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### 1AC - Contention

#### The contention is space tourism.

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

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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.

#### Industry is projected to grow to over 1,000 launches per year

Rosenblum 13 [Andrew Rosenblum is a guest contributor to MIT Technology Review who reports on drones, artificial intelligence, security, and commercial space travel for Popular Science, Wired, Fortune, and other publications. “Space Tourism’s Black Carbon Problem.” May 16, 2013. https://www.popsci.com/science/article/2013-05/space-tourism-experiment-geo-engineering/]

Here’s where space tourism comes into play: The number of space launches annually around the world numbers around 70 today, but that figure could rise drastically, as private companies jockey to turn space tourism into routine adventure travel. The aerospace research firm Futron forecasts that by 2021 the space tourism market will consist of 13,000 potential customers, with possible revenues of roughly $650 million per year. Assuming the business is successful, commercial space travel might very well reach 1,000 launches per year some time in the next decade – XCOR alone plans to ramp up to four launches per day, as part of its “Southwest airlines” model. That creates 1,000 opportunities to shoot black carbon directly into the stratosphere. The amount of black carbon emitted during combustion on Earth, or in the trophosphere, where airlines fly, tends to be low, because of the relatively rich supply of oxygen. Once you get into the stratosphere, where low pressure leads to less oxygen, black carbon can amount to as much as 5% of the products of combustion. The Federal Aviation Administration (F.A.A.), the organization responsible for assessing environmental impacts and deciding whether to grant licenses to launch vehicles into space, says the effects of black carbon in the stratosphere are unclear. “Although black carbon is known to be a short-term climate forcer, research on the potential climate change impacts of black carbon from rockets is in a very early stage, and any projections of impacts are speculative,” writes George Nield, the F.A.A.’s associate administrator for commercial space transportation, in an email. The space-tourism industry has downplayed black carbon’s potential harm. Virgin Galactic declined repeated inquiries to comment. Andrew Nelson, the chief operating officer of XCOR Aerospace, which is currently selling $95,000 tickets for sub-orbital flights, says that the blend of kerosene and liquid oxygen in his XR-5K18 rocket engine powering its Lynx suborbital spaceplane will emit much less in the way of “aromatic” hydrocarbons than traditional kerosene-based rocket fuel. And he says the XR-5K18 will burn much more cleanly than the solid rocket boosters used in the Space Shuttle or “hybrid” rocket engines, which burn both solid and liquid propellant. “XCOR will have di minimus impact on our environment,” Nelson says. “Our fuels are almost completely free of particulate matter. [They have ] 20-40 times less aromatics than traditional rocket fuels, and hundreds, if not thousands of times less particulate matter than hybrids or solids. So the concern about carbon or other particles is moot for us.” Toohey still wants to see peer-reviewed studies of the actual interaction of XCOR and other engines with the stratosphere. “I have not seen any publications that confirm (or refute) the claims of particle-free emissions from combustion of any fuel in the upper atmosphere,” Toohey says. “So I think it is fair to say that we need studies to benchmark the emissions of all rocket types in order to be able to assess their impacts.”

#### The Montreal Protocol worked --- the ozone hole is healing slowly, but new destruction pushes it past the brink

Stone 18 [Maddie Stone is a science journalist. “Our Best Evidence Yet That Humans Are Fixing the Ozone Hole.” January 5, 2018. https://gizmodo.com/our-best-evidence-yet-that-humans-are-fixing-the-ozone-1821808429]

The ozone hole feels like the quintessential ‘80s problem, but unlike car phones and mullets, it remains relevant in a number of ways. For starters, it’s still there, chilling over Antartica. More importantly, it’s slowly healing, and a new study offers some of the best evidence yet that sound environmental policy is responsible. It’s been nearly 30 years since the world adopted the Montreal Protocol, a landmark treaty banning the use of ozone-destroying chlorofluorocarbons (CFCs). But despite a firm scientific understanding of the link between CFCs and ozone depletion, it’s been tough to tell how much of a success the protocol was, because the ozone hole didn’t start showing signs of recovery until a few years back. Moreover, nobody had actually measured the chemistry of the hole to see if ozone-destroying compounds are declining as we’d expect due to the Montreal Protocol. A study published this week in Geophysical Research Letters addresses that knowledge gap. The authors, from NASA’s Goddard Spaceflight Center, made use of data collected by NASA’s Aura satellite, which measures a suite of trace atmospheric gases to understand changes to the ozone layer, Earth’s climate, and air pollution. “It kind of surprised me that no one had done this,” lead study author Susan Strahan told Earther. “The data is there if you’re careful about what data to use.” Strahan and her colleague Anne Douglass looked at changing ozone levels above Antarctica throughout the austral winter from 2005 to 2016, and found that ozone depletion had declined by about 20 percent. Then, they looked at levels of hydrochloric acid in the stratosphere at the end of winter, an indicator of how much ozone had been destroyed by CFCs. Sure enough, chlorine levels declined as well, at a rate of about 0.8 percent per year. That’s in line with model expectations of how much CFC levels should have declined over the same time period thanks to the Montreal Protocol’s ban. “This reaffirms our scientific understanding of what’s controlling ozone,” she said. Bill Randall, an atmospheric scientist at the University Corporation for Atmospheric Research who was not involved with the study, told Earther he thought the paper’s analysis was “very well done.” “They’re seeing net decreases in chlorine that are very consistent with the Montreal Protocol,” he said. “That’s a big take home message, that the Montreal Protocol is doing what we think it should be doing.”

#### Space tourism destroys the ozone --- 2 internal links:

#### First, black carbon buildups, soot, and particle emissions --- destroys ozone and causes catastrophic warming

LiveScience 10 [Live Science Staff. “New Climate Change Worry: Space Tourism Soot.” October 22, 2010. https://www.livescience.com/10202-climate-change-worry-space-tourism-soot.html]

Humans’ attempts to visit space may not be good for the folks back home, according to a new study that finds soot emitted by space tourism rockets could significantly contribute to global climate change in coming decades. The researchers assumed that a fast-growing suborbital space tourism market will develop over the next decade, and they examined the climate impact of soot and carbon dioxide emissions from 1,000 suborbital rocket flights per year, the approximate number advertised in recent materials promoting space tourism. "Rockets are the only direct source of human-produced compounds above about 14 miles (22.5 kilometers), and so it is important to understand how their exhaust affects the atmosphere," said the study's chief researcher, Martin Ross of The Aerospace Corp. in El Segundo, Calif. He and his colleagues describe their findings in a scientific paper that has been accepted for publication in Geophysical Research Letters. A layer of soot According to the study, soot particles emitted by the proposed fleet of space tourism rockets would accumulate at about 25 miles (40 km) altitude, three times higher than the altitude of airline traffic. Unlike soot from jets or coal power plants, which is injected lower in the atmosphere and falls to earth within weeks, the particles created by rockets remain in the atmosphere for years, efficiently absorbing sunlight that would otherwise reach the Earth's surface. The result is a global pattern of change, according to researcher Michael Mills of the National Center for Atmospheric Research (NCAR) in Boulder, Colo. "The response of the climate system to a relatively small input of black carbon is surprising," Mills said in a statement. "Our results show particular climate system sensitivity to the type of particles that rockets emit." Using a computer model of the Earth's atmosphere, the researchers discovered that beneath the predicted layer of soot, the Earth's surface would cool by as much as 1.2 degrees Fahrenheit (0.7 degrees Celsius). Antarctica would warm by 1.5 degrees F (0.8 degrees C). Meanwhile, equatorial regions could lose about 1 percent of their ozone, while the poles could gain 10 percent. The global effect would be an increase in the amount of solar energy absorbed by the Earth's atmosphere. That means the soot from the rockets contributes to atmospheric heating at a rate higher than the carbon dioxide from those same rockets. An earlier study by Ross, published in March 2009 in the journal Astrophysics, found that rocket emissions are particularly harmful to the ozone because they're injected directly into the stratosphere where the ozone layer resides. Considering black carbon The researchers based their predictions on business plans for suborbital space travel in the year 2020, Ross said. The current global fleet of hydrocarbon-fueled orbital rockets emits about one-tenth of the soot assumed in the study. "Climate impact assessments of suborbital and orbital rockets must consider black carbon emissions, or else they ignore the most significant part of the total climate impact from rockets," Ross said. "This includes existing assessments that may need to be brought up to date."

