## Shield

### 1AC Advantage – Space Weather

#### Space superstorms are inevitable in the immediate future – solar maximum makes the risk uniquely high

Kettley 19 [Sebastian Kettley, science reporter citing Dr Kaku, a theoretical physicist at the City College of New York. “Space weather WARNING: 'All hell will break loose' when solar flare CRIPPLES Earth.” January 25, 2019. https://www.express.co.uk/news/science/1077603/Space-weather-warning-solar-flare-hit-earth-michio-kaku-sunspot]

Major solar flares triggered by a solar maximum in [space](https://www.express.co.uk/latest/space) will wreak havoc on Earth and it is only a “matter of time”. Dr Kaku, a theoretical physicist and book author at the City College of New York, has warned modern technology is defenceless against such reckless power. Solar flares are highly-charged streams of gaseous energy particles violently ejected from the Sun out into the solar system. When solar flares strike the atmosphere, they create beautiful displays of light near the North and South Poles, known as aurora. But solar flares also have the power to wipe out communications satellites, disable electronic devices and cause aeroplanes to malfunction. At their worst, solar flares can blow out power stations, disable GPS navigation and ground emergency services. Speaking live on Coast to Coast AM Radio, Dr Kaku said solar flares on this scale are rare – they only strike once every 100 to 200 years. But the last known solar flare this powerful struck 150 years ago, suggesting the planet could be due another solar attack soon. Dr Kaku said: “These are rare events, maybe once in 100 years or once in 200 years, but is it is inevitable.” And once the solar flare does strike, the effects will be much more devastating than the aftermath of Hurricane Katrina. In 1859, a major solar flare struck the planet, lighting up the night skies from the North Pole all the way down to Cuba. The flare was caused by a so-called Coronal Mass Ejection (CME) from the surface of the Sun and has caused one of the largest geomagnetic storms on record. Dr Kaku said: “It’s a matter of time, you know, we’ve had a big one 150 years ago in 1859. We’ve had a huge solar flare that hit the Earth. One of these days one of these solar flares is going to hit the Earth Dr Michio Kaku, Theoretical physicist “Back then they only had telegraph poles but even they got shorted out and you could read the newspaper in Cuba at night by the light of the Northern Lights, the Aurora Borealis, as far south as Cuba. “From that, we physicists can recalculate how big that solar flare of 1859 must have been. “If we were hit by another one like that, it would fry our satellites, communications would go down instantly, power plants would be shorted out, and in the worst case – remember this a worst case scenario – we physicists believe that it could be 20-times worse than Hurricane Katrina. “So image 20 Hurricane Katrinas ravaging the Earth simultaneously and you can begin to estimate the kind of damage if there is a direct hit from one of these solar flares. “And we’re headed toward the maximum, so more flares are going off the Sun – we had a big one last month.” The solar maximum is a period of the tumultuous solar activity during an 11-year-long cycle. During a solar maximum, the highest number of sunspots appears and the amount of energy radiating from the star has been known to change the weather on Earth. According to Dr Kaku, the solar maximum is the most likely window of opportunity for a major solar flare to hit the Earth. He said: “So far we’ve dodged the bullet, so far we’ve been able to miss these sale flares, but these solar flares are like bullets and sunspots are like rifles. “Think of rifles shooting bullets into outer space and missing Earth. “Of course outer space is quite big but one of these days one of these solar flares is going to hit the Earth like what happened in 1858 and all hell can break loose.”

#### **Increasing system vulnerability and weakening Van Allen belts mean solar storms will crush civilization –** sparks resource shortages, economic collapse, grid failure, and pandemics

Pelton 16 [Dr. Joseph N. Pelton, Research Professor, Institute for Applied Space Research, George Washington University; former Chairman of the Board, Dean, International Space University; former Director, Graduate Telecommunications Program and Center for Advanced Research in Telecommunications, University of Colorado at Boulder; former Director, Strategy Policy and Executive Assistant to Director General, Intelsat. Director, Project Share. Vice Chairman, Arthur C. Clarke Foundation and Executive Director, Clarke Institute for Telecommunication and Information (CITI). Member, International Academy of Astronautics, 2016. “Our changing world and the mounting risk of a calamitous solar storm.” https://room.eu.com/article/our-changing-world-and-the-mounting-risk-of-a-calamitous-solar-storm]

In our search of the cosmos for planets that might support intelligent life we have now begun to realise that the existence of what are called ‘Goldilocks worlds’ may very well be rare indeed. And by Goldilocks worlds we mean planets that are just right - not too cold and not too hot. We also mean a planet with water and natural resources as well as an atmosphere and a magnetic field to support life systems and protect them from stellar heat and radiation and coronal mass ejections (CME). But the question of relevance is: Just how safe is Earth from cosmic dangers? We humans, in fact, have become somewhat complacent about the natural protective systems that our six-sextillion ton spacecraft has to protect us from - solar storms, comets, asteroids, and cosmic rays. We forget that our atmosphere and our naturally formed Van Allen belts held in place by the Earth’s magnetic poles serve to shield us from massive blasts of ions that periodically travel from the Sun. These so-called coronal mass ejections travel at millions of kilometres an hour. If one of these CMEs were to hit Earth head-on, it would have the power to create natural electro-magnetic pulses (EMPs) far more effectively than a thermonuclear blast. Over the course of the last half century, the world has finally begun to learn that a massive asteroid or comet strike could create havoc and ruin, on perhaps a planetary scale. After decades of urging, the United Nations has created an International Asteroid Warning Network (IAWN) and even a Space Mission Planning Advisory Group (SMPAG) - pronounced ‘same page’. We even have missions such as the B612 Foundation’s Sentinel Project that is planning to launch an infrared telescope that can scour the skies and give us warning of a killer asteroid that might hit Earth. This article is therefore about how such an innovative megastructure could be designed to save the human species and Earth as we know it today But what we don’t have is a global understanding that there is a much more likely danger that is increasing over time. This is a very real cosmic danger that could knock out our electric power grids, kill key satellite systems for communications and navigation and defence. This cosmic menace could knock out the time synchronization of the global Internet which is essential for it to continue to function day in, day out. A massive coronal mass ejection that brings millions of tons of ions travelling perhaps at two million kilometres an hour, similar to the Carrington Event of 1859, might leave the world’s economic systems and global infrastructure in shambles. And we do not have to look 150 years into the past. The Chicago to Montreal event of 1989 and the Halloween event in Scandinavia of 2003 are indicators that these cosmic hazards are real and relevant to our lives today. NASA and other space agencies have programmes like EarthGuard, NEOWarn, and infrared telescopes to address the asteroid threat. There are many programmes that range from directed energy beam systems to ‘Laser Bees’ to nuclear energy systems that the SMPAG could consider if presented with an actual threat to Earth from a potentially hazardous asteroid and/or comet. But what about the more likely cosmic threat from coronal mass ejections? Here there are literally no active protective programmes under way or under study. The US National Intelligence Committee identified this as one of several ‘Black Swan’ events that could have devastating global impact. Lloyds of London analysed what the economic impacts might be of a major CME event hitting Earth and estimated a devastating negative financial impact of US $2.7 trillion dollars in a report which was silent on the estimated potential mega-death toll. There is likely to be a spike in ‘vulnerability’ in coming years. The reason is that the natural protective shield created by the Van Allen belts, that are held in place by Earth’s magnetic poles, are increasingly at risk of being greatly diminished. ESA’s Swarm mission satellites are designed to measure Earth’s magnetosphere. These satellites confirm what we had begun to suspect - that Earth’s magnetic poles are apparently in a process of shifting from North to South and South to North. Swarm measurements confirm that Earth’s Magnetic North has now shifted down to Siberia and continues to head South. Modelling carried out by the Max Planck Institute in Germany in 2015 suggests that during this shift the shielding provided by the Van Allen belts will essentially go haywire and be reduced to perhaps 15 per cent of its former protective capacity. This means the potential of enormous risk to electric power grids with maybe thousands of electrical transformers burned to a crisp. It also means vital satellites for communications, broadcasting, global navigation and timing, weather forecasting, synchronising the Internet and assisting with aircraft take-off and landing could be suddenly rendered inoperable or severely degraded. As we add more people, more vital infrastructure and move to a highly urban environment with perhaps 70 per cent of all people living in urban centres, the vulnerability of humans all over the globe is growing. A loss of vital infrastructure around the world could mean the failure of transportation, communications and power systems that could put millions of people at risk due to disease, starvation, water shortages or other dangers.

#### **It's the most threatening scenario for extinction – outweighs nuclear war on probability and magnitude**

O’Reilly 14 [William F.B. O’Reilly, corporate and political communications consultant, citing Frank Gaffney, the founder and president of the Center for Security Policy and hedge fund giant Paul Singer, July 31, 2014. “The day we almost went stupid.” <https://www.amny.com/opinion/columnists/william-f-b-o-reilly/the-day-we-almost-went-stupid-william-f-b-o-reilly-1.8933432>]

She popped to mind this week when I heard that the world just missed being sent back to the Bronze Age by a solar flare. It happened on July 23, 2012, but scientists just got around to telling us about it. This flare apparently caused something called a coronal mass ejection, which in turn created an electromagnetic pulse [EMP] that missed Earth by a whisker. A smaller coronal mass ejection caused telegraphs around the world to melt down in 1859 in what became known as the Carrington Event. Pretty big difference between 1859 and 2014 technology-wise. If Carrington had struck in the summer of '12, we'd likely have lost electricity; water services; bank accounts; financial markets; anything online; and car, rail and air travel -- pretty much everything except those solar calculators that now come as tradeshow giveaways. It would take years to bring services back online, experts say. A lot of smart people are taking this threat seriously. Hedge fund giant Paul Singer issued a memo to investors this week, calling the threat of an EMP rendering useless everything with a battery or a plug "the most significant danger" in the world. "While these pages are typically chock full of scary or depressing scenarios," Singer wrote, "there is one risk that is head-and-shoulders above all the rest in terms of the scope of potential damage adjusted for the likelihood of occurrence. Even horrendous nuclear war, except in its most extreme form, can [be] a relatively localized issue, and the threat from asteroids can be mitigated." When the Paul Singers of the world worry enough to alert investors about something, it's probably worth thinking about. Frank Gaffney, the founder and president of the Center for Security Policy, and a former client, has been warning about the threat of EMPs for years. But Gaffney doesn't look to the sun. His concern is China, North Korea, Russia, or a nuclear Iran. Anyone with nuclear capability who can sail a barge near America's shores would be capable of knocking out America's power grid with a high altitude nuclear detonation.

