX was founded in 2002 by Elon Musk, a charismatic entrepreneur, engineer, inventor and investor. The ambition of SpaceX is “to revolutionise space technology, with the ultimate goal of enabling people to live on other planets”. To this end, the company has specialised in the design, manufacture and launch of rockets, providing direct competition to the [United Launch Alliance](http://www.ulalaunch.com/) (between Boeing and Lockheed Martin) that had been the contract holder of choice for launch of NASA and Department of Defense rocket launches.

Its success has been spectacular. Having developed the [Falcon 9](http://www.spacex.com/falcon9) launch vehicle and [Dragon spacecraft](http://www.spacex.com/dragon), it became the first commercial company to dock a spacecraft at the ISS in 2012. The firm now has a regular run there, carrying cargo. But so far, no astronauts. However, the Falcon Heavy is comparable to the Saturn 5 rocket that launched the Apollo astronauts, and SpaceX has designed its vehicle with a view to sending astronauts to the moon by 2018, and to Mars [as early as 2023](https://theconversation.com/elon-musk-releases-details-of-plan-to-colonise-mars-heres-what-a-planetary-expert-thinks-79733).

On September 29, Musk refined his plans, announcing the [BFR project](http://www.bbc.co.uk/news/science-environment-41441877) (which I like to pretend stands for Big F\*\*king Rocket). This would replace the Falcon and Dragon spacecraft – and would not only transport cargo and explorers to the moon and Mars, but could also reduce travel times between cities on Earth. Musk calculates it could take as little as 29 minutes to fly from London to New York.

Whether the company succeeds in sending astronauts to the moon in 2018 remains to be seen. Either way, a lot could be going on then – 2018 is also the year when Blue Origin, founded in 2000 by [Jeff Bezos](https://www.cnbc.com/2017/08/29/inside-jeff-bezos-80-billion-empire.html), the technology and retail entrepreneur behind Amazon, aims to launch people to space. But its ambition is different from that of SpaceX. Blue Origin is focusing on achieving commercially available, sub-orbital human spaceflight – targeting the space tourism industry. The company has developed a vertical launch vehicle ([New Shepard](https://www.blueorigin.com/technology), after the first American astronaut in space, Alan Shepard) that can reach the 100km altitude used to define where “space” begins. The rocket then descends back to Earth, with the engines firing towards the end of the descent, allowing the spacecraft to land vertically. Test flights with no passengers have made successful demonstrations of the technology. The trip to space and back will take about 10 minutes.

But Blue Origin has got some competition from Virgin Galactic, which describes itself as “the world’s first commercial spaceline”. Founded in 2004 by [Richard Branson](https://en.wikipedia.org/wiki/Richard_Branson), also a technology and retail entrepreneur, it plans to carry six passengers at a time into sub-orbital space and give them about six minutes of weightlessness in the course of a two and a half hour flight.

The technology differs from that of SpaceX and Blue Origin in that the launch into space is not from the ground, but from a jet airplane. This mothership flies to an altitude of about 18km (about twice as high as regular aircraft fly) and releases a smaller, rocket-powered spacecraft (SpaceShip Two) which is propelled to an altitude of about 100km. The programme has been delayed by technical difficulties – and then by the tragic loss of pilot [Mike Alsbury](https://www.theguardian.com/science/2014/nov/02/co-pilot-died-virgin-galactic-crash-hailed-renaissance-man), when SpaceShip Two exploded in mid-air during a test flight in 2014. No date is yet set for the first passengers to fly.

There’s also the [Google Lunar XPrize competition](http://lunar.xprize.org/), announced in 2007, with the tagline: “Welcome to the new space race”. The aim of the prize is to launch a robotic mission to the moon, place a lander on the surface and drive 50 metres, sending back high-quality images and video. The competition is still in progress. Five privately funded teams must launch their spacecraft to the moon by the end of 2017.

The changes are taking place against a backdrop of tried and tested international collaboration in space, which took off in earnest at the end of the space race. Throughout the 1980s and 1990s, the US and Russia space programmes complemented each other beautifully – though perhaps not intentionally. Following the cessation of Apollo in 1975, the US space programme focused its efforts on robotic exploration of the solar system.

The Voyager probes gave us [amazing images](https://voyager.jpl.nasa.gov/mission/) of Jupiter, Saturn, Uranus and Neptune. The [Mariner](https://nssdc.gsfc.nasa.gov/planetary/mars/mariner.html) and [Viking missions](https://www.nasa.gov/mission_pages/viking/) to Mars led to Pathfinder, Spirit, Opportunity and Curiosity. Messenger orbited Mercury and Magellan orbited Venus. When New Horizons launched to Pluto in 2006, it was a mission to [visit the last planet left unexplored](https://theconversation.com/new-horizons-finally-gets-up-close-with-pluto-for-15-minutes-44603) in the solar system.

Russia, on the other hand, pursued the goal of human spaceflight, with its incredibly successful [Mir orbiting space station](https://theconversation.com/the-first-space-walk-happened-50-years-ago-and-nearly-ended-in-disaster-38921) and its programme of flights to transfer cosmonauts and cargo backwards and forwards to Mir. Human spaceflight in the US revived with the [Space Shuttle](https://www.nasa.gov/mission_pages/shuttle/main/index.html) and its mission to build and occupy the [International Space Station](https://theconversation.com/five-key-findings-from-15-years-of-the-international-space-station-51540) (ISS). The list of nations that contribute to the ISS continues to grow. The shuttle programme finished in 2011 and, since its successor Orion (built in collaboration with European Space Agency, ESA) is not due to come into service until at least 2023, the international community has been reliant on Russia to keep the ISS fuelled and inhabited.

Today, as well as the US and Russia, there are strong, vibrant and successful space programmes in Europe, Japan, India and China. The European Space Agency was established just two months before the historic handshake of 1975, following many years of independent aeronautical engineering research by individual nations. Similarly, the Chinese, Japanese and Indian space agencies can trace their heritages back to the 1960s. A number of smaller countries including the United Arab Emirates also have ambitious plans.

Of course these countries also compete against each other. There has been widespread speculation that the entry of China into the field was sufficient to introduce a fresh imperative to the US space programme. China has a [well-developed space programme](https://theconversation.com/crashing-space-station-shows-why-china-must-start-to-collaborate-in-orbit-66072) and is currently working towards having a space station in orbit around the Earth by about 2020. A prototype, Tiangong-2, has been in space for almost a year, and was occupied by two astronauts (or “taikonauts”) for a month.

China has also had three successful missions to the moon. And its next mission, Chang’e 5, due to launch towards the end of 2017, [is designed to bring samples from the moon back to Earth](https://theconversation.com/chinas-plan-to-be-first-to-far-side-of-the-moon-could-unveil-inner-lunar-secrets-53253). China also has a declared intent of landing taikonauts on the moon by 2025 – the same time frame in which the US will be testing its new Orion spacecraft in orbit around the moon.

But while there’s an element of competition, the success of the past few decades certainly shows that it is possible to collaborate in space even when tensions rise on the ground. Indeed, space exploration may even act as a buffer zone from international politics, which is surely something worth having. It will be interesting to see how a wider role in space exploration for private companies will affect such international collaborations, especially since so much of the effort is based in the USA.