#### Climate change is existential.

Sears 21 (, N., 2021. Great Powers, Polarity, and Existential Threats to Humanity: An Analysis of the Distribution of the Forces of Total Destruction in International Security. [online] ResearchGate. Available at: <https://www.researchgate.net/publication/350500094> [Accessed 22 November 2021] Nathan Alexander Sears is a PhD Candidate in Political Science at The University of Toronto. Before beginning his PhD, he was a Professor of International Relations at the Universidad de Las Américas, Quito. His research focuses on international security and the existential threats to humanity posed by nuclear weapons, climate change, biotechnology, and artificial intelligence. His PhD dissertation is entitled, “International Politics in the Age of Existential Threats”)-re-cut rahulpenu

Climate Change Humanity faces existential risks from the large-scale destruction of Earth’s natural environment making the planet less hospitable for humankind (Wallace-Wells 2019). The decline of some of Earth’s natural systems may already exceed the “planetary boundaries” that represent a “safe operating space for humanity” (Rockstrom et al. 2009). Humanity has become one of the driving forces behind Earth’s climate system (Crutzen 2002). The major anthropogenic drivers of climate change are the burning of fossil fuels (e.g., coal, oil, and gas), combined with the degradation of Earth’s natural systems for absorbing carbon dioxide, such as deforestation for agriculture (e.g., livestock and monocultures) and resource extraction (e.g., mining and oil), and the warming of the oceans (Kump et al. 2003). While humanity has influenced Earth’s climate since at least the Industrial Revolution, the dramatic increase in greenhouse gas emissions since the mid-twentieth century—the “Great Acceleration” (Steffen et al. 2007; 2015; McNeill & Engelke 2016)— is responsible for contemporary climate change, which has reached approximately 1°C above preindustrial levels (IPCC 2018). Climate change could become an existential threat to humanity if the planet’s climate reaches a “Hothouse Earth” state (Ripple et al. 2020). What are the dangers? There are two mechanisms of climate change that threaten humankind. The direct threat is extreme heat. While human societies possesses some capacity for adaptation and resilience to climate change, the physiological response of humans to heat stress imposes physical limits—with a hard limit at roughly 35°C wet-bulb temperature (Sherwood et al. 2010). A rise in global average temperatures by 3–4°C would increase the risk of heat stress, while 7°C could render some regions uninhabitable, and 11–12°C would leave much of the planet too hot for human habitation (Sherwood et al. 2010). The indirect effects of climate change could include, inter alia, rising sea levels affecting coastal regions (e.g., Miami and Shanghai), or even swallowing entire countries (e.g., Bangladesh and the Maldives); extreme and unpredictable weather and natural disasters (e.g., hurricanes and forest fires); environmental pressures on water and food scarcity (e.g., droughts from less-dispersed rainfall, and lower wheat-yields at higher temperatures); the possible inception of new bacteria and viruses; and, of course, large-scale human migration (World Bank 2012; Wallace-Well 2019; Richards, Lupton & Allywood 2001). While it is difficult to determine the existential implications of extreme environmental conditions, there are historic precedents for the collapse of human societies under environmental pressures (Diamond 2005). Earth’s “big five” mass extinction events have been linked to dramatic shifts in Earth’s climate (Ward 2008; Payne & Clapham 2012; Kolbert 2014; Brannen 2017), and a Hothouse Earth climate would represent terra incognita for humanity. Thus, the assumption here is that a Hothouse Earth climate could pose an existential threat to the habitability of the planet for humanity (Steffen et al. 2018., 5). At what point could climate change cross the threshold of an existential threat to humankind? The complexity of Earth’s natural systems makes it extremely difficult to give a precise figure (Rockstrom et al. 2009; ). However, much of the concern about climate change is over the danger of crossing “tipping points,” whereby positive feedback loops in Earth’s climate system could lead to potentially irreversible and self-reinforcing “runaway” climate change. For example, the melting of Arctic “permafrost” could produce additional warming, as glacial retreat reduces the refractory effect of the ice and releases huge quantities of methane currently trapped beneath it. A recent study suggests that a “planetary threshold” could exist at global average temperature of 2°C above preindustrial levels (Steffen et al. 2018; also IPCC 2018). Therefore, the analysis here takes the 2°C rise in global average temperatures as representing the lower-boundary of an existential threat to humanity, with higher temperatures increasing the risk of runaway climate change leading to a Hothouse Earth. The Paris Agreement on Climate Change set the goal of limiting the increase in global average temperatures to “well below” 2°C and to pursue efforts to limit the increase to 1.5°C. If the Paris Agreement goals are met, then nations would likely keep climate change below the threshold of an existential threat to humanity. According to Climate Action Tracker (2020), however, current policies of states are expected to produce global average temperatures of 2.9°C above preindustrial levels by 2100 (range between +2.1 and +3.9°C), while if states succeed in meeting their pledges and targets, global average temperatures are still projected to increase by 2.6°C (range between +2.1 and +3.3°C). Thus, while the Paris Agreements sets a goal 6 that would reduce the existential risk of climate change, the actual policies of states could easily cross the threshold that would constitute an existential threat to humanity (CAT 2020).

#### Second, water vapor and rocket emissions

Larson 16 (Erik J L Larson (PhD in Atmospheric and Oceanic Studies, Postdoctoral fellow in Organismic and Evolutionary Biology at Harvard, Research Scientists at University of Colorado Boulder), Robert W Portmann (Researchesr from Chemical Sciences Division at NOAA), Karen H Rosenlof (NOAA research scientist), David W. Fahey (Directo of the Chemical Science Division at NOAA), John S Daniel (Chemical Sciences Division NOAA), and Martin N Ross (The Aerospace Corporation). “Global atmospheric response to emissions from a proposed reusable space launch system” Earth’s Future. Volume 5. Issue 1. November 16, 2016. Accessed August 12, 2019.)

1 Introduction

The expected availability of low cost, reusable launch systems and increasing demand for space services suggest that the global space transport industry will grow significantly in the coming decades. Relatively few studies of the chemical and climate effects of rocket emissions have been published that use current state‐of‐the‐art atmospheric models to address the future growth scenarios. Rocket emissions are becoming more like aviation emissions in that the space sector exhibits consistent growth that cannot be reduced without serious economic disruption. Unlike the aviation sector, the most significant method of managing emissions is through prudent use of the various available propellants. Hydrogen (H2) fuel and reusability are likely to play important roles in any future scheme to minimize the atmospheric impacts of rockets; therefore, it is important to understand the consequences of H2 fuel and reentry emissions. Significant increases in space transport will be associated with proportional increases in combustion emissions. Some of the proposed propulsion systems make greater use of “clean‐burning” H2 fuel [Li et al., 2004; Khan et al., 2013], which has H2O as the primary emission and thus avoids the effects of chlorine, alumina, and black carbon emissions associated with current conventional technology [Ross et al., 2009, 2010]. H2 burning rocket engines may also reduce payload‐to‐space costs, which could dramatically increase the number of rocket launches.

Reaction Engines Ltd. (http://www.reactionengines.co.uk/) has proposed the Skylon vehicle, which is a reusable H2‐burning rocket [Martin et al., 2008]. Skylon would be considered a medium lift launch vehicle in the current space transport vernacular. There is a concept plan to use this vehicle to build a space‐based solar power system. To be economically viable, the plan calls for a minimum of 104 launches per year for 10 years [Martin et al., 2008; Henson, 2014]. This rate would transport enough payload to space to build 3000 1‐GW solar power stations as estimated by the National Security Space Office [SBSP Study Group, 2007] and Reaction Engines [Martin et al., 2008].