#### Grid resilience solves extinction – it’s a threat buffer and the impact is understated

Greene 19 [Sherrell R. Greene Mr. Greene received his B.S. and M.S. degrees in Nuclear Engineering from the University of Tennessee. He is a recognized subject matter expert in nuclear reactor safety, nuclear fuel cycle technologies, and advanced reactor concept development. Mr. Greene is widely acclaimed for his systems analysis, team building, innovation, knowledge organization, presentation, and technical communication skills. Mr. Greene worked at the Oak Ridge National Laboratory (ORNL) for over three decades. During his career at ORNL, he served as Director of Research Reactor Development Programs and Director of Nuclear Technology Programs. . "Enhancing Electric Grid, Critical Infrastructure, and Societal Resilience with Resilient Nuclear Power Plants (rNPPs)." <https://ans.tandfonline.com/doi/pdf/10.1080/00295450.2018.1505357?needAccess=true>]

Societies and nations are examples of large-scale, complex social-physical systems. Thus, societal resilience can be defined as the ability of a nation, population, or society to anticipate and prepare for major stressors or calamities and then to absorb, adapt to, recover from, and restore normal functions in the wake of such events when they occur. A nation’s dependence on its Critical Infrastructure systems, and the resilience of those systems, are therefore major components of national and societal resilience. There are a variety of events that could deal crippling blows to a nation’s Grid, Critical Infrastructure, and social fabric. The types of catastrophes under consideration here are “very bad day” scenarios that might result from severe GMDs induced by solar CMEs, HEMP attacks, cyber attacks, etc.5 As briefly discussed in Sec. III.C, the probability of a GMD of the magnitude of the 1859 Carrington Event is now believed to be on the order of 1%/year. The Earth narrowly missed (by only several days) intercepting a CME stream in July 2012 that would have created a GMD equal to or larger than the Carrington Event.41 Lloyd’s, in its 2013 report, “Solar Storm Risk to the North American Electric Grid,” 42 stated the following: “A Carrington-level, extreme geomagnetic storm is almost inevitable in the future…The total U.S. population at risk of extended power outage from a Carrington-level storm is between 20-40 million, with durations of 16 days to 1-2 years…The total economic cost for such a scenario is estimated at $0.6-2.6 trillion USD.” Analyses conducted subsequent to the Lloyd’s assessment indicated the geographical area impacted by the CME would be larger than that estimated in Lloyd’s analysis (extending farther northward along the New England coast of the United States and in the state of Minnesota),43 and that the actual consequences of such an event could actually be greater than estimated by Lloyd’s. Based on “Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures” to Congress in 2008 (Ref. 39), a HEMP attack over the Central U.S. could impact virtually the entire North American continent. The consequences of such an event are difficult to quantify with confidence. Experts affiliated with the aforementioned Commission and others familiar with the details of the Commission’s work have stated in Congressional testimony that such an event could “kill up to 90 percent of the national population through starvation, disease, and societal collapse.” 44,45 Most of these consequences are either direct or indirect impacts of the predicted collapse of virtually the entire U.S. Critical Infrastructure system in the wake of the attack. Last, recent analyses by both the U.S. Department of Energy46 and the U.S. National Academies of Sciences, Engineering, and Medicine47 have concluded that cyber threats to the U.S. Grid from both state-level and substatelevel entities are likely to grow in number and sophistication in the coming years, posing a growing threat to the U.S. Grid. These three “very bad day” scenarios are not creations of overzealous science fiction writers. A variety of mitigating actions to reduce both the vulnerability and the consequences of these events has been identified, and some are being implemented. However, the fact remains that events such as those described here have the potential to change life as we know it in the United States and other developed nations in the 21st century, whether the events occur individually, or simultaneously, and with or without coordinated physical attacks on Critical Infrastructure assets.

#### Pandemics causes extinction

Millett 17 [Piers Consultant for the World Health Organization, PhD in International Relations and Affairs, University of Bradford, Andrew Snyder-Beattie. “Existential Risk and Cost-Effective Biosecurity.” http://online.liebertpub.com/doi/pdfplus/10.1089/hs.2017.0028]

Historically, disease events have been responsible for the greatest death tolls on humanity. The 1918 flu was responsible for more than 50 million deaths,1 while smallpox killed perhaps 10 times that many in the 20th century alone.2 The Black Death was responsible for killing over 25% of the European population,3 while other pandemics, such as the plague of Justinian, are thought to have killed 25 million in the 6th century—constituting over 10% of the world’s population at the time.4 It is an open question whether a future pandemic could result in outright human extinction or the irreversible collapse of civilization. A skeptic would have many good reasons to think that existential risk from disease is unlikely. Such a disease would need to spread worldwide to remote populations, overcome rare genetic resistances, and evade detection, cures, and countermeasures. Even evolution itself may work in humanity’s favor: Virulence and transmission is often a trade-off, and so evolutionary pressures could push against maximally lethal wild-type pathogens.5,6 While these arguments point to a very small risk of human extinction, they do not rule the possibility out entirely. Although rare, there are recorded instances of species going extinct due to disease—primarily in amphibians, but also in 1 mammalian species of rat on Christmas Island.7,8 There are also historical examples of large human populations being almost entirely wiped out by disease, especially when multiple diseases were simultaneously introduced into a population without immunity. The most striking examples of total population collapse include native American tribes exposed to European diseases, such as the Massachusett (86% loss of population), Quiripi-Unquachog (95% loss of population), and theWestern Abenaki (which suffered a staggering 98% loss of population). In the modern context, no single disease currently exists that combines the worst-case levels of transmissibility, lethality, resistance to countermeasures, and global reach. But many diseases are proof of principle that each worst-case attribute can be realized independently. For example, some diseases exhibit nearly a 100% case fatality ratio in the absence of treatment, such as rabies or septicemic plague. Other diseases have a track record of spreading to virtually every human community worldwide, such as the 1918 flu,10 and seroprevalence studies indicate that other pathogens, such as chickenpox and HSV-1, can successfully reach over 95% of a population.11,12 Under optimal virulence theory, natural evolution would be an unlikely source for pathogens with the highest possible levels of transmissibility, virulence, and global reach. But advances in biotechnology might allow the creation of diseases that combine such traits. Recent controversy has already emerged over a number of scientific experiments that resulted in viruses with enhanced transmissibility, lethality, and/or the ability to overcome therapeutics.13-17 Other experiments demonstrated that mousepox could be modified to have a 100% case fatality rate and render a vaccine ineffective.18 In addition to transmissibility and lethality, studies have shown that other disease traits, such as incubation time, environmental survival, and available vectors, could be modified as well.19-2 Although these experiments had scientific merit and were not conducted with malicious intent, their implications are still worrying. This is especially true given that there is also a long historical track record of state-run bioweapon research applying cutting-edge science and technology to design agents not previously seen in nature. The Soviet bioweapons program developed agents with traits such as enhanced virulence, resistance to therapies, greater environmental resilience, increased difficulty to diagnose or treat, and which caused unexpected disease presentations and outcomes.22 Delivery capabilities have also been subject to the cutting edge of technical development, with Canadian, US, and UK bioweapon efforts playing a critical role in developing the discipline of aerobiology.23,24 While there is no evidence of staterun bioweapons programs directly attempting to develop or deploy bioweapons that would pose an existential risk, the logic of deterrence and mutually assured destruction could create such incentives in more unstable political environments or following a breakdown of the Biological Weapons Convention.25 The possibility of a war between great powers could also increase the pressure to use such weapons—during the World Wars, bioweapons were used across multiple continents, with Germany targeting animals in WWI,26 and Japan using plague to cause an epidemic in China during WWII.27

#### Econ decline causes world war – there’s no buffer now

Sundaram 19 [Jomo Kwame Sundaram, a former economics professor, was United Nations Assistant Secretary-General for Economic Development, and received the Wassily Leontief Prize for Advancing the Frontiers of Economic Thought in 2007. Vladimir Popov, a former senior economics researcher in the Soviet Union, Russia and the United Nations Secretariat, is now Research Director at the Dialogue of Civilizations Research Institute in Berlin. Economic Crisis Can Trigger World War. February 12, 2019. www.ipsnews.net/2019/02/economic-crisis-can-trigger-world-war/]

KUALA LUMPUR and BERLIN, Feb 12 2019 (IPS) - Economic recovery efforts since the 2008-2009 global financial crisis have mainly depended on unconventional monetary policies. As fears rise of yet another international financial crisis, there are growing concerns about the increased possibility of large-scale military conflict. More worryingly, in the current political landscape, prolonged economic crisis, combined with rising economic inequality, chauvinistic ethno-populism as well as aggressive jingoist rhetoric, including threats, could easily spin out of control and ‘morph’ into military conflict, and worse, world war. Crisis responses limited The 2008-2009 global financial crisis almost ‘bankrupted’ governments and caused systemic collapse. Policymakers managed to pull the world economy from the brink, but soon switched from counter-cyclical fiscal efforts to unconventional monetary measures, primarily ‘quantitative easing’ and very low, if not negative real interest rates. But while these monetary interventions averted realization of the worst fears at the time by turning the US economy around, they did little to address underlying economic weaknesses, largely due to the ascendance of finance in recent decades at the expense of the real economy. Since then, despite promising to do so, policymakers have not seriously pursued, let alone achieved, such needed reforms. Instead, ostensible structural reformers have taken advantage of the crisis to pursue largely irrelevant efforts to further ‘casualize’ labour markets. This lack of structural reform has meant that the unprecedented liquidity central banks injected into economies has not been well allocated to stimulate resurgence of the real economy. From bust to bubble Instead, easy credit raised asset prices to levels even higher than those prevailing before 2008. US house prices are now 8% more than at the peak of the property bubble in 2006, while its price-to-earnings ratio in late 2018 was even higher than in 2008 and in 1929, when the Wall Street Crash precipitated the Great Depression. As monetary tightening checks asset price bubbles, another economic crisis — possibly more severe than the last, as the economy has become less responsive to such blunt monetary interventions — is considered likely. A decade of such unconventional monetary policies, with very low interest rates, has greatly depleted their ability to revive the economy. The implications beyond the economy of such developments and policy responses are already being seen. Prolonged economic distress has worsened public antipathy towards the culturally alien — not only abroad, but also within. Thus, another round of economic stress is deemed likely to foment unrest, conflict, even war as it is blamed on the foreign. International trade shrank by two-thirds within half a decade after the US passed the Smoot-Hawley Tariff Act in 1930, at the start of the Great Depression, ostensibly to protect American workers and farmers from foreign competition! Liberalization’s discontents Rising economic insecurity, inequalities and deprivation are expected to strengthen ethno-populist and jingoistic nationalist sentiments, and increase social tensions and turmoil, especially among the growing precariat and others who feel vulnerable or threatened. Thus, ethno-populist inspired chauvinistic nationalism may exacerbate tensions, leading to conflicts and tensions among countries, as in the 1930s. Opportunistic leaders have been blaming such misfortunes on outsiders and may seek to reverse policies associated with the perceived causes, such as ‘globalist’ economic liberalization. Policies which successfully check such problems may reduce social tensions, as well as the likelihood of social turmoil and conflict, including among countries. However, these may also inadvertently exacerbate problems. The recent spread of anti-globalization sentiment appears correlated to slow, if not negative per capita income growth and increased economic inequality. To be sure, globalization and liberalization are statistically associated with growing economic inequality and rising ethno-populism. Declining real incomes and growing economic insecurity have apparently strengthened ethno-populism and nationalistic chauvinism, threatening economic liberalization itself, both within and among countries. Insecurity, populism, conflict Thomas Piketty has argued that a sudden increase in income inequality is often followed by a great crisis. Although causality is difficult to prove, with wealth and income inequality now at historical highs, this should give cause for concern. Of course, other factors also contribute to or exacerbate civil and international tensions, with some due to policies intended for other purposes. Nevertheless, even if unintended, such developments could inadvertently catalyse future crises and conflicts. Publics often have good reason to be restless, if not angry, but the emotional appeals of ethno-populism and jingoistic nationalism are leading to chauvinistic policy measures which only make things worse. At the international level, despite the world’s unprecedented and still growing interconnectedness, multilateralism is increasingly being eschewed as the US increasingly resorts to unilateral, sovereigntist policies without bothering to even build coalitions with its usual allies. Avoiding Thucydides’ iceberg Thus, protracted economic distress, economic conflicts or another financial crisis could lead to military confrontation by the protagonists, even if unintended. Less than a decade after the Great Depression started, the Second World War had begun as the Axis powers challenged the earlier entrenched colonial powers.