A benefit of the entry of the private sector into space exploration has been recognition of the high-tech companies that contribute to the growth of the economy as valuable targets for investment. Indeed, [a recent presentation](http://www.goldmansachs.com/our-thinking/podcasts/episodes/05-22-2017-noah-poponak.html?mediaIndex=1&autoPlay=true&cid=sch-pd-google-poponakpodcast64-searchad-201705--&mkwid=8cazG4Ns) at an international investment bank – under a heading of “Space; the next investment frontier” – declared that “investment interest has helped reduce launch costs and spur innovation across related industries, opening up a new chapter in the history of the space economy”.

One of the last engagements of Barack Obama’s presidency was to chair the Whitehouse Frontiers Conference, where space exploration was discussed as much [within the context of US industry](http://www.frontiersconference.org/tracks/interplanetary) as within the drive to explore new worlds. Contributors to the conference included NASA – but overwhelmingly the speakers were from private technology and investment companies.

Perhaps it is cynical to say – but once investment starts to flow, lawyers won’t be far behind. And that is another aspect of the explosion of interest in space commerce and tourism. Laws, statutes and other regulations are necessary to govern the international nature of space exploration. At the moment, the United Nations, through its [Office for Outer Space Affairs](http://www.unoosa.org/), is responsible for promoting international cooperation in the peaceful uses of outer space. It also oversees operation of the [Outer Space Treaty](http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html), which provides a framework for the governance of space and activities that might take place. While the obvious lack of “space police” means that it cannot be practically enforced, it has [never actually been violated](https://theconversation.com/the-outer-space-treaty-has-been-remarkably-successful-but-is-it-fit-for-the-modern-age-71381).

The operation is designed along similar lines to the international treaties that oversee maritime activities and the exploration of Antarctica. This is the closest that there is to international legislation and, since coming into operation in 1967 with the three inaugural signatories of the United States of America, the United Kingdom and the (then) USSR, the treaty has been signed by 106 countries (including China and North Korea). It is necessary to have such controls because although the risks that surround space exploration are high, potential rewards are even higher.

If we look at the way more conventional businesses operate, such as supermarkets, competition drives prices down, and there is little reason to believe that competition between space companies would follow a different model. In which case, greater risks might be taken in order to increase profitability. There is no evidence for this so far – but as the field develops and additional private companies move into space exploration there will be a higher probability of accident or emergency.

The treaty says that a state launching a probe or satellite is liable to pay compensation for damage when accidents occur. However, the costs of space exploration are astronomical and crippling to poorer countries, making them increasingly depend on commercial launchers. But if a private company launches an object that subsequently causes damage in space, the struggling economy will have to pick up the bill. The treaty [may therefore need to be updated](https://theconversation.com/spacex-explosion-shows-why-we-must-slow-down-private-space-exploration-until-we-rewrite-law-65019) to make private companies more liable. There are also serious issues around the safety of astronauts, who have the legal right to a safe existence when in outer space. But even lawyers aren’t sure whether the law does – or should – extend to private astronauts.

Looking to the future, there will be a need for an expanded version of a Civil Aviation Authority, directing and controlling routes, launches and landings on Earth, and between and on planetary bodies. All the safety and security considerations of air and sea travel will pertain to space travel at a vastly enhanced level, because the costs and risks are so much higher. There will have to be firm and well-understood protocols in the event of a spacecraft crashing, or two spacecraft colliding. Not to mention piracy or the possibility of hijack. All this might sound a little gloomy, taking the dash and exhilaration from space exploration, but it will be a necessary development that opens up the era of space travel for citizens beyond those with deep pockets.

The original space race resulted from the ideas and skills of visionary theoretician engineers including: [Robert H Goddard](https://www.nasa.gov/centers/goddard/about/history/dr_goddard.html), [Wernher von Braun](https://www.nasa.gov/centers/marshall/history/vonbraun/bio.html), [Konstantin E. Tsiolkovsky](https://www.nasa.gov/audience/foreducators/rocketry/home/konstantin-tsiolkovsky.html)… Is it too far a stretch to think that the second space race is propelled by a new generation of entrepreneurs, including Bezos, Branson and Musk? If this is the situation, then I would hope that the main enabling factor in the pursuit of space endeavours is not possession of wealth, but that vision, ingenuity and a wish for the betterment of human are the main driving forces.

#### Aff solves - prohibiting appropriation would decrease all private activity in space.

**Babcock, 15** -- Jonathan’s practice involves assisting clients in a range of national security matters, including economic sanctions compliance, export controls compliance, and national security reviews before the Committee on Foreign Investment in the United States (CFIUS). Prior to joining Morrison & Foerster, Jonathan practiced in the International Trade and National Security practice groups of a major D.C. law firm.

[Jonathan Babcock, "The Space Review: Encouraging private investment in space: does the current space law regime have to be changed? (part 1)," The Space Review, 1-5-2015, https://www.thespacereview.com/article/2669/1, accessed 6-25-2021]

Space law, derived mainly from the Outer Space Treaty and the Moon Treaty (the latter’s principles carry weight despite having a few signatory states), prohibits national appropriation in space and states that space is a domain for the “common heritage of mankind.” The meaning of these documents, particularly pertaining to their applicability to private actors in space, is ambiguous and contentious, as will be shown in the following section. In any industry, legal uncertainty hinders private investment. Accordingly, a cloudy legal regime in space has hampered the ability of private individuals and firms to raise the capital necessary to fund space activities.16 Moreover, private actors hold that the absence of a legal regime clearly defining the scope of property rights in space deprives them of the assurance that they will reap benefits that will outweigh the capital they invested.17 They argue that the main impediment to further private action in space is that the current legal regime jeopardizes the ability of private actors to make a profit in space.

This is a discouraging climate for private innovation, and will surely discourage future investment in space. The legal regime governing space must be clarified, added to, altered, or changed entirely to encourage private investment in space by allowing actors to realize financial rewards.18 The question then becomes how to accomplish this. In order to better understand the inadequacies of the current legal regime, it is necessary to analyze what exactly the Outer Space Treaty and Moon Treaty state, and how they dictate the climate in which private actors are operating in space.

## Subpoint A: Space Debris

**Satellites, rockets, and all launches cause space debris.**

**O'Callaghan 16** [Jonathan O'Callaghan. Space journalist that covers spaceflight, space exploration, and astrophysics. “What is space junk and why is it a problem?”. 5-4-2016. National History Museum. <https://www.nhm.ac.uk/discover/what-is-space-junk-and-why-is-it-a-problem.html>] //ab sp

Since the dawn of the space age in the 1950s, we have launched thousands of rockets and sent even more satellites into orbit. Many are still there, and we face an ever-increasing risk of collision as we launch more.

As long as humans have been exploring space, we've also been creating a bit of a mess. Orbiting our planet are thousands of dead satellites, along with bits of debris from all the rockets we've launched over the years. This could pose an issue one day.

Space junk, or space debris, is any piece of machinery or debris left by humans in space.

It can refer to big objects such as dead satellites that have failed or been left in orbit at the end of their mission. It can also refer to smaller things, like bits of debris or paint flecks that have fallen off a rocket.

Some human-made junk has been left on the Moon, too.

While there are about 2,000 active satellites orbiting Earth at the moment, there are also 3,000 dead ones littering space. What's more, there are around 34,000 pieces of space junk bigger than 10 centimetres in size and millions of smaller pieces that could nonetheless prove disastrous if they hit something else.

