# Framing

#### Existential threats independently outweigh – all life has infinite value and extinction eliminates the possibility for future generations

GPP 17 (Global Priorities Project, Future of Humanity Institute at the University of Oxford, Ministry for Foreign Affairs of Finland, “Existential Risk: Diplomacy and Governance,” Global Priorities Project, 2017, <https://www.fhi.ox.ac.uk/wp-content/uploads/Existential-Risks-2017-01-23.pdf>,

1.2. THE ETHICS OF EXISTENTIAL RISK In his book Reasons and Persons, Oxford philosopher Derek Parfit advanced an influential argument about the importance of avoiding extinction: I believe that if we destroy mankind, as we now can, this outcome will be much worse than most people think. Compare three outcomes: (1) Peace. (2) A nuclear war that kills 99% of the world’s existing population. (3) A nuclear war that kills 100%. (2) would be worse than (1), and (3) would be worse than (2). Which is the greater of these two differences? Most people believe that the greater difference is between (1) and (2). I believe that the difference between (2) and (3) is very much greater. ... The Earth will remain habitable for at least another billion years. Civilization began only a few thousand years ago. If we do not destroy mankind, these few thousand years may be only a tiny fraction of the whole of civilized human history. The difference between (2) and (3) may thus be the difference between this tiny fraction and all of the rest of this history. If we compare this possible history to a day, what has occurred so far is only a fraction of a second.65 In this argument, it seems that Parfit is assuming that the survivors of a nuclear war that kills 99% of the population would eventually be able to recover civilisation without long-term effect. As we have seen, this may not be a safe assumption – but for the purposes of this thought experiment, the point stands. What makes existential catastrophes especially bad is that they would “destroy the future,” as another Oxford philosopher, Nick Bostrom, puts it.66 This future could potentially be extremely long and full of flourishing, and would therefore have extremely large value. In standard risk analysis, when working out how to respond to risk, we work out the expected value of risk reduction, by weighing the probability that an action will prevent an adverse event against the severity of the event. Because the value of preventing existential catastrophe is so vast, even a tiny probability of prevention has huge expected value.67 Of course, there is persisting reasonable disagreement about ethics and there are a number of ways one might resist this conclusion.68 Therefore, it would be unjustified to be overconfident in Parfit and Bostrom’s argument. In some areas, government policy does give significant weight to future generations. For example, in assessing the risks of nuclear waste storage, governments have considered timeframes of thousands, hundreds of thousands, and even a million years.69 Justifications for this policy usually appeal to principles of intergenerational equity according to which future generations ought to get as much protection as current generations.70 Similarly, widely accepted norms of sustainable development require development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs.71 However, when it comes to existential risk, it would seem that we fail to live up to principles of intergenerational equity. Existential catastrophe would not only give future generations less than the current generations; it would give them nothing. Indeed, reducing existential risk plausibly has a quite low cost for us in comparison with the huge expected value it has for future generations. In spite of this, relatively little is done to reduce existential risk. Unless we give up on norms of intergenerational equity, they give us a strong case for significantly increasing our efforts to reduce existential risks. 1.3. WHY EXISTENTIAL RISKS MAY BE SYSTEMATICALLY UNDERINVESTED IN, AND THE ROLE OF THE INTERNATIONAL COMMUNITY In spite of the importance of existential risk reduction, it probably receives less attention than is warranted. As a result, concerted international cooperation is required if we are to receive adequate protection from existential risks. 1.3.1. Why existential risks are likely to be underinvested in There are several reasons why existential risk reduction is likely to be underinvested in. Firstly, it is a global public good. Economic theory predicts that such goods tend to be underprovided. The benefits of existential risk reduction are widely and indivisibly dispersed around the globe from the countries responsible for taking action. Consequently, a country which reduces existential risk gains only a small portion of the benefits but bears the full brunt of the costs. Countries thus have strong incentives to free ride, receiving the benefits of risk reduction without contributing. As a result, too few do what is in the common interest. Secondly, as already suggested above, existential risk reduction is an intergenerational public good: most of the benefits are enjoyed by future generations who have no say in the political process. For these goods, the problem is temporal free riding: the current generation enjoys the benefits of inaction while future generations bear the costs. Thirdly, many existential risks, such as machine superintelligence, engineered pandemics, and solar geoengineering, pose an unprecedented and uncertain future threat. Consequently, it is hard to develop a satisfactory governance regime for them: there are few existing governance instruments which can be applied to these risks, and it is unclear what shape new instruments should take. In this way, our position with regard to these emerging risks is comparable to the one we faced when nuclear weapons first became available. Cognitive biases also lead people to underestimate existential risks. Since there have not been any catastrophes of this magnitude, these risks are not salient to politicians and the public.72 This is an example of the misapplication of the availability heuristic, a mental shortcut which assumes that something is important only if it can be readily recalled. Another cognitive bias affecting perceptions of existential risk is scope neglect. In a seminal 1992 study, three groups were asked how much they would be willing to pay to save 2,000, 20,000 or 200,000 birds from drowning in uncovered oil ponds. The groups answered $80, $78, and $88, respectively.73 In this case, the size of the benefits had little effect on the scale of the preferred response. People become numbed to the effect of saving lives when the numbers get too large. 74 Scope neglect is a particularly acute problem for existential risk because the numbers at stake are so large. Due to scope neglect, decision-makers are prone to treat existential risks in a similar way to problems which are less severe by many orders of magnitude. A wide range of other cognitive biases are likely to affect the evaluation of existential risks.75

**Pleasure and pain are intrinsically 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

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.**

#### That justifies Hedonism – we must aggregate in order to determine how behaviors will be conducted based on what is most pleasurable. Anything else is arbitrary and always allows for exclusions, but aggregation solves because it allows us to determine what behaviors are most likely given relative evaluations of pleasure and pain.

#### Thus, the standard is maximizing expected well-being – prefer:

#### 1] Actor specificity – Governments must aggregate since every policy benefits some and harms others, which also means side constraints freeze action. Actor-specificity comes first since different agents have different ethical standings.

2] No act-omission distinction—governments are responsible for everything in the public sphere so inaction is implicit authorization of action: they have to yes/no bills, which means everything collapse to aggregation.

### Plan

#### Plan – states ought to ban the appropriation of outer space for mining activities by private entities.

#### Normal means is ratification of the Moon Treaty

**Mallick and Rajagopalan 19** [(Senjuti Mallick, graduated from ILS Law College, Pune, in 2016. She was a Law Researcher at the High Court of Delhi from 2016 to 2018 and is currently pursuing LL.M in International Law at The Fletcher School of Law and Diplomacy, USA. She has been doing research on Outer Space Law since she was a student at ILS. Presently, she is working on different aspects of Space Law, in particular, Space debris mitigation and removal, and the law of the commons. She has published articles on Space Law in the All India Reporter Law Journal and The Hindu.)( Dr Rajeswari (Raji) Pillai Rajagopalan is the Director of the Centre for Security, Strategy and Technology (CSST) at the Observer Research Foundation, New Delhi.  Dr Rajagopalan was the Technical Advisor to the United Nations Group of Governmental Experts (GGE) on Prevention of Arms Race in Outer Space (PAROS) (July 2018-July 2019).  She was also a Non-Resident Indo-Pacific Fellow at the Perth USAsia Centre from April-December 2020.  As a senior Asia defence writer for The Diplomat, she writes a weekly column on Asian strategic issues.) “If space is ‘the province of mankind’, who owns its resources?” Occasional Papers, January 24, 2019, https://www.orfonline.org/research/if-space-is-the-province-of-mankind-who-owns-its-resources-47561/] TDI   
A third possible option is to get a larger global endorsement of the Moon Treaty, which highlights the common heritage of mankind. The Moon Treaty is important as it addresses a “loophole” of the OST “by banning any ownership of any extraterrestrial property by any organization or private person, unless that organization is international and governmental.”[[lxiv]](https://www.orfonline.org/research/if-space-is-the-province-of-mankind-who-owns-its-resources-47561/#_edn64) But the fact that it has been endorsed only by a handful of countries makes it a “failure” from the international law perspective.[[lxv]](https://www.orfonline.org/research/if-space-is-the-province-of-mankind-who-owns-its-resources-47561/#_edn65) Nevertheless, efforts must be made to strengthen the support base for the Moon Agreement given the potential pitfalls of resource extraction and space mining activities in outer space. Signatories to the Moon Treaty can take the lead within multilateral platforms such as the UN to debate the usefulness of the treaty in the changed context of technological advancements and new geopolitical dynamics, and potentially find compromises where there are disagreements.

## Definition**:**

#### Appropriation: Oxford dictionary. the action of taking something for one's own use, typically without the owner's permission.

#### Outer space:

Cooper 9 [Nikhil D. Cooper, J.D. Candidate at UC Hastings College of the Law with a B.A. Rhetoric and Political Science from UC Berkeley, 1-1-2009, “Circumventing Non-Appropriation: Law and Development of United States Space Commerce,” Hastings Constitutional Law Quarterly, https://repository.uchastings.edu/cgi/viewcontent.cgi?article=1845&context=hastings\_constitutional\_law\_quaterly]/Kankee

The Roots of Space Law Scientists disagree as to exactly where territorial airspace ends and extraterritorial outer space begins.5 Regardless, most scholars generally demarcate 100 to 110 kilometers above Earth sea level as the starting point of space.6 For the space craft's occupants, hurtling past this boundary would signal numerous physical shifts, including, most famously, becoming weightless. However, less obvious is the legal shift that takes place once a craft crosses this boundary. Most notably, the where of the craft changes because the principle of national sovereignty, a defining feature of territorial air space law, is absent once a craft crosses the airspace/outer space boundary.7 A. Outer Space Treaty of 1967

## **Contention 1: Debris Advantage**

#### Private space mining and ownership allowed now

Williams 20 [(Matt Williams, Reporter) “Trump signs an executive order allowing mining the moon and asteroids,” Phys Org, April 13, 2020, <https://phys.org/news/2020-04-trump-moon-asteroids.html>] TDI

Trump signs an executive order allowing mining the moon and asteroids

In 2015, the Obama administration signed the [U.S. Commercial Space Launch Competitiveness Act](https://www.congress.gov/bill/114th-congress/house-bill/2262/text) (CSLCA, or H.R. 2262) into law. This bill was intended to "facilitate a pro-growth environment for the developing commercial space industry" by making it legal for American companies and citizens to own and sell resources that they extract from asteroids and off-world locations (like the moon, Mars or beyond).

On April 6th, the Trump administration took things a step further by signing an [executive order](https://www.space.com/trump-moon-mining-space-resources-executive-order.html) that formally recognizes the rights of private interests to claim resources in [space](https://phys.org/tags/space/). This order, titled "[Encouraging International Support for the Recovery and Use of Space Resources](https://www.whitehouse.gov/presidential-actions/executive-order-encouraging-international-support-recovery-use-space-resources/)," effectively ends the decades-long debate that began with the signing of [the Outer Space Treaty](https://www.universetoday.com/20590/moon-for-sale/) in 1967.