#### Resource shortages generate conflict and refugee flows – goes nuclear

Cribb 19 [Julian Cribb, distinguished science writer with more than thirty awards for journalism, October 3, 2019. “Food or War.” Cambridge University Press. https://www.cambridge.org/core/books/food-or-war/2D6F728A71C0BFEA0CEC85897066DCAF]

Although actual numbers of warheads have continued to fall from its peak of 70,000 weapons in the mid 1980s, scientists argue the danger of nuclear conflict in fact increased in the first two decades of the twenty first century. This was due to the modernisation of existing stockpiles, the adoption of dangerous new technologies such as robot delivery systems, hypersonic missiles, artificial intelligence and electronic warfare, and the continuing leakage of nuclear materials and knowhow to nonnuclear nations and potential terrorist organisations. In early 2018 the hands of the ‘ Doomsday Clock ’ , maintained by the Bulletin of the Atomic Scientists, were re-set at two minutes to midnight, the highest risk to humanity that it has ever shown since the clock was introduced in 1953. This was due not only to the state of the world ’s nuclear arsenal, but also to irresponsible language by world leaders, the growing use of social media to destabilise rival regimes, and to the rising threat of uncontrolled climate change (see below). 12 In an historic moment on 17 July 2017, 122 nations voted in the UN for the first time ever in favour of a treaty banning all nuclear weapons. This called for comprehensive prohibition of “ a full range of nuclear-weapon-related activities, such as undertaking to develop, test, produce, manufacture, acquire, possess or stockpile nuclear weapons or other nuclear explosive devices, as well as the use or threat of use of these weapons. ” 13 However, 71 other countries– including all the nuclear states– either opposed the ban, abstained or declined to vote. The Treaty vote was nonetheless interpreted by some as a promising first step towards abolishing the nuclear nightmare that hangs over the entire human species. In contrast, 192 countries had signed up to the Chemical Weapons Convention to ban the use of chemical weapons, and 180 to the Biological Weapons Convention. As of 2018, 96 per cent of previous world stocks of chemical weapons had been destroyed– but their continued use in the Syrian conflict and in alleged assassination attempts by Russia indicated the world remains at risk. 14 As things stand, the only entities that can afford to own nuclear weapons are nations– and if humanity is to be wiped out, it will most likely be as a result of an atomic conflict between nations. It follows from this that, if the world is to be made safe from such a fate it will need to get rid of nations as a structure of human self-organisation and replace them with wiser, less aggressive forms of self-governance. After all, the nation state really only began in the early nineteenth century and is by no means a permanent feature of self-governance, any more than monarchies, feudal systems or priest states. Although many people still tend to assume it  
 is. Between them, nations have butchered more than 200 million people in the past 150 years and it is increasingly clear the world would be a far safer, more peaceable place without either nations or nationalism. The question is what to replace them with. Although there may at first glance appear to be no close linkage between weapons of mass destruction and food, in the twenty first century with world resources of food, land and water under growing stress, nothing can be ruled out. Indeed, chemical weapons have frequently been deployed in the Syrian civil war, which had drought, agricultural failure and hunger among its early drivers. And nuclear conflict remains a distinct possibility in South Asia and the Middle East, especially, as these regions are already stressed in terms of food, land and water, and their nuclear firepower or access to nuclear materials is multiplying. It remains an open question whether panicking regimes in Russia, the USA or even France would be ruthless enough to deploy atomic weapons in an attempt to quell invasion by tens of millions of desperate refugees, fleeing famine and climate chaos in their own homelands– but the possibility ought not to be ignored. That nuclear war is at least a possible outcome of food and climate crises was first flagged in the report The Age of Consequences by Kurt Campbell and the US-based Centre for Strategic and International Studies, which stated ‘ it is clear that even nuclear war cannot be excluded as a political consequence of global warming ’ . 15 Food insecurity is therefore a driver in the preconditions for the use of nuclear weapons, whether limited or unlimited.

#### Even small disruptions from a space storm risk nuclear accidents and World War III

Dockrill 18 [Peter Dockrill, Deputy Editor of Science Alert and an award-winning science & technology journalist, citing astrophysicist Abraham Loeb from Harvard University and director of research for MIT's Energy Initiative, Francis O'Sullivan, June 21, 2018. “Here's What Would Happen if a Solar Storm Wiped Out Technology as We Know It.” https://www.sciencealert.com/here-s-what-would-happen-if-solar-storm-wiped-out-technology-geomagnetic-carrington-event-coronal-mass-ejection]

It's a strange and lucky irony that the worst solar storm in recorded history happened at a time when human civilisation wasn't yet uniquely vulnerable to the Sun's inescapable geomagnetic fury. The Carrington Event – aka the [solar storm of 1859](https://www.sciencealert.com/how-a-massive-solar-storm-could-wipe-out-modern-technology) – saw a huge solar [coronal mass ejection](https://www.sciencealert.com/geomagnetic-solar-storm-flare-coronal-mass-ejection-february-2018) unleashed at Earth's protective [magnetosphere](https://www.sciencealert.com/scientists-have-detected-a-crack-in-earth-s-magnetic-shield), producing an epic geomagnetic storm the scale of which [modern civilisation had never before witnessed](https://www.sciencealert.com/evidence-of-ancient-solar-storms-is-locked-up-in-tree-rings). As a barrage of charged particles collided with Earth's magnetic field, [intense auroras](https://www.sciencealert.com/aurora-named-steve-explained-subauroral-ion-drift) lit up skies around the world – but with strong electrical currents sweeping across the globe, the repercussions went far beyond colourful visuals. Telegraph systems covering Europe and North America went down, as sparks flew from equipment, giving electric shocks to their human operators and even starting fires. Amid the electrified tumult, machines that had been disconnected from their power supplies [eerily continued to relay their truncated messages](https://www.sciencealert.com/how-a-massive-solar-storm-could-wipe-out-modern-technology). It was, in other words, technological chaos. Yet from the comparatively futuristic perspective of 2018, as far as tech apocalypses go, it all sounds rather quaint and contained. If a similar-scale [solar storm](https://www.sciencealert.com/no-massive-solar-storm-headed-to-earth-march-2018-noaa-g1) were to strike Earth's pervasive technological systems right now – over a century and a half later – what would happen? Nobody knows for sure how bad things would be, but given how scarily reliant we are on today's deep-rooted technological and electronic superstructures – compared to the primitive and relatively rare contraptions of 1859 – it would certainly be no picnic. Perhaps our most relevant clue lies in some strange events that befell the world in the month of [March, 1989](https://en.wikipedia.org/wiki/March_1989_geomagnetic_storm). Back then, a severe but not-Carrington-class solar storm struck Earth, courtesy of another coronal mass ejection from the Sun. Again, intense auroras resulted, leading some to think they could be seeing hazy after-effects of World War III. Yet it wasn't a nuclear strike disrupting radio signals and satellite communication systems, but the flow of charged particles [getting caught up in Earth's magnetic field lines](https://www.sciencealert.com/geomagnetic-solar-storm-flare-coronal-mass-ejection-february-2018). The most extreme results were felt in Quebec, Canada, where the power grid went offline, meaning some 6 million people were immediately deprived of electricity. For many, the outage lasted only hours, but for others it took days for the power to come back on. It's this kind of medieval scenario that has scientists at the White House worried a doomsday-scale geomagnetic storm on the level of the Carrington Event could effectively send the world [back to the Dark Ages](https://www.sciencealert.com/the-white-house-is-prepping-for-a-huge-solar-storm-that-could-kick-us-back-into-the-dark-ages). The thinking goes that ["the big one"](https://www.sciencealert.com/scientists-are-preparing-for-a-solar-storm-so-powerful-they-re-calling-it-the-big-one), when it hits (about [once every 500 years](https://www.sciencealert.com/how-a-massive-solar-storm-could-wipe-out-modern-technology), [if not sooner](https://www.cnet.com/news/we-arent-ready-for-a-solar-storm-smackdown/)) would be powerful enough to knock out electrical and communications systems across Earth for days, months, or even years – nixing power grids, satellites, GPS, the internet, telephones, transportation systems, banking, you name it. And forget taking out Quebec – we could be talking about all of Canada going offline, maybe the whole world – and with only [hours of warning](https://www.sciencealert.com/the-white-house-is-prepping-for-a-huge-solar-storm-that-could-kick-us-back-into-the-dark-ages) before technological darkness falls. It sounds like something out of a disaster movie, but it's not the stuff of fiction. Conservative estimates suggest we could be looking at up to [US$2 trillion of damage](https://www.sciencealert.com/how-a-massive-solar-storm-could-wipe-out-modern-technology) in the first year of such a calamity, with a recovery effort that could take a decade for the world to pull off. On the more extreme side, others say US$20 trillion is a more reasonable figure – an inevitable damage bill that should perhaps make us reassess the risk factors of space-borne destruction. "In terms of risk from the sky, most of the attention in the past was dedicated to asteroids," astrophysicist Abraham Loeb from Harvard University [explained to Universe Today last year](https://www.sciencealert.com/scientists-are-proposing-to-protect-earth-from-solar-flares-with-a-gigantic-shield). "But a century ago, there was not much technological infrastructure around, and technology is growing exponentially. Therefore, the damage is highly asymmetric between the past and future." In a best-case scenario, a severe geomagnetic storm might only result in limited communications disruptions. But as history has shown, even such small-scale interference with the wrong kind of technological systems can have devastating consequences – [like taking the world to the brink of nuclear war](https://www.sciencealert.com/a-solar-storm-in-1967-nearly-took-the-us-to-the-brink-of-nuclear-war). Just where a more powerful solar storm might take us next – or when – is the million-dollar question. Under majestic auroras, we might be forced to undergo a brutal, incalculable reset. "An event of [Carrington] scale could be catastrophic if it happened tomorrow," director of research for MIT's Energy Initiative, Francis O'Sullivan, [told CNET last week](https://www.cnet.com/news/we-arent-ready-for-a-solar-storm-smackdown/). "It's not just the lights going off now. It's bank accounts disappearing… If you think what would happen if the stock exchange was taken offline for a week or month or if communications were down for a week or a month, you very quickly get to a point where this might be one of the most important threats the nation faces, bar none."

#### Space storms trigger global nuclear meltdowns and countermeasures fail – extinction

Stein 12 [Matthew Stein, degree in Mechanical Engineering from Massachusetts Institute of Technology (MIT), March 24, 2012. “Four Hundred Chernobyls: Solar Flares, Electromagnetic Pulses and Nuclear Armageddon.” https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/]