It is often assumed that H2‐fueled rocket engines have no impact on the global atmosphere since the only significant emission is H2O. However, in great enough quantities the emissions from these rockets can alter the stratosphere in many ways. H2O emissions can change stratospheric temperatures and alter the photochemistry controlling ozone (O3). Furthermore, rockets burning liquid H2 and oxygen (O2) use an H2‐rich mixture rather than a stoichiometric ratio for enhanced thrust and emit H2 and HOX in the plume in addition to H2O. Enhancements in HOX can catalytically destroy O3 [Crutzen, 1969]. Superheated air in the engine and exhaust plume result in the production of NOx, which also catalytically destroys O3 [Johnston, 1971; Ross et al., 2009; Lee et al., 2010]. NOx is also created in the mesosphere due to the heat produced during rocket reentry [Park, 1976]. Here we use the Whole Atmosphere Community Climate Model (WACCM) [Marsh et al., 2013] and the 2D National Oceanic and Atmospheric Administration/National Center for Atmospheric Research (NOCAR) model [Portmann and Solomon, 2007] to evaluate the potential effects of high Skylon launch rates on the climate and stratospheric O3.

2 Calculating Emissions

Vertical profiles of NOX, H2, and H2O emitted during a Skylon rocket launch and reentry are estimated based on trajectory data from Reaction Engines Ltd. [http://www.reactionengines.co.uk/tech\_docs.html]. Skylon rockets have two combustion phases as they ascend through the atmosphere. The first phase is air breathing from the surface to 28.5 km. During this phase the engines act as H2 burning jet turbines, combusting H2 with ambient air. The main exhaust is H2O, which can be calculated directly from the amount of H2 fuel consumed. During the second phase from 28 to 80 km the engines run in rocket mode, burning H2 and liquid O2. The H2O produced in rocket mode is calculated from the mass of fuel used assuming a 6:1 mass ratio of oxygen to hydrogen; this assumption is made to be consistent with the fact that many rockets burn hydrogen‐rich fuel for greater thrust (stoichiometric ratio for combustion is 8:1) [Colasurdo et al., 1998]. Although the excess H2 likely oxidizes into H2O in the plume due to high temperatures, H2 emissions are also considered in our simulations as a bounding condition. The bounding cases assume either all or none of the excess H2 is oxidized to H2O in the plume. As discussed in the results, the intermediate combustion products HOX and H2O2 were tested with the NOCAR model and found not to be important contributors to O3 destruction. Thus they are not included in WACCM simulations.

H2 and H2O emission profiles (kg/km/flight) are interpolated with 1‐km vertical resolution (Figure 1a). The spike in emissions at 28 km is due to the spacecraft transition into rocket mode. The total amount of H2O produced from a single flight is estimated to be 6 × 105 kg (assuming completely oxidized H2) with about 4 × 105 kg emitted into the stratosphere (above 17 km). The projected 105 flights per year would deposit 4 × 1010 kg of H2O in the stratosphere every year. To get a sense of how large a perturbation this represents, the yearly emissions are compared to the total amount of stratospheric water. Assuming a uniform mixing ratio of 4.5 parts per million by volume (ppmv) of H2O above 100 hPa (17 km), there is 1.5 × 1012 kg of H2O in the stratosphere. The projected 105 flights would emit approximately 3% of the current stratospheric H2O burden every year. Assuming a constant flight frequency and a 3‐year lifetime of the H2O, when emitted above 100 hPa, this would increase globally averaged stratospheric H2O by approximately 9%. The actual steady‐state perturbation of H2O due to these emissions in WACCM above 100 hPa is 10%; however, the local perturbation would be much larger and increase with height.

Estimating a NOX emission profile for the Skylon vehicle is problematic. Several flight phases must be considered: H2 burned with air as a jet fuel, H2 burned with liquid oxygen as a rocket fuel, and heating of air due to aerodynamic interactions. It is important to note that we consider the shock heating of air during reentry as an emission. When air is heated to temperatures exceeding 1800 K, as in a jet engine or behind the shock wave around a spacecraft during reentry, NOX is produced through the extended Zeldovich mechanism [Zeldovich et al., 1947]. This mechanism is exponentially dependent on temperature so that representative temperatures are required in order to calculate the thermally produced NOX. Detailed estimates of the NOX emissions have not yet been calculated by the rocket designers [R. Varvill, 2015, personal communication]. For this study, reliable estimates of NOX emissions from jet and rocket engines are scaled to the Skylon vehicle with the caveat that our estimates have high uncertainty. Lee et al. [2010], using the International Civil Aviation Organization (ICAO) emissions databank, estimated that 14 ± 3 g of NOX are produced for every kilogram of fuel combusted in jet engines. Emissions may be lower at supersonic speeds and are also a function of the temperature difference between high pressure (∼100 atmospheres) liquid H2 and jet fuel. Most of the engines in the ICAO databank use jet fuel with a 2:1 H:C ratio. The higher fuel density must be taken into consideration in the NOX estimates from H2 combustion. For complete combustion in the jet engine air‐burning phase, two hydrogen and one carbon atoms (14 g/mol) react with three oxygen atoms. For a pure H2 fuel at complete combustion, three oxygen atoms will oxidize six hydrogen atoms (6 g/mol). Thus, from a stoichiometric perspective, burning 1 kg of jet fuel requires as much air as 6/14 kg of H2 fuel. Thus 6/14 kg of H2 fuel is assumed here to produce 14 g (11–17) of NOX during the air‐burning phase. Alternatively, using the heat of combustion per fuel mass to scale the NOX production gives consistent results that are within the uncertainty range. The total production of NOX during the air‐burning Skylon ascent is estimated to be 1400 ± 300 kg, although we acknowledge this range does not encompass all the uncertainties in the assumptions.

Zero NOX emission is assumed during the liquid oxygen burning phase of ascent. NOX would only be produced in H2‐fueled rocket engines in significant amounts (>0.01% of total flow) in afterburning reactions, which occur when ambient air is entrained into the hot underoxidized plume [Brady et al., 1997]. Afterburning is generally not a significant factor for rocket engines above the tropopause. Therefore it is assumed that during this phase of flight, at altitudes greater than 28 km, significant NOX production is unlikely.

Finally, NOX is also produced in the shock wave during spacecraft reentry. Using analytic approximations and a numerical integration, Park [1976] calculated that the NOX produced during a Space Shuttle reentry is 4.5–9% of the mass of the spacecraft. Park and Rakich [1980] later updated this value to 17.5 ± 5.3% of the spacecraft mass, with a peak emission at 68 km. While the predicted Skylon mass is comparable to the Space Shuttle mass, the Skylon reentry flight path is different from that of the Shuttle, and this would affect NOX production. Skylon is expected to require more time above 5 km/s during reentry than the Shuttle did, which would tend to produce more NOX. However, these high speeds would occur at a higher altitude than for the Space Shuttle, which would tend to decrease NOX production [Park, 1976]. Given the compensating factors, and in the absence of actual flight data, Skylon is assumed to have the same vertical profile of reentry NOX emission as the Space Shuttle, with the total values scaled by vehicle mass. The estimated total amount of NOX produced during reentry is therefore 9880 ± 2760 kg per flight. This range does not encompass the uncertainty in all the assumptions made, and thus the stated value of NOX production is considered only representative. The estimated altitude profiles of NOX emissions from the ascent and reentry phases are shown in Figure 1b.

Park [1976] compared NOX formation between the Space Shuttle and meteorites based on the total mass entering the top of the atmosphere. Assuming the natural formation rate of upper atmospheric NOX is from 5.7 × 107 kg of meteorites producing their weight in NOX every year [Park, 1976], then 105 Skylon flight reentries would produce a factor of 20 more NOX than natural production from meteorites. Meteorites produce roughly 5× more NOX per mass than the Space Shuttle due to their much higher velocity when entering the atmosphere.

