## 2

#### Interpretation: The aff must defend the appropriation of outer space by private entities is unjust or a subset thereof

#### Violation: Mega Constellations aren’t appropriation.

#### Megaconstellations are not appropriation since they respect free use, are consistent with existing precedent for non-appropriation, are not stationary, and do not reflect the intent to appropriate.

Johnson 20 [Christopher D. Johnson, “The Legal Status of MegaLEO Constellations and Concerns About Appropriation of Large Swaths of Earth Orbit,” Handbook of Small Satellites, 2020-09-13, p.1337-1358] CT

5.2 No, This Is Not Impermissible Appropriation

An opposite conclusion can also be reasonably arrived at when approached along the following lines. The counter argument would assert that the deployment and operation of these global constellations, such as SpaceX’s Starlink, OneWeb, Kepler, etc., are aligned with and in full conformity with the laws applicable to outer space. These constellations are merely the exercise and enjoyment of the freedom of exploration and use of outer space and do not constitute any impermissible appropriation of the orbits that they transit.

5.2.1 Freedom of Access and Use Permits Constellations

Rather than being a violation of other’s rights to access and explore outer space, the deployment of these constellations is more correctly viewed as the exercise and restrict or impinge on other users of the space domain. Because due regard is therefore displayed for the space domain, and to the interests of others, these constellations do not prejudice or infringe upon the freedoms of use and exploration of the space domain and are therefore not occupation, or possession, much less appropriation.

5.2.4 This Does Not Constitute Possession, or Ownership, or Occupation

The use of LEO by satellite constellations is substantially similar to the use of GSO, and therefore permissible. In each region, individual actors are given permission - either from a national administrator or from an international governing body (the ITU) via a national administer–to use precoordinated subsections of space. In a way that is overwhelmingly similar to the use of orbital slots in GSO, the placement of spacecraft into orbits in LEO or higher orbits does not constitute possession, ownership, or occupation of those orbits. This is because States (and their companies) have been occupying orbital slots in GSO for decades, and these uses of GSO have never been accused of “appropriating” GSO. The users have never claimed to be appropriating GSO, and their exercising of rights to use GSO is respected by other actors in the space domain. This is the same situation for other orbits, including LEO and other non-Geostationary orbits. And while GSO locations are relatively stable (subject to space weather and other perturbations, and require stationkeeping), spacecraft in LEO are actually moving through space and are not stationary, so it is even more difficult to see this use by constellations as occupation, much less appropriation. Moreover, Space Situational Awareness (SSA) and Space Traffic Management (STM) will allow other uses to use these orbits, and nothing about the use of any one user necessarily precludes others. Lastly, there is no intention by operators of constellations to exclusively occupy, must less possess or appropriate, these orbits. Would not the appropriation of outer space be an intentional, volutional act? No such intention can be found in the operators of global constellations.

#### Vote neg – two impacts:

#### Limits. Expanding the topic to anything that involves merely launching something into the atmosphere expands the topic into numerous new tech areas which undermines core neg prep.

#### Topic literature. Our definition has intent to define and exclude in the context of the OST, which is the core of all topic research and the only predictable source.

#### Drop the debater to preserve fairness and education – use competing interps – reasonability invites arbitrary judge intervention and a race to the bottom of questionable argumentation. No RVIs – they don’t get to win for following the rules.

## SSP PIC

#### Mega constellations in low-Earth Orbit by private entities except for space-based solar power megaconstellations are unjust.

#### SSP is viable and requires privatization.

Oberhaus 21 [DANIEL OBERHAUS, “Space Solar Power: An Extraterrestrial Energy Resource For The U.S.,” Innovation Frontier Project, August 18, 2021. <https://innovationfrontier.org/space-solar-power-an-extraterrestrial-energy-resource-for-the-u-s/>] CT

FUTURE OF SSP

The United States’ reluctance to pursue SSP can be attributed to a number of causes. In the 1970s and 80s, the exorbitant projected costs of an SSP station guaranteed that the project would not be pursued by NASA, the DOE, or the DOD. At the same time, the agency’s emphasis on developing nuclear space technologies — a trend that continues to this day — undermined enthusiasm for other ambitious energy projects like SSP. Finally, the fact that SSP is a space project meant to provide commercial levels of electrical power on Earth meant that it wasn’t obvious whether it fell within the purview of NASA or the DOE, and so both agencies were reluctant to allocate a substantial portion of their budget for its development. Today, the low cost of natural gas and renewables like wind and solar makes it seem challenging to justify a space energy project of this scale. But SSP offers several unique benefits as an energy resource, including its resiliency, its ability to provide flexible baseload power to geographically distant locations, its capacity to accelerate decarbonization directly by providing clean energy and indirectly by expediting the transition to off-world heavy industry, and its strategic benefits as a tool for diplomacy and national security. Given SSP’s benefits and the interest in the technology from most other space agencies, it’s puzzling that policymakers in the United States have not prioritized SSP R&D. The development of key technologies such as reusable rockets and thin film solar panels has finally made SSP economically and technically viable. But there is still a lot of fundamental research on SSP that needs to be done and it is in the United States’ national interest to begin this research program as soon as possible. So far, the only glimmer of hope for an American SSP program has come from the DOD’s efforts. In 2019, the Air Force Research Lab awarded a $100 million contract to Northrop Grumman as part of the new Space Solar Power Incremental Demonstrations and Research (SSPIDR) Project, which aims to develop hardware for in-orbit SSP experiments based on the design developed at Caltech.105 This is by far the United States’ largest federal expenditure on SSP R&D, but it is only a fraction of what will be required to build a large-scale SSP station and the specific technologies included in the SSPIDR program will not result in a system that could ever provide commercial power to civilians. SSP is a key tool for ensuring the prosperity and security of the United States in the latter half of the 21st century. It is imperative that NASA and the DOE prioritize the development of SSP. We believe the federal government should earmark approximately $1 billion for SSP research over the next five years with a special emphasis on advancing emerging technologies and in-space hardware demonstrations. Congress must take the first step in establishing a civilian SSP platform by directing NASA and the DOE to collaborate on a public-private initiative similar to NASA’s commercial crew program or its more recent commercial lunar payload services program. The directive must clearly delineate responsibilities between the agencies in order to avoid leadership paralysis that has stymied domestic SSP research in the past. Furthermore, a public-private program must be structured so that there is competition among multiple private companies, which must hit key milestones in order to continue receiving contracts. These contracts should be awarded with a fixed-price structure to avoid the massive cost overruns and delays that are typical of cost-plus contracts in the aerospace and defense sector. This is also an approach likely to find support among new launch providers and spacecraft manufacturers that have demonstrated the innovation that occurs when operating within the relative constraints of fixed price contracts. In fact, the main trade group for the aerospace sector has advocated for the increased use of fixed-price contracts in the past.106 Alternatively, it may be more efficient to establish a focused research organization (FRO) dedicated to SSP technologies to avoid delays associated with collaboration between two federal agencies on multi-year—and perhaps multi-decade—projects. FROs are independent entities that exist outside of national laboratories and universities. They are effectively a startup for basic research and deep technological development that requires large-scale engineering collaboration on technologies that may not yet have a market or are not readily monetizable.107 Recently, the U.S. Congress created five FRO-like centers in the DOE’s national labs as part of the National Quantum Initiative Act, which can serve as a framework for the creation of similar FROs dedicated to space solar power.108 While there are several approaches to a large-scale SSP system, we believe the most fruitful pathway is to focus on cost reduction over energy efficiency. This would prioritize highly modular systems similar to ALPHA, which benefit from the substantially reduced costs of mass manufacturing standardized components. We believe that it is possible to conduct a civilian SSP demonstration in low-Earth orbit within three years of the program’s start with less than $250 million in funding. The first phase of this program would involve conducting a series of ground tests with prototype systems over the course of about 18 months. Based on the results of this program, a system could be selected for an in-space demonstration capable of generating up to 300kw of power in low-Earth orbit. After a successful LEO demonstration mission, the next step would be to build a larger SSP system in mid-Earth orbit capable of producing commercial amounts of power (e.g., 1-10 MW). While this orbital altitude is not sufficient for maintaining the SSP system over a fixed spot on the Earth, it would stay on a fixed path so that it always passed over the same spots on the Earth. While the power from this MEO demonstrator would not be competitive with terrestrial electricity prices — we expect a cost of about $1/kwh — it would be a critical step toward proving the system’s ability to provide commercial power. We expect that the MEO demonstrator could be built and launched for approximately $1 billion. The success of the MEO demonstrator would lay the foundation for an SSP system in geostationary orbit that would be large enough to provide meaningful amounts of baseload power. We expect the initial version of this SSP system to be capable of delivering around 2 GW of solar energy to the surface. We expect that a 2 GW SSP system in geostationary orbit could be built for about $10 billion. Here we start to see the cost savings of mass manufacturing modular SSP components. This system would be capable of delivering more than 200 times more power than the MEO demonstrator for only 10 times the cost. We believe that a public-private SSP program jointly led by NASA and the DOE could result in a commercially viable SSP platform in geostationary orbit by the end of the decade. In addition to providing a critical pathway for SSP, it also has the potential to lead to substantial advancements in solar power and wireless power transmission technologies that would be useful on Earth. If policymakers do not take action on advancing domestic SSP capabilities soon, the United States will find itself losing its leadership position in space and increasingly vulnerable to natural and human-made disasters on the ground.