All space junk is the result of us launching objects from Earth, and it remains in orbit until it re-enters the atmosphere.

Some objects in lower orbits of a few hundred kilometres can return quickly. They often re-enter the atmosphere after a few years and, for the most part, they'll burn up - so they don't reach the ground. But debris or satellites left at higher altitudes of 36,000 kilometres - where communications and weather satellites are often placed in geostationary orbits - can continue to circle Earth for hundreds or even thousands of years.

Some space junk results from collisions or anti-satellite tests in orbit. When two satellites collide, they can smash apart into thousands of new pieces, creating lots of new debris. This is rare, but several countries including the USA, China and India have used missiles to practice blowing up their own satellites. This creates thousands of new pieces of dangerous debris.

**The amount of space debris is increasing because of private companies like SpaceX – can endanger other spacecraft.**

**Gorman 21** [Alice Gorman. Internationally recognized scholar in space archaeology. “Opinion: The growing problem of space junk”. 5-8-2021. CNN. <https://www.cnn.com/2021/05/08/opinions/long-march-5b-space-junk-growing-problem-gorman/index.html>] //ab sp

More than 3 million years ago, members of an unknown hominin species sat on a river bank at the site of Lomekwi, in what is now Kenya, and made a set of stone tools for their daily tasks. Only a trained eye can distinguish the detritus they left behind from naturally broken rocks. In the intervening millennia, human trash has grown in complexity and quantity, introducing novel materials like plastics and metal alloys. What humans discard is fodder for archaeologists, but it's also an environmental problem that is becoming interplanetary.

The Soviet satellite Sputnik 1, which launched on October 4, 1957, was the first human-made object in space. It kick-started the space race and inspired dreams of holidays on the moon and Martian colonies. But the satellite's orbit decayed just three months later, and it burned up as it reentered Earth's atmosphere. It was the first piece of space trash.

Nothing survived of the basketball-sized aluminum sphere with distinctive antennas. That's not likely to be the case for the Long March 5B rocket, which is expected to fall back to Earth this weekend after delivering the Tianhe module of the new Chinese space station to orbit in April. It's one of the largest uncontrolled space objects to fall out of orbit. The rocket uses cryogenic fuel, so its fuel tanks are extremely robust to contain liquid oxygen and hydrogen under high pressure. Based on my observations, fuel system components are the most common rocket element to make it back to Earth.

Most concerns about the uncontrolled reentry of the 22-ton rocket are about how much will remain intact and the potential damage it might inflict on life and property on Earth. But we shouldn't just focus on what makes its way back to the ground. Old satellites, rocket bodies, fragments and particles make up an estimated 9,000 tons of material circling Earth, from a few hundred kilometers to more than 35,000 kilometers in altitude. Most of it is in low-Earth orbit, and pieces of space junk can lose altitude over time and incinerate in the atmosphere. Space junk reenters the atmosphere on a daily basis, although it mostly goes unnoticed because it burns up long before it can hit the ground.

Reentry is considered the most desirable outcome as it removes the space junk from orbit where it can collide with functioning satellites, create more junk, and threaten human life when it comes to crewed spacecraft. But very little work has been done on the effects of reentry on the upper atmosphere and the incineration that happens creates alumina particles that can have an environmental impact.

Studies of fuel exhaust from rocket launches have shown that particles of soot and alumina remain trapped in the stratosphere and can deplete the ozone layer. The ozone layer protects life on Earth from the savage effects of ultraviolet radiation by absorbing it. It's been under threat before, from chlorofluorocarbons or CFCs, which were once commonly used in aerosols and as coolants in refrigerators (the ozone is recovering after international action under the 1987 Montreal Protocols). As the number of rocket launches increases, the more space junk there will be -- and it's unclear what the long-term effects on the atmosphere may be. The quantity of human materials in orbit is only increasing more rapidly with the launch of "megaconstellations" of communication satellites, like Starlink, SpaceX's plan to provide low-cost satellite Internet access. While the effects may be small- scale at the moment, the number of satellites could increase from about 6,000 to 15,000 in the coming decade. This means the number of reentries will also increase.

Scientists are now looking at novel materials for spacecraft manufacture that will not create alumina particles as a by-product of combustion. Silica-based ceramics, like the tiles used for heat shields on the US space shuttles, are durable and light and already widely used in aerospace. A Japanese company has been developing satellites encased in wood with a view to reducing harmful particles. Antennas and electronics are protected from the space environment inside the shell, and no alumina particulates would be created on reentry. It sounds unusual but the creative use of new materials has great potential.

Earth's atmosphere has become a liminal zone that marks a zombie spacecraft's transition to true death. It's now effectively the equivalent of landfill for the space industry. Humans have been discarding junk on Earth for millions of years and the Industrial Revolution brought on a dramatic increase of emissions into the atmosphere. Just like the international waters of the ocean, the atmosphere is considered a global commons. As space activity accelerates over the coming decade, events like the Long March 5b reentry remind us to take nothing on Earth for granted.

#### Private actors are uniquely key to avoid debris cascades – they have lower safety standards and won’t cooperate with others

Yuan 21 [Alda Yuan, Public Health Analyst U.S. Department of Health and Human Services and visiting attorney at the Enivornmental Law Institute with a JD from Yale, 2021, “FILLING THE VACUUM: ADAPTING INTERNATIONAL SPACE LAW TO MEET THE PRESSURES CREATED BY PRIVATE SPACE ENTERPRISES,” Hein Online, https://heinonline.org/HOL/P?h=hein.journals/denilp49&i=27]/Kankee