In the past 152 years, Earth has been struck by roughly 100 solar storms, causing significant geomagnetic disturbances (GMD), two of which were powerful enough to rank as “extreme GMDs.” If an extreme GMD of such magnitude were to occur today, in all likelihood, it would initiate a chain of events leading to catastrophic failures at the vast majority of our world’s nuclear reactors, similar to but over 100 times worse than, the disasters at both Chernobyl and Fukushima. When massive solar flares launch a huge mass of highly charged plasma (a coronal mass ejection, or CME) directly toward Earth, colliding with our planet’s outer atmosphere and magnetosphere, the result is a significant geomagnetic disturbance. The last extreme GMD of a magnitude that could collapse much of the US grid was in May of 1921, long before the advent of modern electronics, widespread electric power grids, and nuclear power plants. We are, mostly, blissfully unaware of this threat and unprepared for its consequences. The good news is that relatively affordable equipment and processes could be installed to protect critical components in the electric power grid and its nuclear reactors, thereby averting this “end-of-the-world-as-we-know-it” scenario. The bad news is that even though panels of scientists and engineers have studied the problem, and the bipartisan Congressional electromagnetic pulse (EMP) commission has presented a list of specific recommendations to Congress, our leaders have yet to approve and implement any significant preventative measures. Most of us believe that an emergency like this could never happen, and that, if it could, our “authorities” would do everything in their power to prevent such an apocalypse. Unfortunately, the opposite is true. “How could this happen?” you might ask. Nuclear Power Plants and the Electric Power Grid Our current global system of electrical power generation and distribution (“the grid”), upon which our modern lifestyles are utterly dependent, is extremely vulnerable to severe geomagnetic storms, which tend to strike our planet on an average of approximately once every 70 to 100 years. We depend on this grid to maintain food production and distribution, telecommunications, Internet services, medical services, military defense, transportation, government, water treatment, sewage and garbage removal, refrigeration, oil refining, gas pumping and all forms of commerce. Unfortunately, the world’s nuclear power plants, as they are currently designed, are critically dependent upon maintaining connection to a functioning electrical grid, for all but relatively short periods of electrical blackouts, in order to keep their reactor cores continuously cooled so as to avoid catastrophic reactor core meltdowns and fires in storage ponds for spent fuel rods. If an extreme GMD were to cause widespread grid collapse (which it most certainly will), in as little as one or two hours after each nuclear reactor facility’s backup generators either fail to start, or run out of fuel, the reactor cores will start to melt down. After a few days without electricity to run the cooling system pumps, the water bath covering the spent fuel rods stored in “spent-fuel ponds” will boil away, allowing the stored fuel rods to melt down and burn [[2]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#2). Since the Nuclear Regulatory Commission (NRC) currently mandates that only one week’s supply of backup generator fuel needs to be stored at each reactor site, it is likely that, after we witness the spectacular nighttime celestial light show from the next extreme GMD, we will have about one week in which to prepare ourselves for Armageddon. To do nothing is to behave like ostriches with our heads in the sand, blindly believing that “everything will be okay” as our world drifts towards the next natural, inevitable super solar storm and resultant extreme GMD. Such a storm would end the industrialized world as we know it, creating almost incalculable suffering, death and environmental destruction on a scale not seen since the extinction of the dinosaurs some 65 million years ago. The End of “The Grid” as We Know It There are records from the 1850s to today of roughly 100 significant geomagnetic solar storms, two of which, in the last 25 years, were strong enough to cause millions of dollars worth of damage to key components that keep our modern grid powered. In March of 1989, a severe solar storm induced powerful electric currents in grid wiring that fried a main power transformer in the HydroQuebec system, causing a cascading grid failure that knocked out power to 6 million customers for nine hours and damaging similar transformers in New Jersey and the UK. More recently, in 2003, a less intense but longer solar storm caused a blackout in Sweden and induced powerful currents in the South African grid that severely damaged or destroyed 14 of their major power transformers, impairing commerce and comfort over major portions of that country as it was forced to resort to massive rolling blackouts that dragged on for many months.[[3]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#3) During the great geomagnetic storm of May 14-15, 1921, brilliant aurora displays were reported in the Northern Hemisphere as far south as Mexico and Puerto Rico, and in the Southern Hemisphere as far north as Samoa.[[4]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#4) This extreme GMD produced ground currents roughly ten times as strong as the 1989 Quebec incident. Just 62 years earlier, the great granddaddy of recorded GMDs, referred to as “the Carrington Event,” raged from August 28 to September 4, 1859. This extreme GMD induced currents so powerful that telegraph lines, towers and stations caught on fire at a number of locations around the world. Best estimates are that the Carrington Event was approximately 50 percent stronger than the 1921 storm.[[5]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#5) Since we are headed into an active solar period much like the one preceding the Carrington Event, scientists are concerned that conditions could be ripe for the next extreme GMD.[[6]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#6) Prior to the advent of the microchip and modern extra-high-voltage (EHV) transformers (key grid components that were first introduced in the late 1960s), most electrical systems were relatively robust and resistant to the effects of GMDs. Given that a simple electrostatic spark can fry a microchip and thousands of miles of power lines could act like giant antennas for capturing massive amounts of GMD-spawned electromagnetic energy, modern electrical systems are far more vulnerable than their predecessors. The federal government recently sponsored a detailed scientific study to better understand how much critical components of our national electrical power grid might be affected by either a naturally occurring GMD or a man-made EMP. Under the auspices of the EMP Commission and the Federal Emergency Management Agency (FEMA), and reviewed in depth by the Oak Ridge National Laboratory and the National Academy of Sciences, Metatech Corporation undertook extensive modeling and analysis of the potential effects of extreme geomagnetic storms on the US electrical power grid. Based upon a storm as intense as the 1921 storm, Metatech estimated that within the United States, induced voltage and current spikes, combined with harmonic anomalies, would severely damage or destroy over 350 EHV power transformers critical to the functioning of the US grid and possibly impact well over 2000 EHV transformers worldwide.[[7]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#7) EHV transformers are made to order and custom-designed for each installation, each weighing as much as 300 tons and costing well over $1 million. Given that there is currently a three-year waiting list for a single EHV transformer (due to recent demand from China and India, lead times grew from one to three years), and that the total global manufacturing capacity is roughly 100 EHV transformers per year when the world’s manufacturing centers are functioning properly, you can begin to grasp the implications of widespread transformer losses. The loss of thousands of EHV transformers worldwide would cause a catastrophic grid collapse across much of the industrialized world. It will take years, at best, for the industrialized world to put itself back together after such an event, especially considering the fact that most of the manufacturing centers that make this equipment will also be grappling with widespread grid failure. Our Nuclear “Achilles Heel” Five years ago, I visited the still highly contaminated areas of Ukraine and the Belarus border where much of the radioactive plume from Chernobyl descended on 26 April 1986. I challenge chief scientist John Beddington and environmentalists like George Monbiot or any of the pundits now downplaying the risks of radiation to talk to the doctors, the scientists, the mothers, children and villagers who have been left with the consequences of a major nuclear accident. It was grim. We went from hospital to hospital and from one contaminated village to another. We found deformed and genetically mutated babies in the wards; pitifully sick children in the homes; adolescents with stunted growth and dwarf torsos; fetuses without thighs or fingers and villagers who told us every member of their family was sick. This was 20 years after the accident, but we heard of many unusual clusters of people with rare bone cancers…. Villages testified that ‘the Chernobyl necklace’ – thyroid cancer – was so common as to be unremarkable. – John Vidal, “Nuclear’s Green Cheerleaders Forget Chernobyl at Our Peril,” The Guardian, April 1, 2011 [[8]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#8) What do extended grid blackouts have to do with potential nuclear catastrophes? Nuclear power plants are designed to disconnect automatically from the grid in the event of a local power failure or major grid anomaly; once disconnected, they begin the process of shutting down the reactor’s core. In the event of the loss of coolant flow to an active nuclear reactor’s core, the reactor will start to melt down and fail catastrophically within a matter of a few hours, at most. In an extreme GMD, nearly every reactor in the world could be affected. It was a short-term cooling-system failure that caused the partial reactor core meltdown in March 1979 at Three Mile Island, Pennsylvania. Similarly, according to Japanese authorities, it was not direct damage from Japan’s 9.0 magnitude Tohoku Earthquake on March 11, 2011, that caused the Fukushima Daiichi nuclear reactor disaster, but the loss of electric power to the reactor’s cooling system pumps when the reactor’s backup batteries and diesel generators were wiped out by the ensuing tidal waves. In the hours and days after the tidal waves shuttered the cooling systems, the cores of reactors number 1, 2 and 3 were in full meltdown and released hydrogen gas, fueling explosions which breached several reactor containment vessels and blew the roof off the building housing reactor number 4’s spent-fuel storage pond. Of even greater danger and concern than the reactor cores themselves are the spent fuel rods stored in on-site cooling ponds. Lacking a permanent spent nuclear fuel storage facility, so-called “temporary” nuclear fuel containment ponds are features common to nearly all nuclear reactor facilities. They typically contain the accumulated spent fuel from ten or more decommissioned reactor cores. Due to lack of a permanent repository, most of these fuel containment ponds are greatly overloaded and tightly packed beyond original design. They are generally surrounded by common light industrial buildings with concrete walls and corrugated steel roofs. Unlike the active reactor cores, which are encased inside massive “containment vessels” with thick walls of concrete and steel, the buildings surrounding spent fuel rod storage ponds would do practically nothing to contain radioactive contaminants in the event of prolonged cooling system failures. Since spent fuel ponds typically hold far greater quantities of highly radioactive material then the active nuclear reactors locked inside reinforced containment vessels, they clearly present far greater potential for the catastrophic spread of highly radioactive contaminants over huge swaths of land, polluting the environment for multiple generations. A study by the Nuclear Regulatory Commission (NRC) determined that the “boil down time” for spent fuel rod containment ponds runs from between 4 and 22 days after loss of cooling system power before degenerating into a Fukushima-like situation, depending upon the type of nuclear reactor and how recently its latest batch of fuel rods had been decommissioned.[[9]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#9) Reactor fuel rods have a protective zirconium cladding, which, if superheated while exposed to air, will burn with intense, self-generating heat, much like a magnesium fire, releasing highly radioactive aerosols and smoke. According to nuclear whistleblower and former senior vice president for Nuclear Engineering Services Arnie Gundersen, once a zirconium fire has started, due to its extreme temperatures and high reactivity, contact with water will result in the water dissociating into hydrogen and oxygen gases, which will almost certainly lead to violent explosions. Gundersen says that once a zirconium fuel rod fire has started, the worst thing you could do is to try to quench the fire with water streams, which would cause violent explosions. Gundersen believes the massive explosion that blew the roof off the spent fuel pond at Fukushima was caused by zirconium-induced hydrogen dissociation.[[10]](https://truthout.org/articles/400-chernobyls-solar-flares-electromagnetic-pulses-and-nuclear-armageddon/#10) Had it not been for heroic efforts on the part of Japan’s nuclear workers to replenish waters in the spent fuel pool at Fukushima, those spent fuel rods would have melted down and ignited their zirconium cladding, which most likely would have released far more radioactive contamination than what came from the three reactor core meltdowns. Japanese officials have estimated that Fukushima Daiichi has already released just over half as much total radioactive contamination as was released by Chernobyl into the local environment, but other sources estimate it could be significantly more than at Chernobyl. In the event of an extreme GMD-induced long-term grid collapse covering much of the globe, if just half of the world’s spent fuel ponds were to boil off their water and become radioactive, zirconium-fed infernos, the ensuing contamination could far exceed the cumulative effect of 400 Chernobyls.

#### Correct for your bias to dismiss high-magnitude, low-frequency events – solar superstorms are real, likely, and existential

Rosen 16 [Julia Rosen, science reporter citing Anders Sandberg, a catastrophe researcher at the University of Oxford’s Future of Humanity Institute, Bill Murtagh, serves in the White House Office of Science and Technology Policy as the assistant director for Space Weather, Energy, and Environment Division, Patricia Reiff, a space physicist at Rice University in Houston, Texas, “Here’s how the world could end—and what we can do about it.” July 14, 2016. <https://www.sciencemag.org/news/2016/07/here-s-how-world-could-end-and-what-we-can-do-about-it>]