#### SSP solves warming. In the short term provides cheap, renewable, and flexible baseload power for on and off-world applications. It’s also key to transition heavy industry to space.

Oberhaus 21 [DANIEL OBERHAUS, “Space Solar Power: An Extraterrestrial Energy Resource For The U.S.,” Innovation Frontier Project, August 18, 2021. <https://innovationfrontier.org/space-solar-power-an-extraterrestrial-energy-resource-for-the-u-s/>] CT

EXECUTIVE SUMMARY

What is often left unsaid in discussions about extraterrestrial industrialization and deep space settlement is how to supply the energy needed for large scale infrastructure projects. Nuclear energy has long been the power source of choice for deep space missions.2 This is largely because nuclear power systems can operate for decades without intervention and in locations where there is limited or non-existent sunlight. But nuclear energy is limited in its ability to scale and also creates serious health hazards for near-Earth operation.3 In this paper, we make the case for space-based solar power (SSP) megaprojects as relatively low-cost, scalable, renewable, and always-on power source for on-and-off world applications. Although SSP is a space-based energy asset, it has the potential to rapidly accelerate decarbonization on Earth while also fulfilling space exploration priorities. SSP is a decades-old idea that has only recently become economically viable due to the rapidly falling costs of space access and technological advancements such as higher efficiency electronics, low-cost mass-production of modular space systems like satellites, robotic in-space construction, and wireless power transmission. NASA, the Department of Energy, and several other research agencies have conducted in-depth studies and limited experiments on SSP, but the development of this energy resource was hindered by unfavorable economics. Things have changed and it is time to reconsider SSP as a valuable tool in the nation’s decarbonization strategy. This paper shows how the development of SSP can serve several national imperatives at once. In space, it can provide a renewable and cost-effective source of energy for moon bases and deep space missions. SSP can also provide a valuable source of energy — both electric and thermal — for industrial processes in cislunar space. This will facilitate the transition of heavy industry from Earth to space, which will mitigate carbon emissions in the medium-to-long term on Earth. Critically, SSP will have a massive impact on terrestrial greenhouse gas (GHG) emissions in the near term through wireless energy transfer from space to Earth. This is SSP’s original “killer app,” and multiple studies have shown that SSP can meet a substantial portion of Earth’s energy needs. Unlike terrestrial solar power, SSP is always on. It can provide solar power rain or shine, day or night. It is also flexible and can be quickly redirected to ground stations in geographically distant locations

to meet rapidly changing energy needs. The dream for SSP is to have a source of clean baseload energy that’s available regardless of weather, location, or time of day. The baseload is the minimum electrical energy demand on a grid, which has historically been provided by power stations that are able to generate large and relatively constant amounts of energy. But as more renewables penetrate the grid and create fluctuations in electric supply, the base load power stations of the future must be flexible enough to rapidly ramp up and down to meet the evolving supply and demand dynamics of the grid. Much like the advent of GPS, a robust SSP capacity would have profound geopolitical implications. China is investing heavily in SSP and plans to have the first operating SSP plant in orbit by the end of the decade.4 The Department of Defense (DOD) is also pursuing SSP research for military applications. Notably, the Air Force Research Laboratory recently created a $100 million program to advance key SSP technologies.5 This paper concludes that the U.S. must allocate substantially more human and financial capital to SSP as part of its national security, domestic energy, and space exploration strategies.

#### Solving warming is not all-or-nothing – every additional fraction of a degree is irreversible and costs millions of lives—prefer IPCC assessments that are the gold standard for warming consensus.

David Wallace-Wells 19 [National Fellow at New America. He is deputy editor of New York Magazine, where he also writes frequently about climate and the near future of science and technology, including his widely read and debated 2017 cover story on worst-case scenarios for global warming], *The Uninhabitable Earth: A Story of the Future* (Kindle Edition: Allen Lane, 2019), pg. 8-30, beckert

* Every degree key – each bit 🡪 hundreds of millions of lives
* IPCC🡪best ev b/c conservative estimate + still really big impact
* Now key – not reversible, feedback loops 🡪 speeds up later