C. Non-state Actors Introduce Practical Challenges that Endanger the Future of Space Travel If companies are permitted to access space without a proper legal framework or sufficient coordination, the practical risks may doom the project of humanity in outer space for the near future. The opening anecdote dramatized the risks, but the fact that a chain of cascading destruction might preclude the use of whole bands of outer space or make launches impossible is not farfetched. 99 Indeed, it is already happening.0 Because space missions always create debris and there is a correlation between the number of objects orbiting earth and the chances of collision, which thereby creates more debris, even no further activity in space will eventually result in a belt of debris encircling the earth.10 1 This cascade effect, called the Kessler Syndrome, 102 has the potential to speed up astronomically if activities in outer space expand without contingent regulation and mitigation measures.1 1 3 At current rates and in the absence of a catastrophic event, lower earth orbit, in particular, might reach a tipping point within the next ten to fifty years.1 4 If the space debris problem is permitted to reach this tipping point, access to space may well be cut off for the near future because it will be impossible to launch satellites.1 5 Given that we do not have the technology to clean up debris yet, space travel faces an existential threat. In light of this, most space-faring states cooperate, working together to develop guidelines and pool resources to track the debris already orbiting the earth to minimize the chances of a collision.106 Given the high speeds the debris travels at, approximately 10 km/second,107 and the amount of damage even tiny pieces can do, 108 the existing tracking systems are not an absolute fix. At these speeds, a piece of debris weighing a mere two grams can produce an impact force equivalent to a kilogram of TNT.109 More than three hundred thousand pieces of debris greater than one cm in diameter," and therefore capable of causing enormous damage, orbit the earth while the US Space Surveillance Network (SSN) system can only track objects over five cm in diameter." There are millions of fragments smaller than one cm, which are impossible to track and yet can still cause significant damage.11 2 Still, the tracking system is important. In the last twenty years, the International Space Station has carried out several avoidance maneuvers to avoid potential collision with pieces of space debris being tracked by the SSN system.113 Between April of 2011 and April of 2012, the ISS performed four evasive maneuvers." 4 On two additional occasions, the crew fell back to the Soyuz since there was no time to set up an evasive maneuver." 5 This sort of cooperation works given the limited number of actors involved and the aligned interests of the nation-state parties. Commercial space companies do not have the same incentives to cooperate to share data and new technologies. This is why many have called for the creation of a new convention on managing orbital debris. 16 However, escalation of the Kessler Syndrome is not the only problem that might arise by failing to accommodate for the rise of the commercial corporations, so such a convention would not eliminate the threat. For instance, many satellites use nuclear power sources (NPS), which can break up upon reentry." As early as 1978, the Cosmos-954 incident scattered radioactive debris over Canada.118 Other accidents of this type could raise fallout concerns, especially if they occur over more densely populated regions. In an attempt to alleviate this risk and decrease the chances of collisions, various nations have cooperated to design and standardize methods of decommissioning satellites. 119 One strategy is to supply spacecraft with additional fuel and nudge it out of orbit so it will burn up in the atmosphere over the ocean. 120 Another is to push the ailing satellite into a graveyard orbit. 121 These methods require additional research and design and incur additional costs. 12 2 Private companies may not spontaneously take the steps necessary to comport with the common practices of space-faring nations. Thus, the rise of private corporations, while opening up new possibilities, may also threaten space travel itself and the international legal order in which coordination currently occurs. The coordination necessary to prevent and manage the unique problems that arise in space requires a more pragmatic framework. Directly binding private non-state actors benefits the international community because it prevents abusive practices and permits the coordination of efforts that make space safer. However, it will also benefit the private sector by providing companies with a background legal structure, neutral dispute resolution, and common guidelines to even the playing field. More importantly, if companies not subject to regulation and oversight are permitted to operate in outer space, disasters cannot be effectively prevented. In that case, space exploration and the benefits stemming from it might be closed off for all. III. SPACE IS A GLOBAL COMMONS UNDER CUSTOMARY INTERNATIONAL LAW

#### By definition, mega-constellations make debris cascades inevitable

Siegel 20 [Ethan Siegel, astrophysicist, author, and science communicator, who professes physics and astronomy at various colleges, 2-19-2020, "Flaremageddon: How Satellite Mega-Constellations Could Create A New Natural Disaster," Forbes, https://www.forbes.com/sites/startswithabang/2020/02/19/flaremageddon-how-satellite-mega-constellations-could-create-a-new-natural-disaster/#51403cf049cf]/Kankee

Over the next few years, the night sky and the volume of space that surrounds the Earth are both poised to become very different than they've been for all of human history. As of 2019, humanity had launched an estimated total of between 8,000 and 9,000 satellites, with approximately 2,000 of them still active. As SpaceX's Starlink, OneWeb, Amazon's Project Kuiper, Telesat and other companies prepare to provide worldwide 5G coverage from space (more than 300 new satellites have gone up for these purposes [in the last 9 months](https://www.forbes.com/sites/jonathanocallaghan/2020/02/17/spacex-launches-fifth-starlink-mission-and-takes-its-total-number-of-satellites-up-to-300/)), humanity is beginning to enter the era of satellite mega-constellations. While media coverage has largely mentioned only one detrimental effect so far — [the damage that these satellites are already causing to astronomy](https://www.forbes.com/sites/startswithabang/2020/01/30/dangers-to-astronomy-intensify-with-spacexs-latest-starlink-launch/) — there's a second consequence that could be even more disastrous: Kessler syndrome. With tens or even hundreds of thousands of satellites in orbit, a single collision could trigger a chain reaction. With the realities of solar flares and the technological needs of mega-constellations, this new type of natural disaster may be unavoidable. The idea of [Kessler syndrome](https://en.wikipedia.org/wiki/Kessler_syndrome) is a simple one: if there are too many satellites around Earth, an unfortunate collision between any two of them could create enough debris that another collision becomes inevitable. Although [there is not widespread agreement](http://physics.ucsc.edu/cosmo/Mountbat.PDF) on when that point will be reached, it's widely recognized that greater numbers of larger satellites greatly increases this risk. With Starlink alone proposing a total of 42,000 satellites in three different orbital shells and many other companies sure to soon follow suit, the danger of Kessler syndrome is poised to increase by orders of magnitude over the 2020s. In prior years, satellites were launched into orbits that were tracked and knowable, but with occasional collisions occurring due to inactive satellites whose orbits were decaying due to atmospheric drag. With mega-constellations, however, artificial intelligence will be entering the picture, and this poses a tremendous danger. With so many objects in orbit at the same altitude, artificial intelligence will be required in order to constantly leverage the on-board thrusters to accomplish three main goals: to ensure the correct, continuous spacing of the satellites to provide the necessary internet coverage, to compensate for the drag of Earth's atmosphere, and to perform any necessary boosts or orbital alterations to avoid collisions with other satellites. This last point is absolutely critical. Any two orbits at the same altitude always have two points where they will cross, and satellite drift would make a collision inevitable. Only by having the satellites correct their own courses in real-time can they ensure a collision-free scenario. But this plan comes along with a catastrophic scenario: what if the satellites are rendered non-responsive by some event? If constant orbital corrections are needed in order to avoid collisions with other satellites, the worst thing that could happen would be a scenario that ~~paralyzed~~ [stopped] the satellites and made them unable to respond to not only the artificial intelligence, but to a manual command. This is not some science-fiction horror scenario, but something as inevitable as the Sun itself: space weather. Events like solar flares, coronal mass ejections, and even the plain old solar wind all send charged particles away from the Sun. When they happen to get sent on their way towards planet Earth, our surface is protected by our world's magnetic field and our atmosphere. The danger to humans or any biological organism is essentially zero, with the largest effect that commonly occurs being a spectacular looking auroral display. But in space, even in low-Earth orbit, the atmosphere offers no protection, and the magnetic field offers no guarantee of redirecting these particles away from satellites. [According to NOAA](https://www.swpc.noaa.gov/impacts): Solar Energetic Particles (energetic protons) can penetrate satellite electronics and cause electrical failure. These energetic particles also block radio communications at high latitudes in during Solar Radiation Storms. Right now, the Sun is in the quietest part of its periodic solar cycle. On timescales of 11 years, the number of sunspots — which correlates directly with the odds of flaring activity and coronal mass ejections — goes from essentially zero (a quiet Sun) to solar maximum and back to zero again. Right now, in 2020, we're just leaving the last solar minimum, with the next maximum anticipated to occur in 2024 or 2025 and every 11 years after that. There's a tremendous danger to satellites whenever this type of space weather impacts them. If these energetic protons cause any type of electrical failure in these satellites, they will be unable to adjust their course via artificial intelligence or any other means. If they cannot adjust their course, the question of any two of these satellites colliding becomes a game of Russian roulette, where there are likely to be a series of near-misses before the inevitable — an in-space collision between two of them — occurs. The worst-case scenario, and this scenario gets worse with every new large satellite that goes up (and every communications satellite is "large" by this metric), is that each collision increases both the likelihood and frequency of in-orbit collisions. In short order, potentially just weeks or months, the region around Earth will become a debris field, with a significant percent of existing satellites destroyed. At present, every space disaster, [including collisions](https://en.wikipedia.org/wiki/2009_satellite_collision) and failed missions that have exploded or malfunctioned in various ways, means that there are perhaps a few hundred thousand pieces of space debris the size of your fingernail or larger. These are already hazardous to our existing satellites, with one of them colliding with the International Space Station just a few years ago, cracking a window. But with hundreds of thousands of large satellites, a single collision could set off a catastrophic chain reaction like we've never seen. In short order, the number of pieces of space debris could rise into the tens of millions, impacting satellites in both low-Earth orbit and medium-Earth orbit. The first company whose satellites cause such a disaster would likely impact every other one, to say nothing of military and scientific satellites presently in orbit. Not only will satellite technology become an impossibility for decades or even many generations, but routine space launches will become an enormous gamble. The greatest danger that the Sun poses to Earth today is a large-scale coronal mass ejection, which — if it heads right for us with the wrong magnetic field orientation — could lead to a wide-scale electrical catastrophe that could knock out power grids all over the Earth, starting fires and causing trillions of dollar in damage to our infrastructure.