#### New investments coming and companies are launching – economic incentives make it alluring

Tosar 20 [(Borja Tosar, reporter) “Asteroid Mining: A New Space Race,” OpenMind BBVA, May 18, 2020, <https://www.bbvaopenmind.com/en/science/physics/asteroid-mining-a-new-space-race/>] TDI

This is not science fiction. There are now space mining companies, such as [Planetary Resources,](https://www.consensys.space/pr) which has already launched several mini-satellites to test several of its patents. Other companies like [Asteroid Mining Corporation](https://asteroidminingcorporation.co.uk/) or [Trans Astronautica Corporation,](https://www.transastracorp.com/) although still far from their goal, are already attracting millions of dollars of private investment interested in being on the front line of a possible future space business.

Is asteroid mining possible? This new space race already began back when the Hayabusa missions successfully returned a few grams of an asteroid’s regolith, so the technology to harvest asteroid material exists, we just have to change the scale. It is no longer a technological problem.

Is it economically viable? We are increasingly dependent on rare elements (such as those in the palladium group), which are expensive to exploit on Earth and come with a high environmental cost, so the sum of these two factors could make it profitable to travel to the asteroids to extract these raw materials. Astrophysicist Neil deGrasse argues that [the planet’s first trillionaire will undoubtedly be a space miner.](https://www.cnbc.com/2015/05/01/build-the-economy-here-on-earth-by-exploring-space-tyson.html)

#### Increasing space debris levels inevitably set off a chain of collisions.

Chelsea Muñoz-Patchen, 19 - (J.D. Candidate at The University of Chicago Law School., "Regulating the Space Commons: Treating Space Debris as Abandoned Property in Violation of the Outer Space Treaty," University of Chicago, 2019, 12-6-2021, https://cjil.uchicago.edu/publication/regulating-space-commons-treating-space-debris-abandoned-property-violation-outer-space)//AW

Debris poses a threat to functioning space objects and astronauts in space, and may cause damage to the earth’s surface upon re-entry.29 Much of the small debris cannot be tracked due to its size and the velocity at which it travels, making it impossible to anticipate and maneuver to avoid collisions.30 To remain in orbit, debris must travel at speeds of up to 17,500 miles per hour.31 At this speed even very small pieces of debris can cause serious damage, threatening a spacecraft and causing expensive damage.32 There are millions of these very small pieces, and thousands of larger ones.33 The small-to-medium pieces of debris “continuously shed fragments like lens caps, booster upper stages, nuts, bolts, paint chips, motor sprays of aluminum particles, glass splinters, waste water, and bits of foil,” and may stay in orbit for decades or even centuries, posing an ongoing risk.34 Debris ten centimeters or larger in diameter creates the likelihood of complete destruction for any functioning satellite with which it collides.35 Large nonfunctional objects remaining in orbit are a collision threat, capable of creating huge amounts of space debris and taking up otherwise useful orbit space.36 This issue is of growing importance as more nations and companies gain the ability to launch satellites and other objects into space.37 From February 2009 through the end of 2010, more than thirty-two collision-avoidance maneuvers were reportedly used to avoid debris by various space agencies and satellite companies, and as of March 2012, the crew of the International Space Station (ISS) had to take shelter three times due to close calls with passing debris.38 These maneuvers require costly fuel usage and place a strain on astronauts.39 Furthermore, the launches of some spacecraft have “been delayed because of the presence of space debris in the planned flight paths.”40 In 2011, Euroconsult, a satellite consultant, projected that there would be “a 51% increase in satellites launched in the next decade over the number launched in the past decade.”41 In addition to satellites, the rise of commercial space tourism will also increase the number of objects launched into space and thus the amount of debris.42 The more objects are sent into space, and the more collisions create cascades of debris, the greater the risk of damage to vital satellites and other devices relied on for “weather forecasting, telecommunications, commerce, and national security.”43 The Space Debris Mitigation Guidelines44 were created by UNCOPUOS with input from the IADC and adopted in 2007.45 The guidelines were developed to address the problem of space debris and were intended to “increase mutual understanding on acceptable activities in space.”46 These guidelines are nonbinding but suggest best practices to implement at the national level when planning for a launch. Many nations have adopted the guidelines to some degree, and some have gone beyond what the guidelines suggest.47 While the guidelines do not address existing debris, they do much to prevent the creation of new debris. The Kessler Syndrome is the biggest concern with space debris. The Kessler Syndrome is a cascade created when debris hits a space object, creating new debris and setting off a chain reaction of collisions that eventually closes off entire orbits.48 The concern is that this cascade will occur when a tipping point is reached at which the natural removal rate cannot keep up with the amount of new debris added.49 At this point a collision could set off a cascade destroying all space objects within the orbit.50 In 2011, The National Research Council predicted that the Kessler Syndrome could happen within ten to twenty years.51 Donald J. Kessler, the astrophysicist and NASA scientist who theorized the Kessler Syndrome in 1978, believes this cascade may be a century away, meaning that there is still time to develop a solution.52

#### Collisions make orbit unusable, causing nuclear war, mass starvation, and economic destruction. Jonson 13

Les Johnson 13, Deputy Manager for NASA's Advanced Concepts Office at the Marshall Space Flight Center, Co-Investigator for the JAXA T-Rex Space Tether Experiment and PI of NASA's ProSEDS Experiment, Master's Degree in Physics from Vanderbilt University, Popular Science Writer, and NASA Technologist, Frequent Contributor to the Journal of the British Interplanetary Sodety and Member of the American Institute of Aeronautics and Astronautics, National Space Society, the World Future Society, and MENSA, Sky Alert!: When Satellites Fail, p. 9-12

Whatever the initial cause, the result may be the same. A satellite destroyed in orbit will break apart into thousands of pieces, each traveling at over 8 km/sec. This virtual shotgun blast, with pellets traveling 20 times faster than a bullet, will quickly spread out, with each pellet now following its own orbit around the Earth. With over 300,000 other pieces of junk already there, the tipping point is crossed and a runaway series of collisions begins. A few orbits later, two of the new debris pieces strike other satellites, causing them to explode into thousands more pieces of debris. The rate of collisions increases, now with more spacecraft being destroyed. Called the "Kessler Effect", after the NASA scientist who first warned of its dangers, these debris objects, now numbering in the millions, cascade around the Earth, destroying every satellite in low Earth orbit. Without an atmosphere to slow them down, thus allowing debris pieces to bum up, most debris (perhaps numbering in the millions) will remain in space for hundreds or thousands of years. Any new satellite will be threatened by destruction as soon as it enters space, effectively rendering many Earth orbits unusable. But what about us on the ground? How will this affect us? Imagine a world that suddenly loses all of its space technology. If you are like most people, then you would probably have a few fleeting thoughts about the Apollo-era missions to the Moon, perhaps a vision of the Space Shuttle launching astronauts into space for a visit to the International Space Station (ISS), or you might fondly recall the "wow" images taken by the orbiting Hubble Space Telescope. In short, you would know that things important to science would be lost, but you would likely not assume that their loss would have any impact on your daily life. Now imagine a world that suddenly loses network and cable television, accurate weather forecasts, Global Positioning System (GPS) navigation, some cellular phone networks, on-time delivery of food and medical supplies via truck and train to stores and hospitals in virtually every community in America, as well as science useful in monitoring such things as climate change and agricultural sustainability. Add to this the ~~crippling~~ of the US military who now depend upon spy satellites, space-based communications systems, and GPS to know where their troops and supplies are located at all times and anywhere in the world. The result is a nightmarish world, one step away from nuclear war, economic disaster, and potential mass starvation. This is the world in which we are now perilously close to living. Space satellites now touch our lives in many ways. And, unfortunately, these satellites are extremely vulnerable to risks arising from a half-century of carelessness regarding protecting the space environment around the Earth as well as from potential adversaries such as China, North Korea, and Iran. No government policy has put us at risk. It has not been the result of a conspiracy. No, we are dependent upon them simply because they offer capabilities that are simply unavailable any other way. Individuals, corporations, and governments found ways to use the unique environment of space to provide services, make money, and better defend the country. In fact, only a few space visionaries and futurists could have foreseen where the advent of rocketry and space technology would take us a mere 50 years since those first satellites orbited the Earth. It was the slow progression of capability followed by dependence that puts us at risk. The exploration and use of space began in 1957 with the launch of Sputnik 1 by the Soviet Union. The United States soon followed with Explorer 1. Since then, the nations of the world have launched over 8,000 spacecraft. Of these, several hundred are still providing information and services to the global economy and the world's governments. Over time, nations, corporations, and individuals have grown accustomed to the services these spacecraft provide and many are dependent upon them. Commercial aviation, shipping, emergency services, vehicle fleet tracking, financial transactions, and agriculture are areas of the economy that are increasingly reliant on space. Telestar 1, launched into space in the year of my birth, 1962, relayed the world's first live transatlantic news feed and showed that space satellites can be used to relay television signals, telephone calls, and data. The modern telecommunications age was born. We've come a long way since Telstar; most television networks now distribute most, if not ali, of their programming via satellite. Cable television signals are received by local providers from satellite relays before being sent to our homes and businesses using cables. With 65% of US households relying on cable television and a growing percentage using satellite dishes to receive signals from direct-to-home satellite television providers, a large number of people would be cut off from vital information in an emergency should these satellites be destroyed. And communications satellites relay more than television signals. They serve as hosts to corporate video conferences and convey business, banking, and other commercial information to and from all areas of the planet. The first successful weather satellite was TIROS. Launched in 1960, TIROS operated for only 78 days but it served as the precursor for today's much more long-lived weather satellites, which provide continuous monitoring of weather conditions around the world. Without them, providing accurate weather forecasts for virtually any place on the globe more than a day in advance would be nearly impossible. Figure !.1 shows a satellite image of Hurricane Ivan approaching the Alabama Gulf coast in 2004. Without this type of information, evacuation warnings would have to be given more generally, resulting in needless evacuations and lost economic activity (from areas that avoid landfall) and potentially increasing loss of life in areas that may be unexpectedly hit. The formerly top-secret Corona spy satellites began operation in 1959 and provided critical information about the Soviet Union's military and industrial capabilities to a nervous West in a time of unprecedented paranoia and nuclear risk. With these satellites, US military planners were able to understand and assess the real military threat posed by the Soviet Union. They used information provided by spy satellites to help avert potential military confrontations on numerous occasions. Conversely, the Soviet Union's spy satellites were able to observe the United States and its allies, with similar results. It is nearly impossible to move an army and hide it from multiple eyes in the sky. Satellite information is critical to all aspects of US intelligence and military planning. Spy satellites are used to monitor compliance with international arms treaties and to assess the military activities of countries such as China, Russia, Iran, and North Korea. Figure 1.2 shows the capability of modem unclassified space-based imaging. The capability of the classified systems is presumed to be significantly better, providing much more detail. Losing these satellites would place global militaries on high alert and have them operating, literally, in the blind. Our military would suddenly become vulnerable in other areas as well. GPS, a network of 24-32 satellites in medium-Earth orbit, was developed to provide precise position information to the military, and it is now in common use by individuals and industry. The network, which became fully operational in 1993, allows our armed forces to know their exact locations anywhere in the world. It is used to guide bombs to their targets with unprecedented accuracy, requiring that only one bomb be used to destroy a target that would have previously required perhaps hundreds of bombs to destroy in the pre-GPS world (which, incidentally, has resulted in us reducing our stockpile of non-GPS-guided munitions dramatically). It allows soldiers to navigate in the dark or in adverse weather or sandstorms. Without GPS, our military advantage over potential adversaries would be dramatically reduced or eliminated.