There is almost no chance we will avoid that scenario. The Kyoto Protocol achieved, practically, nothing; in the twenty years since, despite all of our climate advocacy and legislation and progress on green energy, we have produced more emissions than in the twenty years before. In 2016, the Paris accords established two degrees as a global goal, and, to read our newspapers, that level of warming remains something like the scariest scenario it is responsible to consider; just a few years later, with no single industrial nation on track to meet its Paris commitments, two degrees looks more like a best-case outcome, at present hard to credit, with an entire bell curve of more horrific possibilities extending beyond it and yet shrouded, delicately, from public view.28 For those telling stories about climate, such horrific possibilities—and the fact that we had squandered our chance of landing anywhere on the better half of that curve—had become somehow unseemly to consider. The reasons are almost too many to count, and so half-formed they might better be called impulses. We chose not to discuss a world warmed beyond two degrees out of decency, perhaps; or simple fear; or fear of fearmongering; or technocratic faith, which is really market faith; or deference to partisan debates or even partisan priorities; or skepticism about the environmental Left of the kind I’d always had; or disinterest in the fates of distant ecosystems like I’d also always had. We felt confusion about the science and its many technical terms and hard-to-parse numbers, or at least an intuition that others would be easily confused about the science and its many technical terms and hard-to-parse numbers. We suffered from slowness apprehending the speed of change, or semi-conspiratorial confidence in the responsibility of global elites and their institutions, or obeisance toward those elites and their institutions, whatever we thought of them. Perhaps we felt unable to really trust scarier projections because we’d only just heard about warming, we thought, and things couldn’t possibly have gotten that much worse just since the first Inconvenient Truth; or because we liked driving our cars and eating our beef and living as we did in every other way and didn’t want to think too hard about that; or because we felt so “postindustrial” we couldn’t believe we were still drawing material breaths from fossil fuel furnaces. Perhaps it was because we were so sociopathically good at collating bad news into a sickening evolving sense of what constituted “normal,” or because we looked outside and things seemed still okay. Because we were bored with writing, or reading, the same story again and again, because climate was so global and therefore nontribal it suggested only the corniest politics, because we didn’t yet appreciate how fully it would ravage our lives, and because, selfishly, we didn’t mind destroying the planet for others living elsewhere on it or those not yet born who would inherit it from us, outraged. Because we had too much faith in the teleological shape of history and the arrow of human progress to countenance the idea that the arc of history would bend toward anything but environmental justice, too. Because when we were being really honest with ourselves we already thought of the world as a zero-sum resource competition and believed that whatever happened we were probably going to continue to be the victors, relatively speaking anyway, advantages of class being what they are and our own luck in the natalist lottery being what it was. Perhaps we were too panicked about our own jobs and industries to fret about the future of jobs and industry; or perhaps we were also really afraid of robots or were too busy looking at our new phones; or perhaps, however easy we found the apocalypse reflex in our culture and the path of panic in our politics, we truly had a good-news bias when it came to the big picture; or, really, who knows why—there are so many aspects to the climate kaleidoscope that transforms our intuitions about environmental devastation into an uncanny complacency that it can be hard to pull the whole picture of climate distortion into focus. But we simply wouldn’t, or couldn’t, or anyway didn’t look squarely in the face ﻿of the science. This is not a book about the science of warming; it is about what warming means to the way we live on this planet. But what does that science say? It is complicated research, because it is built on two layers of uncertainty: what humans will do, mostly in terms of emitting greenhouse gases, and how the climate will respond, both through straightforward heating and a variety of more complicated, and sometimes contradictory, feedback loops. But even shaded by those uncertainty bars it is also very clear research, in fact terrifyingly clear. The United Nations’ Intergovernmental Panel on Climate Change (IPCC) offers the gold-standard assessments of the state of the planet and the likely trajectory for climate change—gold-standard, in part, because it is conservative, integrating only new research that passes the threshold of inarguability. A new report is expected in 2022, but the most recent one says that if we take action on emissions soon, instituting immediately all of the commitments made in the Paris accords but nowhere yet actually implemented, we are likely to get about 3.2 degrees of warming, or about three times as much warming as the planet has seen since the beginning of industrialization—bringing the unthinkable collapse of the planet’s ice sheets not just into the realm of the real but into the present.29, 30 That would eventually flood not just Miami and Dhaka but Shanghai and Hong Kong and a hundred other cities around the world.31 The tipping point for that collapse is said to be around two degrees; according to several recent studies, even a rapid cessation of carbon emissions could bring us that amount of warming by the end of the century.32 The assaults of climate change do not end at 2100 just because most modeling, by convention, sunsets at that point. This is why some studying global warming call the hundred years to follow the “century of hell.”33 Climate change is fast, much faster than it seems we have the capacity to recognize and acknowledge; but it is also long, almost longer than we can truly imagine. In reading about warming, you will often come across analogies from the planetary record: the last time the planet was this much warmer, the logic runs, sea levels were here. These conditions are not coincidences. The sea level was there largely because the planet was that much warmer, and the geologic record is the best model we have for understanding the very complicated climate system and gauging just how much damage will come from turning up the temperature by two or four or six degrees. Which is why it is especially concerning that recent research into the deep history of the planet suggests that our current climate models may be underestimating the amount of warming we are due for in 2100 by as much as half.34 In other words, temperatures could rise, ultimately, by as much as double what the IPCC predicts. Hit our Paris emissions targets and we may still get four degrees of warming, meaning a green Sahara and the planet’s tropical forests transformed into fire-dominated savanna.35 The authors of one recent paper suggested the warming could be more dramatic still—slashing our emissions could still bring us to four or five degrees Celsius, a scenario they said would pose severe risks to the habitability of the entire planet. “Hothouse Earth,” they called it.36 Because these numbers are so small, we tend to trivialize the differences between them—one, two, four, five. Human experience and memory offer no good analogy for how we should think of those thresholds, but, as with world wars or recurrences of cancer, you don’t want to see even one. At two degrees, the ice sheets will begin their collapse, 400 million more people will suffer from water scarcity, major cities in the equatorial band of the planet will become unlivable, and even in the northern latitudes heat waves will kill thousands each summer.37, 38 There would be thirty-two times as many extreme heat waves in India, and each would last five times as long, exposing ninety-three times more people.39 This is our best-case scenario. At three degrees, southern Europe would be in permanent drought, and the average drought in Central America would last nineteen months longer and in the Caribbean twenty-one months longer. In northern Africa, the figure is sixty months longer—five years. The areas burned each year by wildfires would double in the Mediterranean and sextuple, or more, in the United States. At four degrees, there would be eight million more cases of dengue fever each year in Latin America alone and close to annual global food crises.41 There could be 9 percent more heat-related deaths.40 Damages from river flooding would grow thirtyfold in Bangladesh, twentyfold in India, and as much as sixtyfold in the United Kingdom. In certain places, six climate-driven natural disasters could strike simultaneously, and, globally, damages could pass $600 trillion—more than twice the wealth as exists in the world today. Conflict and warfare could double. Even if we pull the planet up short of two degrees by 2100, we will be left with an atmosphere that contains 500 parts per million of carbon—perhaps more. The last time that was the case, sixteen million years ago, the planet was not two degrees warmer; it was somewhere between five and eight, giving the planet about 130 feet of sea-level rise, enough to draw a new American coastline as far west as I-95.42 Some of these processes take thousands of years to unfold, but they are also irreversible, and therefore effectively permanent. You might hope to simply reverse climate change; you can’t. It will outrun all of us. This is part of what makes climate change what the theorist Timothy Morton calls a “hyperobject”—a conceptual fact so large and complex that, like the internet, it can never be properly comprehended.43 There are many features of climate change—its size, its scope, its brutality—that, alone, satisfy this definition; together they might elevate it into a higher and more incomprehensible conceptual ﻿category yet. But time is perhaps the most mind-bending feature, the worst outcomes arriving so long from now that we reflexively discount their reality. Yet those outcomes promise to mock us and our own sense of the real in return. The ecological dramas we have unleashed through our land use and by burning fossil fuels—slowly for about a century and very rapidly for only a few decades—will play out over many millennia, in fact over a longer span of time than humans have even been around, performed in part by creatures and in environments we do not yet even know, ushered onto the world stage by the force of warming. And so, in a convenient cognitive bargain, we have chosen to consider climate change only as it will present itself this century. By 2100, the United Nations says, we are due for about 4.5 degrees of warming, following the path we are on today.44 That is, farther from the Paris track than the Paris track is from the two-degree threshold of catastrophe, which it more than doubles. As Naomi Oreskes has noted, there are far too many uncertainties in our models to take their predictions as gospel.45 Just running those models many times, as Gernot Wagner and Martin Weitzman do in their book Climate Shock, yields an 11 percent chance we overshoot six degrees.46 Recent work by the Nobel laureate William Nordhaus suggests that better-than-anticipated economic growth means better than one-in-three odds that our emissions will exceed the U.47N.’s worst-case “business as usual” scenario. In other words, a temperature rise of five degrees or possibly more. The upper end of the probability curve put forward by the U.N. to estimate the end-of-the-century, business-as-usual scenario—the worst-case outcome of a worst-case emissions path—puts us at eight degrees. At that temperature, humans at the equator and in the tropics would not be able to move around outside without dying.48 In that world, eight degrees warmer, direct heat effects would be the least of it: the oceans would eventually swell two hundred feet higher, flooding what are now two-thirds of the world’s major cities; hardly any land on the planet would be capable of efficiently producing any of the food we now eat; forests would be roiled by rolling storms of fire, and coasts would be punished by more and more intense hurricanes; the suffocating hood of tropical disease would reach northward to enclose parts of what we now call the Arctic; probably about a third of the planet would be made unlivable by direct heat; and what are today literally unprecedented and intolerable droughts and heat waves would be the quotidian condition of whatever human life was able to endure.49, 50, 51, 52 We will, almost certainly, avoid eight degrees of warming; in fact, several recent papers have suggested the climate is actually less sensitive to emissions than we’d thought, and that even the upper bound of a business-as-usual path would bring us to about five degrees, with a likely destination around four.53 But five degrees is nearly as unthinkable as eight, and four degrees not much better: the world in a permanent food deficit, the Alps as arid as the Atlas Mountains.54 Between that scenario and the world we live in now lies only the open question of human response. Some amount of further warming is already baked in, thanks to the protracted processes by which the planet adapts to greenhouse gas. But all of those paths projected from the present—to two degrees, to three, to four, five, or even eight—will be carved overwhelmingly by what we choose to do now. There is nothing stopping us from four degrees other than our own will to change course, which we have yet to display. Because the planet is as big as it is, and as ecologically diverse; because humans have proven themselves an adaptable species, and will likely continue to adapt to outmaneuver a lethal threat; and because the devastating effects of warming will soon become too extreme to ignore, or deny, if they haven’t already; because of all that, it is unlikely that climate change will render the planet truly uninhabitable. But if we do nothing about carbon emissions, if the next thirty years of industrial activity trace the same arc upward as the last thirty years have, whole regions will become unlivable by any standard we have today as soon as the end of this century. ﻿A few years ago, E. O. Wilson proposed a term, “Half-Earth,” to help us think through how we might adapt to the pressures of a changing climate, letting nature run its rehabilitative course on half the planet and sequestering humanity in the remaining, habitable half of the world.55 The fraction may be smaller than that, possibly considerably, and not by choice; the subtitle of his book was Our Planet’s Fight for Life. On longer timescales, the even-bleaker outcome is possible, too—the livable planet darkening as it approaches a human dusk. It would take a spectacular coincidence of bad choices and bad luck to make that kind of zero earth possible within our lifetime. But the fact that we have brought that nightmare eventuality into play at all is perhaps the overwhelming cultural and historical fact of the modern era—what historians of the future will likely study about us, and what we’d have hoped the generations before ours would have had the foresight to focus on, too. Whatever we do to stop warming, and however aggressively we act to protect ourselves from its ravages, we will have pulled the