**The Kessler Syndrome is when there is so much debris in space that nothing can launch safely. This will have huge impacts for climate and weather prediction.**

**Undseth et al 21** [Marit Undseth, OECD Space Forum, Claire Jolly, OECD Space Forum, Mattia Olivari, OECD Space Forum, “The Economics of Space Debris in Perspective,” 8th European Conference on Space Debris, https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/12/SDC8-paper12.pdf]

The current costs of space debris are nothing compared with future prospects. In a worst-case scenario, certain orbits may become unusable, due to continued, self-reinforcing space debris generation (Kessler Syndrome). This would have significant negative impacts on the provision of several important government services and would most probably also slow down economic growth in the space sector. The social costs would be unequally distributed, with lower-income and rural regions more hardly hit, in view of their growing dependence on satellite communications, in particular. These costs are listed in Tab. 2 and are further elaborated in the following paragraphs. Loss of unique applications and functionalities: The orbits most likely to be disrupted by the Kessler Syndrome are found at 650-1000 km and towards 1400 km altitude in the low-earth orbit, where the thickest belts of debris are located. For instance, the 2009 collision between Iridium-33 and Kosmos-2251 satellites took place at 776 km altitude. In some cases, the disruption or loss of certain low earth orbits would have severe impacts on terrestrial applications, for which space observations (from these orbits) are either the best or the only source of data and signals. (Tab. 3). This applies in particular to polar-orbiting weather and earth observation satellites, which make unique contributions to weather forecasting and climate change observations and research. Polar-orbiting weather satellites provide essential inputs to numerical weather prediction models, reducing errors and improving forecast accuracy [23]. The European Centre for Medium-Range Weather Forecasts has found that a simultaneous loss of both European and US polarorbiting satellites would cause a 15-20% reduction in accuracy [24]. For instance, estimated benefits from satellitebased meteorological observations to the UK economy amount to between GBP 670-1000 million annually [25]. The loss of polarorbiting weather satellite observations would also heavily affect the Southern hemisphere, where there are fewer terrestrial observations. Lives lost: The International Space Station is located at about 400 km altitude. The planned Chinese Space Station will have a similar location. Although debris at that altitude decays naturally, it still poses a real collision threat. The International Space Station has seen a significant increase in debris avoidance manoeuvres, with seventeen manoeuvres taking place between 2009 and 2017, compared to eight manoeuvres in the 1999- 2008 timeframe [26], [27]. Interrupted time series for earth science and climate research: Uninterrupted time series are crucial for the accuracy and reliability of weather prediction and climate models. Several weather and earth observation satellites in affected orbits make unique measurements for climate observations. The Jason-2 and Jason-3 satellites, located at 1336 km altitude, measure variations in sea surface height, which provide information about global sea levels, the speed and direction of ocean currents, and heat stored in the ocean. Curbed economic growth in the space sector: Current commercial operators (mostly earth observation and telecom) are mainly located at 400-700 km altitudes [28]. Although the current value of commercial operations in the low-earth orbit is significantly lower than that of telecommunications activities in the geostationary orbit, satellite broadband is widely considered a key driver of space activities and revenues in the coming decades, despite uncertainty concerning business models and viability. Many LEO communication services would be affected by space debris, on orbit and/or during orbitraising, as several of the planned constellations are located near or above the thickest LEO debris belts. This could have knock-on effects on other industry segments, such as manufacturing and launch. Reduced access to finance for space ventures: While the current financial climate is favourable for space sector investments, it is important to acknowledge that many space applications face growing competition from terrestrial applications (e.g. communications, earth observation). It is reasonable to expect that a growing space debris problem may deter investments into the sector, with investors preferring more affordable and less risky terrestrial alternatives. Negative distributional effects: The loss or perturbation of certain low-earth orbits would affect some groups and geographic regions more heavily than others, depending on the coverage and quality of existing terrestrial infrastructure. In some low-income countries, satellite systems may provide more reliable and accurate data and signals than terrestrial alternatives. One of the big selling points for space broadband is its ability to connect hard-to-reach places, including rural regions in both developed and developing countries.

**Clean up isn’t viable – the best way to solve the debris problem is to stop making it.**

**David 21** [Leonard David. author of*Moon Rush: The New Space Race* (National Geographic, 2019) and*Mars: Our Future on the Red Planet*(National Geographic, 2016). He has been reporting on the space industry for more than five decades. “Space Junk Removal Is Not Going Smoothly”. 4-14-2021. Scientific American. https://www.scientificamerican.com/article/space-junk-removal-is-not-going-smoothly/.]

A Space Age “tragedy of the commons” is unfolding right under our nose—or, really, right over our head—and no consensus yet exists on how to stop it. For more than a half-century, humans have been hurling objects into low-Earth orbit in ever growing numbers. And with few meaningful limitations on further launches into that increasingly congested realm, the prevailing attitude has been persistently permissive: in orbit, it seems, there is always room for one more.

After so many decades of the buildup of high-speed clutter in the form of spent rocket stages, stray bolts and paint chips, solid-rocket-motor slag, dead or dying satellites and the scattered fragments from antisatellite tests—all of which could individually damage or destroy other assets—low-Earth orbit is finally on the verge of becoming too crowded for comfort. And the problem is now poised to get much worse because of the rise of satellite “mega constellations” requiring thousands of spacecraft, such as SpaceX’s Starlink, a broadband Internet network. Starlink is but one of many similar projects: Another mega constellation from a company called OneWeb is already being deployed. And Amazon’s Project Kuiper is seeking to create a mega constellation of up to 3,200 satellites in the near future.

As the congestion has grown, so too have close calls between orbiting assets. The International Space Station, for instance, regularly tweaks its orbit to avoid potentially hazardous debris. Worse yet, there has been an uptick in the threat of full-on collisions that generate menacing refuse that exacerbates the already bad situation. Consider the February 2009 run-in between a dead Russian Cosmos satellite and a commercial Iridium spacecraft, which produced an enormous amount of debris.

Finding ways to remove at least some of all that space junk should be a top global priority, says Donald Kessler, a retired NASA senior scientist for orbital debris research. In the late 1970s he foretold the possibility of a scenario that has been dubbed the Kessler syndrome: as the density of space rubbish increases, a cascading, self-sustaining runaway cycle of debris-generating collisions can arise that might ultimately make low-Earth orbit too hazardous to support most space activities.