### Contention 2 – Soot

#### Space tourism is a burgeoning market --- 2021 was just the beginning

Howell 21 [Elizabeth Howell, Ph.D., is a contributing writer for Space.com; she holds a Ph.D. and M.Sc. in Space Studies from the University of North Dakota, and a Bachelor of Journalism from Canada's Carleton University. Her latest book, NASA Leadership Moments, is co-written with astronaut Dave Williams. “Space Tourism Took a Giant Leap in 2021: Here’s 10 Milestones from the Year.” December 27, 2021. https://www.space.com/space-tourism-giant-leap-2021-milestones]

This year saw more space tourists fly to space on a bunch of different systems, and the story has only just begun. Virgin Galactic, Blue Origin and SpaceX each flew their first tourist-focused missions this year, sending aloft several people each with minimal training in professional spaceflight. Meanwhile, Roscosmos (the Russian federal space agency) brought two sets of space tourists into space, including a mission with Space Adventures. With 2022 also set to be busy, between more tourist flights and the expected addition of company Axiom Space (using a SpaceX Crew Dragon), we rounded up some of the main milestones of 2021 below. The four members of the Axiom Space Ax-1 crew: Michael Lopez-Alegria, former NASA astronaut, Axiom Space vice president and Ax-1 commander; Larry Connor, U.S. real estate entrepreneur and Ax-1 pilot; Mark Pathy, Canadian investor and philanthropist; and Eytan Stibbe, Israeli businessman and fighter pilot. (Image credit: collectSPACE.com) Axiom Space revealed its clients Jan. 26 for its first privately-funded and operated mission to the International Space Station (ISS). Called Axiom Mission 1 (Ax-1), the flight is arranged under a commercial agreement with NASA. Slated to launch on a SpaceX Dragon spacecraft are Larry Connor, an American real estate and technology entrepreneur; Eytan Stibbe, a businessman and former Israeli fighter pilot; Mark Pathy, a Canadian investor and philanthropist; and Michael Lopez-Alegria, a retired NASA astronaut with nearly 260 days in space already across four missions. In June, SpaceX and Axiom announced an agreement to fly three more missions to the orbiting complex after Ax-1. NASA officially cleared the Ax-1 crew for flight on Dec. 20. 2) Starship launches test flight and sticks the landing After several attempts on previous test landing that didn't make it safely to landing, SpaceX's Starship SN-15 prototype launched its own test flight May 5 and made it all the way from takeoff to touchdown. The uncrewed test flight coincidentally fell on the 60th anniversary of the United States' first-ever crewed spaceflight, which saw NASA astronaut Alan Shepard make it to suborbital space. SpaceX has said it hopes to use Starship to branch out in the solar system, especially for crewed Mars missions. 3) Virgin Galactic launches Richard Branson On July 11, Virgin Galactic launched its first operational tourist flight, featuring founder Richard Branson. It was "the experience of a lifetime," Branson said during a live broadcast of the flight. The four-person crew and two pilots of the Unity 22 test flight mission took off from the company's Spaceport America facility in New Mexico and flew just above the boundary of space, where everyone experienced about four minutes of weightlessness. Future flights of Virgin Galactic, though, have been delayed due to a Federal Aviation Administration investigation into a reported incident that happened during the spaceflight. That said, Virgin has opened up tickets again to paying spaceflyers, now at $450,000 apiece. 4) Blue Origin launches Jeff Bezos to space Days after the Virgin flight, Blue Origin launched its first crewed spaceflight on July 20, featuring founder Jeff Bezos and a set of other three space tourists, including Mercury 13 aviator Wally Funk. Since the system flies autonomously, no pilots were required to be on board (although Funk is highly qualified as an aviator) as the New Shepard system lifted off from Blue Origin's Launch Site One near the West Texas town of Van Horn. While Bezos and Branson denied their companies were in competition, the broadcast of Bezos' flight made several cutting remarks about the company flying above the Kármán line, an internationally recognized boundary of spaceflight that Virgin Galactic flights don't reach. Bezos also said in an interview in July that Blue Origin is not focused on competition, but building a "road to space." The company has adopted that catchphrase as a tagline and repeats it frequently during live broadcasts. 5) SpaceX stacks tallest booster ever with Starship SpaceX's first orbital Starship SN20 is stacked atop its massive Super Heavy Booster 4 for the first time on Aug. 6, 2021 at the company's Starbase facility near Boca Chica Village in South Texas. They stood 395 feet tall, taller than NASA's Saturn V moon rocket. (Image credit: SpaceX) SpaceX's newest Starship prototype (SN-20) perched on its massive Super Heavy booster for the first time on Friday (Aug. 6), briefly setting a new record for the world's tallest rocket during preparations for an orbital mission. The hour-long fit check brought the stack to 395 feet tall (120 m), taller than NASA's massive Saturn V moon rocket, which was 363 feet tall (110 m). Super Heavy alone stands 230 feet (70 meters) tall and Starship SN4 includes another 165 feet (50 m) of height. The next major milestone for Starship is the orbital launch that may take place in 2022, pending an environmental review by the Federal Aviation Administration and related government groups. SpaceX founder Elon Musk has pushed back launch estimates several times due to the review. 6) Inspiration4 launches 4 civilians on first orbital mission Billionaire Jared Isaacman's privately chartered spaceflight launched on Sept. 15, 2021 aboard a SpaceX Crew Dragon spacecraft, flying high in Earth orbit on a nearly three-day mission. Inspiration4 was the first crewed orbital mission with no professional astronauts on board (as the Virgin Galactic and Blue Origin flights preceding it were all suborbital missions.) Isaacman, a pilot, commanded the flight and was accompanied by physician assistant Hayley Arceneaux, data engineer Chris Sembroski, and geoscientist and science communication specialist Sian Proctor. Sembroski and Proctor won their seats in contests to support St. Jude Children's Research Hospital in Memphis, while Arceneaux is employed at that hospital. Resilience and its crew circled Earth for three days, splashing down off the Florida coast on Sept. 18. The mission exceeded its fundraising goal for St. Jude. 7) Blue Origin launches William Shatner A "Star Trek" star boldly went into suborbital space Oct. 13 on Blue Origin's second crewed space mission, called NS-18. William Shatner, 90, is best known for playing Captain James T. Kirk on "Star Trek: The Original Series." "That was unlike anything they described," Shatner was heard saying via a radio link as the capsule parachuted back to Earth, after carrying him and three other crew members to suborbital space. Shatner is now the oldest person to have ever flown to space, beating the record set by Wally Funk, 82, who flew on Blue Origin's first crewed flight July 20. Crew member Glen de Vries died in a plane crash weeks after the flight and Blue Origin dedicated their next crewed mission in December to him. 8) Russian film crew shoots drama on ISS Russian actress Yulia Peresild (center), director Klim Shipenko (second from right) and cosmonaut Oleg Novitskiy (right) bid farewell to their Russian crewmates Anton Shkaplerov (second from left) and Pyotr Dubrov before returning to Earth on Oct. 17, 2021. (Image credit: Roscosmos/Anton Shkaplerov via Twitter) Just days after Shatner's ride to space, a Russian film crew including actress Yulia Peresild and producer Klim Shipenko landed with cosmonaut Oleg Novitskiy of the Russian federal space corporation Roscosmos on Oct. 17. "Вызов" ("Challenge" in English) is the movie in production. It follows the fictional story of a surgeon (Peresild) who is launched to the station to perform emergency surgery on a cosmonaut (Novitskiy, who would play the role well given he is a cosmonaut in real life.) The effort is a joint production of Roscosmos, the Russian television station Channel One and the studio Yellow, Black and White. Given the small crew on hand in space, Shipenko took on several behind-the-scenes roles, including director, make-up artist, sound editor and cinematographer. 9) Blue Origin launches 'Good Morning America' host to space Blue Origin's next (and likely last) crewed flight of 2021 filled out all six seats in the New Shepard spacecraft during a successful launch and landing Dec. 11. The starring guest was Michael Strahan, host of "Good Morning America", who is a retired football player. (The crew threw mini-footballs in space to celebrate his past career.) Strahan said the experience was amazing. "I want to go back," he told Blue Origin founder Jeff Bezos after returning to Earth. "Touchdown has a new meaning now!!!" he wrote on Twitter after the flight. Also on the flight was Laura Shepard Churchley, 74, the daughter of NASA astronaut Shepard after whom the New Shepard system is named, and four other individuals who paid for their seats. Blue Origin has not yet released per-seat pricing for customers, and we are also awaiting details on their next planned crew launch. 10) Japanese billionaire Yusaku Maezawa flies to ISS A Russian Soyuz spacecraft carrying Japanese billionaire Yusaku Maezawa, video producer Yozo Hirano and cosmonaut Alexander Misurkin launched on Dec. 8 to the International Space Station for a 12-day mission to the orbiting lab. Maezawa is also planning to fly around the moon on a SpaceX mission that he paid for, tentatively slotted for 2023, but chose to visit the space station as well on a mission brokered by the U.S. space tourism company Space Adventures with Russia's Roscosmos space agency. It was not revealed how much Maezawa paid for the flight, but single seats in the past have cost up to $35 million. And Maezawa bought two seats, one for himself and for Hirano, who recorded videos of Maezawa in space. Maezawa, the CEO of Start Today and the founder of online clothing retailer ZOZO, bought the seats for himself and Hirano. Hirano documented the mission and participate in some health and performance research. They also made the first Uber Eats delivery in space on the flight. The trio returned to Earth on Dec. 19. And that's a wrap at the biggest space tourism moments in 2021. The year 2022 is expected to bring more milestones as the company Axiom Space plans to launch its first fully private crew to the International Space Station early in the year, with SpaceX, Blue Origin and Virgin Galactic all expected to continue their private spaceflight pace.

#### Private space tourism is set to increase drastically -- that leaves behind soot

Pultarova 21 Tereza is a London-based science and technology journalist. She has a Master's in Science from the International Space University, France, and 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. July 26, 2021. “The rise of space tourism could affect Earth's climate in unforeseen ways, scientists worry” [Scientists worry about environmental effects of space tourism | Space](https://www.space.com/environmental-impact-space-tourism-flights) Accessed 1-4 // gord0

Scientists worry that growing numbers of rocket flights and the rise of [space tourism](https://www.space.com/topics/space-tourism) could harm [Earth's atmosphere](https://www.space.com/17683-earth-atmosphere.html) and contribute to climate change.