As end-of-humanity scenarios go, that bleak vision from [Fritz Leiber’s 1951 short story “A Pail of Air”](http://www.gutenberg.org/ebooks/51461) is a fairly remote possibility. Scholars who ponder such things think a self-induced catastrophe such as nuclear war or a bioengineered pandemic is most likely to do us in. However, a number of other extreme natural hazards—including threats from space and geologic upheavals here on Earth—could still derail life as we know it, unraveling advanced civilization, wiping out billions of people, or potentially even exterminating our species. Yet there’s been surprisingly little research on the subject, says Anders Sandberg, a catastrophe researcher at the [University of Oxford’s Future of Humanity Institute](http://www.fhi.ox.ac.uk/) in the United Kingdom. Last he checked, “there are more papers about dung beetle reproduction than human extinction,” he says. “We might have our priorities slightly wrong.” Frequent, moderately severe disasters such as earthquakes attract far more funding than low-probability apocalyptic ones. Prejudice may also be at work; for instance, scientists who pioneered studies of asteroid and comet impacts complained about confronting a pervasive “giggle factor.” Consciously or unconsciously, Sandberg says, many researchers consider catastrophic risks the province of fiction or fantasy—not serious science. A handful of researchers, however, persist in thinking the unthinkable. With enough knowledge and proper planning, they say, it’s possible to prepare for—or in some cases prevent—rare but devastating natural disasters. Giggle all you want, but the survival of human civilization could be at stake. Threat one: Solar storms One threat to civilization could come not from too little sun, as in Leiber’s story, but from too much. Bill Murtagh has seen how it might start. On the morning of 23 July 2012, he sat before a colorful array of screens at the [National Oceanic and Atmospheric Administration’s Space Weather Prediction Center](http://www.swpc.noaa.gov/) in Boulder, Colorado, watching twin clouds of energetic particles—known as a coronal mass ejection (CME)—erupt from the sun and barrel into space. A mere 19 hours later, the solar buckshot blazed past the spot where Earth had been just days before. If it had hit us, scientists say, we might still be reeling. Now the assistant director of space weather at the [White House Office of Science and Technology Policy](http://www.whitehouse.gov/administration/eop/ostp) in Washington, D.C., Murtagh spends much of his time pondering solar eruptions. CMEs don’t harm human beings directly, and their effects can be spectacular. By funneling charged particles into Earth’s magnetic field, they can trigger geomagnetic storms that ignite dazzling auroral displays. But those storms can also induce dangerous electrical currents in long-distance power lines. The currents last only a few minutes, but they can take out electrical grids by destroying high-voltage transformers—particularly at high latitudes, where Earth’s magnetic field lines converge as they arc toward the surface. The worst CME event in recent history struck in 1989, frying a transformer in New Jersey and leaving 6 million people in Quebec province in Canada without power. The largest one on record—the Carrington Event of 1859, named after the U.K. astronomer who witnessed the accompanying solar flare—was up to 10 times more intense. It sent searing currents racing through telegraph cables, sparking fires and shocking operators, while the northern lights danced as far south as Cuba. “It was awesome,” says Patricia Reiff, a space physicist at Rice University in Houston, Texas. But if another storm that size struck today’s infrastructure, she says, “there would be tremendous consequences.” Some researchers fear that another Carrington-like event could destroy tens to hundreds of transformers, plunging vast portions of entire continents into the dark for weeks or months—perhaps even years, Murtagh says. That’s because the custom-built, house-sized replacement transformers can’t be bought off the shelf. Transformer manufacturers maintain that such fears are overblown and that most equipment would survive. But Thomas Overbye, an electrical engineer at the University of Illinois, Urbana-Champaign, says nobody knows for sure. “We don’t have a lot of data associated with large storms because they are very rare,” he says. What’s clear is that widespread blackouts could be catastrophic, especially in countries that depend on highly developed electrical grids. “We’ve done a marvelous job creating a great vulnerability to this threat,” Murtagh says. Information technologies, fuel pipelines, water pumps, ATMs, everything with a plug would be rendered useless. “That’s going to affect our ability to govern the country,” Murtagh says. A major event could occur within our lifetimes. Research suggests that Carrington-like storms strike Earth once every few centuries; a recent study found a 12% chance that such a storm will occur in the next decade.

### 1AC Solar Shield – Geoengineering

#### A solar shade placed at the L1 point is the *most* optimal form of geoengineering. The tech exists, is feasible, and *solves* warming. Alternatives fail, lead to accidents, and don’t allow for flexibility.

Cummings et al, 17

(\*Laura, Vice President - Georgetown Space Law Society, Federal Aviation Administration, Georgetown University Law Center, \*David Brain is an Assistant Professor at the University of Colorado at Boulder in the Laboratory for Atmospheric and Space Physics and the Department of Astrophysical and Planetary Sciences, “A Shadow of the Future: A Proposal for Construction of A Solar Shade and its Implementation through International Cooperation”, University of Colorado, Boulder, <https://scholar.colorado.edu/cgi/viewcontent.cgi?article=2728&context=honr_theses>, Fall 2017)

- Dr. Joy Singarayer, Associate Professor of Palaeoclimatology in the Department of Meteorology, senior lecturer in the School of Geographical Sciences at the University of Bristol in the School of Geographical Sciences

- Fernando Velez, Assistant Professor, Department of Electromechanical Engineering of Universidade da Beira Interior

- Dr. Robert Lungolole, Department of Physics, Kyambogo University

- Dr. Paul Crutzen, Nobel Prize-winning, atmospheric chemist, University of Stockholm National Oceanic and Atmospheric Administration, Department of Atmospheric Chemistry at the Max Planck Institute for Chemistry

4. The Science of Changing Insolation

Changing insolation. An idea that sounds like science fiction at first – reducing the amount of sunlight a planet receives? Hogwash.

But the idea isn’t crazy, not anymore. All of the required technology exists: the engineers, the materials, the mathematicians, and the models. The following section will lay out the required technological pieces for a solar shade, and calculate how to achieve the desired drop in insolation.

This is not a permanent fix. This is not a license for the world to continue massive emissions of pollutants that are acidifying oceans. Instead, this is a way stop the Earth’s temperature equilibrium from deviating so far from the mean that natural mechanisms cannot restore balance. This is a solution to give humanity time to develop the technology needed to remove carbon dioxide from the atmosphere. This is necessary.

[All calculations are available in Appendix D, with explanations]

4.1 The Considerations of Changing Insolation

To begin, an important definition is that insolation is the amount of solar radiation reaching a given area. Changing insolation of Earth will change the amount of heat Earth re-radiates into its atmosphere as longwave radiation, decreasing the amount of energy into the system, and thus the temperature.

As discussed in “Global Temperature Rise: Solar Variability Contribution to Warming”, solar luminosity fluctuates with the sunspot cycle, as well due to stellar aging.

This may have an impact on a solar shade because a change in luminosity correlates to a change in insolation. Luminosity is the total energy (light) radiated by a blackbody, and insolation is the amount of light received over an area. So, changing light output changes light received over an area.

One of these mechanisms, change in luminosity over the age of the Sun, is of no concern on a time scale of less than thousands of years. The Sun has increased luminosity 30% over 4.6 billion years – this equates to a 0.000065% change in luminosity every million years. Notable, yes. Concerning for this project or impactful on the variation of insolation received, no. The second mechanism, sunspots and faculae, must be discussed as well. The Earth experiences changes in irradiance regularly due to both, but that is not something that this proposal is aiming to correct. Putting a solar shade between the Earth and Sun will decrease the amount of insolation the Earth receives as determined by what change in temperature of the Earth’s climate is desired15. It will do this regardless of whether the Sun is in a sunspot minimum or maximum, regardless of how many faculae are present. Total solar irradiance is not a specific number – it has fluctuations on day and month-long time scales. A solar shade is not correcting for these, so there need not be concern over adapting a shade daily based on whether the irradiance is slightly higher or lower than average. The Sun is at a steady average total irradiance, and this average value is what will be used in all the following calculations.

4.1.1 Calculation – Percentage Drop in Sunlight

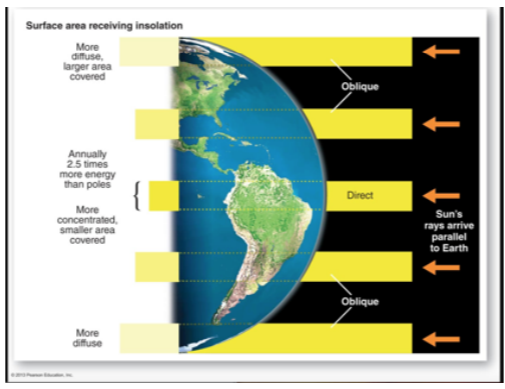
The first computation is how much of Earth’s warming is to be countered. It is desirable to re-establish a temperature that the biosphere is accustomed to, and that would preserve ice sheets and permafrost areas. The goal of this proposal is to counter anthropogenic warming, as this warming is contrary to what climate should be if in adherence with the Milankovitch cycles, and is instead due to unnaturally high flux into the atmospheric carbon reservoir. “The total anthropogenic radiative forcing over 1750 – 2011 is calculated to be a warming effect of 2.3 [1.1 to 3.3] W/m2 ,” (Climate Change 2014, 2014, p. 44). Given the purview and the sophistication of IPCC climate models, this proposal will utilize their conclusions. Therefore, the calculation will determine how much total irradiance must be decreased, in order to counter a warming of 2.3 W/m2.

4.1.2 Area Coverage at L1

As shown in the calculations, there needs to be coverage of area totaling 2.0996x1011 m2 at the L1 point to counter anthropogenic warming of 2.3 W/m2 . Notice, this is the total area that needs to be covered. However, it does not mean that there must be one shade of this size. Instead, this proposal advocates of fleet of satellites, positioned over a given area, to block sunlight. Nevertheless, this would still require a very large number of units. If each sunshade were 1200 m2 16 [INS Footnote 16 This number is not arbitrary, it is the size of the solar-sail Sunjammer, originally commissioned by NASA (the contract was not renewed after expiration in 2013) (Leone, 2013, np.).], 175 million spacecraft would be required. The feasibility of this will be addressed in a later section.

There should be further investigation into the exact dispersion pattern of these shades. Insolation is also affected by latitude. To better understand, imagine the Earth orbiting the Sun. Due to the inclination of the poles, the Northern Hemisphere is pointed away from the Sun in winter, and towards in summer. This means that the higher latitudes have more ‘glancing’ sunlight than direct sunlight.

A good companion study for this proposal would be how insolation is dispersed across the globe, and how to keep that same ratio of insolation during deployment of a solar shade. The comprehensive mathematics to model these shadowing relationships are beyond the extent of this proposal, but such a relationship would be valuable to understand and model in further research.



4. 2 Construction of Solar Shade – Elements

This proposal will now outline the suggested assembly and dispersion mechanism of the solar shade. However, this proposal is not an in-depth engineering model, and as such will be moderately vague when it comes to assembly specifics. Nevertheless, it will be illustrated sufficiently that this model is executable – all of the required technology currently exists in the world, and if not commonplace as of yet, is still currently functional.

4.2.1 A Fleet of Drones

The first image that comes to mind for many when the word ‘solar-shade’ is thrown around is that of a giant umbrella or some such in space. This is a shade, true, but it is by no way the best way to do things. Instead, a solar shade should be constructed of multiple individual bodies that each have a deployable shade (this will be discussed in detail in a following section). Having multiple bodies is of benefit for a few reasons. The first is that multiple repeating systems to construct a whole means redundancy. “An element is redundant if it contains backups to do its work if it fails; a system is redundant if it contains redundant elements,” (Downer, 2009, p. 4). A single shade the size needed for Earth shading is huge, and technologically not feasible at this point. A whole solar shade, constructed of multiple mini-shades, accomplishes the same effect of shading while being more reliable. Multiple small shades, though, are entirely possible, and have the added benefit of being redundant. If one shade breaks, it is only a small percentage error and can be easily fixed or replaced, versus the catastrophe of an error in a large and complicated single structure. “Redundancy has served as a central tenet of high reliability engineering for over 50 years,” (Downer, 2009, p.4). As a system, multiple shades acting together to shade a required area is not only feasible, it is reliable.

The second benefit to having multiple shades is the ability to construct and place them over a longer period of time. Normally, when something like a telescope goes into space, it is all one payload. This means there are no results until 100% of the body has finished construction. With a multi-piece solar shade, this is not so. Different pieces can go up at different times, and effects begin with the first piece in place; it is not required to 44 wait until 100% of the units are built to launch and begin blocking sunlight. This flexibility thus allows, concurrently, immediate action, funds to be solicited over a period of time, and proposals for better shade deployment to be developed and considered – this solar shade is not something to wait around for 50 years to be assembled. The parts are simple enough, the mechanisms are already employed on other spacecraft, the materials are already sold by companies. This is a solution to climate change that is currently actionable.