3 Model Descriptions

Table 1 summarizes the simulations that are run and includes the rocket emissions considered in each case. The Community Earth System Model (CESM v1.0.6) using the WACCM model [Marsh et al., 2013] is used to simulate these emissions. WACCM was chosen because the model domain extends higher than most climate models (140 km) and it can include interactive chemistry. Simulations are run with fixed sea surface temperatures and perpetual year 2000 anthropogenic emissions and CO2 concentrations at 1.9 × 2.5° resolution with 66 vertical levels using a hybrid sigma coordinate system. Cases with different emissions and flight frequency are compared to a zero‐emission control case. Vertical emission profiles of H2O, H2, and NOX are included into two model horizontal grid cells spanning the equator. An equatorial launch is assumed because the energy required to put a rocket into orbit increases with launch latitude. Sensitivity tests are also run with the NOCAR model as these tests would be computationally expensive using WACCM. The NOCAR model is used to evaluate the sensitivity of our results to launch location, chlorine and greenhouse gas concentrations, emissions products, and number of launches per year. Including emissions into global model grid cells effectively dilutes the concentration of emissions compared to an actual rocket plume. The size of the equatorial grid cells is roughly 200 × 250 km2, which is about 1000 times larger in area than a rocket plume. The concentrations used in the model are thus 1000 times less than exist in the initial rocket plumes. Another assumption is that the emissions fill the grid cell before any chemical changes take place. Studies such as Lohn et al. [1999] and Ross et al. [1997] have looked into O3 depletion and other atmospheric effects inside rocket plumes. Lohn et al. [1999] found that solid rocket motor exhaust plumes from Titan class rockets destroy all of the O3 in the wake of the rocket. These predictions were verified by in situ plume measurements [Ross et al., 1997]. The ozone‐depleted regions are several square kilometers in size and last about an hour before dissipating to background concentrations. It is expected that plume chemistry will affect the composition and abundance of the rocket emissions that exist at the grid scale after the plume disperses. However, for the Skylon emissions, the amount of excess H2 emitted during rocket mode that is oxidized in the plume versus the amount present at the grid scale is unknown. Thus, the limiting cases are explored, one in which all the excess H2 is immediately oxidized (simulation 4) and one in which it all persists to the grid scale (simulation 5). The sensitivity of two of our assumptions are tested with the NOCAR model; specifically that H2O and H2 are the only relevant HOY species emitted, and secondly, that year 2000 greenhouse gas and chlorine levels are appropriate choices for this study. Some hydrogen will be emitted as HOY species, although it is likely to be very small. Swain et al. [1990] measured H2O2 in hydrogen burning engine exhaust and found it to be undetectable under normal operating conditions and up to 1000 ppmv under extremely inefficient conditions when the fuel to air ratio was around 5. Despite this, we simulate some of the hydrogen emitted as HOX or H2O2 using the NOCAR model. Note that due to the family chemistry scheme in NOCAR, we cannot emit OH directly, but instead emitted an equivalent quantity as HOX, which should produce the same amount of ozone destruction. The H2O2 can be emitted directly because it is long lived. Table 2 displays the global mean total column ozone changes relative to simulation 7 (Table 1) with and without these emissions. Including these emissions, even at relatively high amounts (1% mole fraction), results in essentially no change in O3 loss. The global mean total column ozone loss in these simulations is within 0.05 Dobson Units (DU) of the base case (simulation 7). Thus, these species (OH and H2O2) are not important to include in the WACCM simulations. The WACCM simulations assume year 2000 conditions; however, we note that flights of the Skylon space plane, especially at rates assumed in this paper, are decades away at best. Future levels of greenhouse gases and chlorine are estimated to be much higher and lower, respectively, than in the year 2000 [IPCC, 2013]. Thus, we also test the sensitivity of ozone loss on greenhouse gas and chlorine levels with the NOCAR model. These results are shown in Table 3. Using year 2100 chlorine levels increases the global total column ozone loss by 6% compared to simulation 7. Under a lower chlorine concentration, NOX increases destroy more ozone due to reduced formation of chlorine nitrate. However, water vapor increases induce less ozone destruction from polar stratospheric cloud (PSC) increases due to decreased chlorine. The net effect is increased ozone losses from rocket emissions. Increasing greenhouse gas levels to year 2100 offsets some of this extra loss and the sign of the final change depends on the relative amounts of the three greenhouse gases in the scenario. CO2 increases cause the rocket‐induced change to increase, while CH4 and N2O increases cause it to decrease. However, the changes are relatively small in all cases using the NOCAR model and we consider our WACCM simulations using year 2000 values as representative of any time between now and year 2100.

4 Stratospheric Ozone and Temperature Perturbations

Our base case scenario for 105 flights per year is simulation 7 in Table 1, which includes NOX, H2, and H2O emissions. The components of the emissions are modeled separately in simulations 1–6 to better understand the changes to O3. Plots of the O3 change due to the individual emission components can be found in the supplement. Preliminary WACCM simulations using a different emissions profile than Figure 1 and 104 flights per year did not produce any statistically significant global changes to the atmosphere. At 105 flights per year, as seen in simulation 7, stratospheric NOX concentrations increase by 0.3–3 parts per billion (ppb) and stratospheric H2O increases by 0–3 ppm. At this and higher flight frequencies significant changes occur in the stratosphere as shown in Figure 2.

At 105 flights per year O3 decreases significantly at all latitudes at altitudes above about 25 km and above 20 km at the poles as seen in simulation 7 (Figure 2a). The overlaid hatching (Figure 2a) indicates statistical significance from two different tests. As seen in Table 1, this depletion in O3 is predominantly due to catalytic destruction by NOX [Crutzen, 1970]. Our simulations with just NOX emissions (simulation 1) had almost the same amount of ozone destruction as the simulation with NOX, H2O, and H2 (simulation 7), and much more than simulations without NOX (simulations 4 and 5). Both sources of NOX, air‐breathing ascent and reentry, contribute to the destruction of O3 as seen in simulations 2 and 3. However, the models disagree about the relative contribution from these two emission sources. The NOCAR model attributes more O3 loss than WACCM does to NOX created in the mesosphere during reentry (simulation 2). In addition, including H2 emissions may further reduce total O3 compared to H2O emissions alone in WACCM simulations. Note that including H2 emissions does not exacerbate O3 loss in the NOCAR runs; in fact O3 loss is lessened between simulations 4 and 5. Moreover, assuming H2O emissions alone seems to lead to an increase in O3 in WACCM; however these results are within the range of internal variability.

#### That crosses tipping points

Loren Grush 18. Senior reporter. "Why it’s time to study how rocket emissions change the atmosphere". The Verge. 5-31-2018. https://www.theverge.com/2018/5/31/17287062/rocket-emissions-black-carbon-alumina-particles-ozone-layer-stratosphere