When billionaires [Richard Branson](https://www.space.com/virgin-galactic-unity-22-branson-flight-success) and [Jeff Bezos](https://www.space.com/jeff-bezos-blue-origin-first-astronaut-launch) soared into space this month aboard their companies' suborbital tourism vehicles, much of the world clapped in awe.

But for some scientists, these milestones represented something other than just a technical accomplishment. Achieved after years of delays and despite [significant setbacks](https://www.space.com/30073-virgin-galactic-spaceshiptwo-crash-pilot-error.html), the flights marked the potential beginning of a long-awaited era that might see rockets fly through the so-far rather pristine upper layers of the atmosphere far more often than they do today. In the case of SpaceShipTwo, the vehicle operated by Branson's Virgin Galactic, these flights are powered by a hybrid engine that burns rubber and leaves behind a cloud of soot.

"Hybrid engines can use different types of fuels, but they always generate a lot of soot," said Filippo Maggi, associate professor of aerospace engineering at Politecnico di Milano, Italy, who researches rocket propulsion technologies and was part of a team that several years ago published an extensive [analysis](https://www.researchgate.net/publication/256474986_Characterization_of_HTPB-based_solid_fuel_formulations_Performance_mechanical_properties_and_pollution)of hybrid rocket engine emissions. "These engines work like a candle, and their burning process creates conditions that are favorable for soot generation."

According to Dallas Kasaboski, principal analyst at the space consultancy Northern Sky Research, a single Virgin Galactic suborbital space tourism flight, lasting about an hour and a half, can generate as much pollution as a 10-hour trans-Atlantic flight. Some scientists consider that disconcerting, in light of Virgin Galactic’s ambitions to fly paying tourists to the edge of space several times a day.

"Even if the suborbital tourism market is launching at a fraction of the number of launches compared to the rest of the [tourism] industry, each of their flights has a much higher contribution, and that could be a problem," Kasaboski told Space.com.

Virgin Galactic's rockets are, of course, not the only culprits. All rocket motors burning hydrocarbon fuels generate soot, Maggi said. Solid rocket engines, such as those used in the past in the boosters of NASA's [space shuttle](https://www.space.com/16726-space-shuttle.html), burn metallic compounds and emit aluminum oxide particles together with hydrochloric acid, both of which have a damaging effect on the atmosphere.

The BE-3 engine that powers Blue Origin's New Shepard suborbital vehicle, on the other hand, combines liquid hydrogen and liquid oxygen to create thrust. The BE-3 is not a big polluter compared to other rocket engines, emitting mainly water along with some minor combustion products, [experts say](https://www.livescience.com/new-shepard-emissions.html).

Too little is known

For Karen Rosenlof, senior scientist at the Chemical Sciences Laboratory at the U.S. National Oceanic and Atmospheric Administration (NOAA), the biggest problem is that rockets pollute the higher layers of the atmosphere — the stratosphere, which starts at an altitude of about 6.2 miles (10 kilometers), and the mesosphere, which goes upward from 31 miles (50 km).

"You are emitting pollutants in places where you don't normally emit it," Rosenlof told Space.com. "We really need to understand. If we increase these things, what is the potential damage?"

So far, the impact of rocket launches on the atmosphere has been negligible, according to Martin Ross, an atmospheric scientist at the Aerospace Corporation who often works with Rosenlof. But that's simply because there have not been that many launches.

"The amount of fuel currently burned by the space industry is less than 1% of the fuel burned by aviation," Ross told Space.com. "So there has not been a lot of research, and that makes sense. But things are changing in a way that suggests that we should learn about this in more detail."

Northern Sky Research predicts that the number of space tourism flights will skyrocket over the next decade, from maybe 10 a year in the near future to 360 a year by 2030, Kasaboski said. This estimate is still far below the growth rate that space tourism companies like Virgin Galactic and [Blue Origin](https://www.space.com/topics/blue-origin) envision for themselves.

"Demand for suborbital tourism is extremely high," Kasaboski said. "These companies virtually have customers waiting in a line, and therefore they want to scale up. Ultimately, they would want to fly multiple times a day, just like short-haul aircraft do."

The rate of rocket launches delivering satellites into orbit is expected to grow as well. But Kasaboski sees bigger potential for growth in space tourism.

"It's like the difference between a cargo flight and a passenger flight," Kasaboski said. "There's a lot more passengers that are looking to fly."

The problem is, according to Ross, that the scientific community has no idea and not enough data to tell at what point rocket launches will start having a measurable effect on the planet's climate. At the same time, the stratosphere is already changing as the number of rocket launches sneakily grows.

"The impacts of these [rocket-generated] particles are not well understood even to an order of magnitude, the factor of 10," Ross said. "The uncertainty is large, and we need to narrow that down and predict how space might be impacting the atmosphere."

#### Soot warms the Earth, and space tourism exponentially increases pollution levels

Heilweil 21 Rebecca Heilweil is a reporter for Open Sourced, covering emerging technologies, artificial intelligence, and logistics. July 25, 2021. “How bad is space tourism for the environment, and other space travel questions, answered” [How bad is space tourism for the environment? And other space travel questions, answered. (msn.com)](https://www.msn.com/en-us/news/technology/how-bad-is-space-tourism-for-the-environment-and-other-space-travel-questions-answered/ar-AAMxyEw?pfr=1#image=1) Accessed 1/5 // gord0

The emissions of a flight to space can be worse than those of a typical airplane flight because just a few people hop aboard one of these flights, so the emissions per passenger are much higher. That pollution could become much worse if space tourism becomes more popular. Virgin Galactic alone eventually aims to launch [400 of these flights](https://www.cnbc.com/2020/11/06/virgin-galactic-each-spaceport-is-1-billion-annual-revenue-opportunity.html) annually.

“The carbon footprint of launching yourself into space in one of these rockets is incredibly high, close to about 100 times higher than if you took a long-haul flight,” [Eloise Marais](https://theconversation.com/space-tourism-rockets-emit-100-times-more-co-per-passenger-than-flights-imagine-a-whole-industry-164601), a physical geography professor at the University College London, told Recode. “It’s incredibly problematic if we want to be environmentally conscious and consider our carbon footprint.”

These flights’ effects on the environment will differ depending on factors like the fuel they use, the energy required to manufacture that fuel, and where they’re headed — and all these factors make it difficult to model their environmental impact. For instance, Jeff Bezos has argued that the liquid hydrogen and oxygen fuel Blue Origin uses is less damaging to the environment than the other space competitors (technically, his flight didn’t [release carbon dioxide](https://www.politifact.com/factchecks/2021/jul/20/tweets/how-much-co2-did-bezos-rocket-ride-release-close-z/)), but experts told Recode it could still have [significant environmental effects](https://gizmodo.com/space-tourism-is-a-waste-1847285820).

There are also other risks we need to [keep studying](https://www.theverge.com/2018/5/31/17287062/rocket-emissions-black-carbon-alumina-particles-ozone-layer-stratosphere), including the release of [soot](https://www.livescience.com/new-shepard-emissions.html) that could hurt the stratosphere and the ozone. A [study](https://www.nbcnews.com/id/wbna39806493) from 2010 found that the soot released by 1,000 space tourism flights could warm Antarctica by nearly 1 degree Celsius. “There are some risks that are unknown,” Paul Peeters, a [tourism sustainability professor](https://www.buas.nl/en/research/professorships/sustainable-transport-and-tourism) at the Breda University of Applied Sciences, told Recode. “We should do much more work to assess those risks and make sure that they do not occur or to alleviate them somehow — before you start this space tourism business.” Overall, he thinks the environmental costs are reason enough not to take such a trip.

#### Increased levels of soot risks a huge threat, possibly greater than warming – studies

Tollefson 13 US correspondent at Nature covering energy, environment and development. January 15, 2013. “Soot a major contributor to climate change” [Soot a major contributor to climate change | Nature](https://www.nature.com/articles/nature.2013.12225) Accessed 1-5 // gord0

The contribution of soot to global warming is much higher than previously thought, according to a comprehensive assessment that ranks 'black carbon' second only to carbon dioxide in terms of its warming impact on the current climate. Published online by the Journal of Geophysical Research, the four-year study roughly doubles most of the previous estimates of the warming that occurs when carbon particles absorb solar radiation, which heats the atmosphere and results in the melting of snow and ice. Black carbon’s impact on the climate is larger than that of methane and roughly two-thirds that of carbon dioxide, according to the study 1. Although many scientists had suspected that global climate models underestimated the role of black carbon, the magnitude of the impact has surprised many of the report's authors, says David Fahey, an atmospheric scientist at the US National Oceanic and Atmospheric Administration in Boulder, Colorado, and a lead author. Diesel emissions and agricultural waste fires are major sources of black carbon in industrialized countries, whereas in the developing world, the soot comes from sources such as burning of biomass for cooking and heat. “This study suggests we should be putting even more effort into reducing black carbon pollution,” says Durwood Zaelke, who heads the Institute for Governance and Sustainable Development in Washington DC. Although CO dominates the long-term effect, understanding the timescale is crucial, Zaelke says. “Reducing black carbon gives you immediate cooling.” Cutting carbon A study published in Science last year estimated that aggressive action on black carbon and methane could cut the rate of warming in half within the next 40 years2. This is an appealing idea given the lack of progress for the United Nations climate negotiations, which often get hung up on carbon dioxide reductions. The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, formed last year, now has 25 member countries, and is targeting reductions in diesel emissions and biomass cookstoves. The latest report includes data from a ground-based aerosol sensor network, run by NASA, as well as satellite observations and global emissions inventories. The team used detailed atmospheric models to analyse the movement and evolution of aerosol particles. The results align well with the work of Veerabhadran Ramanathan, a climate scientist at the Scripps Institution of Oceanography in La Jolla, California, who has long emphasized black carbon’s impacts on climate, regional weather and human health. Ramanathan says that the study seems to confirm the bigger impact that black carbon has on the temperature of the atmosphere, but does not answer questions about the overall effect of aerosols, which include climate-cooling particles such as sulphates. On this point, Ramanathan says, “there are no new insights from this study”. Fahey also acknowledges other uncertainties in the study. Although black carbon contributes to warming, the impact of aerosol emissions on climate could end up being significantly positive or negative. “It’s not over yet, he says.”

#### Space tourism definitively causes warming -- carbon dioxide emissions, soot and water vapor

Marais 21 Eloise Marais, Associate Professor in Physical Geography, UCL. July 19, 2021. “Space tourism: rockets emit 100 times more CO₂ per passenger than flights – imagine a whole industry” [Space tourism: rockets emit 100 times more CO₂ per passenger than flights – imagine a whole industry (theconversation.com)](https://theconversation.com/space-tourism-rockets-emit-100-times-more-co-per-passenger-than-flights-imagine-a-whole-industry-164601) Accessed 1-5 // gord0

The commercial race to get tourists to space is heating up between Virgin Group founder Sir Richard Branson and former Amazon CEO Jeff Bezos. On Sunday 11 July, Branson ascended 80 km to reach the edge of space in his piloted [Virgin Galactic VSS Unity](https://www.bbc.co.uk/news/science-environment-57797297) spaceplane. Bezos’ autonomous Blue Origin rocket [is due to launch on July 20](https://www.cnbc.com/2021/06/07/jeff-bezos-to-fly-on-blue-origin-first-passenger-flight-in-july.html), coinciding with the anniversary of the Apollo 11 Moon landing.