This multi-pieced, space based system, has a third added benefit. One large and reasonable hesitation to geoengineering is the fact that there may be unintended consequences. The proposed solar shade is of such construction as to assuage those fears.

For one, this geoengineering does not actually take place as any form of input into to Earth. No chemicals sprayed in the atmosphere, no land lost to giant whitewashing in an attempt to bolster albedo. Only 0.00168% of incoming light is being blocked - as such, this should not have a detrimental impact on plant photosynthesis, and will not even be noticeable to the naked eye (Singarayer et al., 2009, p. 2). The final fail safe? All sails are variable, meaning that they can be expanded and contracted at will. If there is an unforeseen circumstance in which an Earth system responds by an extreme perturbation, the solar shade can be effectively withdrawn. And, on the other end of the spectrum, if it turns out there is not enough shading, more solar shades could be added to the whole to increase shaded area. Overall, a total solar shade constructed of redundant parts not only assures higher reliability, it enables an increase or decrease in the amount of shading, allowing flexibility as changes in the Earth’s systems are observed and geoengineering technique becomes more developed.

The last point to be addressed for construction is how to coordinate so many moving parts. The answer is cutting-edge drone technology. “An arm of the Pentagon charged with fielding critical new technologies has developed a drone that not only carries out its mission without human piloting, but can talk to other drones to collaborate on getting the job done. The Perdix autonomous drone operates in cooperative swarms of 20 or more, working together towards a single goal,” (Mizokami, 2017, np.). This quote says 20 or more, whereas the operation reported on in the article involved 103 drones.

The fact that the technology is the purview of the Pentagon may make it seem inaccessible. In reality, the US has a highly intertwined military and civilian space program, and it has been since the conception under Eisenhower. “Space was likely to be just such a ‘big ticket’ enterprise, and Eisenhower accordingly pursued an apparatus for space R & D that was subservient to the White House, isolated from its most powerful claimants, but still adequate to discharge legitimate space missions for science and defense,” (McDougall, 1997, p.165). Just because the Pentagon controls a technology at the moment does not mean it would be unusable for a space shade. In fact, it is probably quite the opposite: after all, global warming is a national security crisis.

Drones on Earth have to contend with all of the problems that the atmosphere poses, such as gas drag, thrust, etc. This in turn means programmers and engineers must figure out how to address such issues. “Flight is energetically expensive, particularly when the size of the device is reduced. This is often due to practical issues that arise when scaling a vehicle down,” (Floreano & Wood, 2015, np.). Luckily, space is a zero-g environment, so what electronics would usually be taken up by flight/power considerations can be left open for other necessities. For example, communication must also be considered. The shades in space will have a communication setup much like the one utilized in the drone project HANCAD. “A heterogeneous communication architecture is necessary in many real-world task scenarios. In HANCAD, all drones have short-range communication capabilities used for local coordination, while few are equipped with long-range communication technology, and serve as gateways between the operator and the swarm,” (Velez et al., 2015, p.1). Essentially, the shades will communicate with each other, while main ‘heads’ are directed by ground control. An example of such a ‘head’ is NASA’s Tracking and Data Relay Satellite (TDRS), “TDRS serves as a way to pass along the satellite’s information. Nine TDRS sit about 35,4000 kilometers above the Earth and are able to forward information from a satellite,” (Campbell, 2017, np.). As should be sufficiently clear by now, the logistics for coordination and communication for a venture involving many bodies already exists, and is highly applicable and desirable for a solar shade design.

4.2.2 CubeSat Cores

In order to maximize shading while minimizing mass, it would be ideal to have small control bodies with very large shades that unfold from them. CubeSats, a novel type of compact and inexpensive satellite, are perfect for integration with solar technology. “CubeSats are a class of research spacecraft called nanosatellites. The cubeshaped satellites are spacecraft size in units or U’s, typically up to 12U (a unit is defined as a volume of about 10 cm x 10 cm x 10 cm and typically weighing less than 1.33 kg)” (Jackson, 2017, np.). CubeSats are small, lightweight, and would only need to be a ‘head’ for a solar shade – no other instrumentation is required. They have the capacity for cold gas thrusters or chemical propulsion, and electric propulsion is in development (CubeSat, 2017, np.). While the majority of satellites are relatively large, with masses in the low thousands of kilograms, CubeSats are small and lightweight. Since no instrumentation is required for solar shade units besides propulsion, communication, and the shade itself, CubeSats would be the perfect platform for the ‘head’ of each shade in the conglomeration.

4.2.3 Shade Movements and Material

In addition to drone technology, the advent of deployable space structures is what enables this solar shade construction. This ability is most recently highlighted in the construction of the new James Webb Telescope. “The tennis court-sized sunshield, which is the largest part of the observatory, will be folded up around the Webb telescope’s mirrors and instruments during launch. As the telescope travels to its orbit one million miles from Earth, it will receive a command to unfold and separate the sunshield’s five layers,” (Loff, 2014, np.). For a deployed sun shade, there is no need to be five layers thick17, only one is needed. The James Webb sun shield will be comparable to a solar shade, in that it has a large area and is deployed after launch.

From the James Webb example, it can also be concluded that materials which are durable and deployable on spacecraft are already invented and have been successfully produced. A recommendation would be to highly consider the same material used in the James Webb solar shield - Kapton. Kapton has been around since the 1960s, and is a polyimide film that can remain stable from negative 269 degrees Celsius to 400 degrees Celsius (Kapton, 2017, np.). To increase the reflectivity of the Kapton, and to increase longevity, the material can be coated in aluminum, much like the James Webb.

Aluminum has a close to 100% reflectivity, making it ideal for a solar shade. “Aluminum was used because it is widely available primarily as ore bauxite that makes 8% of the earth’s solid surface…Aluminum films used as metallization contacts have low specific resistivity, good thermal stability, high uniformity across the flat substrate, low particle contamination, and good adherence to substrate. These properties have led aluminum to be irreplaceable and its demand is on increase in many areas of today’s rapidly developing technologies especially optical industries. Highly specular aluminum films made in an ultrahigh vacuum deposition process have a solar reflectance of 92%,” (Lugolole & Obwoya, 2015, p. 3). Aluminum would be most desirable for a reflective coating on Kapton, and the current market price for aluminum is $0.94 per pound, making it a cheap material to acquire and utilize (Aluminum Prices, 2017, np.).

The table above indicates the reflectivity of aluminum at specific wavelengths. More research should be done into the feasibility of reaching 100% reflectivity, or into what additional materials may block wavelengths where aluminum is not as highly reflective18. In addition to being readily accessible, the materials needed for the construction of the shade are lightweight. On the James Webb, the aluminum coating applied to the solar shield was ~100 nm (3.93 microns) thick (Lynn, 2016, np.). Kapton comes in a range of thicknesses, from 7.6 micrometers to 127 micrometers. This means it varies in weight from 1 kg per 93 m2 to 1 kg per 4.7 m2 (DuPont Kapton, 2017, p.17). For another comparison of thickness, the sail for the Sunjammer project was 5 micrometers thick (Leone, 2014, np.). The shade for the solar shade will have very minimal mass for its size, making it cheap to launch while effectively shading a large area.

Furthermore, the durability of the shade, and thus its materials, must be considered. Kapton holds its shape very well and is extremely durable – a 25 micrometerthick film has only 0.17% shrinkage at 150 degrees Celsius, and a folding endurance of 285,000 MIT19. There are also additional treatments to increase durability. For the James Webb telescope, a technology called Thermal Spot Bond was used to ensure the solar shield would not become unusable if struck by space debris. This method is recommended for utilization in the solar shades; as it ensures a hole does not enlarge if a shade is pierced, further ensuring the longevity of the shade (Lynn, 2016, np.). The durability of Kapton, the fact it is already manufactured and being used in another spacecraft, and ability to be treated with Thermal Spot Bond makes it a perfect candidate for the material construction of solar shades.

Another exciting technology that may be applied to constructing solar shades is that of origami. While origami has a very long historical tradition, it is newly being integrated with space technology. Origami is valuable because the mathematical precision and intricacies of developed folds allow material to be folded for launch, and then reliably unfolded in space, resulting in very large spacecraft. “Last year, Zirbel and Trease collaborated with origami expert Robert Lang and BYU professor Larry Howell to develop a solar array that folds up to be 2.7 meters in diameter. Unfold it, and you’ve got a structure 25 meters across,” (Greicius, 2015, np.). Even more exciting is the fact that for some folds, only one ‘chord’ needs to be pulled for deployment, meaning only one input is required, greatly simplifying the mechanism. “Trease envisions that foldable solar arrays could be used in conjunction with small satellites called CubeSats…It could be especially appropriate for spacecraft applications where it’s beneficial to deploy an object radially,” (Greicius, 2015, np.). Clearly, the concept of origami in conjunction with solar shades is highly applicable, and would be an advantageous route to explore. It is highly recommended to employ folding techniques in solar shades to maximize shade area per unit, and thus effectively reduce cost per area shaded.

4.3.4 Position in Space – Lagrange 1 Point

One main issue for construction of a large space body is the decision of where to place it. With gravitational forces at play, a shade would be worthless if it became misaligned due to the passing gravitational interactions with another body. Luckily, there are 5 mathematical positions around the Earth, where gravitational balances between the Earth and Sun occur. It is proposed that these points offer the best position for a solar shade.

The solar shade should be placed at a position called the Lagrange 1 point. “A Lagrange point is a location in space where the combined gravitational forces of two large bodies, such as Earth and the sun or Earth and the moon, equal centrifugal force felt by a much smaller third body. The interaction of the forces created a point of equilibrium where a spacecraft may be ‘parked’ to make observations,” (Howell, 2017, np.). The L1 point is the position that lies directly between the sun and the Earth, at about 1.5 million km. The L1 point, as opposed to L4 and L5, is a ‘saddle’, meaning the point of gravitational balance is rather precarious. It is possible to keep spacecraft there (the Solar and Heliospheric Observatory Satellite is there currently), but it is required that they have some propulsion system to occasionally re-balance them. This means that every solar shade piece will need some form of propulsion.

A benefit of being positioned at the L1 point is that the shadow of the solar shade will not directly darken any region of Earth with an umbral shadow. “The preferred location is near the Earth-sun inner Lagrange point (L1) in an orbit with the same 1-year period as the Earth, in line with the sun at a distance >/= 1.5 million km. From this distance, the penumbra shadow covers and thus cools the entire planet,” (Angel, 2006, p.1). As mentioned above, insolation may be affected, but overall the diffusion of penumbral shadow will equally shade the entire Earth.

[See appendix E for this calculation.]

A final consideration for solar shade placement is what impediment it will have upon Earth. The L1 point minimizes any impact, specifically on the field of astronomy.

Most astronomers would take issue with any more items being placed in orbit, as they further interrupt already difficult ground-based observations. Putting objects in low Earth orbit is also becoming more difficult and potentially dangerous, as over 50 years of contributing satellites and other space junk has increased the possibility of interspace collisions. Since the solar shade will be placed at L1, it will never be in view of nightside Earth, and will never block field of view for observations as well as not adding to near Earth space debris. Unfortunately, solar observatories will be impacted. The Dunn Solar Telescope in Sacramento will likely not be able to continue its observations.

However, its necessity is drawn into question by the placement of SOHO in space in 1995, as its imaging of the Sun is not attenuated by Earth’s atmosphere. As recently as November of 2016, NOAA’s GOES-16 satellite was launched and now tracks solar weather, among other things, from space. While the loss of ground based solar observations may be lamentable, they will not be of the magnitude to adversely affect the research and development of solar science.

Overall, the placement at L1 is the most desirable position for a solar shade. The distance from the sun means the size of the solar shade is less than if it were located at Earth. The equilibrium of gravities at the position will keep the solar shade continuously between the Earth and sun, while requiring only minimal orbital corrections. L1 shading will be far enough away to not eclipse any specific portion of the Earth (even if the solar shade were one collective body instead of multiple pieces), and will not negatively impact ground-based astronomical observations. L1 is the most economic and feasible position for a solar shade.