devastation of human life on Earth into view—close enough that we can see clearly what it would look like and know, with some degree of precision, how it will punish our children and grandchildren. Close enough, in fact, that we are already beginning to feel its effects ourselves, when we do not turn away. ﻿It is almost hard to believe just how much has happened and how quickly. In the late summer of 2017, three major hurricanes arose in the Atlantic at once, proceeding at first along the same route as though they were battalions of an army on the march.56 Hurricane Harvey, when it struck Houston, delivered such epic rainfall it was described in some areas as a “500,000-year event”—meaning that we should expect that amount of rain to hit that area once every five hundred millennia.57 Sophisticated consumers of environmental news have already learned how meaningless climate change has rendered such terms, which were meant to describe storms that had a 1-in-500,000 chance of striking in any given year. But the figures do help in this way: to remind us just how far global warming has already taken us from any natural-disaster benchmark our grandparents would have recognized. To dwell on the more common 500-year figure just for a moment, it would mean a storm that struck once during the entire history of the Roman Empire. Five hundred years ago, there were no English settlements across the Atlantic, so we are talking about a storm that should hit just once as Europeans arrived and established colonies, as colonists fought a revolution and Americans a civil war and two world wars, as their descendants established an empire of cotton on the backs of slaves, freed them, and then brutalized their descendants, industrialized and postindustrialized, triumphed in the Cold War, ushered in the “end of history,” and witnessed, just a decade later, its dramatic return. One storm in all that time, is what the meteorological record has taught us to expect. Just one. Harvey was the third such flood to hit Houston since 2015.58 And the storm struck, in places, with an intensity that was supposed to be a thousand times rarer still. That same season, an Atlantic hurricane hit Ireland, 45 million were flooded from their homes in South Asia, and unprecedented wildfires tilled much of California into ash.59, 60 And then there was the new category of quotidian nightmare, climate change inventing the once-unimaginable category of obscure natural disasters—crises so large they would once have been inscribed in folklore for centuries today passing across our horizons ignored, overlooked, or forgotten. In 2016, a “thousand-year flood” drowned small-town Ellicott City, Maryland, to take but one example almost at random; it was followed, two years later, in the same small town, by another.61 One week that summer of 2018, dozens of places all over the world were hit with record heat waves, from Denver to Burlington to Ottawa; from Glasgow to Shannon to Belfast; from Tbilisi, in Georgia, and Yerevan, in Armenia, to whole swaths of southern Russia.62 The previous month, the daytime temperature of one city in Oman reached above 121 degrees Fahrenheit, and did not drop below 108 all night, and in Quebec, Canada, fifty-four died from the heat.63 That same week, one hundred major wildfires burned in the American West, including one in California that grew 4,000 acres in one day, and another, in Colorado, that produced a volcano-like 300-foot eruption of flames, swallowing an entire subdivision and inventing a new term, “fire tsunami,” along the way.64, 65, 66 On the other side of the planet, biblical rains flooded Japan, where 1.2 million were evacuated from their homes.67 Later that summer, Typhoon Mangkhut forced the evacuation of 2.45 million from mainland China, the same week that Hurricane Florence struck the Carolinas, turning the port city of Wilmington briefly into an island and flooding large parts of the state with hog manure and coal ash.68, 69, 70 Along the way, the winds of Florence produced dozens of tornadoes across the region.71 The previous month, in India, the state of Kerala was hit with its worst floods in almost a hundred years.72 That October, a hurricane in the Pacific wiped Hawaii’s East Island entirely off the map.73 And in November, which has traditionally marked the beginning of the rainy season in California, the state was hit instead with the deadliest fire in its history—the Camp Fire, which scorched several hundred square miles outside of Chico, killing dozens and leaving many more missing in a place called, proverbially, Paradise.74 The devastation was so complete, you could almost forget the Woolsey Fire, closer to Los Angeles, which burned at the same time and forced the sudden evacuation of 170,000. It is tempting to look at these strings of disasters and think, Climate change is here. And one response to seeing things long predicted actually come to pass is to feel that we have settled into a new era, with everything transformed. In fact, that is how California governor Jerry Brown described the state of things in the midst of the state’s wildfire disaster: “a new normal.”75 The truth is actually much scarier. That is, the end of normal; never normal again. We have already exited the state of environmental conditions that allowed the human animal to evolve in the first place, in an unsure and unplanned bet on just what that animal can endure. The climate system that raised us, and raised everything we now know as human culture and civilization, is now, like a parent, dead. And the climate system we have been observing for the last several years, the one that has battered the planet again and again, is not our bleak future in preview. It would be more precise to say that it is a product of our recent climate past, already passing behind us into a dustbin of environmental nostalgia. There is no longer any such thing as a “natural disaster,” but not only will things get worse; technically speaking, they have already gotten worse. Even if, miraculously, humans immediately ceased emitting carbon, we’d still be due for some additional warming from just the stuff we’ve put into the air already. And of course, with global emissions still increasing, we’re very far from zeroing out on carbon, and therefore very far from stalling climate change. The devastation we are now seeing all around us is a beyond-best-case scenario for the future of warming and all the climate disasters it will bring. ﻿What that means is that we have not, at all, arrived at a new equilibrium. It is more like we’ve taken one step out on the plank off a pirate ship. Perhaps because of the exhausting false debate about whether climate change is “real,” too many of us have developed a misleading impression that its effects are binary. But global warming is not “yes” or “no,” nor is it “today’s weather forever” or “doomsday tomorrow.” It is a function that gets worse over time as long as we continue to produce greenhouse gas. And so the experience of life in a climate transformed by human activity is not just a matter of stepping from one stable ecosystem into another, somewhat worse one, no matter how degraded or destructive the transformed climate is. The effects will grow and build as the planet continues to warm: from 1 degree to 1.5 to almost certainly 2 degrees and beyond. The last few years of climate disasters may look like about as much as the planet can take. In fact, we are only just entering our brave new world, one that collapses below us as soon as we set foot on it. Many of these new disasters arrived accompanied by debate about their cause—about how much of what they have done to us comes from what we have done to the planet. For those hoping to better understand precisely how a monstrous hurricane arises out of a placid ocean, these inquiries are worthwhile, but for all practical purposes the debate yields no real meaning or insight. A particular hurricane may owe 40 percent of its force to anthropogenic global warming, the evolving models might suggest, and a particular drought may be half again as bad as it might have been in the seventeenth century. But climate change is not a discrete clue we can find at the scene of a local crime—one hurricane, one heat wave, one famine, one war. Global warming isn’t a perpetrator; it’s a conspiracy. We all live within climate and within all the changes we have produced in it, which enclose us all and everything we do. If hurricanes of a certain force are now five times as likely as in the pre-Columbian Caribbean, it is parsimonious to the point of triviality to argue over whether this one or that one was “climate-caused.” All hurricanes now unfold in the weather systems we have wrecked on their behalf, which is why there are more of them, and why they are stronger. The same is true for wildfires: this one or that one may be “caused” by a cookout or a downed power line, but each is burning faster, bigger, and longer because of global warming, which gives no reprieve to fire season. Climate change isn’t something happening here or there but everywhere, and all at once. And unless we choose to halt it, it will never stop. Over the past few decades, the term “Anthropocene” has climbed out of academic discourse and into the popular imagination—a name given to the geologic era we live in now, and a way to signal that it is a new era, defined on the wall chart of deep history by human intervention. One problem with the term is that it implies a conquest of nature, even echoing the biblical “dominion.” But however sanguine you might be about the proposition that we have already ravaged the natural world, which we surely have, it is another thing entirely to consider the possibility that we have only provoked it, engineering first in ignorance and then in denial a climate system that will now go to war with us for many centuries, perhaps until it destroys us. That is what Wally Broecker, the avuncular oceanographer, means when he calls the planet an “angry beast.”76 You could also go with “war machine.” Each day we arm it more. The assaults will not be discrete—this is another climate delusion. Instead, they will produce a new kind of cascading violence, waterfalls and avalanches of devastation, the planet pummeled again and again, with increasing intensity and in ways that build on each other and undermine our ability to respond, uprooting much of the landscape we have taken for granted, for centuries, as the stable foundation on which we walk, build homes and highways, shepherd our children through schools and into adulthood under the promise of safety—and subverting the promise that the world we have engineered and built for ourselves, out of nature, will also protect us against it, rather than conspiring with disaster against its makers. Consider those California wildfires. In March 2018, Santa Barbara County issued mandatory evacuation orders for those living in Montecito, Goleta, Santa Barbara, Summerland, and Carpinteria—where the previous December’s fires had hit hardest. It was the fourth evacuation order precipitated by a climate event in the county in just three months, but only the first had been for fire.77 The others were for mudslides ushered into possibility by that fire, one of the toniest communities in the most glamorous state of the world’s preeminently powerful country upended by fear that their toy vineyards and hobby stables, their world-class beaches and lavishly funded public schools, would be inundated by rivers of mud, the community as thoroughly ravaged as the sprawling camps of temporary shacks housing Rohingya refugees from Myanmar in the monsoon region of Bangladesh.78 It was. More than a dozen died, including a toddler swept away by mud and carried miles down the mountainslope to the sea; schools closed and highways flooded, foreclosing the routes of emergency vehicles and making the community an inland island, as if behind a blockade, choked off by a mud noose.79 Some climate cascades will unfold at the global level—cascades so large their effects will seem, by the curious legerdemain of environmental change, imperceptible. A warming planet leads to melting Arctic ice, which means less sunlight reflected back to the sun and more absorbed by a planet warming faster still, which means an ocean less able to absorb atmospheric carbon and so a planet warming faster still. A warming planet will also melt Arctic permafrost, which contains 1.8 trillion tons of carbon, more than twice as much as is currently suspended in the earth’s atmosphere, and some of which, when it thaws and is released, may evaporate as methane, which is thirty-four times as powerful a greenhouse-gas warming blanket as carbon dioxide when judged on the timescale of a century; when﻿ judged on the timescale of two decades, it is eighty-six times as powerful.80, 81 A hotter planet is, on net, bad for plant life, which means what is called “forest dieback”—the decline and retreat of jungle basins as big as countries and woods that sprawl for so many miles they used to contain whole folklores—which means a dramatic stripping-back of the planet’s natural ability to absorb carbon and turn it into oxygen, which means still hotter temperatures, which means more dieback, and so on. Higher temperatures means more forest fires means fewer trees means less carbon absorption, means more carbon in the atmosphere, means a hotter planet still—and so on. A warmer planet means more water vapor in the atmosphere, and, water vapor being a greenhouse gas, this brings higher temperatures still—and so on. Warmer oceans can absorb less heat, which means more stays in the air, and contain less oxygen, which is doom for phytoplankton—which does for the ocean what plants do on land, eating carbon and producing oxygen—which leaves us with more carbon, which heats the planet further. And so on. These are the systems climate scientists call “feedbacks”; there are more.82 Some work in the other direction, moderating climate change. But many more point toward an acceleration of warming, should we trigger them. And just how these complicated, countervailing systems will interact—what effects will be exaggerated and what undermined by feedbacks—is unknown, which pulls a dark cloud of uncertainty over any effort to plan ahead for the climate future. We know what a best-case outcome for climate change looks like, however unrealistic, because it quite closely resembles the world as we live on it today. But we have not yet begun to contemplate those cascades that may bring us to the infernal range of the bell curve. Other cascades are regional, collapsing on human communities and buckling them where they fall. These can be literal cascades—human-triggered avalanches are on the rise, with 50,000 people killed by avalanches globally between 2004 and 2016.83 In Switzerland, climate change has unleashed a whole new kind, thanks to what are called “rain-on-snow” events, which also caused the overflow of the Oroville Dam in Northern California and the 2013 flood of Alberta, Canada, with damages approaching $5 billion.84 But there are other kinds of cascade, too. Climate-driven water shortages or crop failures push climate refugees into nearby regions already struggling with resource scarcity. Sea-level rise inundates cropland with more and more saltwater flooding, transforming agricultural areas into brackish sponges no longer able to adequately feed those living off them; flooding power plants, knocking regions offline just as electricity may be needed most; and crippling chemical and nuclear plants, which, malfunctioning, breathe out their toxic plumes. The rains that followed the Camp Fire flooded the tent cities hastily assembled for the first disaster’s