Though Bezos loses to Branson in time, he is set to reach higher altitudes ([about 120 km](https://www.ft.com/content/621ddc59-11fe-4101-8abf-701a53b2475f)). The launch will demonstrate his offering to very wealthy tourists: the opportunity to truly reach outer space. Both tour packages will provide passengers with a brief ten-minute frolic in zero gravity and glimpses of Earth from space. Not to be outdone, Elon Musk’s SpaceX will provide four to five days of [orbital travel](https://www.space.com/spacex-crew-dragon-will-fly-space-tourists.html) with its Crew Dragon capsule later in 2021.

What are the environmental consequences of a space tourism industry likely to be? Bezos boasts his Blue Origin rockets are [greener](https://twitter.com/blueorigin/status/1413521631717122059?s=20) than Branson’s VSS Unity. The Blue Engine 3 (BE-3) will [launch](https://www.space.com/blue-origin-jeff-bezos-new-shepard-first-crewed-launch-explained) Bezos, his brother and two guests into space using liquid hydrogen and liquid oxygen propellants. VSS Unity used [a hybrid propellant](https://www.bbc.co.uk/news/science-environment-57798167) comprised of a solid carbon-based fuel, hydroxyl-terminated polybutadiene (HTPB), and a liquid oxidant, nitrous oxide (laughing gas). The SpaceX Falcon series of reusable rockets will propel the Crew Dragon into orbit using liquid kerosene and liquid oxygen.

Burning these propellants provides the energy needed to launch rockets into space while also generating greenhouse gases and air pollutants. Large quantities of water vapour are produced by burning the BE-3 propellant, while combustion of both the VSS Unity and Falcon fuels produces CO₂, soot and some water vapour. The nitrogen-based oxidant used by VSS Unity also generates nitrogen oxides, compounds that contribute to air pollution closer to Earth.

Roughly [two-thirds](https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016EF000399) of the propellant exhaust is released into the stratosphere (12 km-50 km) and mesosphere (50 km-85 km), where it can persist for at least two to three years. The very high temperatures during launch and re-entry (when the protective heat shields of the returning crafts burn up) also convert stable nitrogen in the air into reactive nitrogen oxides.

These gases and particles have many negative effects on the atmosphere. In the stratosphere, nitrogen oxides and chemicals formed from the breakdown of water vapour convert ozone into oxygen, depleting the ozone layer which guards life on Earth against harmful UV radiation. Water vapour also produces stratospheric clouds that provide a surface for this reaction to occur at a faster pace than it otherwise would.

Space tourism and climate change

Exhaust emissions of CO₂ and soot trap heat in the atmosphere, contributing to global warming. Cooling of the atmosphere can also occur, as clouds formed from the emitted water vapour reflect incoming sunlight back to space. A depleted ozone layer would also absorb less incoming sunlight, and so heat the stratosphere less.

Figuring out the overall effect of rocket launches on the atmosphere will require detailed modelling, in order to account for these complex processes and the persistence of these pollutants in the upper atmosphere. Equally important is a clear understanding of how the space tourism industry will develop.

Virgin Galactic anticipates it will offer [400 spaceflights each year](https://www.ft.com/content/0d9c9174-9374-4c48-a25b-3ae7dd6764b3) to the privileged few who can afford them. Blue Origin and SpaceX have yet to announce their plans. But globally, rocket launches wouldn’t need to increase by much from the current [100 or so performed each year](https://www.spacelaunchreport.com/logyear.html) to induce harmful effects that are [competitive with other sources](https://everydayastronaut.com/rocket-pollution/), like ozone-depleting chlorofluorocarbons (CFCs), and CO₂ from aircraft.



A SpaceX Falcon 9 rocket launch in December 2018. [US Air Force Photo/Alamy Stock Photo](https://www.alamy.com/the-spacex-falcon-9-rocket-carrying-the-spaceflight-sso-smallsat-express-a-satellites-blasts-off-from-space-launch-complex-4-at-vandenberg-air-force-base-december-3-2018-near-lompoc-california-the-smallsat-express-is-the-first-fully-dedicated-rideshare-mission-carrying-64-spacecraft-from-34-different-organizations-into-a-sun-synchronous-low-earth-orbit-image229069145.html?pv=1&stamp=2&imageid=700E6D67-9257-4150-855A-4C09DAE9005B&p=145884&n=0&orientation=0&pn=1&searchtype=0&IsFromSearch=1&srch=foo%3dbar%26st%3d0%26pn%3d1%26ps%3d100%26sortby%3d2%26resultview%3dsortbyPopular%26npgs%3d0%26qt%3drocket%2520launch%26qt_raw%3drocket%2520launch%26lic%3d3%26mr%3d0%26pr%3d0%26ot%3d0%26creative%3d%26ag%3d0%26hc%3d0%26pc%3d%26blackwhite%3d%26cutout%3d%26tbar%3d1%26et%3d0x000000000000000000000%26vp%3d0%26loc%3d0%26imgt%3d0%26dtfr%3d%26dtto%3d%26size%3d0xFF%26archive%3d1%26groupid%3d%26pseudoid%3d%26a%3d%26cdid%3d%26cdsrt%3d%26name%3d%26qn%3d%26apalib%3d%26apalic%3d%26lightbox%3d%26gname%3d%26gtype%3d%26xstx%3d0%26simid%3d%26saveQry%3d%26editorial%3d%26nu%3d%26t%3d%26edoptin%3d%26customgeoip%3dGB%26cap%3d1%26cbstore%3d1%26vd%3d0%26lb%3d%26fi%3d2%26edrf%3d0%26ispremium%3d1%26flip%3d0%26pl%3d)

During launch, rockets can emit between four and ten times more nitrogen oxides than [Drax](https://naei.beis.gov.uk/data/map-large-source), the largest thermal power plant in the UK, over the same period. CO₂ emissions for the four or so tourists on a space flight will be between 50 and 100 times more than the [one to three tonnes](https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year) per passenger on a long-haul flight. In order for international regulators to keep up with this nascent industry and control its pollution properly, scientists need a better understanding of the effect these billionaire astronauts will have on our planet’s atmosphere.

#### Extinction and it outweighs– tipping points, sea level rise, adaptability limit

Ng ’19 [Yew-Kwang; May 2019; Professor of Economics at Nanyang Technology University, Fellow of the Academy of Social Sciences in Australia and Member of the Advisory Board at the Global Priorities Institute at Oxford University, Ph.D. in Economics from Sydney University; Global Policy, “Keynote: Global Extinction and Animal Welfare: Two Priorities for Effective Altruism,” vol. 10, no. 2, p. 258-266]

Catastrophic climate change

Though by no means certain, CCC causing global extinction is possible due to interrelated factors of non‐linearity, cascading effects, positive feedbacks, multiplicative factors, critical thresholds and tipping points (e.g. Barnosky and Hadly, [2016](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0005); Belaia et al., [2017](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0008); Buldyrev et al., [2010](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0016); Grainger, [2017](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0027); Hansen and Sato, [2012](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0029); IPCC [2014](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0031); Kareiva and Carranza, [2018](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0033); Osmond and Klausmeier, [2017](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0056); Rothman, [2017](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0066); Schuur et al., [2015](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0069); Sims and Finnoff, [2016](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0072); Van Aalst, [2006](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0079)).[7](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-note-1009_67)

A possibly imminent tipping point could be in the form of ‘an abrupt ice sheet collapse [that] could cause a rapid sea level rise’ (Baum et al., [2011](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0006), p. 399). There are many avenues for positive feedback in global warming, including:

* the replacement of an ice sea by a liquid ocean surface from melting reduces the reflection and increases the absorption of sunlight, leading to faster warming;
* the drying of forests from warming increases forest fires and the release of more carbon; and
* higher ocean temperatures may lead to the release of methane trapped under the ocean floor, producing runaway global warming.

Though there are also avenues for negative feedback, the scientific consensus is for an overall net positive feedback (Roe and Baker, [2007](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0065)). Thus, the Global Challenges Foundation ([2017](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0026), p. 25) concludes, ‘The world is currently completely unprepared to envisage, and even less deal with, the consequences of CCC’.

The threat of sea‐level rising from global warming is well known, but there are also other likely and more imminent threats to the survivability of mankind and other living things. For example, Sherwood and Huber ([2010](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0071)) emphasize the adaptability limit to climate change due to heat stress from high environmental wet‐bulb temperature. They show that ‘even modest global warming could … expose large fractions of the [world] population to unprecedented heat stress’ p. 9552 and that with substantial global warming, ‘the area of land rendered uninhabitable by heat stress would dwarf that affected by rising sea level’ p. 9555, making extinction much more likely and the relatively moderate damages estimated by most integrated assessment models unreliably low.

While imminent extinction is very unlikely and may not come for a long time even under business as usual, the main point is that we cannot rule it out. Annan and Hargreaves ([2011](https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/full/10.1111/1758-5899.12647#gpol12647-bib-0004), pp. 434–435) may be right that there is ‘an upper 95 per cent probability limit for S [temperature increase] … to lie close to 4°C, and certainly well below 6°C’. However, probabilities of 5 per cent, 0.5 per cent, 0.05 per cent or even 0.005 per cent of excessive warming and the resulting extinction probabilities cannot be ruled out and are unacceptable. Even if there is only a 1 per cent probability that there is a time bomb in the airplane, you probably want to change your flight. Extinction of the whole world is more important to avoid by literally a trillion times.