Every time a rocket launches, it produces a plume of exhaust in its wake that leaves a mark on the environment. These plumes are filled with materials that can collect in the air over time, potentially altering the atmosphere in dangerous ways. It’s a phenomenon that’s not well-understood, and some scientists say we need to start studying these emissions now before the number of rocket launches increases significantly. It’s not the gas in these plumes that’s most concerning. Some rockets do produce heat-trapping greenhouse gases, like carbon dioxide, but those emissions are negligible, according to experts. “The rocket business could grow by a factor of 1,000 and the carbon dioxide and water vapor emissions would still be small compared to other industrial sources,” Martin Ross, a senior project engineer at the Aerospace Corporation who studies the effects of rockets on the atmosphere, tells The Verge. Instead, it’s tiny particles that are produced inside the trail that we need to watch out for, Ross says. Small pieces of soot and a chemical called alumina are created in the wakes of rocket launches. They then get injected into the stratosphere, the layer of Earth’s atmosphere that begins six miles up and ends around 32 miles high. Research shows that this material may build up in the stratosphere over time and slowly lead to the depletion of a layer of oxygen known as the ozone. The ozone acts like a big shield, protecting Earth against the Sun’s harmful ultraviolet radiation. However, the magnitude of this ozone depletion isn’t totally known, says Ross. That’s why he and others at the Aerospace Corporation, a nonprofit that provides research and guidance on space missions, are calling for more studies. They say it’s especially important now since the private space industry is at the early stages of a launch revolution. Currently, the number of launches each year is relatively small, around 80 to 90, so the aerospace industry’s impact on the atmosphere is not much of a concern. But in a new paper published in April, Ross and his colleague Jim Vedda argue that as launches increase, policymakers will eventually want to know what kind of damage these vehicles are causing to the environment and if regulations are necessary. When that time comes, it will be better to have as much data as possible to make the best decisions. “It’s a call for more research in this area to know exactly what we’re putting into the upper atmosphere and in what quantities,” Vedda, a senior policy analyst at the Aerospace Corporation, tells The Verge. “So when the debates start, we have the good hard data that says, ‘Here’s a well-defined model of what’s actually happening.’” So far, the research we have about these emissions mostly comes from lab experiments, modeling, and some direct detections of rocket plumes. At the turn of the century, a few high-altitude planes equipped with sensors flew through plumes created by the Space Shuttle and other vehicles to figure out what was inside. Drifting plumes created by the Space Shuttle Atlantis. Image: NASA It turns out that all kinds of rockets produce these emissions, but some types of vehicles produce more than others. Rockets that run on solid propellants produce a higher amount of alumina particles, a combination of aluminum and oxygen that is white and reflective. Most orbital rockets don’t run on solid propellants these days, though some launch companies like the United Launch Alliance do add solid rocket boosters to vehicles to give them extra thrust. Meanwhile, rockets that run on liquid kerosene, a type of refined oil, produce more of the dark soot particles, what is known as black carbon. Kerosene is used as a propellant for rockets such as ULA’s Atlas V and SpaceX’s Falcon 9. Alumina and black carbon from rockets can stick around in the stratosphere for three to five years, according to Ross. As these materials collect high above the Earth, they can have interesting effects on the air. Black carbon forms a thin layer that intercepts and absorbs the sunlight that hits Earth. “It would act as a thin, black umbrella,” says Ross. That may help keep the lower atmosphere cool, but the intercepted energy from the Sun doesn’t just go away; it gets deposited into the stratosphere, warming it up. This warming ultimately causes chemical reactions that could lead to the depletion of the ozone layer. The reflective alumina particles can also affect the ozone but in a different way. Whereas the soot acts like a black umbrella, the alumina acts like a white one, reflecting sunlight back into space. However, chemical reactions occur on the surface of these white particles, which, in turn, destroy the ozone layer, Ross says. Black carbon and alumina have actually been proposed by scientists as possible geoengineering agents or tools for cooling down our warming climate. But while they may keep the lower atmosphere cool, geoengineering agents may have other unwanted side effects, too. They might interact with jet streams, causing droughts or more tropical storms. That’s why many scientists have criticized the idea of geoengineering to combat climate change. However, rockets are putting these particles into the air no matter what, and this byproduct of ozone loss is particularly concerning for Ross and Vedda. As the ozone diminishes, more of the Sun’s harmful radiation could reach the ground. These UVB rays can cause skin cancer and cataracts. “That’s what we need to understand — the ozone depletion aspect of this because protection of the ozone layer is an international imperative,” says Ross. The 1987 Montreal Protocol, for example, is an international agreement to phase out materials that deplete the ozone. Right now, Ross estimates that rocket launches around the world inject 10 gigagrams, or 11,000 tons, of soot and alumina particles into the atmosphere each year. But that number could be going up. SpaceX has vowed to increase the number of launches it does each year, and numerous other companies are going to start launching their own vehicles soon. What kind of impact that will have on the atmosphere is unclear. That’s why Ross and Vedda suggest the government and universities invest in a series of research programs, in which scientists collect more data on rocket particles from aircraft and satellites. “All of this plays into the scenario in which we’re envisioning a very significant increase in the number of launches, as these very large satellite constellations are deployed and as more nations get involved in space activities,” says Vedda. “Rocket emissions have been a pretty minuscule part of the emissions into the atmosphere, but this is going to change as the activity accelerates.” Vedda and Ross argue we should get ahead of the pollution issue before it has more drastic consequences, as we should have done with space debris. In the early days of spaceflight, no one was really concerned with how many spacecraft were put into space. But soon, experts recognized that this space debris could collide and build up over time, making low Earth orbit unusable someday. So now, there are regulations in place to prevent the problem from getting worse, but a lot of the damage had already been done. The researchers hope to be much more prepared about these rocket emissions: study as much as we can now, so we can make the best policy decisions in the future. “At some point, there will be a tipping point where all of a sudden, everybody says, ‘Wait a minute we need to understand this better,’” says Ross. “We want to be proactive before this tipping point occurs.”

#### That causes a laundry list of negative impacts --- increases diseases, causes food insecurity, and ocean biodiversity loss

Michele M. Betsill 16. Professor in Residence and Chair of Political Science department at Colorado State University, Ph.D in Environmental Politics and Policy, “Impacts Of Stratospheric Ozone Depletion” http://www.climate-policy-watcher.org/hydrology/impacts-of-stratospheric-ozone-depletion.html

Stratospheric ozone depletion was recognized as an environmental problem in need of international attention because it impacts both humans and the natural environment. When stratospheric ozone levels decrease, the amount of UV-B reaching Earth's surface increases (WMO, 1995). The changes in UV-B radiation are highest at high and midlatitudes in both hemispheres while the increases are fairly small in the tropics (UNEP, 1994). Increased levels of UV-B affect human health, the productivity of plant and animal species, as well as the composition of ecosystems. Impacts on Human Health Ultraviolet exposure does have some benefits for humans. For example, it initiates the production of vitamin D3, which is believed to inhibit the growth of tumor cells (UNEP, 1996). However, the balance of evidence indicates that the effects of stratospheric ozone depletion on human health are negative. The major risks include increased incidence of eye diseases, skin cancer, and infectious diseases. When UV-B levels increase, two main organ systems are exposed: the eyes and the skin. The impacts of ozone depletion are mediated through these two systems (Longstreth et al„ 1995; UNEP, 1998). Evidence suggests that increased UV-B radiation exposure may be associated with an increase in the incidence of cataracts, a clouding of the lens of the eye (Longstreth et al, 1995; UNEP, 1998). One review of research on this problem reported that a 1% increase in stratospheric ozone depletion would result in a 0.6 to 0.8% increase in the incidence of cataracts (UNEP, 1994; see also UNEP, 1998). The most widely known impact of increased UV-B radiation on human health is skin cancer. UV-B radiation damages deoxyribonucleic acid (DNA), which may cause gene mutations and the formation of cancer cells. Some studies estimate that a sustained 10% decrease in average stratospheric ozone concentrations would result in 250,000 new cases of nonmelanoma skin cancer. This is in addition to the 1.2 million cases already reported each year (Longstreth et al., 1995; UNEP, 1996). Many animal species, such as cows, goats, sheep, cats, and dogs, are also at increased risk of developing skin cancer as a result of increased exposure to UV-B radiation (UNEP, 1998). In an assessment of the effect of the Montreal Protocol and its amendments in protecting the ozone layer, Slaper and his colleagues (1996) concluded these efforts will substantially decrease the growth rate of the incidence of skin cancer over the next century. They found that under a scenario where there were no limits on the production and consumption of ozone-depleting substances, there would be a quadrupling in the incidence of skin cancer by the year 2100. Under the provisions of the Montreal Protocol (a 50% reduction in the production of CFCs by 1999), a doubling in the incidence of skin cancer could be expected in that same period. In contrast, they found the Copenhagen Amendments scenario (a complete phase-out in the production of 21 ozone-depleting substances by January 1, 1996) would result in a 10% increase in skin cancer incidence, peaking in the year 2060. This study lends support to the importance of international efforts to combat stratospheric ozone depletion. Researchers believe that skin exposure to increased levels of UV-B radiation is also linked to modifications in the human immune system. As a result, the ability of the immune system to respond to certain infectious diseases, such as tuberculosis, leprosy, and Lyme disease, is impaired (UNEP, 1998). Longstreth and her colleagues (1995) predict that higher levels of UV-B will result in increased severity and duration of diseases such as lupus rather than an increase in their incidence. Impacts on Aquatic Systems The balance of evidence indicates that increased UV-B radiation can have harmful effects on many species of aquatic organisms and the aquatic systems in which they live (SCOPE, 1993; UNEP, 1998). For example, studies in the Antarctic have linked increased UV-B levels to reduced phytoplankton productivity. Phytoplankton are the basis for the oceanic food chain. UV-B radiation affects the DNA, photosynthesis, enzyme activity, and nitrogen incorporation of phytoplankton. Reduced phytoplankton productivity will likely lead to reduced productivity further up the food chain. It has been estimated that a 16% reduction in stratospheric ozone could lead to a 5% loss of phytoplankton causing a loss of 7 million tons of fish worldwide per year (Hader et al., 1995; UNEP, 1994, 1996). Figure 1 illustrates the effects of UV-B radiation on phytoplankton. Researchers have also found that enhanced UV-B radiation disrupts the early development of several species of fish, shrimp, and crabs, ultimately affecting their motility (Hader et al., 1995). In damaging aquatic organisms, stratospheric Effects of enhanced solar UV-B irradiation on phytoplai Motility Vertical distribution In the water column Global consequences Reduced carbon dioxide sink? Effects of enhanced solar UV-B irradiation on phytoplai Motility Vertical distribution In the water column Reduced biomass production? Competition between species? Temperature increase? Food web in the ocean? Figure 1 Effects of UV-B radiation on phytoplankton (from Hader et al, 1995, p. 178). ozone depletion has serious implications for the world food supply. Globally, 30% of the animal protein consumed by humans comes from the oceans. The percentage is much higher in developing countries (UNEP, 1998). These impacts are particularly worrisome in light of the growing world population. Impacts on Terrestrial Plants and Ecosystems Scientific understanding of the impact of enhanced UV-B on terrestrial plants and ecosystems is incomplete. The majority of studies have been conducted in growth chambers and greenhouses under controlled conditions, conditions that are often quite different from those experienced in the field. Thus, researchers contend it is necessary to use caution in making generalizations about the impacts of enhanced UV-B on terrestrial plants. The results of existing studies need to be verified under field conditions (Caldwell et al., 1995). Keeping the limitations of existing research in mind, it is still possible to make some statements about the effect of enhanced UV-B on terrestrial plants. It appears that increased UV-B radiation may have both direct and indirect effects on plants. Some plant species exhibit a reduction in leaf area and/or stem growth when exposed to higher levels of UV-B. In addition, UV-B may also inhibit photosynthesis, damage plant DNA, and alter the time of flowering as well as the number of flowers in some species. The latter has implication for the availability of pollinators and thus the reproductive capacity of plants (Caldwell et al., 1995; UNEP, 1998). The effects of UV-B on plants are not always straightforward but rather depend on the species, the cultivar, and developmental stage of the plants as well as mineral nutrition in the soil, drought, and local air pollutants (Caldwell et al., 1995; UNEP, 1998). In affecting plants, enhanced UV-B radiation may ultimately lead to changes in entire ecosystems. In nonagricultural ecosystems (e.g., forests and grasslands), the balance of plants may change as some species are less able to respond to increases in UV-B radiation and their productivity declines. At the same time, the productivity of more responsive species will likely increase. The overall species composition of ecosystems will change, as will species interactions and ecosystem dynamics (Caldwell et al., 1995; UNEP, 1998).