“There is now agreement within the community that the debris environment has reached a ‘tipping point’ where debris would continue to increase even if all launches were stopped,” Kessler says. “It takes an Iridium-Cosmos-type collision to get everyone’s attention. That’s what it boils down to.... And we’re overdue for something like that to happen.”

As for the Kessler syndrome, “it has already started,” the debris expert says. “There are collisions taking place all the time—less dramatic and not at the large size scale,” Kessler adds.

Kessler’s nightmare scenario has yielded no shortage of possible debris-flushing fixes: nets, laser blasts, harpoons, giant foam balls, puffs of air, tethers and solar sails—as well as garbage-gathering robotic arms and tentacles—have all been proposed as solutions for taking out our orbital trash.

A new entrant in grappling with this worrisome state of affairs is the just launched End-of-Life Services by Astroscale Demonstration (ELSA-d) mission. ELSA-d is a two-satellite mission developed by Astroscale, a Japan-based satellite services company: it consists of a “servicer” satellite designed to safely remove debris from orbit and a “client” one that doubles as an object of interest. The project aims to showcase a magnetic system that can capture stable and even tumbling objects, whether for disposal or servicing in orbit. Following a multiphase test agenda, the servicer and client will then deorbit together, disintegrating during their fiery plunge into Earth’s atmosphere.

ELSA-d is now circling in Earth orbit. The mission was lofted on March 22 via a Russian Soyuz rocket that tossed scads of other hitchhiking satellites into space. Following the liftoff, Astroscale’s founder and CEO Nobu Okada said [ELSA-d will prove out debris-removal capabilities](https://astroscale.com/astroscale-celebrates-successful-launch-of-elsa-d/) and “propel regulatory developments and advance the business case for end-of-life and active debris removal services.” The launch is a step toward realizing “safe and sustainable development of space for the benefit of future generations,” he said.

Although ELSA-d and other technology demonstrations of its ilk are unquestionably positive developments for clearing orbital debris, they should not be mistaken for cure-alls. Despite their modest successes, such missions are falling short of addressing the dynamic dilemma at hand, and the proliferation of space junk continues essentially unabated.

“From my perspective, the best solution to dealing with space debris is not to generate it in the first place,” says T. S. Kelso, a scientist at CelesTrak, an analytic group that keeps an eye on Earth-orbiting objects. “Like any environmental issue, it is easier and far less expensive to prevent pollution than to clean it up later. Stop leaving things in orbit after they have completed their mission.”

There simply is no “one-size-fits-all solution” to the problem of space junk, Kelso says. Removing large rocket bodies is a significantly different task than removing the equivalent mass of a lot more smaller objects, which are in a wide range of orbits, he observes. Meanwhile innovations by companies such as SpaceX are dramatically lowering launch costs, opening the floodgates for far more satellites to reach low-Earth orbit, where some will inevitably fail and become drifting, debris-generating hazards (unless they are removed by ELSA-d-like space tugs). “Many of these operators are starting to understand the difficulty and complexity of continuing to dodge the growing number of debris.”

Space junk ranges from nanoparticles to whole spacecraft such as the European Space Agency’s Envisat, which is the size of a double-decker bus and at the top of everyone's removal hit list, says Alice Gorman, a space archaeologist and space junk expert at Flinders University in Australia.

There are also objects such as despin weights, which are solid lumps of metal, and thermal blankets, which are paper-thin. “They’ll cause different types of damage and may need different strategies to remove. There is no way that a one-size-fits-all approach is going to do it,” Gorman says*.*

The most serious risks, she says, come from debris particles between one and 10 centimeters in size. “There’s far more of them than whole defunct spacecraft, and there is a far greater probability of collision,” Gorman says. “While debris this size might not cause a catastrophic breakup, collision with it can certainly damage working satellites and create new debris particles.”

Turning her attention to satellite mega constellations, Gorman worries about their effects in a low-Earth orbital environment that is already congested. “We also know that orbital dynamics can be unpredictable,” she says. “I want to see some of these mega constellation operators releasing their long-term modeling for collisions as more and more satellites are launched.”

There is no doubt that active orbital debris removal is technically challenging, Gorman says. “However, the big issue is that any successful technology that can remove an existing piece of debris can also be used as an antisatellite weapon,” she says. “This is a whole other can of worms that requires diplomacy and negotiation and, most importantly, trust at the international level.”

Indeed, the ability to cozy up to spacecraft in orbit and perform servicing or sabotage has spurred considerable interest from military planners in recent years, says Mariel Borowitz, an associate professor at the Georgia Institute of Technology’s Sam Nunn School of International Affairs. “These rapidly advancing technologies have the potential to be used for peaceful space activities or for warfare in space,” she says. “Given the dual-use nature of their capabilities, it’s impossible to know for sure in advance how they’ll be used on any given day.”

For now, according to Moriba Jah, an orbital debris expert at the University of Texas at Austin, the business case for space debris removal is not monetizable and is more a “PowerPoint talk” than a real marketplace.

“I think people are hoping that government basically comes to some common sense to help create and establish a marketplace for industries to engage in these sorts of activities,” Jah says. In order for that to happen, he believes that spacefaring nations have to agree that near-Earth space is an ecosystem like land, air and the ocean. “It’s not infinite, so we need environmental protection,” he says.

Jah has in mind space sustainability metrics akin to a carbon footprint. “Let’s call it a ‘space traffic’ footprint,” he says. “We need a way we can quantify at what point an ‘orbital highway’ gets saturated with traffic so that it’s not usable. Then you can assign a bounty for objects and talk about nonconsensual debris removal. Maybe there is a penalty to the sovereign owner of their dead asset that’s taking up capacity of an orbit. This could definitely create a marketplace where space-object-removal technologies can thrive.”

A classification scheme for objects in space is also needed. Having such a taxonomy, Jah says, would help sort out what types of technologies are required for removing different pedigrees of orbital clutter.

As for the big picture, Jah says it is a simple numbers game: the rate of launches exceeds the rate of space objects reentering Earth’s atmosphere. “That’s not a great kind of energy balance,” he adds.

Alas, Jah says, policy makers are still sluggish in their reactions to the problem. After all, although events such as the 2009 Cosmos-Iridium collision generate massive amounts of debris, they are still quite rare—for now.

“In my view, that 2009 collision was equivalent to passengers on the *Titanic* feeling that bump from an iceberg, and then there’s a band playing on deck,” Jah says. “In terms of hazardous orbital debris, things are already going a detrimental way because we haven’t changed our behavior.”