### Contention 3– Ozone

#### Space tourism increases CO2 and NOx in the stratosphere which causes ozone depletion – defense doesn’t account for combined emissions at high altitude

Scott 20 Malcolm, UC Business School, College of Business and Law, University of Canterbury, Christchurch, New Zealand. 24 August, 2020. “A space tourism destination: environmental, geopolitical and tourism branding considerations for New Zealand as a ‘launch state’” [A space tourism destination: environmental, geopolitical and tourism branding considerations for New Zealand as a ‘launch state’ (tandfonline.com)](https://www.tandfonline.com/doi/epub/10.1080/09669582.2020.1817049?needAccess=true) Accessed 1-24 // gord0

Rocket and high-altitude vehicle emissions and climate change

According to the International Air Transport Association (IATA) aviation accounts for approximately 2% of global CO2 emissions (Cohen & Kantenbacher, [2020](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0016)). However, the CO2 emissions from aircraft are only one part of the overall emission profile from **airliners** and does not account for atmospheric damage due to other combustion contaminants. By boosting fuel economy by 50% since the early 1970s jet engine manufacturers have cut emissions of unburned hydrocarbons and carbon monoxide by about 80% and 60% respectively, but the higher operating temperatures needed to boost fuel combustion and efficiency result in higher levels of noxious nitrogen oxides (NOx) emissions (Thomas, [2004](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0081), p.17). At airliner cruising altitudes, above 12,000 metres, NOx persists in the atmosphere for about a year and contributes to the breakdown of atmospheric Ozone, the “decrease in the ozone and the increase in CO2 both lead to a cooling of the stratosphere and enhance the ‘greenhouse’ effect” (Egli, [1991](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0023)). Robert Elgi’s research was reported by *Newscientist* (Peace, [1994](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0059)) with ‘evidence that nitrogen oxides (NOx) and water vapour in these emissions play a key role in destroying ozone’, and that “aircraft emissions could cause up to 8 per cent of the warming caused by greenhouse gases” (n.p.). The ‘2% of global CO2 emissions’ frequently referred to by researchers and industry groups such as the IATA effectively understates the actual GHG effect at altitude of combined CO2 & NOx emissions from aircraft. Additionally, carbon offsetting schemes offered by airlines do not mitigate ozone depletion and may be typically focused on forest projects (tree planting) which represent ‘uncertain long-term biological sinks’ (Ritchie et al., [2020](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0067)). Elgi called for the airline industry to limit commercial flights to below 9,000 metres to reduce ozone damage, but this would have increased travel times and brought greater public attention to aircraft emission damage which was clearly unattractive to competitive airline operators and, nearly 30 years since Elgi’s research was first published, would be equally unattractive to space tourism operators as well.

Any type of space tourism whether it be high-altitude vehicle joy-rides for the rich, such as Virgin Galactic’s planned suborbital VSS Enterprise or SpaceShipTwo, or ground-based activities the likes of launch site visits and public launch viewings (e.g. Kennedy Space Centre visitor complex), will have a very high emissions profile. How high exactly? It’s unlikely space tourism operators would want to discuss that, but consider the combined carbon footprint (and unaccounted ozone depletion) from international and domestic air travel to reach the launch facility; ground travel and accommodation; rocket manufacturing, fuelling, launch emissions and rocket component wastage; the total per capita tourist GHG emission profile would be extreme. Carbon offsetting whether covered by the operator or passed on to the consumer as a voluntary optional-extra will not mitigate ozone damage and atmospheric degradation at high altitudes. Launch vehicle emissions at ground level, while being toxic, are transient and air quality can be monitored by local authorities under existing air quality legislation (if they bother to do this). According to Ross and Vedda ([2018](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0069)) rocket emissions in the stratosphere are far more concerning and can cause stratospheric heating and thermal changes that, like aircraft emissions, deplete ozone resulting in changes in the atmosphere’s net radiative balance, a radiative forcing that ‘results in temperature changes throughout the atmosphere’. Additionally, due to the much higher altitudes of rocket-powered vehicles Ross and Vedda ([2018](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0069)) attribute rocket emissions as a form of geoengineering: “the BC [Black Carbon] and alumina component of rocket emissions is directly related to the physics of attempts to mitigate climate change: so-called geoengineering or climate intervention” (p.9). Atmospheric geoengineering is controversial and is not covered by formal international policy or regulation which Ross & Vedda caution the launch community about and to ‘be prepared to respond to regulatory attention and inquiry’. In 2019 the Swiss government introduced a resolution to the UN Environment Assembly calling for an assessment of potential methods and governance frameworks with the head of Switzerland’s Federal Office for the Environment reportedly stating: “Some are already testing solar radiation management, scientific research is already going on. We cannot close our eyes anymore and say this is only science fiction” (Stefanini, [2019](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0077), n.p.). The hazards and risks to ozone damage from deliberated aerosols into the stratosphere and associated GHG effects (Heckendorn et al., [2009](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0032)) as well as a wide range of research concerning atmospheric aerosols as climate change mitigation technologies (Brewer, [2007](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0008); Carlin, [2007](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0012); Goes et al., [2011](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0027); Pidgeon et al., [2013](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0061); Pierce et al., [2010](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0062); Robock, 2008), ethical concerns (Corner & Pidgeon, [2010](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0018)), and discussion about ways geoengineering technologies could be governed or regulated (Parson & Keith, [2013](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0058); Rayner et al., [2013](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0065)) are widely documented within the geoengineering literature. However, attention to the toxic effects of these aerosol chemicals on humans through fallout (Whiteside & Herndon, [2018](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0088)), or exposure at ground level at processing, airport or rocket launch facilities is extremely scarce (Effiong & Neitzel, [2016](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0022)). Unlike any other type of new or emerging tourism, space tourism is uniquely entwined with the fossil fuels industries, climate change and the global climate emergency, national security and surveillance, military domination and the weaponisation of space. Unsurprisingly space tourism operators appear to prefer to steer public perception away from toxic rocket engine emissions with ‘cliché-ridden promotional messaging’ encouraging customers to “prepare to turn dreams into reality with the ultimate space flight experience” or promising “the highest-end luxury experience you can imagine” (Thompson, [2014](https://www.tandfonline.com/reader/content/17e8f3bf706/10.1080/09669582.2020.1817049/format/epub/EPUB/xhtml/index.xhtml#CIT0082), n.p.). SpaceBase’s stated mission to ‘democratise space for everyone’ might be considered as aspirational, but in terms of the points being outlined in this paper also confronts significant challenges.

#### Space travel releases large amounts of greenhouse gases.(READ IF HAVE TIME)

Gammon 21

(Katharine Gammon is an award winning journalist. https://www.theguardian.com/science/2021/jul/19/billionaires-space-tourism-environment-emissions. Published 7/19/21. Accessed 12/6/21)

Last week [Virgin Galactic](https://www.theguardian.com/science/virgin-galactic) took Richard Branson past the edge of space, roughly 86 km up – part of a new space race with the Amazon billionaire Jeff Bezos, who aims to make a similar journey on Tuesday.

Both very wealthy businessmen hope to vastly expand the number of people in space. “We’re here to make space more accessible to all,” [said Branson](https://www.reuters.com/lifestyle/science/virgin-galactics-branson-ready-space-launch-aboard-rocket-plane-2021-07-11/), shortly after his flight. “Welcome to the dawn of a new space age.”

Already, people are buying tickets to space. Companies including [SpaceX](https://www.theguardian.com/science/spacex), Virgin Galactic and Space Adventures want to make space tourism more common.

The Japanese billionaire Yusaku Maezawa spent an undisclosed sum of money with SpaceX in 2018 for a possible future private trip around the moon and back. And this June, an anonymous space lover paid $28m to fly on Blue Origin’s New Shepard with Bezos – though later backed out due to a [“scheduling conflict”](https://www.npr.org/2021/07/15/1016510564/blue-origin-space-18-year-old-bezos-oliver-daemen-netherlands).

But this launch of a new **private space industry** that is cultivating tourism and popular use could **come with vast environmental costs**, says Eloise Marais, an associate professor of physical geography at University College London. Marais studies the impact of fuels and industries on the atmosphere.

When **rockets** launch into space, they **require a huge amount of propellants to make it out of the Earth’s atmosphere.** For SpaceX’s Falcon 9 rocket, it is kerosene, and for Nasa it is liquid hydrogen in their new [Space](https://www.theguardian.com/science/space) Launch System. **Those fuels emit a variety of substances into the atmosphere, including carbon dioxide, water, chlorine and other chemicals.**

The carbon emissions from rockets are small compared with the aircraft industry, she says. But they are increasing at nearly 5.6% a year, and Marais has been running a simulation for a decade, to figure out at what point will they compete with traditional sources we are familiar with.

“For one long-haul plane flight it’s one to three tons of carbon dioxide [per passenger],” says Marais. **For one rocket launch 200-300 tonnes of carbon dioxide** are split between 4 or so passengers, according to Marais. “So it doesn’t need to grow that much more to compete with other sources.”

Right now, the number of rocket flights is very small: in the whole of 2020, for instance, there were 114 attempted orbital launches in the world, according to Nasa. That compares with the airline industry’s more than 100,000 flights each day on average.

But **emissions from rockets are emitted right into the upper atmosphere, which means they stay there for a long time**: two to three years. **Even water injected into the upper atmosphere** – where it can form clouds – **can have warming impacts**, says Marais. “Even something as seemingly innocuous as water can have an impact.”

Closer to the ground, all fuels emit huge amounts of heat, which can add ozone to the troposphere, where it acts like a greenhouse gas and retains heat. In addition to carbon dioxide, fuels like kerosene and methane also produce soot. And **in the upper atmosphere, the ozone layer can be destroyed** by the combination of elements from burning fuels.

“While there are a number of environmental impacts resulting from the launch of space vehicles, the depletion of stratospheric ozone is the most studied and most immediately concerning,” wrote Jessica Dallas, a senior policy adviser at the New Zealand Space Agency, in an analysis of [research on space launch emissions](https://www.sciencedirect.com/science/article/abs/pii/S0959652620302560) published last year.

Another [report from 2019](https://aerospace.org/sites/default/files/2018-05/RocketEmissions_0.pdf) penned by the Center for Space Policy and Strategy likened the space emissions problem to that of space debris, which the authors say creates an existential risk to the industry. “Today, launch vehicle emissions present a distinctive echo of the space debris problem. Rocket engine exhaust emitted into the stratosphere during ascent to orbit adversely impacts the global atmosphere,” they wrote.

“We just don’t know how large the space tourism industry could become,” says Marais.

A new market report estimates that the global suborbital transportation and space tourism market is estimated to reach $2.58bn in 2031, growing 17.15% each year of the next decade.

“The major driving factor for the market’s robustness will be focused efforts to enable space transportation, emerging startups in suborbital transportation, and increasing developments in low-cost launching sites,” the [report](https://www.prnewswire.com/news-releases/outlook-on-the-sub-orbital-transportation-and-space-tourism-global-market-to-2031---featuring-blue-origin-spacex-and-virgin-galactic-among-others-301333701.html) says.

In the past, most space transportation has been focused on cargo supply missions to the International Space Station and satellite launch services, but currently, this focus has shifted to in-space transportation, planetary explorations, crewed missions, suborbital transportation and space tourism.

Several companies, including SpaceX, Blue Origin and Virgin Galactic, have been focusing on developing platforms such as rocket-powered suborbital vehicles that will enable the industry to carry out suborbital transportation and space tourism.

People have pointed out that the money these billionaires have poured into space technology could be invested in making life better on our planet, where wildfires, heatwaves and other climate disasters are becoming more frequent as the globe warms up in the climate crisis.

“Is anyone else alarmed that billionaires are having their own private space race while record-breaking heatwaves are sparking a ‘fire-breathing dragon of clouds’ and cooking sea creatures to death in their shells?” the former US Labor Secretary Robert Reich [tweeted](https://twitter.com/RBReich/status/1413266215385001986) last week.

Marais says that there is always an element of excitement to new developments in space – but it’s still possible to be responsible while doing something exciting. She urges caution as the space tourism industry grows, and says there are currently no international rules around the kinds of fuels used and their impact on the environment. “We have no regulations currently around rocket emissions,” she says. “The time to act is now – while the billionaires are still buying their tickets.”