#### That causes viruses to human bacterial genome --- the next pandemic will be existential

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Expert argues that human-caused changes to the environment can lead to the emergence of pathogens, not only from outside but also from our own microbiome, which can pave the way for large-scale destruction of humans and **even our extinction**. Whenever there is a change in any system, it will cause other changes to reach a balance or equilibrium, generally at a point different from the original balance. Although this principle was originally posited by the French chemist Henry Le Chatelier for chemical reactions, this theory can be applied to almost anything else. In an essay published on the online server Preprints\*, Eleftherios P. Diamandis of the University of Toronto and the Mount Sinai Hospital, Toronto, argues that changes caused by humans, to the climate, and everything around us will lead to changes that may have a dramatic impact on human life. Because our ecosystems are so complex, we don’t know how our actions will affect us in the long run, so humans generally disregard them. Changing our environment Everything around us is changing, from living organisms to the climate, water, and soil. Some estimates say about half the organisms that existed 50 years ago have already become extinct, and about 80% of the species may become extinct in the future. As the debate on global warming continues, according to data, the last six years have been the warmest on record. Global warming is melting ice, and sea levels have been increasing. The changing climate is causing more and more wildfires, which are leading to other related damage. At the same time, increased flooding is causing large-scale devastation. One question that arises is how much environmental damage have humans already done? A recent study compared the natural biomass on Earth to the mass produced by humans and found humans produce a mass equal to their weight every week. This human-made mass is mainly for buildings, roads, and plastic products. In the early 1900s, human-made mass was about 3% of the global biomass. Today both are about equal. Projections say by 2040, the human-made mass will be triple that of Earth’s biomass. But, slowing down human activity that causes such production may be difficult, given it is considered part of our growth as a civilization. Emerging pathogens Although we are made up of human cells, we have almost ten times that of bacteria just in our guts and more on our skin. These microbes not only affect locally but also affect the entire body. There is a balance between the good and bad bacteria, and any change in the environment may cause this balance to shift, especially on the skin, the consequences of which are unknown. Although most bacteria on and inside of us are harmless, gut bacteria can also have viruses. If viruses don’t kill the bacteria immediately, they can incorporate into the bacterial genome and stay latent for a long time until reactivation by environmental factors, when they can become pathogenic. They can also escape from the gut and enter other organs or the bloodstream. Bacteria can then use these viruses to kill other bacteria or help them evolve to more virulent strains. An example of the evolution of pathogens is the cause of the current pandemic, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Several mutations are now known that make the virus more infectious and resistant to immune responses, and strengthening its to enter cells via surface receptors. The brain There is evidence that the SARS-CoV-2 can also affect the brain. The virus may enter the brain via the olfactory tract or through the angiotensin-converting enzyme 2 (ACE2) pathway. Viruses can also affect our senses, such as a loss of smell and taste, and there could be other so far unkown neurological effects. The loss of smell seen in COVID-19 could be a new viral syndrome specific to this disease. Many books and movies have described pandemics caused by pathogens that wipe out large populations and cause severe diseases. In the essay, the author provides a hypothetical scenario where a gut bacteria suddenly starts producing viral proteins. Some virions spread through the body and get transmitted through the human population. After a few months, the virus started causing blindness, and within a year, large populations lost their vision. Pandemics can cause other diseases that can threaten humanity’s entire existence. **The COVID-19 pandemic brought this possibility to the forefront**. If we continue disturbing the equilibrium between us and the environment, we don’t know what the consequences may be and **the next pandemic could lead us to extinction.**

#### Oceans are key to overall biodiversity

Schofield 14 3-10-2014 “Why our precious oceans are under threat” <http://uowblogs.com/globalchallenges/2014/03/10/the-threats-facing-our-precious-oceans/> (Director of Research at the Australian Centre for Ocean Resource and Security University of Wollongong)//Elmer

Science fiction author Arthur C Clarke once observed, “How inappropriate to call this planet Earth when it is quite clearly Ocean.” Good point, well made. The oceans clearly dominate the world spatially, encompassing around 72 per cent of the surface of the planet. The vast extent of the oceans only tells part of the story, however. The oceans are critical to the global environment and human survival in numerous ways – they are vital to the global nutrient cycling, represent a key repository and supporter of biological diversity on a world scale and play a fundamental role in driving the global atmospheric system.Coastal and marine environments support and sustain key habitats and living resources, notably fisheries and aquaculture. These resources continue to provide a critical source of food for hundreds of millions of people.The fishing industry supports the livelihoods of an estimated 540 million people worldwide and fisheries supply more than 15 per cent of the animal protein consumed by 4.2 billion people globally. Moreover, the oceans are an increasing source of energy resources and underpin the global economy through sea borne trade. Overall, it has been estimated that 61 per cent of global GNP is sourced from the oceans and coastal areas within 100km of the sea. Coasts and marine zones also provide essential, but often not fully acknowledged, ecosystem services. Coasts and marine zones are therefore of critical importance across scales, from the global to the regional, national and sub-national coastal community levels. At the same time the oceans also remain largely (95 per cent) unexplored.