4.3.5 Engineering with Current Technology

The main selling point for a solar shade at L11 as a way to confront climate change is that the technology for a solar shade solution currently exists. Geoengineering seems far-fetched, because a majority of the time it is – far in the sense that the technology required for the solution is still waiting to be invented. For example, another paper that proposes cooling Earth using crystals at the L1 position, suggest implementing the system through electromagnetic launch, (i.e. a rail-gun as it is commonly referred to in literature). The theory and designs for such a device exist, but have never been constructed or implemented on such a scale due to high cost, unlikelihood of payloads to survive extreme acceleration, and air drag issues due to low launch angles (Angel, 2006, p. 3). In juxtaposition, this proposal employs existent and actionable materials and methods; waiting for future solutions to correct global warming is ill advised when the Earth is already rapidly approaching a climate tipping point.

The technology, in summation, is as follows. Drone configuration and communication is in its infancy, but exists. As proven by the aforementioned Department of Defense deployment, it is even possible to configure over 100 drones to run autonomous missions. NASA has relay satellites that communicate commands to multiple other orbiters, proving only few ‘heads’ are needed to control a whole. Rockets to achieve orbit exist. CubeSats are a condensed and simplistic satellite that will be perfect for integration with folding solar shades, hopefully using origami techniques. A possible shade material is already in production by Kapton, and the methods for improving its durability and reflectivity have been modeled by the James Webb Telescope. All together, none of this technology is something that is missing theory, or needs time for development. All of the pieces to construct cheap, lightweight, and effective solar shades exist today. And today is when the world needs a solution to climate change.

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4. The Science of Changing Insolation – Conclusion

It has been thoroughly demonstrated that the possibility of changing Earth’s insolation is not in the realm of science fiction: it is implementable technology. The technologies and materials recommended in this section are to provide a baseline investigation. This does not mean that every technology or material mentioned in this section is necessary for final construction – this proposal does not assume to be a detailed blueprint. Rather, this section presents a rough jigsaw of the pieces needed to fabricate a solar shade. The stage for a solar shade at the L1 point is thus set.

5. The Science of Controlling Earth’s Temperature

This section of the proposal will delve into the specifics of how to affect the temperature of Earth. To begin, a survey or the atmosphere, which will include its layers and composition. In addition, some atmospheric chemistry will be mentioned. This will be followed by a commentary on modeling the atmosphere. This section will end by examining other geoengineering methods that have been proposed.

5.1 The Atmosphere

To begin a discussion of the atmosphere, it is important to first understand the composition and reactions that occur there. The atmosphere is (by mass) 76% nitrogen, 23% oxygen, 1.3% argon; the main trace gases are carbon dioxide (0.05%), neon (1.2 x 10-3 %), helium (8 x 10-4 %), krypton (2.9 x 10-4 %), hydrogen (0.35 x 10-5 %), xenon (3.6 x 10-5 %), and ozone (0.17 x 10-5 %) (Saha, 2008, p. 10). As can be seen in the diagram below, due to the composition of the atmosphere, some wavelengths of light are transmitted all the way to the ground, while many are not.

One of the reasons most animals see in the visible portion of the spectrum is because these are the wavelengths that penetrate all the way to Earth’s surface – if eyes were constructed to ‘see’ x-rays, the whole world would essentially look dark, as the atmosphere is not transparent to that wavelength. Therefore, for a solar shade, it is of import to block light that will be transmitted all the way to the surface, while it is permissible to allow other energies of light to be attenuated by the upper atmosphere.

5.1.1 Distinctions of Each Layer of the Atmosphere

The atmosphere of Earth is typically divided into five layers. The bottommost layer is the troposphere, typically defined to reach to an altitude of 6 – 20 km. The troposphere, being the lowest layer, is where most particles of the atmosphere reside – the troposphere contains 75-80% of the mass of the whole atmosphere. This is also the layer were most clouds are found, and where almost all weather occurs (The Troposphere – overview, 2011, np.). It is transparent to wavelengths in the visible spectrum, and microwave. The troposphere behaves essentially like a turbulent fluid, moving particles constantly as pressure, temperature, and forces all fluctuate with local weather systems.

This means that any aerosol, instead of being confined to one local area, is quickly transported, usually large distances. Additionally, gases in the atmosphere also have specific lifetimes. The result of atmospheric lifetimes and mixing due to weather is that, “…few gases react rapidly enough for their effects of be confined to the local scale. Most are primarily global in effect…therefore, the effects of local emissions are felt throughout the troposphere,” (Graedel, 1985, p.49). This is pertinent to climate change, as it emphasizes that the effects of emissions from one entity will be felt by the whole world.

The next layer of the atmosphere is the stratosphere, extending to 50 kilometers. The stratosphere is where the majority of photochemistry happens due to a sufficiently high concentration of molecules coupled with energetic photons. The stratosphere is most notable for containing the ozone. Ozone is chemically O3, and effectively absorbs ultraviolet radiation. Far UV light is effectively absorbed by the stratosphere (and upper atmosphere) that a shade would still be effective, even if transparent to these wavelengths. However, longer-length UV would need to be shaded, as the longer wavelength UV is mostly transmitted through the atmosphere.

The mesosphere is next, extending to 85 kilometers. The composition and chemistry of the mesosphere is more difficult to study than that of other layers because of its height – it is not accessible by weather balloon, and satellites orbit above it, and are not able to directly measure it. As altitude increases, temperature decreases in this layer, indicating that it does not contain UV absorbers. Additionally, because this is the layer where meteorites and space debris burn up, it has a higher concentration of iron and affiliated metals than do the other layers (The Mesosphere – overview, 2008, np.).

The thermosphere is the next layer, extending to 600 kilometers. The upper atmosphere is the section that most strongly mitigates short wavelengths, less than 0.2 micrometers (the far UV and x-ray). The thermosphere is responsible for absorbing 0.02 – 0.1-micrometer wavelengths, creating ionization (Torr, 1985, p. 167). While important in UV absorption, the thermosphere (and ionosphere) is transparent to visible wavelengths. As such, if a solar shade were to not reflect extreme UV and x-ray, they would still be effectively abated by the thermosphere. This implies solar shade materials would still be effective even if these wavelengths were not reflected.

Finally, the exosphere is last, and is the upper limit on the atmosphere. It extends to (up to) 10,000 kilometers (Zell, 2015, np.). All of the different layers of the atmosphere are interesting and intriguing in their own right. For a more in-depth relation of the different layers and their functions, see Appendix A.

Chemical differences in layers of the atmosphere and different photochemical reactions that occur in those layers are of high import. Responsible science requires that the differences and sensitivities be understood and investigated before directly implementing systems that may affect these layers and the chemistry within. The exact research into such is beyond the scope of this paper. However, it is arguable that due diligence has been done, because at most, insolation would be decreased by 0.00168% - a fraction of a percent. It would be foolish to argue that a diminishing of sunlight will have no atmospheric or photochemical effect; however, it is equally thoughtless to presume that such a marginal change in sunlight would have sizeable atmospheric repercussions.

5.1.2 Material of Shade Construction and Photochemistry

The material for shade construction must be required to block visible light and low-energy UV light. Atmospheric chemistry is energized by wavelengths in the range of visible to UV; it is important that if photochemical reaction rates decrease, they should ideally decreases proportionally and equally across all reactions. Additionally, cost should be taken into account when choosing materials for construction – if two materials reflective abilities vary by a marginal amount, the cheaper material should be given preference.

As mentioned in the “Construction of Solar Shade” section, aluminum coated Kapton material would be a strong candidate for such a shade. Unfortunately, the exact engineering of materials is outside the purview of this proposal, so it is suggested that there be an in-depth investigation into possible materials. Another material that would be a strong candidate is silver coated polymer. There is a significant increase in papers discussing the uses of silver coated polymers around the 1980s, likely due to a U.S. Department of Energy interest in their development. Unfortunately, no new (and therefore appropriate) sources on the subject are available. However, in one resource it is reported, “The hemispherical reflectance of a freshly deposited silver film weighted over the solar spectrum (250-2500 nm) is greater than 97%,” (Mittal et al., 1989, p. 79). This is a very large range of wavelengths blocked with amazing completeness. However, the paper goes on to report that the durability of silver-coated materials is less than five years. There may be hope that this material has become more durable with technological advances since the 1980s, but clearly more investigation of material sciences for a solar shade is needed.

5.2 Modeling Earth’s Atmosphere

One of the largest issues that any geoengineering proposal must contend with is the fact that affecting global systems means modeling hundreds of interactions and interplays between variables. There are so many components to consider in atmospheric modeling that no future model can be 100% accurate in its predicted outcome (as of yet).

Clouds are one of the trickiest components of the atmosphere to model correctly in any global model. This is because the ‘reservoir’ of cloud cover is not constant, but varies as water vapor, water vapor saturation pressure, condensation nuclei20, and freezing nuclei21 vary. Indeed, “without condensation nuclei high degrees of supersaturation would have to occur before droplets could form and not immediately evaporate away,” (Kyle, 1991). The multitude of factors that go into cloud production would make it difficult to predict cloud formation patterns. To make matters even worse, all variables change from region to region of the Earth, as temperature, weather systems, and particle movement in the atmosphere change. Hence, clouds remain one of the toughest challenges when creating an atmospheric model.

Attempts to conquer the challenge of modeling clouds and cloud formation are estimable, because clouds have great consequences on the atmosphere. Specifically, different types of clouds affect the absorption and radiation of incident solar radiation. “At any given time, clouds cover some 40% of the earth’s surface. Their effect on radiation varies greatly with wavelength.” However, “the overall effect of all clouds together is that the Earth’s surface is cooler than it would be if the atmosphere had no clouds,” (Graham, 1999). This phenomenon is often referred to as cloud forcing.

Now it must be observed that different types of clouds actually have different effects on the overall energy budget of the Earth. High clouds (above ~6 km), mainly cirrus clouds, are composed of ice particles and are highly transparent to shortwave radiation22 (Graham, 1999, np.). This means that they do not contribute greatly to the albedo of Earth, and reflect minimal shortwave radiation. Additionally, the water within cirrus clouds is an amazingly efficient greenhouse gas, absorbing a large portion of outward-bound longwave (IR) energy. After absorption, this outgoing energy is reradiated in all directions, not just up and out, but back to Earth too. This means that, “the overall effect of the high thin cirrus clouds then is to enhance atmospheric greenhouse warming,” (Graham, 1999, np.).

Another point must be considered is in reference to high-altitude cirrus clouds. Recall from the section “Melting of Permafrost” the fact that a significant percentage of permafrost outgassing due to thawing is in the form of methane. It just so happens that methane presence in the stratosphere produces a large amount of water23. “In fact, CH4 is a major source of stratospheric H2O above ~20 km. Globally, about 6 x 107 metric tons of H2O are formed in the stratosphere each year from CH4,” (Turco, 1985, p. 100). An increase in stratospheric water is equivalent to an increase in greenhouse gases, and contributes to increased cirrus cloud formation. This should be just another added weight to an argument for solar irradiance mitigation: if the permafrost is allowed to melt, global warming will be amplified not only by an increase in methane, but also by the reactions methane enables. Essentially, methane is an extremely effective greenhouse gas, while also being a catalyst for formation of stratospheric greenhouse gases (water).

Additionally, one problem with predicting the formation of high, icy clouds is that the process of their formation is not fully understood. This is because there has not been sufficient investigation into what condensation nuclei will serve as freezing condensation nuclei. “…Experience has shown that all kinds of nuclei are not equally effective, for injection of particles of quartz, salt, and many other substances were found to have no effect on production of ice particles in supercooled spaces…Apparently, the nature of the surface and the crystal structure of the sublimation nuclei play a great role in this business,” (Saha, 2008, p. 68). The obscuration of the mechanism of high cloud formation adds one more challenge in the seemingly insurmountable process of trying to model cloud effects on the planet.