 This article was amended on 22 July 2021 to clarify the section comparing the carbon footprint of a long-haul flight with a rocket launch; an earlier version did not make it clear that the CO2 figure given for the flight was per passenger.

#### Rocket launches sufficient to destroy the ozone

Martin Ross & James Vedda 18. Martin Ross, Ph.D. planetary science from UCLA, senior project engineer in civil and commercial launch programs at the Aerospace Corporation; James Vedda, Ph.D. political science from the University of Florida, senior policy analyst at the Aerospace Corporation’s Center for Space Policy & Strategy. "Time To Clear The Air About Launch Pollution". SpaceNews. 7-3-2018. https://spacenews.com/op-ed-time-to-clear-the-air-about-launch-pollution/

In recent years, governments, intergovernmental organizations, and businesses have begun to focus on the challenge posed by orbital debris. As often seems to be the case, we appear to be a decade or two too slow in coming to consensus on the risks. If we had foreseen a half-century ago the challenges that orbital debris presents today, what would we have done differently? Combustion emissions from launch vehicles present the space industry with a comparable concern that we can begin to address now, before it grows and becomes a potential impediment to space access. Most human-generated pollution is concentrated on or near the surface of the Earth, whether on land, sea, or in the troposphere, the lowest layer of the atmosphere. However, rockets emit a variety of gases and particles directly into all levels of the stratosphere, the only industrial activity to do so. The stratosphere extends roughly from 10 to 50 kilometers above the Earth’s surface and contains the Earth’s ozone layer. The global civil aviation fleet generally cruises in the troposphere, only occasionally polluting the stratosphere directly. Among the most consequential emissions are soot and alumina, which are long-lived and accumulate in the stratosphere. These accumulations promote chemical reactions and absorption and scattering of sunlight that modify the composition and flow of radiation in the stratosphere. Ultimately, these processes reduce stratospheric ozone, warm the stratosphere, and cool the Earth’s surface. Little is known about these particle accumulations and their contributions to stratospheric ozone depletion and thermal perturbations because of a lack of consistent and focused research. Since 1987, emissions of ozone-depleting pollutants are highly regulated by international agreement through the Montreal Protocol on Substances That Deplete the Ozone Layer. Even with recent advances in reusability and the introduction of large launch vehicles and new launch sites around the globe, rocket launches occur irregularly so that concerns about the damage done to the ozone layer by rocket emissions have not elicited regulation. But with projections that the global launch rate will at least double in the coming decade, increased scrutiny under the Montreal Protocol is likely. Increased concerns about the environmental impact of rocket launches, provoked by perceptions of a rapidly growing launch industry, could result in international calls for launch limitations or the phase-out of propellants that the launch industry has come to depend on. The timing and intensity of a regulatory backlash as launch rates increase is impossible to predict accurately, especially because the science of rocket emissions is still not well understood. Rather than allow a legal and regulatory process to unfold in the absence of high-quality, peer-reviewed data, governments and the launch industry should conduct the scientific research needed to fill the knowledge gaps. This will allow the launch community to engage in future far reaching discussions regarding the impacts of rocket emissions with the support of empirical data and computer models that carry the imprimatur of the rocket engineering and atmospheric science communities. The launch industry has enjoyed freedom of action with respect to rocket engine emissions since the start of the space age. Studies of future launch architectures, market demand, and lifecycle costs rarely consider regulation of emissions as a potential future risk factor. Even when emissions are considered, the impacts are examined on a system-by-system basis; the cumulative impact of the global launch fleet is not acknowledged. The net impacts of the global launch industry, across all propellant types, are the parameters of interest to international regulators and, therefore, the global impacts create the regulatory risk. In addition to acknowledging the risks and potential unintended consequences of launch emissions for ozone and the flow of radiation in the atmosphere, the space industry must recognize the extent that other emerging actors may interact with the stratosphere. For example, so-called “geoengineering” or “climate intervention” schemes propose to inject particles into the stratosphere to intercept sunlight and mitigate the warming effects of carbon dioxide and other greenhouse gases. Regulation of such geoengineering activity is already under discussion. Space launch operators, as contributors of stratospheric emissions, could get swept up into these discussions, which involve the same types of particulate matter associated with rocket emissions. Any resulting regulations or guidelines must include adequate consideration of launch activities, which will require a better understanding of rocket emissions than we have today. To improve that understanding, industry should encourage and support scientific research on rocket engine emissions and how they affect the atmosphere. There has been little research to date. The few research papers that have appeared in recent decades mostly point out the knowledge gaps rather than add to the knowledge base. The research has been unfocused, disorganized, and not suited to the needs of the launch industry. As it stands today, the scientific community can predict ozone depletion attributable to rocket emissions to no better than an order of magnitude. In an environment of growing launch rates, new propellants, larger, reusable launch vehicles, and the emergence of other stratospheric polluters, this is not sufficient. Lack of accurate information inevitably invites distorted competitive claims and unwarranted and overly restrictive regulation. A vigorous research program would be guided by the goal to collect high confidence information and data that describe rocket emissions as inputs into global atmosphere models and would include the following components: All of the instrumentation, models, and expertise to carry out this research already exists within the engineering and scientific communities. The in situ and test stand measurements would validate combustion and plume models. Validated models permit the development of emission profiles for particular rocket engine types. These profiles, with various growth assumptions, would be used to construct global emission projections. Finally, the global emissions scenarios would provide data to construct input profiles for modern three-dimensional whole atmospheric chemistry and climate models in order to estimate ozone loss, climate forcing, and a variety of secondary effects such as changes in the global circulation and cloud formation. A policy to promote objective and vigorous research, across the full range of propellant types, will provide the space industry with the information required to take ownership of the problem and exert strong influence on the future debate. By accepting the reality of the risk to freedom of action presented by rocket emissions, and promoting a full and complete scientific understanding of the global impacts, the industry can best inoculate itself from attempts to regulate or limit launch development and operations and disassociate itself from other polluters. There is historical precedent for such an approach. In order to promote supersonic civil aviation development, during the 1990s NASA partnered with the aviation industry to carry out the High Speed Research (HSR) program. One of the goals of HSR was to understand how High Speed Civil Transport (HSCT) aircraft would affect stratospheric ozone. Earlier HSCT efforts in the 1970s were severely and wrongly hampered by knowledge gaps with respect to ozone depletion. HSR demonstrated the airframe, engine, and operational combinations that would minimize ozone impacts and permit (if the economics had been convincing) unregulated development and deployment. The launch industry should organize around a similar approach and partner with the scientific and regulatory communities to determine how space launch can freely develop while minimizing the risks of regulatory intervention. As launch rates and launch vehicle sizes increase, the impact of rocket emissions approaches a “tipping point” when international regulation becomes likely, probably beginning with efforts to protect the ozone layer or limit stratospheric pollution to ward off geoengineering. If the launch industry moves quickly to support the necessary scientific research and fully understand these impacts – in concert with other private-sector and government stakeholders – it is more likely that future regulation will be well-informed and as limiting as possible. As with other large-scale ventures, the application of specialized expertise is essential to anticipating the risks and needs of the enterprise and to managing the impacts on society. With irrefutable data, modeling, and analyses, emissions-related regulations or limitations can be anticipated and configured to ensure that space-based capabilities and systems continue to enhance and improve human life and extend the space industry’s progress made over the past six decades.

#### Ozone collapse causes UV radiation

Simmons 20 [Carla Simmons,, The Science Times, "A Repeat of One of the Biggest Extinctions Caused by Ozone Layer Erosion 359M Years Ago Possible, Warn Scientists | Science Times", May 27, 2020, https://www.sciencetimes.com/articles/25838/20200527/repeat-one-biggest-extinctions-caused-ozone-layer-erosion-359m-years.htm] BD

University of Southampton researchers have delved deeper into an extinction event that occurred about 360 million years ago. According to their research, the ozone layer's breakdown caused by ultraviolet (UV) radiation vanquished much of the Earth's marine life and greenery. Moreover, their discovery led to weighty indications for today's continually warming Earth.

Numerous episodes of mass extinction occurred in the geological past. One of the most notorious ones caused the extinction of dinosaurs about 66 million years ago. Their destruction was believed to have been caused by an asteroid hitting the Earth.

Additionally, two chapters were caused by large-scale volcanic eruptions that created the imbalance of oceans and atmospheres in the planets. Another one happened during the end of Permian Great Dying, which, according to Stanford, wiped out 96% of the Earth's aquatic species.

Scientists have discovered evidence pointing to high levels of UV radiation responsible for collapsing forest ecosystems and killing off water animal species during the Devonian geological period about 359 million years ago.

Their research revealed that warming temperatures after an intense ice age could have caused the ozone to collapse. The researchers suggest that the Earth might possibly reach comparable temperatures, thus might face the same consequences that occurred in the past.

The findings of their study are published in the journal Science Advances. Additionally, the research was partly funded by a grant from the National Geographic Society. It was also regulated in collaboration with The Sedgwick Museum of Earth Sciences at the University of Cambridge.

The team collected various rock samples during expeditions in locations in South America. They formed clues as to what was happening at the edge of the melting Devonian ice sheet, which allowed them to compare between the extinction event close to the pole and near the equator.

The rocks were then dissolved in hydrofluoric acid back in the laboratory. The dissolved rocks released microscopic plant spores, which were preserved for hundreds of millions of years. On microscopic examination, the scientists found many of the spores had bizarrely formed spines on their surface.

According to the researchers, the spikes were due to UV radiation damaging their DNA. Furthermore, they found that many spores had dark pigmented walls. These walls were thought to be a protective 'shield' against the increasing and damaging UV levels.

From their findings, the scientists have concluded that during a time of expeditious global warming, the ozone layer collapsed for a short while. Moreover, the ozone collapse exposed life on Earth to harmful UV radiation levels and, therefore, triggered a mass extinction event. This affected life on land and in shallow water at the Devonian-Carboniferous boundary.

From Climate Change to Climate Emergency

Professor John Marshall, the lead researcher from the University of Southampton's School of Ocean and Earth Science, said that our ozone layer is currently in a state of alteration. He adds that they have seen this pattern in the past, where a stimulant or impetus was unnecessary for the phenomenon to kick in.

He also says that current approximate calculations suggest that the Earth will reach similar global temperatures to those of 360 million years ago. Furthermore, they say it is possible that a similar collapse of the ozone layer could occur again, dangerously exposing surface and shallow sea life to harmful radiation.