#### Biodiversity loss causes extinction

Torres 16 Phil Torres 4-11-2016 “Biodiversity loss: An existential risk comparable to climate change” thebulletin.org/biodiversity-loss-existential-risk-comparable-climate-change9329 (founder of the X-Risks Institute, an affiliate scholar at the Institute for Ethics and Emerging Technologies)//Elmer

The sixth extinction. The repercussions of biodiversity loss are potentially as severe as those anticipated from climate change, or even a nuclear conflict. For example, according to a 2015 study published in Science Advances, the best available evidence reveals “an exceptionally rapid loss of biodiversity over the last few centuries, indicating that a sixth mass extinction is already under way.” This conclusion holds, even on the most optimistic assumptions about the background rate of species losses and the current rate of vertebrate extinctions. The group classified as “vertebrates” includes mammals, birds, reptiles, fish, and all other creatures with a backbone. The article argues that, using its conservative figures, the average loss of vertebrate species was 100 times higher in the past century relative to the background rate of extinction. (Other scientists have suggested that the current extinction rate could be as much as 10,000 times higher than normal.) As the authors write, “The evidence is incontrovertible that recent extinction rates are unprecedented in human history and highly unusual in Earth’s history.” Perhaps the term “Big Six” should enter the popular lexicon—to add the current extinction to the previous “Big Five,” the last of which wiped out the dinosaurs 66 million years ago. But the concept of biodiversity encompasses more than just the total number of species on the planet. It also refers to the size of different populations of species. With respect to this phenomenon, multiple studies have confirmed that wild populations around the world are dwindling and disappearing at an alarming rate. For example, the 2010 Global Biodiversity Outlook report found that the population of wild vertebrates living in the tropics dropped by 59 percent between 1970 and 2006. The report also found that the population of farmland birds in Europe has dropped by 50 percent since 1980; bird populations in the grasslands of North America declined by almost 40 percent between 1968 and 2003; and the population of birds in North American arid lands has fallen by almost 30 percent since the 1960s. Similarly, 42 percent of all amphibian species (a type of vertebrate that is sometimes called an “ecological indicator”) are undergoing population declines, and 23 percent of all plant species “are estimated to be threatened with extinction.” Other studies have found that some 20 percent of all reptile species, 48 percent of the world’s primates, and 50 percent of freshwater turtles are threatened. Underwater, about 10 percent of all coral reefs are now dead, and another 60 percent are in danger of dying. Consistent with these data, the 2014 Living Planet Report shows that the global population of wild vertebrates dropped by 52 percent in only four decades—from 1970 to 2010. While biologists often avoid projecting historical trends into the future because of the complexity of ecological systems, it’s tempting to extrapolate this figure to, say, the year 2050, which is four decades from 2010. As it happens, a 2006 study published in Science does precisely this: It projects past trends of marine biodiversity loss into the 21st century, concluding that, unless significant changes are made to patterns of human activity, there will be virtually no more wild-caught seafood by 2048. Catastrophic consequences for civilization. The consequences of this rapid pruning of the evolutionary tree of life extend beyond the obvious. There could be surprising effects of biodiversity loss that scientists are unable to fully anticipate in advance. For example, prior research has shown that localized ecosystems can undergo abrupt and irreversible shifts when they reach a tipping point. According to a 2012 paper published in Nature, there are reasons for thinking that we may be approaching a tipping point of this sort in the global ecosystem, beyond which the consequences could be catastrophic for civilization. As the authors write, a planetary-scale transition could precipitate “substantial losses of ecosystem services required to sustain the human population.” An ecosystem service is any ecological process that benefits humanity, such as food production and crop pollination. If the global ecosystem were to cross a tipping point and substantial ecosystem services were lost, the results could be “widespread social unrest, economic instability, and loss of human life.” According to Missouri Botanical Garden ecologist Adam Smith, one of the paper’s co-authors, this could occur in a matter of decades—far more quickly than most of the expected consequences of climate change, yet equally destructive. Biodiversity loss is a “threat multiplier” that, by pushing societies to the brink of collapse, will exacerbate existing conflicts and introduce entirely new struggles between state and non-state actors. Indeed, it could even fuel the rise of terrorism. (After all, climate change has been linked to the emergence of ISIS in Syria, and multiple high-ranking US officials, such as former US Defense Secretary Chuck Hagel and CIA director John Brennan, have affirmed that climate change and terrorism are connected.) The reality is that we are entering the sixth mass extinction in the 3.8-billion-year history of life on Earth, and the impact of this event could be felt by civilization “in as little as three human lifetimes,” as the aforementioned 2012 Nature paper notes. Furthermore, the widespread decline of biological populations could plausibly initiate a dramatic transformation of the global ecosystem on an even faster timescale: perhaps a single human lifetime. The unavoidable conclusion is that biodiversity loss constitutes an existential threat in its own right. As such, it ought to be considered alongside climate change and nuclear weapons as one of the most significant contemporary risks to human prosperity and survival.

#### Thus, I defend --- Resolved: The appropriation of outer space by private entities for private space tourism is unjust.

### 1AC - Framing

#### I value morality, as implied by the word ought in the resolution. The standard is maximizing wellbeing.

#### 1] only it can explain degrees of wrongness- it is worse to kill thousands than to lie to a friend- either ethical theories cannot explain comparative badness, or it collapses

#### 2] Use util – it’s impartial, specific to public actors, and resolves infinite regress which explains all value. Reject flawed calc indicts that misunderstand happiness and rely on problematic intuitions.

Greene 15 — (Joshua Greene, Professor of Psychology @ Harvard, being interviewed by Russ Roberts, “Joshua Greene on Moral Tribes, Moral Dilemmas, and Utilitarianism”, The Library of Economics and Liberty, 1-5-15, Available Online at <https://www.econtalk.org/joshua-greene-on-moral-tribes-moral-dilemmas-and-utilitarianism/#audio-highlights>, accessed 5-17-20, HKR-AM) \*\*NB: Guest = Greene, and only his lines are highlighted/underlined

Guest: Okay. So, I think utilitarianism is very much misunderstood. And this is part of the reason why we shouldn't even call it utilitarianism at all. We should call it what I call 'deep pragmatism', which I think better captures what I think utilitarianism is really like, if you really apply it in real life, in light of an understanding of human nature. But, we can come back to that. The idea, going back to the tragedy of common-sense morality is you've got all these different tribes with all of these different values based on their different ways of life. What can they do to get along? And I think that the best answer that we have is--well, let's back up. In order to resolve any kind of tradeoff, you have to have some kind of common metric. You have to have some kind of common currency. And I think that what utilitarianism, whether it's the moral truth or not, is provide a kind of common currency. So, what is utilitarianism? It's basically the idea that--it's really two ideas put together. One is the idea of impartiality. That is, at least as social decision makers, we should regard everybody's interests as of equal worth. Everybody counts the same. And then you might say, 'Well, but okay, what does it mean to count everybody the same? What is it that really matters for you and for me and for everybody else?' And there the utilitarian's answer is what is sometimes called, somewhat accurately and somewhat misleadingly, happiness. But it's not really happiness in the sense of cherries on sundaes, things that make you smile. It's really the quality of conscious experience. So, the idea is that if you start with anything that you value, and say, 'Why do you care about that?' and keep asking, 'Why do you care about that?' or 'Why do you care about that?' you ultimately come down to the quality of someone's conscious experience. So if I were to say, 'Why did you go to work today?' you'd say, 'Well, I need to make money; and I also enjoy my work.' 'Well, what do you need your money for?' 'Well, I need to have a place to live; it costs money.' 'Well, why can't you just live outside?' 'Well, I need a place to sleep; it's cold at night.' 'Well, what's wrong with being cold?' 'Well, it's uncomfortable.' 'What's wrong with being uncomfortable?' 'It's just bad.' Right? At some point if you keep asking why, why, why, it's going to come down to the conscious experience--in Bentham's terms, again somewhat misleading, the pleasure and pain of either you or somebody else that you care about. So the utilitarian idea is to say, Okay, we all have our pleasures and pains, and as a moral philosophy we should all count equally. And so a good standard for resolving public disagreements is to say we should go with whatever option is going to produce the best overall experience for the people who are affected. Which you can think of as shorthand as maximizing happiness--although I think that that's somewhat misleading. And the solution has a lot of merit to it. But it also has endured a couple of centuries of legitimate criticism. And one of the biggest criticisms--and now we're getting back to the Trolley cases, is that utilitarianism doesn't adequately account for people's rights. So, take the footbridge case. It seems that it's wrong to push that guy off the footbridge. Even if you stipulate that you can save more people's lives. And so anyone who is going to defend utilitarianism as a meta-morality--that is, a solution to the tragedy of common sense morality, as a moral system to adjudicate among competing tribal moral systems--if you are going to defend it in that way, as I do, you have to face up to these philosophical challenges: is it okay to kill on person to save five people in this kind of situation? So I spend a lot of the book trying to understand the psychology of cases like the footbridge case. And you mention these being kind of unrealistic and weird cases. That's actually part of my defense.

Russ: Yeah, there's some plus to it, I agree.