refugees. In the case of the Santa Barbara mudslides, drought produced a state full of dry brush ripe for a spark; then a year of anomalously monsoonish rain produced only more growth, and wildfires tore through the landscape, leaving a mountainside without much plant life to hold in place the millions of tons of loose earth that make up the towering coastal range where the clouds tend to gather and the rain first falls. Some of those watching from afar wondered, incredulously, how a mudslide could kill so many. The answer is, the same way as hurricanes or tornadoes—by weaponizing the environment, whether “man-made” or “natural.” Wind disasters do not kill by wind, however brutal it gets, but by tugging trees out of earth and transforming them into clubs, making power lines into loose whips and electrified nooses, collapsing homes on cowering residents, and turning cars into tumbling boulders. And they kill slowly, too, by cutting off food delivery and medical supplies, making roads impassable even to first responders, knocking out phone lines and cell towers so that the ill and elderly must suffer, and hope to endure, in silence and without aid. Most of the world is not Santa Barbara, with its Mission-style impasto of infinite-seeming wealth, and in the coming decades many of the most punishing climate horrors will indeed hit those least able to respond and recover. This is what is often called the problem of environmental justice; a sharper, less gauzy phrase would be “climate caste system.” The problem is acute within countries, even wealthy ones, where the poorest are those who live in the marshes, the swamps, the floodplains, the inadequately irrigated places with the most vulnerable infrastructure—altogether an unwitting environmental apartheid. Just in Texas, 500,000 poor Latinos live in shantytowns called “colonias” with no drainage systems to deal with increased flooding.85 The cleavage is even sharper globally, where the poorest countries will suffer more in our hot new world. In fact, with one exception—Australia—countries with lower GDPs will warm the most.86 That is notwithstanding the fact that much of the global south has not, to this point, defiled the atmosphere of the planet all that much. This is one of the many historical ironies of climate change that would better be called cruelties, so merciless is the suffering they will inflict. But disproportionately as it will fall on the world’s least, the devastation of global warming cannot be easily quarantined in the developing world, as much as those in the Northern Hemisphere would probably, and not to our credit, prefer it. Climate disaster is too indiscriminate for that. In fact, the belief that climate could be plausibly governed, or managed, by any institution or human instrument presently at hand is another wide-eyed climate delusion. The planet survived many millennia without anything approaching a world government, in fact endured nearly the entire span of human civilization that way, organized into competitive tribes and fiefdoms and kingdoms and nation-states, and only began to build something resembling a cooperative blueprint, very piecemeal, after brutal world wars—in the ﻿form of the League of Nations and United Nations and European Union and even the market fabric of globalization, whatever its flaws still a vision of cross-national participation, imbued with the neoliberal ethos that life on Earth was a positive-sum game. If you had to invent a threat grand enough, and global enough, to plausibly conjure into being a system of true international cooperation, climate change would be it—the threat everywhere, and overwhelming, and total. And yet now, just as the need for that kind of cooperation is paramount, indeed necessary for anything like the world we know to survive, we are only unbuilding those alliances—recoiling into nationalistic corners and retreating from collective responsibility and from each other. That collapse of trust is a cascade, too. ﻿Just how completely the world below our feet will become unknown to us is not yet clear, and how we register its transformation remains an open question. One legacy of the environmentalist creed that long prized the natural world as an otherworldly retreat is that we see its degradation as a sequestered story, unfolding separately from our own modern lives—so separately that the degradation acquires the comfortable contours of parable, like pages from Aesop, aestheticized even when we know the losses as tragedy. Climate change could soon mean that, in the fall, trees may simply turn brown, and so we will look differently at entire schools of painting, which stretched for generations, devoted to best capturing the oranges and reds we can no longer see ourselves out the windows of our cars as we drive along our highways.87 The coffee plants of Latin America will no longer produce fruit; beach homes will be built on higher and higher stilts and still be drowned.88 In many cases, it is better to use the present tense. In just the last forty years, according to the World Wildlife Fund, more than half of the world’s vertebrate animals have died; in just the last twenty-five, one study of German nature preserves found, the flying insect population declined by three-quarters.89, 90 The delicate dance of flowers and their pollinators has been disrupted, as have the migration patterns of cod, which have fled up the Eastern Seaboard toward the Arctic, evading the communities of fishermen that fed on them for centuries; as have the hibernation patterns of black bears, many of which now stay awake all winter.91, 92, 93 Species individuated over millions of years of evolution but forced together by climate change have begun to mate with one another for the first time, producing a whole new class of hybrid species: the pizzly bear, the coy-wolf.94 The zoos are already natural history museums, the children’s books already out of date. Older fables, too, will be remade: the story of Atlantis, having endured and enchanted for several millennia, will compete with the real-time sagas of the Marshall Islands and Miami Beach, each sinking over time into snorkelers’ paradises; the strange fantasy of Santa and his polar workshop will grow eerier still in an Arctic of ice-free summers; and there is a terrible poignancy in contemplating how desertification of the entire Mediterranean Basin will change our reading of the Odyssey, or how it will discolor the shine of Greek islands for dust from the Sahara to permanently blanket their skies, or how it will recast the meaning of the Pyramids for the Nile to be dramatically drained.95, 96, 97 We will think of the border with Mexico differently, presumably, when the Rio Grande is a line traced through a dry riverbed—the Rio Sand, it’s already been called.98 The imperious West has spent five centuries looking down its nose at the plight of those living within the pale of tropical disease, and one wonders how that will change when mosquitoes carrying malaria and dengue are flying through the streets of Copenhagen and Chicago, too. But we have for so long understood stories about nature as allegories that we seem unable to recognize that the meaning of climate change is not sequestered in parable. It encompasses us; in a very real way it governs us—our crop yields, our pandemics, our migration patterns and civil wars, crime waves and domestic assaults, hurricanes and heat waves and rain bombs and megadroughts, the shape of our economic growth and everything that flows downstream from it, which today means nearly everything. Eight hundred million in South Asia alone, the World Bank says, would see their living conditions sharply diminish by 2050 on the current emissions track, and perhaps a climate slowdown will even reveal the bounty of what Andreas Malm calls fossil capitalism to be an illusion, sustained over just a few centuries by the arithmetic of adding the energy value of burned fossil fuels to what had been, before wood and coal and oil, an eternal Malthusian trap.99, 100 In which case, we would have to retire the intuition that history will inevitably extract material progress from the planet, at least in any reliable or global pattern, and come to terms, somehow, with just how pervasively that intuition ruled even our inner lives, often tyrannically. Adaptation to climate change is often viewed in terms of market trade-offs, but in the coming decades the trade will work in the opposite direction, with relative prosperity a benefit of more aggressive action. Every degree of warming, it’s been estimated, costs a temperate country like the United States about one percentage point of GDP, and according to one recent paper, at 1.5 degrees the world would be $20 trillion richer than at 2 degrees.101, 102 Turn the dial up another degree or two, and the costs balloon—the compound interest of environmental catastrophe. 3.7 degrees of warming would produce $551 trillion in damages, research suggests; total worldwide wealth is today about $280 trillion.103, 104 Our current emissions trajectory takes us over 4 degrees by 2100; multiply that by that 1 percent of GDP and you have almost entirely wiped out the very possibility of economic growth, which has not topped 5 percent globally in over forty years.105 A fringe group of alarmed academics call this prospect “steady-state economics,” but it ultimately suggests a more ﻿complete retreat from economics as an orienting beacon, and from growth as the lingua franca through which modern life launders all of its aspirations.106 “Steady-state” also gives a name to the creeping panic that history may be less progressive, as we’ve come to believe really only over the last several centuries, than cyclical, as we were sure it was for the many millennia before. More than that: in the vision steady-state economics projects of a state-of-nature competitive scramble, everything from politics to trade and war seems brutally zero-sum. For centuries we have looked to nature as a mirror onto which to first project, then observe, ourselves. But what is the moral? There is nothing to learn from global warming, because we do not have the time, or the distance, to contemplate its lessons; we are after all not merely telling the story but living it. That is, trying to; the threat is immense. How immense? One 2018 paper sketches the math in horrifying detail. In the journal Nature Climate Change, a team led by Drew Shindell tried to quantify the suffering that would be avoided if warming was kept to 1.5 degrees, rather than 2 degrees—in other words, how much additional suffering would result from just that additional half-degree of warming. Their answer: 150 million more people would die from air pollution alone in a 2-degree warmer world than in a 1.1075-degree warmer one. Later that year, the IPCC raised the stakes further: in the gap between 1.1085 degrees and 2, it said, hundreds of millions of lives were at stake. Numbers that large can be hard to grasp, but 150 million is the equivalent of twenty-five Holocausts. It is three times the size of the death toll of the Great Leap Forward—the largest nonmilitary death toll humanity has ever produced. It is more than twice the greatest death toll of any kind, World War II. The numbers don’t begin to climb only when we hit 1.5 degrees, of course. As should not surprise you, they are already accumulating, at a rate of at least seven million deaths, from air pollution alone, each year—an annual Holocaust, pursued and prosecuted by what brand of nihilism? This is what is meant when climate change is called an “existential crisis”—a drama we are now haphazardly improvising between two hellish poles, in which our best-case outcome is death and suffering at the scale of twenty-five Holocausts, and the worst-case outcome puts us on the brink of extinction.109 Rhetoric often fails us on climate because the only factually appropriate language is of a kind we’ve been trained, by a buoyant culture of sunny-side-up optimism, to dismiss, categorically, as hyperbole. Here, the facts are hysterical, and the dimensions of the drama that will play out between those poles incomprehensibly large—large enough to enclose not just all of present-day humanity but all of our possible futures, as well. Global warming has improbably compressed into two generations the entire story of human civilization. First, the project of remaking the planet so that it is undeniably ours, a project whose exhaust, the poison of emissions, now casually works its way through millennia of ice so quickly you can see the melt with a naked eye, destroying the environmental conditions that have held stable and steadily governed for literally all of human history. That has been the work of a single generation. The second generation faces a very different task: the project of preserving our collective future, forestalling that devastation and engineering an alternate path. There is simply no analogy to draw on, outside of mythology and theology—and perhaps the Cold War prospect of mutually assured destruction. Few feel like gods in the face of warming, but that the totality of climate change should make us feel so passive—that is another of its delusions. In folklore and comic books and church pews and movie theaters, stories about the fate of the earth often perversely counsel passivity in their audiences, and perhaps it should not surprise us that the threat of climate change is no different. By the end of the Cold War, the prospect of nuclear winter had clouded every corner of our pop culture and psychology, a pervasive nightmare that the human experiment might be brought to an end by two jousting sets of proud, rivalrous tacticians, just a few sets of twitchy hands hovering over the planet’s self-destruct buttons. The threat of climate change is more dramatic still, and ultimately more democratic, with responsibility shared by each of us even as we shiver in fear of it; and yet we have processed that threat only in parts, typically not concretely or explicitly, displacing certain anxieties and inventing others, choosing to ignore the bleakest features of our possible future and letting our political fatalism and technological faith blur, as though we’d gone cross-eyed, into a remarkably familiar consumer fantasy: that someone else will fix the problem for us, at no cost. Those more panicked are often hardly less complacent, living instead through climate fatalism as though it were climate optimism. Over the last few years, as the planet’s own environmental rhythms have seemed to grow more fatalistic, skeptics have found themselves arguing not that climate change isn’t happening, since extreme weather has made that undeniable, but that its causes are unclear—suggesting that the changes we are seeing are the result of natural cycles rather than human activities and interventions. It is a very strange argument; if the planet is warming at a terrifying pace and on a horrifying scale, it should transparently concern us more, rather than less, that the warming is beyond our control, possibly even our comprehension. That we know global warming is our doing should be a comfort, not a cause for despair, however incomprehensively large and complicated we find the processes that have brought it into being; that we know we are, ourselves, responsible for all of its punishing effects ﻿should be empowering, and not just perversely. Global warming is, after all, a human invention. And the flip side of our real-time guilt is that we remain in command. No matter how out-of-control the climate system seems—with its roiling typhoons, unprecedented famines and heat waves, refugee crises and climate conflicts—we are all its authors. And still writing.