#### UV floods cause extinction—no defense assumes rampant UV poisoning that suppresses immune responses.

Lucas et al 14 (R. M. Lucas (National Centre for Epidemiology and Population Health, The Australian National University, Canberra 2601, Australia, Telethon Kids Institute, University of Western Australia, Perth 6008, Australia), M. Norval (Biomedical Sciences, University of Edinburgh Medical School, Edinburgh EH8 9AG, Scotland, UK), R. E. Neale (QIMR Berghofer Medical Research Institute, Brisbane 4029, Australia), A. R. Young (King's College London (KCL), St John's Institute of Dermatology, London SE1 9RT, UK), F. R. de Gruijl (Department of Dermatology, Leiden University Medical Centre, P.O. Box 9600, NL-2300 RC Leiden, The Netherlands), Y. (Akita University Graduate School of Medicine, Akita-shi, Akita Prefecture, Japan, National Institute for Minamata Diseases, Minamata-sh, Kumamoto Prefecture, Japan) and J. C. van der Leun (iEcofys, Kanaalweg 16G, NL-3526 KL Utrecht, The Netherlands), “The consequences for human health of stratospheric ozone depletion in association with other environmental factors”, November 10th, 2014, <https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b>) CS

Effects of solar UV radiation on immune function and consequences for disease Mechanisms UV photons penetrate the epidermis and upper dermis162 and are absorbed by chromophores ([Table 2](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#tab2)), which then **initiate a cascade leading to changes in immune responses**. Table 2 Cutaneous chromophores involved in the initiation of UV-induced changes in immune function (reviewed in [ref. 163](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit163)While much of this information has been gathered from studies in vitro or in rodent models, less is known about humans. However, an action spectrum for the UV-induced suppression of the human immune response to a previously-encountered antigen (termed memory or recall immune responses) has been constructed: it has two peaks, one within the UV-B waveband at 300 nm and one at 370 nm in the UV-A waveband.[164,165](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit164) There is also evidence from studies in both humans and mice that interactive and additive effects between wavebands can occur.[166–168](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit166) Briefly, exposure to UV radiation causes up-regulation of some innate immune responses, **and down-regulation of** some acquired primary and memory **immune responses**, mainly through effects on T cell activity (reviewed in Gibbs & Norval,[163](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit163) Schwarz & Schwarz,[169](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit169) and Ullrich & Byrne[170](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit170)). The up-regulation includes the production of several antimicrobial peptides (AMPs) in the epidermis,[171,172](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit171) possibly through a vitamin D pathway (see below). The AMPs provide immediate protection against a variety of pathogens (bacteria, fungi, and viruses having a viral envelope) and they are also involved in the promotion of cell growth, healing, and angiogenesis. In contrast to these stimulatory functions, exposure to UV radiation induces T regulatory cells (Tregs) and other cell types which contribute to immunosuppression and help to restore cutaneous homeostasis.[172,173](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit172) Mediators such as platelet-activating factor, prostaglandin E2, histamine, and tumour necrosis factor-α are produced locally at the irradiated site. These alter the migration patterns and functions of various populations of immune cells. The end result is the generation of cell subsets with suppressive activity which are thought to remain for the life-time of the individual.[174,175](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit174) The UV-induced alterations in the normal immune response can be beneficial for some human diseases and detrimental for others. Vitamin D, synthesised following exposure of the skin to UV-B radiation, also has positive and negative effects on immune-related diseases. Indeed, it is difficult to distinguish between immunoregulation by vitamin D and other mediators induced by UV radiation,[176–180](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit176) since the downstream effects on immune parameters are similar. For clarity, the effects of UV radiation and those of vitamin D have been assessed separately in the sections below. We first focus on the effects of UV radiation on immunity, and address vitamin D-related effects on immune function in the section specifically on vitamin D. Polymorphic light eruption Polymorphic light eruption (PLE) is the commonest of the photodermatoses, with a prevalence of up to 20%.[181](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit181) PLE manifests as an intermittent itchy red skin eruption which resolves without scarring after a few days to weeks. It occurs 2–3 times more frequently in women than in men, with onset typically in the first three decades of life,[181](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit181) and is found predominantly in those with fair skin, although all skin types can be affected.[181](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit181) A recent study of Indian patients with dark skin phototypes (IV and V) who suffered from various photodermatoses revealed that PLE was the commonest of these, affecting 60% of the group.[182](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit182) The lesions occur most often in the spring and early summer or during a sunny holiday, following the first exposure to a large dose of sunlight. After repeated exposures, the lesions are less likely to occur. This process, called photohardening, is used therapeutically with good results. Recent investigations indicate that key events in photohardening include a decrease in the number of Langerhans cells in the epidermis and recruitment of mast cells into the dermis,[183](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit183) together with changes in systemic cytokine levels.[184](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit184) PLE is immunologically-mediated as a result of a failure to establish the normal suppression of immune responses following exposure to UV radiation. The antigen involved has not been identified but is likely to be novel, induced by the **DNA damaging properties of UV radiation**. Various abnormalities in the cutaneous immune response following UV radiation have been demonstrated in people with PLE compared with controls.[185,186](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit185) This disease therefore illustrates the positive evolutionary advantage of UV-induced immunosuppression in individuals who are not susceptible to PLE and what can happen if it is absent. Asthma **Asthma** comprises a group of diseases that evidence as wheeze, chest tightness, or shortness of breath, occurring as a result of obstruction of the airways and restriction of airflow that is usually reversible. The level of severity, frequency of symptoms, age of onset, main inflammatory phenotypes, and triggers and pathways are variable. This heterogeneity may explain the current lack of consistency in results from studies examining the relationship between UV radiation and the risk of asthma. There are anecdotal accounts that sunny holidays or living at high altitude decrease asthma symptoms. The prevalence of asthma was inversely associated with the intensity of UV radiation,[187](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit187) or past personal exposure to solar UV radiation.[188](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit188) However, in a study where different sub-types of asthma were considered, residence at latitudes closer to the equator (and with greater intensity of UV-B radiation) was associated with an increased risk of having asthma in atopic participants (with a history of allergic responses to specific antigens) but a decreased risk in those without atopy.[189](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit189) These findings highlight the importance of differentiating between subtypes of asthma in examining associations with exposure to UV radiation. Nevertheless, individual-level exposure to UV radiation was not measured (only latitude and ambient UV radiation), so the results could reflect exposure to other latitude-associated factors such as temperature and indoor heating. Infection and vaccination Studies over the past 20 years have shown that **exposure to solar UV radiation suppresses** microbe-specific acquired **immune responses in** animal models of **infection**. This modulation can lead to an **increased microbial load, reactivation from latency, and more severe symptoms, including death** (reviewed in Norval et al.[190](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit190)). A recent study showed that spending 8 or more hours outdoors per week when the UV Index was ≥4 was associated with an increased risk of ocular recurrence of herpes simplex virus (HSV) infection resulting in eruptive lesions.[191](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit191) **UV radiation prior to vaccination** causes a **less effective immune response** in several mouse models (reviewed in Norval & Woods[192](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit192)), but whether exposure to UV radiation adversely affects the course of infections and the efficacy of vaccination in humans remains an open question. Despite the paucity of new information, there remains the possibility that UV-induced immunosuppression could **convert an asymptomatic infection into a symptomatic one**, **reactivate** a range of **persistent infections**, increase the oncogenic potential of microbes, and **reduce the memory immune response,** for example after vaccination, so that it is no longer protective. Autoimmune diseases Many autoimmune diseases are considered to have both environmental and genetic risk factors. Evidence to support the importance of environmental exposures comes from geographical variation (changing incidence with changing latitude), temporal patterns (such as variations in incidence with season or season-of-birth) and results from observational epidemiological studies. Several studies show an inverse association between exposure to UV radiation and immune-mediated diseases, suggesting that the UV may be protective. In many cases, the assumed pathway has been through enhanced synthesis of vitamin D (see section on Vitamin D below). However, this evidence is now being re-evaluated in light of possible alternative pathways, including UV-induced immune modulation and altered susceptibility to relevant viral infections, and non-UV pathways such as changes in the secretion of melatonin (reviewed in Hart et al.[193](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit193)). While there have been suggestions that exposure to UV radiation may be important for conditions such as inflammatory bowel disease (for example, Nerich et al.[194](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit194)), type 1 diabetes,[195](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit195) and rheumatic diseases (including rheumatoid arthritis, systemic lupus erythematosus, dermatomyositis, and others),[196](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit196) the strongest evidence is for multiple sclerosis. Multiple sclerosis. Many studies (but not all) have shown that the prevalence, incidence, or mortality from multiple sclerosis (MS) increases with increasing latitude and decreasing altitude or intensity of ambient UV radiation, in predominantly fair-skinned populations (reviewed in Hewer et al.[197](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit197)). In the US Nurses Health Studies, a latitudinal gradient present in a cohort of female nurses born before 1946 was not apparent in a similar cohort born after 1946.[198](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit198) The findings reflected an increase in incidence in the south in the later cohort (rather than a decrease in the north). One explanation given to explain this change was that increasing sun-protective behaviours in the south had reduced the difference in personal dose of UV between the north and south.[199](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit199) Studies from the northern[200](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit200) and southern[201](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit201) hemispheres show that, compared to the general population, people with MS were more likely to have been born in late spring and less likely to have been born in late autumn. This timing would be consistent with a hypothesis that exposure of the mother to more UV radiation during the late first trimester, when the foetal nervous system is developing and maturing, is protective for the development of MS in later life.[201](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit201) Alternatively, it is also possible that exposures early in infancy, rather than in pregnancy, influence risk, or other factors that vary seasonally could be important. Animal studies suggest that UV-B irradiation can prevent the onset of experimental autoimmune encephalomyelitis, used as a model for MS,[202](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit202) and there is supportive evidence from recent studies in humans.[203,204](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit203) The role of UV-induced immune suppression in skin cancer Cutaneous malignant melanoma. Evidence that the immune response is important for the development of CMM is clearly shown by the increase in incidence following organ transplantation that requires ongoing treatment with immunosuppressive medications.[205](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit205) UV radiation, particularly UV-B, can cause suppression of many aspects of cell-mediated immunity but, until recently, how it influenced the initiation of CMM was unknown. In a transgenic mouse model, the recruitment of macrophages to the skin following UV-B irradiation and their subsequent proliferation were shown to be critical in the survival of melanocytes, including those with UV-induced DNA damage.[206–208](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit206) In addition, inflammation induced by UV radiation increased metastasis of melanoma, with neutrophils being the main drivers of the inflammatory process.[209](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit209) Consistent with these reports from animal models, in patients with metastatic melanoma there was a shorter survival time if metastases contained a high proportion of macrophages.[210](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit210) Non-melanoma skin cancer. Tumours induced by UV radiation are highly antigenic. UV-induced immune suppression plays a critical role in the development of NMSC as evidenced by the dramatically increased incidence in immunosuppressed people, for example, following organ transplantation.[211](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit211) This is especially shown for SCCs in organ transplant recipients receiving immunosuppressive drugs that suppress T cell activity, suggesting that effector T cells are of particular importance in the control of SCC.[212](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit212) Furthermore, Tregs induced by UV irradiation infiltrate SCCs and surround BCCs. Pharmacologically blocking steps in the pathway of UV-induced immunosuppression may be effective in preventing the development of skin cancers and actinic keratoses.[212–214](https://pubs.rsc.org/en/content/articlehtml/2015/pp/c4pp90033b#cit212)