Guest: Right. And the idea is that your amygdala is responding to an act of violence. And most acts of violence are bad. And so it is good for us to have a gut reaction, which is really a reaction in your amygdala that's then sending a signal to your ventromedial prefrontal cortex and so on and so forth, and we can talk about that. It's good to have that reaction that says, 'Don't push people off of footbridges.' But if you construct a case in which you stipulate that committing this act of violence is going to lead to the greater good, and it still feels wrong, I think it's a mistake to interpret that gut reaction as a challenge to the theory that says we should do whatever in general is going to promote the greater good. That is, our gut reactions are somewhat limited. They are good for everyday life. It's good that you have a gut reaction that says, 'Don't go shoving people off of high places.' But that shouldn't be a veto against a general idea that otherwise makes a lot of sense. Which is that in the modern world, we have a lot of different competing value systems, and that the way to resolve disagreements among those different competing value systems is to say, 'What's going to actually produce the best consequences?' And best consequences measured in terms of the quality of people's experience. So, that's kind of completing or partially completing the circle between the tragedy of the commons, that discussion, and how do we get to the Trolleys.

#### 3] high magnitude threats outweigh-

#### A] they o/w under any framework- moral uncertainty and future gens

Pummer 15 — (Theron Pummer, Junior Research Fellow in Philosophy at St. Anne's College, University of Oxford, “Moral Agreement on Saving the World“, Practical Ethics University of Oxford, 5-18-2015, Available Online at http://blog.practicalethics.ox.ac.uk/2015/05/moral-agreement-on-saving-the-world/, accessed 7-2-2018, HKR-AM) \*\*we do not endorse ableist language=

There appears to be lot of disagreement in moral philosophy. Whether these many apparent disagreements are deep and irresolvable, I believe there is at least one thing it is reasonable to agree on right now, whatever general moral view we adopt: that it is very important to reduce the risk that all intelligent beings on this planet are eliminated by an enormous catastrophe, such as a nuclear war. How we might in fact try to reduce such existential risks is discussed elsewhere. My claim here is only that we – whether we’re consequentialists, deontologists, or virtue ethicists – should all agree that we should try to save the world. According to consequentialism, we should maximize the good, where this is taken to be the goodness, from an impartial perspective, of outcomes. Clearly one thing that makes an outcome good is that the people in it are doing well. There is little disagreement here. If the happiness or well-being of possible future people is just as important as that of people who already exist, and if they would have good lives, it is not hard to see how reducing existential risk is easily the most important thing in the whole world. This is for the familiar reason that there are so many people who could exist in the future – there are trillions upon trillions… upon trillions. There are so many possible future people that reducing existential risk is arguably the most important thing in the world, even if the well-being of these possible people were given only 0.001% as much weight as that of existing people. Even on a wholly person-affecting view – according to which there’s nothing (apart from effects on existing people) to be said in favor of creating happy people – the case for reducing existential risk is very strong. As noted in this seminal paper, this case is strengthened by the fact that there’s a good chance that many existing people will, with the aid of life-extension technology, live very long and very high quality lives. You might think what I have just argued applies to consequentialists only. There is a tendency to assume that, if an argument appeals to consequentialist considerations (the goodness of outcomes), it is irrelevant to non-consequentialists. But that is a huge mistake. Non-consequentialism is the view that there’s more that determines rightness than the goodness of consequences or outcomes; it is not the view that the latter don’t matter. Even John Rawls wrote, “All ethical doctrines worth our attention take consequences into account in judging rightness. One which did not would simply be irrational, crazy.” Minimally plausible versions of deontology and virtue ethics must be concerned in part with promoting the good, from an impartial point of view. They’d thus imply very strong reasons to reduce existential risk, at least when this doesn’t significantly involve doing harm to others or damaging one’s character. What’s even more surprising, perhaps, is that even if our own good (or that of those near and dear to us) has much greater weight than goodness from the impartial “point of view of the universe,” indeed even if the latter is entirely morally irrelevant, we may nonetheless have very strong reasons to reduce existential risk. Even egoism, the view that each agent should maximize her own good, might imply strong reasons to reduce existential risk. It will depend, among other things, on what one’s own good consists in. If well-being consisted in pleasure only, it is somewhat harder to argue that egoism would imply strong reasons to reduce existential risk – perhaps we could argue that one would maximize her expected hedonic well-being by funding life extension technology or by having herself cryogenically frozen at the time of her bodily death as well as giving money to reduce existential risk (so that there is a world for her to live in!). I am not sure, however, how strong the reasons to do this would be. But views which imply that, if I don’t care about other people, I have no or very little reason to help them are not even minimally plausible views (in addition to hedonistic egoism, I here have in mind views that imply that one has no reason to perform an act unless one actually desires to do that act). To be minimally plausible, egoism will need to be paired with a more sophisticated account of well-being. To see this, it is enough to consider, as Plato did, the possibility of a ring of invisibility – suppose that, while wearing it, Ayn could derive some pleasure by helping the poor, but instead could derive just a bit more by severely harming them. Hedonistic egoism would absurdly imply she should do the latter. To avoid this implication, egoists would need to build something like the meaningfulness of a life into well-being, in some robust way, where this would to a significant extent be a function of other-regarding concerns (see chapter 12 of this classic intro to ethics). But once these elements are included, we can (roughly, as above) argue that this sort of egoism will imply strong reasons to reduce existential risk. Add to all of this Samuel Scheffler’s recent intriguing arguments (quick podcast version available here) that most of what makes our lives go well would be undermined if there were no future generations of intelligent persons. On his view, my life would contain vastly less well-being if (say) a year after my death the world came to an end. So obviously if Scheffler were right I’d have very strong reason to reduce existential risk. We should also take into account moral uncertainty. What is it reasonable for one to do, when one is uncertain not (only) about the empirical facts, but also about the moral facts? I’ve just argued that there’s agreement among minimally plausible ethical views that we have strong reason to reduce existential risk – not only consequentialists, but also deontologists, virtue ethicists, and sophisticated egoists should agree. But even those (hedonistic egoists) who disagree should have a significant level of confidence that they are mistaken, and that one of the above views is correct. Even if they were 90% sure that their view is the correct one (and 10% sure that one of these other ones is correct), they would have pretty strong reason, from the standpoint of moral uncertainty, to reduce existential risk. Perhaps most disturbingly still, even if we are only 1% sure that the well-being of possible future people matters, it is at least arguable that, from the standpoint of moral uncertainty, reducing existential risk is the most important thing in the world. Again, this is largely for the reason that there are so many people who could exist in the future – there are trillions upon trillions… upon trillions. (For more on this and other related issues, see this excellent dissertation). Of course, it is uncertain whether these untold trillions would, in general, have good lives. It’s possible they’ll be miserable. It is enough for my claim that there is moral agreement in the relevant sense if, at least given certain empirical claims about what future lives would most likely be like, all minimally plausible moral views would converge on the conclusion that we should try to save the world. While there are some non-crazy views that place significantly greater moral weight on avoiding suffering than on promoting happiness, for reasons others have offered (and for independent reasons I won’t get into here unless requested to), they nonetheless seem to be fairly implausible views. And even if things did not go well for our ancestors, I am optimistic that they will overall go fantastically well for our descendants, if we allow them to. I suspect that most of us alive today – at least those of us not suffering from extreme illness or poverty – have lives that are well worth living, and that things will continue to improve. Derek Parfit, whose work has emphasized future generations as well as agreement in ethics, described our situation clearly and accurately: “We live during the hinge of history. Given the scientific and technological discoveries of the last two centuries, the world has never changed as fast. We shall soon have even greater powers to transform, not only our surroundings, but ourselves and our successors. If we act wisely in the next few centuries, humanity will survive its most dangerous and decisive period. Our descendants could, if necessary, go elsewhere, spreading through this galaxy…. Our descendants might, I believe, make the further future very good. But that good future may also depend in part on us. If our selfish recklessness ends human history, we would be acting very wrongly.” (From chapter 36 of On What Matters)

#### B] Cognitive biases to under-estimate existential risk --- overcorrect in favor the AFF’s probability.

--- must preserve infinite lives and generations.

--- question of intergenerational equity.

--- existential threats are underestimated: global public good, intergenerational, unprecedented, scope neglect.

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>, Accessed 7/22/2017, Kent Denver-jKIM)

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