## Subpoint B: Launch Emissions

**Rocket launches severely damage the environment and are increasing fast.**

**Miraux 21** [Loïs Miraux, Project Lead for Environmental Impact @ The Space Generation Advisory Council, “Environmental limits to the space sector's growth,” Science of the Total Environment, https://www.sciencedirect.com/science/article/abs/pii/S0048969721059404]

The amount of material emitted by the ≈100 rockets launched every year is about 40,000 tons, only 0.01% of the fuel burned by the global aviation sector (Ross and Sheaffer, 2014). However, during their ascent from ground to orbit, they release gases and particles in all the layers of the atmosphere. This is a unique characteristic because rockets are the only anthropogenic source of pollution in the middle and upper atmosphere, that is, above 15 km where airlines emissions stop (Ross and Sheaffer, 2014). Emissions into the troposphere, the lower layer of the atmosphere, are not important besides transient, local pollution. However, emissions in the stratosphere, the layer above the troposphere, are more concerning for two main reasons. First, the stratosphere being dynamically isolated from the troposphere, emissions components of hundreds of launches accumulate for several years (Ross and Vedda, 2018). Then, the stratosphere is the home of the ozone layer, a region of high concentration of ozone at 15–35 km altitudes, absorbing most of the Sun's harmful ultraviolet radiation and thereby protecting living organisms on the ground (Fig. 4). In addition to these particularities, the magnitude of the effects of rocket emissions on the atmosphere varies significantly depending on the type of propellant combination used. Liquid Rocket Engines (LREs) use propellants in the liquid form, such as liquid oxygen combined with liquid hydrogen as a fuel (e.g. Ariane 5) or kerosene (e.g. SpaceX's Falcon 9). This allows thrust variability, but LREs are often coupled with Solid RocketMotors (SRMs) (e.g. Ariane 5 boosters) because they grant higher energy density for lift-off. SRMs typically use a combination of solid aluminium fuel with ammonium perchlorate as an oxidizer. A third type of rocket is being used more recently: Hybrid Rocket Engines (HREs), using a liquid oxidizer and a solid fuel, often a hydrocarbon. They grant high safety, making them popular for space tourism applications (e.g. Virgin Galactic's SpaceShipTwo). Although there are still many uncertainties and serious knowledge gaps on the effect of launch emissions on the atmosphere (Ross and Vedda, 2018), estimates of orders of magnitude are available in the literature. 3.2. Stratospheric ozone depletion During the lifecycle of complete space missions, the launch event has been reported to contribute to almost 100% of the ozone depletion potential (Chanoine, 2017).Ozone is destructed mostly by highly reactive radicals(oxides of chlorine, nitrogen, bromine, and hydrogen), with a single molecule able to destroy up to 100,000 ozone molecules(Ross et al., 2009). Ozone depletion from SRMs particles has historically been the main concern with the first studies carried out by Cicerone (Cicerone, 1974). LREs exhausts contain less reactive chemicals and particles and are, therefore, responsible for ozone loss one order of magnitude smaller than SRMs (Ross et al., 2009). The ozone loss caused by the global launch fleet has been estimated to be greater than 0.01% and less than 0.1%, with regional effects reaching several percent and with complete destruction in the surroundings of exhaust plumes (Voigt et al., 2013). This is to be compared to the ozone loss caused by ozone-depleting substances(ODSs) banned by the Montreal Protocol of about 3% (Ross and Vedda, 2018) (of the total amount of ozone). As a consequence, the present-day contribution of rockets to ozone loss is small. It represents a few percent of the total anthropogenic contribution to ozone depletion, about the same relative impact that global aviation has on climate radiative forcing (Ross et al., 2009). However, the trends discussed in the introduction make an increase of launch emissions by a factor of 10 credible, which would make the contribution of rockets comparable to that of banned ODSs, as Ross and Vedda warn (Ross and Vedda, 2018). A 2009 study highlighted the limitations to the growth of the space sector due to ozone depletion. It showed that, considering launch rates required by proposed space systems at that time (i.e. to be implemented in the future), global ozone loss could become significant, even using only LREs (Ross et al., 2009). Moreover, a 2010 study found that a fleet of 1000 launches per year of hydrocarbonbased HREs typically used for space tourism would cause ozone loss up to 6% in polar regions(Ross et al., 2010). With the anticipated growth of the space sector, the contribution of rockets to ozone depletion will inevitably increase in the future. As the study warns, there will be a growing risk of regulation of rocket exhaust compounds in the name of ozone protection. Important data uncertainties combined with the fact that the Montreal Protocol lacks adapted metrics to tackle rocket emissions effectively make this risk even more important (Ross and Vedda, 2018). If left unregulated, by 2050 rocket emissions could deplete ozone more than ODSs ever did (Ross et al., 2009; ScienceDaily, 2009). 3.3. Contribution to climate change While the effect of rocket emissions on the ozone layer has been studied for several decades, the concern about their impact on climate is more recent. Available life cycle assessment studies of space missions are scarce and often do not account for emissions occurring during the launch event, or only partially, due to lack of data availability and modeling complexity (Maury et al., 2020a; Chanoine, 2017; Harris and Landis, 2019; Gallice andMaury, 2018). Yet, launch emissions are likely to be the most important contributor to the impact on climate change of the global space sector. Rocket exhausts contain greenhouse gases(e.g. CO2, H2O) but also particles (e.g. alumina, black carbon). The amount of greenhouse gases emitted by rockets is dwarfed by that of other industrial sectors, making their contribution to the problem insignificant. However, the effect of particles is much more concerning. Black carbon particles accumulate in the stratosphere and absorb a fraction of sunlight, resulting in a warming of the stratosphere. Because some rockets can emit about 10,000 times more black carbon than modern turbine engines(Ross and Sheaffer, 2014), the amount of black carbon emitted by rockets in the stratosphere in 2018 was comparable to that emitted by global aviation (Ross and Toohey, 2019). On the other hand, alumina features amore complex behavior by both reflecting incoming radiation into space and absorbing upwelling radiation from the Earth. This also results in a warming of the stratosphere (Ross and Sheaffer, 2014). At the same time, the reduction in solar flux caused by this accumulation of particles in the stratosphere leads to a cooling of the lower atmosphere (the troposphere) and the ground (Fig. 4). In 2014, Ross and Sheaffer estimated that rocket emissions globally contributed to warm the stratosphere by about 16 ± 8 mW/m2, with relative contributions of 70% for black carbon, 28% for alumina, 2% for H2O, and ≈0% for CO2 (Ross and Sheaffer, 2014). This means that hydrocarbon-based rockets emitting black carbon (e.g. kerosene-fueled LREs, or most HREs) and SRMs emitting alumina are responsible for most of rockets' climate impact. As a consequence, studies considering only CO2 emissions to assess the contribution of rockets to climate change underestimate it by several orders of magnitude. Although this value is only an approximation subjected to uncertainties and requiring further confirmation, the study makes an interesting comparison with the contribution of global aviation to radiative forcing,which in 2014 was bigger only by a factor of 4, in absolute values (Ross and Sheaffer, 2014). This means that the magnitude of cooling of the troposphere from rockets could be comparable to the magnitude of warming from aviation. However, this should not be interpreted too quickly as something “positive”. Stratospheric injection of particles has long been discussed by climate scientists as a method of solar geoengineering to counteract the warming of greenhouse gases. But this has always been very controversial and encountered strong opposition. Rocket emissions compounds act as geoengineering agents and, therefore, launchers are already beginning this process in an uncontrolled manner, while black carbon geoengineering — on a much larger scale — has been found to present potentially catastrophic side effects (Kravitz et al., 2012). In addition, since rocket emissions are not distributed homogeneously around the globe, they can cool the troposphere in certain regions but still warm it in other regions because of the complex response of the global climate (Ross et al., 2010). Consequently, Ross and Vedda warn that it is uncertain how policymakers would respond to significant growth in launch activities in a context of growing concerns on climate intervention. Once again, this risk is further increased by the lack of confidence in current radiative forcing estimations (Ross and Vedda, 2018). The projects mentioned in the introduction could fuel such an important growth. For instance, after a decade of launches at a rate of 1000 per year, the fleet of hydrocarbon-based HREs(typical for space tourism applications) would create the same radiative forcing as global aviation (Ross et al., 2010), and could rise polar surface temperatures as much as 1 °C. Interestingly, Ross and Sheaffer estimated that the carbon footprint of a passenger in a typical sub-orbital space tourism flight is comparable to that of a passenger travelling thousands of times in aircraft between Los Angeles and London (Ross and Sheaffer, 2014). This illustrates that, in addition to possible future policy implications, the potential climate impact of space tourism raises important issues related to climate justice in the age of “flygskam”. But space tourism is not the only emerging market with high launch rate potential. The Chinese solar power plant is planned to require more than 100 launches of Long March 9, a heavy rocket fueled by kerosene (SpaceNews, 2021). Current plans of SpaceX for Earth-toEarth travel and Mars colonization will be based on its Starship that relies on a liquid oxygen/liquid methane combination expected to be less harmful than kerosene, but this maybe largely offset by the significant associated increase in launch rate.