#### The most feasible SSP systems would require a large number of satellites in LEO. More satellites lower the risk of collisions.

Zekavat et al 10 [Zekavat, Seyed A.; Abdelkhalik, Ossama; Goh, Shu T.; Fuhrmann, Daniel R. (2010). [IEEE 2010 IEEE Aerospace Conference - Big Sky, MT, USA (2010.03.6-2010.03.13)] 2010 IEEE Aerospace Conference - A novel space-based solar power collection via LEO satellite networks: Orbital management via wireless local positioning systems. , (0), 1–9. doi:10.1109/aero.2010.5447033 1. INTRODUCTION

Climate change coupled with rising oil prices, dwindling oil resources, and increasing government support are driving increasing renewable energy legislation, incentives and Solar energy has recently gained considerable attention. Solar cells installed on the Earth surface receive an average of 250 watts per square meter, while in space, near the Earth, a square meter receives 1.366 kilowatts of solar radiation [1]. Moreover, compared to the Earth-based solar power, the impact of weather, e.g., clouds, on space-based solar power is minimal. In addition, higher altitudes result in shorter eclipse periods which allow for higher energy collection. Japan has already announced a firm program for the development and installation of such a system by 2030 [2]. In the 1970s, a great deal of research was conducted by NASA and the Department of Energy (DOE) on the feasibility ofthe SBSP concept. The US Congress Office of Technology Assessment evaluated these studies and did not recommend immediate action toward implementation because of the technical challenges and high cost of the proposed mission at that time [3]. However, NASA and DOE did establish the scientific feasibility of the concept and produced a design for a 5 GW system. Unfortunately, other lower-cost energy alternatives were given priority over further SBSP development. In the 1990s, NASA directed a "Fresh Look Study" on the concept. Although the study recommended the development of focus areas for the SBSP, it did not recommend or discourage further investments in this direction [4]. Policy makers elected not to pursue a development effort. Yet, a strong motion toward implementing the concept can be observed nationally [4] and internationally [5], [6]. In 2007, the Advanced Concepts Office of the National Security Agency presented the idea of SBSP as a potential opportunity to address not only energy security, but also environmental, economic, intellectual, and space security [1]. A Space-Based Solar Power (SBSP) satellite structure was proposed by Glaser in 1968 to use the Sun energy effectively. This architecture suffers from many problems: (1) It requires the SBSP structure to be in GEO which is congested by other satellites; (2) Launching satellites to higher orbits is more expensive than lower orbits; (3) Assembly of huge structures in space is costly; (4) The structure may get destroyed by debris and solar waves, due to its huge size; and (5) Focused high-power energy generated by huge structures has environmental effects. In this work, we propose to implement space-based solar power technology by networks of small Low Earth Orbit (LEO) satellites [7]. Here, a number of satellites located within the visibility zone of a power-collecting base-station (PCBS) form clusters, and they independently collect solar power, and transmit it to an earth PCBS. A given LEO satellite cannot communicate with a PCBS - that is installed on the earth - at all times. Thus, multiple PCBSs are needed. As a LEO satellite moves from one point in space to another, it switches from one PCBS to another. Multiple satellites communicate with each PCBS at any time instance. This creates a shower of low-power signals compared to the stronger power beams created by the traditional SBSP. The proposed structures incorporate LEO satellites. This: (a) Reduces launching cost, (b) Increases power transmission efficiency to the Earth, due to satellites' low orbits: path loss would be lower; (c) Avoids the high cost of assembly of huge structures in space; (d) Avoids the existence ofthe problems such as structural collapse due to solar waves; (e) Decreases environmental effects due to the transmission oflow power signals from the satellites to the PCBSs. This paper investigates the installation of a cluster of satellites in the orbit. Here, we propose to use a novel Wireless Local Positioning System (WLPS) for satellite relative remote positioning [8]. The WLPS performs independent of the availability of other localization systems such as GPS. Thus, when GPS does not function or is jammed, WLPS will be operational. The WLPS, installed at each satellite, enables the satellite to determine the relative position of other satellites located in its coverage area via time-of-arrival (TOA) and direction-of-arrival (DOA) measurements. This allows us to manage the orbit of all satellites, apply adjustments to the orbit of satellites, and enable a minimum number ofsatellites to communicate with a ground base station at all times. The WLPS consists of two basic components: A dynamic base station (DBS) and a transponder (TRX). Each DBS broadcasts an identification (ID) signal to its coverage area. A TRX within the coverage area receives and transmits a response signal that includes its own ID back to the DBS. This enables each DBS to localize TRXs that are located in its coverage area. Two scenarios for orbital management are possible: (i) a specific group of satellites form a cluster and stay in formation at all times (a formation flying); (ii) the cluster is formed similar to an ad-hoc network based on the availability of satellites in the visibility zone of a PCBS. In this paper, only scenario (i) is considered. In order to maintain the cluster ofsatellites, a control system is required. The measurements needed for control purposes usually include the relative distances between satellites. Each satellite measures the position of other satellites in its coverage area using WLPS. The measured positions are transmitted to a reference satellite. The reference satellite processes the measured positions in order to improve the localization accuracy. An Extended Kalman Filter (EKF) will be implemented for the problem. Initial analysis suggests that for a small number ofsatellites, on the order offour, the stability ofthe EKF depends on the ranges between satellites. In this paper, the effect of the number of satellites in the formation on the relative positions estimation will be studied. Since each satellite is equipped with a DBS and a TRX, then each satellite can measure the relative positions of all other satellites in the formation. Therefore, increasing the number of satellites increases the number of independent measurements for each satellite in the formation. Simulations are conducted to investigate the effect of number ofsatellites in the cluster on maintaining the formation. Results depict that increasing the number of satellites will increase the stability of the EKF estimation and accordingly the formation. The results of cluster stability are incorporated to discuss an important issue in the implementation of this system, Le., intersatellite synchronization. If the signals transmitted by satellites are not synchronized in phase and frequency, the received signals at the PCBS add destructively and do not create a high amount of power. Section II introduces the proposed satellite network. Section III introduces the structure of WLPS, and Section IV explains how the proposed WLPS structure is implemented to maintain satellite clusters via EKF. Section V concludes the paper.

2. THE PROPOSED LEO SATELLITE NETWORK

Here, we propose a novel technique for implementing solar power technology that is based on small Low Earth Orbit (LEO) satellites. LEO satellites do not maintain a specific position above the earth; thus, a LEO satellite cannot communicate with a single power collecting base station (PCBS) at all times. Therefore, as shown in Figure 1, use of LEOs requires multiple PCBSs on the ground. In the proposed system, each small LEO satellite can communicate with a PCBS at any time instance; the specific PCBS will vary based on the LEO's position. In addition, many small LEO satellites are proposed for different LEO orbits. Thus, at any time instance, a large number ofsatellites will be able to communicate with each PCBS. This creates a "shower" of power signals wirelessly transferred from a cluster of satellites to each PCBS. Maintaining synchronous transmission across all satellites communicating with one PCBS will result in strong reception at the PCBS which can be converted into electricity. Thus, the development of inter-satellite synchronization techniques is vital for the ultimate success ofthe proposed system. The concept of the system proposed here is analogous to that of mobile communications. In mobile communications, a user may communicate with a base station at a given time instance and with another one in the next time instance. In addition, a group of users may communicate simultaneously with a base station. In the process of communication, the power of each user is indeed transferred to base stations The proposed system is also analogous to wireless communications in its "handoff' process; as satellites move from one point in space to another, they change their point of contact from one PCBS to another. In the proposed system, the number of PCBSs installed on the ground and the orbit of LEO satellites should be designed to allow all satellites to communicate with one PCBS at all times. The associated orbital design is an important research component that will be addressed in future works. As depicted in Figure 1, a large number ofLEO satellites will independently collect solar power, and transmit it to one PCBS. The PCBS will then collect the received energy and convert it to usable energy. This can be accomplished by allowing all satellites to directly transmit the collected power to the Earth as shown in Figure 1(a). Another option is to form a cluster using a group of satellites that are located in the visibility zone of a PCBS [see Figure 1(b)]. A satellite within the cluster would serve as the leader satellite. In this method, follower (power collecting) satellites would first transmit collected power to the leader satellite. Next, the leader (relay) satellite would relay the signal to a PCBS. The attenuation frequency response of the ionosphere (high altitude) is not similar to that of the atmosphere (low altitude). The technique of Figure 1(b) allows leader satellite to be installed in a lower orbit. Thus, a proper frequency can be allocated to follower satellites (installed in high orbit) to transmit to the leader (installed lower), and another frequency allocated for leader satellite transmission to the PCBS. Figure 2 represents this scenario. One of the problems in this system is inter-satellite synchronization. One proposed technique to address this is distributed beamforming. Distributed beamforming is also called "transmit beamforming" [9], "collaborative beamforming" [10],[11] and "virtual antenna arrays" [12]. It has also been discussed in the context of coherent cooperative transmission [13] and cooperative multi-input/single-output (MISO) [14], [15] as well as multiple-input/multiple-output (MIMO) transmission [16]. One distributed beamforming approach is realized via pre-compensation for the distance (trip delay) in order to maintain the same phase across all satellites upon transmission [17]. In other words, the satellite clock will need to be readjusted to maintain the same phase at the PCBS single antenna. The trip delay will be measured by broadcasting a signal that includes timing information from the PCBS back to all satellites [9],[18]. In distributed beamforming, it is assumed that the nodes (here satellites) to be almost stationary in the process of synchronization. However, in our problems, satellites move with a relatively high speed. In order to implement this synchronization, satellite position should be precisely estimated. In addition, the velocity of satellites should be precisely estimated. This estimation can be maintained via WLPS. Position and velocity estimation via WLPS will be discussed in Section IV ofthis paper. However, errors in WLPS positioning are inevitable and precise localization cannot be reached. In addition, the distance of the PCBS and satellites is very large and within the signal round trip between their move, the satellites will highly change their location. If the new position of satellite with respect to the ground PCBS is not well estimated, synchronization would not be possible. Thus, it is anticipated that synchronization across multiple satellites transmitting to the ground PCBS, shown in Figure 1(a), would be difficult. However, in the structure of Figure I(b), this synchronization should be applied across multiple follower satellites when they are transmitting to the leader one. The distance and/or the orbit ofthe follower and leader satellites can be adjusted such that synchronization across follower satellites transmitting to a single leader satellite is maintained. In this case, the orbits and the number of satellites should be designed to ensure a large number of follower satellites are located close to a leader, one at a time, to generate and deliver the required power to a given PCBS. Thus, the proposed technique requires a well-designed cyber-physical system to control the satellites and their orbits to ensure sufficient power transfer. This process needs the installation of localization systems that can monitor the position and velocity of the satellites at any given time. WLPS is a strong candidate that can fulfill this requirement. The next section introduces such a system.

### NC Shell – Tradable Debris CP

#### CP: States ought to adopt a binding international treaty establishing a system of tradeable allowances for space debris in LEO.

* There’s academic consensus that the CP solves debris better than regulatory mechanisms proposed by the aff: more effectively prevents debris generation, encourages innovation in debris removal, which is necessary to avoid Kessler, and minimizes circumvention.
* CP is mutually exclusive since tradeable allowances create require appropriation by establishing property rights in debris generating activities like satellite launches in LEO.

*{They get to pick between solving their plan and the perm because the CP allows for Starlink.}*

Prefer evidence that directly compares solvency mechanisms to the analytic conjecture of the 1AR.

Taylor 11 [Taylor, Jared B. "Tragedy of the space commons: a market mechanism solution to the space debris problem." Colum. J. Transnat'l L. 50 (2011): 253. <https://heinonline.org/HOL/LandingPage?handle=hein.journals/cjtl50&div=9&id=&page=>] CT

2. The Optimal Strategy to Manage the Space Resource

In order to avoid a tragedy of the commons in space, any management strategy of a common property resource must keep resource use at or below a maximum sustainable level of use.105 If resource use increases above this sustainability level, rivalrous consumption will eventually deplete the resource beyond the point at which it can be repaired. The fundamental premise of the tragedy of the commons is that a rational actor utilizing a common resource is incentivized to use as much of the resource as quickly as possible (by reaping full rewards while bearing fractional costs), even as the aggregate use of the resource passes beyond the maximum sustainable level.106 Similarly, any resource user who decides to reduce resource consumption bears the full costs of abatement while only gaining a fraction of the benefits of that abatement, which are shared among all resource users. 107 Professor Carol Rose, who has written extensively on property rights and environmental law, suggests that commons management strategies fall into four conceptual groups: DO NOTHING, KEEPOUT, RIGHTWAY and PROP. The DO NOTHING strategy employs, as its name implies, no regulation over resource use whatsoever. 10 8 The KEEPOUT strategy operates by converting an openaccess resource into a closed-access resource. 10 9 The RIGHTWAY strategy implements conduct regulation: for example, environmental command-and-control regulations or standards that specify the right way to use the resource. 110 Finally, the PROP strategy is equivalent to the implementation of an incentive-based market mechanism, which internalizes the external costs of resource use111 so that an individual resource user's interests align with the group's interest in preserving the resource. This market mechanism can be implemented in the form of either a taxation scheme or a tradable allowance scheme. Each commons management strategy (DO NOTHING, KEEPOUT, RIGHTWAY, PROP) is increasingly more capable of constraining resource use, but is also proportionately more costly to implement. 112 As a resource becomes more valuable or the costs of exploiting it decrease, the incentive to use the resource increases.' 13 This incentive attracts more resource users whose use puts even greater pressure on the resource, causing it to be more congested and closer to its maximum sustainable level.1 14 A more congested resource requires a more effective management system in order to maintain the desired level of resource use. 15 Hence, the proper management system is a function of a resource's congestion level in relation to its maximum sustainable level of use. An important corollary is that employing a costly strategy for a resource that is not near its maximum sustainable level is not optimal, because in that case, a rarely used resource would be regulated at an inefficiently high cost. Thus, when choosing the optimal management strategy, it is critical to evaluate the level of the resource's congestion in relation to its maximum sustainable level. As previously noted, the incentive-based market mechanisms of a PROP strategy can be implemented either through a taxation scheme1 16 or a tradable allowance scheme.1 17 In theory, both incentive- based strategies are equally cost-effective.1 18 Taxes on pollution emissions aim to induce a certain total level of pollution.' 19 In this scenario, pollution sources abate their pollution until the marginal cost of abatement equals the tax on the next unit of pollution. 120 In a similar manner, a limited number of tradable allowances could be allocated to pollution sources. 12 1 In order for a source to pollute, it must hold an allowance for each quantity of pollution emitted. 122 Sources could then buy and sell allowances on a market depending on their need. Due to the limited distribution of allowances, however, the total level of pollution would be capped.12 3 In this scenario, sources would abate their pollution until the marginal cost of abatement would equal the market price of a tradable allowance.12 4 If the tax rate or number of allowances were properly determined, the market price of a tradable allowance would equal the tax rate.12 5 However, to achieve symmetrical cost-effectiveness, regulators must determine the marginal costs and marginal benefits of pollution abatement.12 6 When this information is uncertain, a tax caps abatement cost but induces an uncertain level of pollution emis-sions. 127 Tradable allowances, on the other hand, cap pollution emissions but induce an uncertain level of abatement cost. 128 The choice between taxes and tradable allowances therefore depends in part on the preference between certain costs or certain pollution control. 129 Cost-effectiveness, however, is only one aspect of a potentially optimal strategy-there are two other relevant considerations. First, it is important to evaluate a strategy's capacity to generate innovation. 130 Innovation becomes critical as a resource is approaching its maximum sustainable level of use because innovation can artificially increase the resource's maximum sustainable level of use and/or decrease the rate at which resource use approaches the maximum sustainable level of use (through cleaner and less-polluting technology along with resource-preserving and resource-renewing technology). Second, it is important to evaluate a strategy's chances of implementation. Because the space debris problem is global in nature, its solution must be implemented at a global level through an international treaty. Thus, a management strategy must be able to attract the voluntary participation of sovereign nations in a treaty. 131 A management strategy is "participation efficient" when it "secure[s] participation at the least cost. ' 132 The sensible way to differentiate between the various types of management strategies is to balance each one's cost-effectiveness, capacity to generate innovation and participation efficiency. 133