## Impact: Climate Change

**Launches and debris damage the ozone in multiple ways.**

**O'Donnel 18** [Josy O'Donnel. Founder of the conservation institue. “What Happens to the "Space Junk" that Falls back to Earth?”. 12-10-2018. Our Planet. <https://ourplnt.com/space-junk-earth/>] //ab sp

The ozone is a protective layer in the upper atmosphere that shields the Earth from the ultraviolet rays of the Sun. Environmentalists have long warned of the harmful effects to this layer by earth-based human activity. Some modern scientists believe that space activity may also adversely affect the ozone layer.

This destruction can happen in three ways. First, when rockets are launched, their emissions in the upper atmosphere may be harmful to the ozone. Though more research is needed, some experts like engineer [Martin Ross](https://www.scientificamerican.com/article/how-much-air-pollution-is-produced-by-rockets/) of the Aerospace Corporation theorize that the rocket exhaust particles remain in the upper reaches of the atmosphere, increasing the temperature through their absorption of solar energy.

Second, as the orbits of human-made debris degrade, and they re-enter the earth’s atmosphere, a shock wave occurs in the upper reaches of the layer of ozone. This physical stress on the area can be damaging to the protective buffer. Researchers have discovered that the impact of objects entering the atmosphere at high speed can produce [nitric oxide](https://books.google.com/books?id=Gpwgm022ltMC&pg=PA284&lpg=PA284&dq=shock+waves+create+nitrous+oxide+in+stratosphere&source=bl&ots=YM-MlE1TWQ&sig=CeRXiNYPpEvUEvJYovnl6Bo6DyE&hl=en&sa=X&ved=2ahUKEwiJqJvG9I7fAhUFLqwKHXuOBjs4ChDoATAFegQIABAB#v=onepage&q=shock%20waves%20create%20nitrous%20oxide%20in%20stratosphere&f=false) during the rapid cooling that follows the splitting of oxygen and nitrogen. Nitric oxide is very destructive to the ozone layer.

Finally, though most of the debris that re-enters the earth’s atmosphere is vaporized due to the build-up of intense heat, the chemical residue of this material can also react with the ozone and deplete it.

Some scientists fear that erosion of the ozone layer may cause global climate change. They predict that these altered weather patterns could transform fertile farmland into deserts and threaten human life on the planet. Thus, the environmental effect of space debris upon the ozone is of great concern to these experts.

#### Warming is existential

#### Xu and Ramanathan 17

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We are proposing the following extension to the DAI risk categorization: warming greater than 1.5 °C as “dangerous”; warming greater than 3 °C as “catastrophic?”; and warming in excess of 5 °C as “unknown??,” with the understanding that changes of this magnitude, not experienced in the last 20+ million years, pose existential threats to a majority of the population. The question mark denotes the subjective nature of our deduction and the fact that catastrophe can strike at even lower warming levels. The justifications for the proposed extension to risk categorization are given below. From the IPCC burning embers diagram and from the language of the Paris Agreement, we infer that the DAI begins at warming greater than 1.5 °C. Our criteria for extending the risk category beyond DAI include the potential risks of climate change to the physical climate system, the ecosystem, human health, and species extinction. Let us first consider the category of catastrophic (3 to 5 °C warming). The first major concern is the issue of tipping points. Several studies (48, 49) have concluded that 3 to 5 °C global warming is likely to be the threshold for tipping points such as the collapse of the western Antarctic ice sheet, shutdown of deep water circulation in the North Atlantic, dieback of Amazon rainforests as well as boreal forests, and collapse of the West African monsoon, among others. While natural scientists refer to these as abrupt and irreversible climate changes, economists refer to them as catastrophic events (49). Warming of such magnitudes also has catastrophic human health effects. Many recent studies (50, 51) have focused on the direct influence of extreme events such as heat waves on public health by evaluating exposure to heat stress and hyperthermia. It has been estimated that the likelihood of extreme events (defined as 3-sigma events), including heat waves, has increased 10-fold in the recent decades (52). Human beings are extremely sensitive to heat stress. For example, the 2013 European heat wave led to about 70,000 premature mortalities (53). The major finding of a recent study (51) is that, currently, about 13.6% of land area with a population of 30.6% is exposed to deadly heat. The authors of that study defined deadly heat as exceeding a threshold of temperature as well as humidity. The thresholds were determined from numerous heat wave events and data for mortalities attributed to heat waves. According to this study, a 2 °C warming would double the land area subject to deadly heat and expose 48% of the population. A 4 °C warming by 2100 would subject 47% of the land area and almost 74% of the world population to deadly heat, which could pose existential risks to humans and mammals alike unless massive adaptation measures are implemented, such as providing air conditioning to the entire population or a massive relocation of most of the population to safer climates. Climate risks can vary markedly depending on the socioeconomic status and culture of the population, and so we must take up the question of “dangerous to whom?” (54). Our discussion in this study is focused more on people and not on the ecosystem, and even with this limited scope, there are multitudes of categories of people. We will focus on the poorest 3 billion people living mostly in tropical rural areas, who are still relying on 18th-century technologies for meeting basic needs such as cooking and heating. Their contribution to CO2 pollution is roughly 5% compared with the 50% contribution by the wealthiest 1 billion (55). This bottom 3 billion population comprises mostly subsistent farmers, whose livelihood will be severely impacted, if not destroyed, with a one- to five-year megadrought, heat waves, or heavy floods; for those among the bottom 3 billion of the world’s population who are living in coastal areas, a 1- to 2-m rise in sea level (likely with a warming in excess of 3 °C) poses existential threat if they do not relocate or migrate. It has been estimated that several hundred million people would be subject to famine with warming in excess of 4 °C (54). However, there has essentially been no discussion on warming beyond 5 °C. Climate change-induced species extinction is one major concern with warming of such large magnitudes (>5 °C). The current rate of loss of species is ∼1,000-fold the historical rate, due largely to habitat destruction. At this rate, about 25% of species are in danger of extinction in the coming decades (56). Global warming of 6 °C or more (accompanied by increase in ocean acidity due to increased CO2) can act as a major force multiplier and expose as much as 90% of species to the dangers of extinction (57). The bodily harms combined with climate change-forced species destruction, biodiversity loss, and threats to water and food security, as summarized recently (58), motivated us to categorize warming beyond 5 °C as unknown??, implying the possibility of existential threats. Fig. 2 displays these three risk categorizations (vertical dashed lines).