3. The Current Management Strategy Is Not Optimal

The current management strategy of the space resource is primarily a RIGHTWAY conduct-based strategy. Mitigation guidelines regulate the way in which the resource is used by directing space programs to follow a set of best practices. 134 These guidelines are nonetheless either non-binding or can be easily departed from, and hence, assuming the resource is sufficiently congested, do not provide incentives that motivate polluters to reduce resource use and pollution. How congested, exactly, is the space resource? Although catastrophic collisions between spacecraft and space debris are currently rare, 135 scientific modeling indicates that LEO is already so polluted with space debris that "collisions will become the most dominant debris- generating mechanism in the future." 136 Even in the absence of any further space activities, debris congestion will continue to increase because collision fragmentation between existing debris and satellites will outpace the natural rate at which these objects re-enter the Earth's atmosphere. 137 Scientists believe that present space debris mitigation measures are not enough to maintain LEO in a usable condition and that some debris must be removed from orbit in order to save the resource. 138 It is, however, particularly difficult to clean the space environment of debris. The only way the space resource naturally renews itself is through a process of orbital decay, whereby gravity pulls debris into the Earth's atmosphere. This process, as previously noted, can take thousands of years 139 and contemporary technology cannot easily or cost-effectively accelerate this process. 140 An optimal space management strategy must therefore incentivize innovation in the form of cost-effective and feasible space debris removal technology. A conduct-based strategy does not provide this incentive. Finally, the space debris problem is a global problem that touches every nation and therefore must be addressed in a global context. The fact that nations are sovereign entities and difficult to compel into action cannot be ignored. 141 Accordingly, in order for mitigation guidelines to stem the growing tide of space debris, every nation that can access space must voluntarily agree to adopt the guidelines. Space debris mitigation confers the greatest benefits to countries that have the most functioning satellites in orbit, because they bear the highest aggregate costs as a result of space debris. The greater the risk of collision, the greater the aggregate shielding, avoidance and monitoring costs become. Conversely, space debris mitigation imposes the greatest burden on those countries with the fewest satellites in orbit (generally, new entrants to the space-faring community). New entrants to space are most likely to be the least technologically advanced and therefore the greatest debris polluters and the greatest cost avoiders. Without an incentive to balance the extra cost of debris mitigation against the benefits of using the space resource, new space entrants are unlikely to voluntarily adopt mitigation guidelines. The current management strategy therefore does not effectively prevent a tragedy of the space commons. The space resource is too fragile and too congested to be left in the hands of unenforceable guidelines. A more effective strategy is necessary to reduce debris pollution, to generate the innovation of feasible space debris removal technology and to secure the participation of all nations in a management system.

Ill. A FRAMEWORK FOR SOLVING THE TRAGEDY OF THE SPACE COMMONS

In order to prevent the emerging tragedy of the space commons, the international community must take steps to reduce the space debris threat because current mitigation measures fail to minimize space debris pollution. The first step is to control the introduction of space debris into the orbital environment more effectively. This step alone, however, will not end the threat posed by space debris. There is already enough space debris that collision fragmentation will outpace debris removal by orbital decay. Thus, the optimal management strategy must also incentivize the development of space debris removal technology. Furthermore, an optimal strategy must have a realistic chance of adoption by the international community. As stated before, this Note suggests that, as an alternative to mitigation guidelines, a market mechanism strategy would most effectively prevent a tragedy of the space commons.

A. Minimizing the Addition of Future Space Debris

Currently, space debris is an unavoidable consequence of space-related activities. In light of the fragile and increasingly congested nature of LEO, a highly effective regulatory instrument is necessary to protect the space environment. To be efficient, an optimal management strategy should minimize the addition of future space debris at the lowest possible cost.142 It is well established in academic literature that incentive based market mechanisms (PROP strategies) are preferable to conduct- based regulatory strategies (RIGHTWAY strategies) on cost efficiency grounds. 143 Market mechanisms, in contrast with conduct strategies, "harness the power of the market

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to generate efficient outcomes and do not rely on regulators to attempt to identify and mandate those outcomes." 144 Market-based strategies assume that the polluter is more knowledgeable about its pollution and abatement costs than a regulatory agent. This approach is cost-effective because the polluter, after internalizing its external costs, is given both the incentive and the flexibility to self-regulate. 145 In the context of the space debris problem, a satellite operator would invest in technology to reduce space debris until the marginal cost of doing so equaled the cost of a tax or the cost of buying a tradable allowance for the next unit of debris. By setting a tax at the correct level or by issuing the correct number of debris permits, debris emissions could be capped at a sustainable level at the lowest possible cost. Therefore, a market mechanism is preferable to the current conduct-based regulations (mitigation guidelines) on cost-efficiency grounds.

B. Encouraging Space Debris Removal Technology

It is equally important in the context of the space resource that the optimal management strategy encourage innovation in space debris removal technology. Different commons management strategies have varying abilities to generate externality-reducing innovation. Conduct-based strategies (in addition to DO NOTHING, KEEPOUT and other RIGHTWAY strategies) do not internalize the external benefits of resource improvement and therefore do not incentivize investment in resource-preserving or resource-renewing technology. When using these management strategies, improvements to the resource are shared among all resource users, and thus are only fractionally beneficial to the innovator. Given that the costs of innovation likely outweigh the fractional benefits of improvement, current conduct-based strategies offer little incentive to develop space debris removal technology. Market mechanisms, on the other hand, encourage the invention of resource-renewal technology. Market mechanisms internalize both the external costs of resource use and the external benefits of resource improvement. In a taxation scheme, tax credit could be given for any debris removed from orbit. Initially, this credit could be set at a high value to provide a strong incentive for third parties to develop feasible space debris removal technology. 146 Satellite operators could then pay specialized debris removal companies to remove debris on their behalf in order to thereby receive the benefit of the tax credit. Operators would pay for space debris removal until the marginal net cost of paying for that removal 147 equaled the marginal cost of paying the tax. The story would be similar if a tradable allowance scheme were adopted. In this scenario, satellite operators could offset future debris pollution against debris that was removed from orbit. The operator would pay for space debris removal until the marginal net cost of paying for removal equaled the marginal cost of buying a tradable allowance on the market.

C. Attracting Global Participation

Most environmental problems are regulated on a national level by a central authority. 148 The space debris problem, however, is not constrained by national boundaries. Because no nation is likely to cede its sovereignty, an effective management strategy must be adopted on a voluntary basis, through an international treaty. Unlike regulatory decisions on a national level, where a single vote 149 or a majority vote can bind the minority, "[t]reaties bind only those who consent to be bound." 150 Thus, a space management strategy should be Pareto-improving; that is, it should make some nations better off but make none worse off.' 5' If a treaty were not Pareto-improving, nations made worse off by the terms of the treaty would refuse to be bound by it. 152 On the grounds of cost-efficiency and innovationgeneration, both types of market mechanisms are equally superior to conduct-based regulatory strategies. When evaluated for participation- efficiency, however, tradable allowances become preferable to taxes. First, both market mechanism strategies impose costs on debris sources. 153 A treaty will induce participation, and thereby pollution abatement, only when the benefits outweigh the costs of participation. For some participants, the benefits of operating satellites and spacecraft in a cleaner LEO will outweigh the costs of debris abatement. These participants will be the least cost participants, likely nations with the most advanced technological capabilities. For other participants, abatement costs will exceed the participation benefits. The participation of these pollution sources in a treaty will have to be encouraged through a set of side payments that compensate for loss-es. 154 In other words, the net beneficiaries of environmental regulation must pay the net losers enough to cover the losers' losses, but not so much that they lose the financial benefits of regulation. 155 In a tax strategy, such side payments undercut the efficacy of the regulations. At the margin, a polluter will choose to abate its debris pollution when the cost of the tax is greater than the cost of abatement. If the cost of the tax is reimbursed through a side payment, however, polluting is costless in comparison with abatement. Thus, a tax with side payments undercuts the incentive of sources that receive the side payment to reduce debris pollution. 156 Tradable allowances, on the other hand, cap the total level of debris emissions while attracting global participation without the perverse incentives of a tax strategy. 157 Sources have no incentive to pollute and then seek compensatory side payments precisely because a tradable allowance scheme caps total pollution. 158 Participation losers would be allocated extra allowances during the initial distribution of allowances in order to secure their participation. But once those extra allowances were bought on the market, the losers would bear the full burden of any extra pollution they emitted. Thus, under a tax scheme, subsidized debris sources could continue to pollute and receive side payments, but under a tradable allowance scheme, side payments are fixed during the initial distribution of allowances.

CONCLUSION

Space is a resource worth preserving. Unfortunately, the legal regime that governs space treats it as a common property resource, and nations realize the full benefits of use while bearing only a fractional share of its costs. Consequently, space is quickly heading towards a tragedy of the commons. Current debris mitigation measures are not a viable long-term solution to this problem: space is too fragile and too congested a resource. Instead, an international treaty that implements a tradable allowance scheme would be a preferable solution. Tradable allowances are more cost-effective, generate more innovation and facilitate greater global participation than any other resource management strategy. Thus, tradable allowances offer the most promising solution to the tragedy of the space commons.