In the middle range of high (ice) and low (water) clouds, there lies another enigma of clouds. This puzzle is that water-composed clouds have been found to form at altitudes so high that the water in these clouds is supercooled, but has not transformed into ice. “The surprising fact is that clouds consisting even entirely of water droplets are found on high mountain tops and in airplane ascents even when the temperature is much below the freezing point, and are found to be the same size as the fog droplets. These droplets are ‘supercooled’ and are, therefore, in unstable equilibrium. They generally transform themselves into ice-particles as soon as they strike against any hard surface or obstacles, like airplane sides,” (Saha, 2008, p. 66). Essentially, the correlation between temperature and formation of water or ice clouds is not understood. As ice and water have different impacts on energy radiation, ignorance of the correlation means inaccuracies in models.

Finally, low clouds tend to have the exact opposite effect as high clouds on trapping radiation. Low clouds are most commonly stratocumulus clouds, which are much thicker and therefore not transparent. Much less solar radiation is able to penetrate these clouds to reach the ground in areas covered by these clouds. The tops of these clouds create an albedo forcing, reflecting visible light before it can be absorbed. Additionally, these clouds are generally so low that radiated longwave only marginally contributes to warming. Overall, these clouds have a net cooling effect, (Graham, 1999).

It can be concluded from the above evidence that modeling clouds in the Earth’s atmosphere is, at best, a hazy issue. It is a valid concern that reducing incoming insolation to the Earth would have a moderate to extreme effect on cloud formation. These fears may be addressed by the following: decreasing insolation will not have effect on condensation nuclei or freezing nuclei for clouds. Decreasing sunlight is not an immediate impact on the amount of particulates in the atmosphere, so it may be assumed that the cloud cycle will continue without any drastic changes. There is always a possibility that a change in insolation will alter atmospheric patterns, but a watchdog program will be implemented to minimize the impact. In-depth models for cloud cover do not yet exist, but global averages do, and these will be the mean and standard deviation to which cloud data will be compared after the placement of a solar shade. Thus, it would be possible to react to cloud coverage perturbations that may occur before they cause drastic changes.

Atmospheric modeling is still a rapidly growing area of understanding. It wasn’t until the late 1950s that scientists even realized what a complex and multilayered system the atmosphere is (Rowlands, 1995, p. 66). With that being said, it is still within the ability of current models to account for how large-scale systems will respond, especially as new models are developed and tested against each other. Unfortunately, the access and ability to use these models is beyond the author’s ability; nevertheless, they would be a valuable asset in the assessment of the outcomes of solar irradiance alteration.

5.2.1 Controlling How Insolation is Modified

The primary reason that this solar shade proposal is of acceptable design, regardless of climate modeling ability, is because of the ability for revocation. A cornerstone of this solar shade design is that shades can be deployed as well as refolded.

This means that there will be continuous control, and the ability to continuously alter the amount of insolation being blocked. If an unpredicted detrimental effect begins to emerge, insolation reduction can be halted or reversed. Abdusamatov, Lapovok, and Khankov have a marvelous paper “Monitoring the earth’s energy balance from Lagrange point L1” (2014) which details the requirements for a telescope at the L1 point to monitor the Earth, with the possibility of recording variations of bond albedo at the 0.1% level. Such a telescope could be launched along with the solar shade, enabling real-time feedback at a highly detailed level.

There is always some risk involved with cutting-edge science. The makers of the atomic bomb half thought that setting off one explosion would cause a chain reaction of splitting all atoms, effectively ending the world. Luckily, constructing and implementing a solar shade is nowhere near that risk level. It is true that the climate is a complicated monstrosity, and that as of now there are no 100% accurate models for such a system. The strength of this proposal is that it has acceptable risk levels because of self-mitigation that will be built into every system. It is a system that can be monitored and corrected in real time, with a high capacity for risk minimization.

5.3 Other Suggested Solutions

As the world grows more desperate for a solution to climate change, the literature on geoengineering has been growing. Indeed, interest was greatly increased by a paper published in the journal Climate Change in 2006 by Nobel Prize-winning Paul Crutzen, an atmospheric chemist. His paper, although not the first to propose the idea, became an acclaimed proposal for stratospheric aerosol injection. This paper prompted a wider scientific interest into geoengineering, “The climate engineering literature has expanded rapidly since 2006, as indicated by growth from six abstracts in WoS in 2006 to 55 in 2013, for a total of 234 abstracts,” (Linner & Wibeck, 2015, p. 258). If one assumes that the majority of climate engineering, to be feasible, must be up to date with atmospheric and technological knowledge, the majority of papers written before the 21st century are readily disregarded. This means there is a rather limited field of research into geoengineering, leaving room for innovation. To highlight how this proposal is innovative and practical in its approach, a fair examination of other proposed geoengineering tactics is required. Following are three options that represent the other primary archetypes of research in the field of solar-radiation management (SRM). Carbon dioxide removal is not examined in detail because it does not have the same foundational science as this proposal, but will be mentioned briefly. This section will conclude with a summation of why this solar shade proposal advances the most advantageous geoengineering design.

5.3.1 Method 1 – Stratospheric Aerosol Injection

The most common example toted when geoengineering is mentioned is the one first proposed in 1977 by Russian scientist Budyko, but made famous by Paul Crutzen: stratospheric aerosol injection. The crux of this idea lies in emulating the effect that volcanic eruptions have on Earth’s climate system. When volcanoes erupt, they send gigatons of various particles into the air, one of which is sulfur. The sulfur particles then backscatter light to space, essentially reducing solar radiation during their atmospheric residences. Sulfur, out of the multitude of elements deployed by volcanoes, was singled out because it has a relatively isolated atmospheric chemistry. Unlike constituents such as odd-hydrogen or odd-nitrogen, sulfur is not a catalyst for any major atmospheric reactions, and has a limited range of atmospheric molecules. Thus, sulfur particles seem enticing for atmospherically increasing albedo, without inducing significant interactive photochemistry with other particles.

Another facet of volcanoes that made them icons for emulation is that they spew particles to great heights in the atmosphere. The majority of atmospheric particles reside in the troposphere (~80%), but volcanic eruptions place materials into the stratosphere, which extends from 20-50 kilometers. Stratospheric residence time of particles is extended as compared to tropospheric residence times, due to limited weather and mixings, which act to percolate molecules out of the atmospheric system. Thus, those who advocate for solar radiation management through sulfur injections advocate injections into the stratosphere. “Although climate cooling by sulfate aerosols also occurs in the troposphere, the great advantage of placing reflective particles in the stratosphere is their long residence time of about 1-2 years, compared to a week in the troposphere. Thus, much less sulfur, only a few percent, would be required in the stratosphere to achieve similar cooling as the tropospheric sulfate aerosol,” (Crutzen, 2006, p. 212). On top of that, stratospheric sulfur injection would be relatively cheap, about $8 billion per year by some estimates (Barrett, 2008, p. 47). This seems pretty good so far. The fact that sulfur injection naturally occurs via volcanoes, their limited atmospheric chemistry, and low cost, all make stratospheric sulfur injections seem a reasonable possibility for a geoengineering technique.

The major issue with sulfur atmospheric injections lies in the unpredictability of one main factor: the atmosphere. Humans can split the atom, can send machines to distant worlds, alter the courses of rivers, but one major thing that still eludes definition is an accurate working model of the atmosphere system as a whole. Even an atmospheric model that is slightly off is still unobtainable – all models currently used for current or future projects have major error bars in their analyses.

But here’s what it is possible to know will happen, should sulfur be injected into the stratosphere. First, the sulfur will eventually percolate out of the atmosphere, causing ecological and economical damage. If it does this through water, it forms acid rain. Acid rain destroys the natural pH of ecosystems, greatly increasing ecological damage that is already happening. Corrosive interactions with solids can also pull sulfur out of the atmosphere. “The principal agents of atmospheric corrosion are compounds of chlorine and sulfur, aided by high humidity, solar radiation, and the presence of atmospheric oxidants…losses may amount to 70 billion dollars annually,” (Graedel, 1985, p. 73). Second, sulfur is a catalyst for ozone destruction. It can be seen from post-volcanic event data that whenever large amounts of sulfur are injected into the atmosphere, there is ozone loss. “Local ozone destruction in the El Chichon case was about 16% at 20 km altitude at mid-latitudes. For Mount Pinatubo, global column ozone loss was about 2.5%,” (Crutzen, 2006, p. 216). The Earth has just barely begun to rebuild ozone since the Arctic ozone hole incident– does it really need more destruction? Finally, sulfur in the stratosphere will also act to form more cirrus clouds, as it is an effective cloud nuclei. As mentioned in the previous section, cirrus clouds act as a positive forcing on atmospheric warming, meaning sulfur injections will create externalities that contribute to warming.

The final overwhelming reason sulfur injections are a poor idea? There is no undo button. If the technology doesn’t exist in large capacities to scrub CO2 from the atmosphere, it surely doesn’t for sulfur. This is the risk that is so pivotal to so many arguments against geoengineering, and is highly applicable to this idea. “Once we put aerosols in the air, we cannot remove them,” (Robock, 2008, p. 16). Climate change and pollution have already introduced enough extraneous particles into Earth’s atmosphere – compounding the issue is not the way to solve it.

5.3.2 Method 2 – Space-Based Reflection

The next idea, which is the most similar to the one presented in this proposal, is advanced by Roger Angel, in a paper called “Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point (L1)” (2006). One can extrapolate from the title that the subject matter is similar. However, Angel proposes using small crystals as the ‘spacecraft’, populating an area at L1 with them to create a ‘cloud’ that diffracts and reflects sunlight. The failure in the paper is to utilize present technology and thus have an immediately implementable plan – Angel proposes using an electromagnetic propulsion system (commonly called a ‘railgun’) to cheaply deliver crystals to the L1 point. Unfortunately, the technology for these types of propulsion systems has yet to reach the efficiency or have the range required for this project. A final drawback in the paper is, again, the absence of an ‘undo’ button. True, crystals would eventually drift from saddle point at L1 and exit the geosynchronous orbit, but lag time for this exit is still a concern. The novelty of geoengineering requires that, in order to be actionable and receive public approval, there needs to be a failsafe built into the system. Earth climate models have yet to be perfected, or even within the range of acceptable error, and until they are, it is unfeasible and immoral to enact a geoengineering plan that is not immediately stoppable.

5.3.3 Method 3 – Albedo Enhancements

The last solar radiation management technique that is most often suggested to combat global warming is that of changing ground-based albedo. As was previously explored in the “Changing Albedo” section, a major issue with this idea is that groundbased albedo alterations have minimal effect on the overall albedo of the Earth. “Qu and Hall (2005) found that surface reflection accounts for less than 25% of the climatological planetary albedo in the ice- and snow-covered regions of the planet and the remainder is due to clouds. They also found that, although the year-to-year variability of planetary albedo in cryospheric regions is mainly due to changes in surface albedo, atmospheric processes attenuate the effect of the surface albedo changes on the local planetary albedo by as much as 90% (i.e. the change in planetary albedo is 10% of the change in surface albedo),” (Donohoe & Battisti, 2010, p. 4403). The sad reality is that any albedo changed that is enacted on the ground will be marginally successful regardless of the extent, due to strong atmospheric attenuation.

This is not to say that ground-based albedo alterations cannot help combat climate change on the local scale. On the contrary, there is research to suggest that supplementing a generic food crop with its lighter-leafed counterpart would have noticeable seasonal/regional impacts. For example, “albedo variations of up to 0.01 and 0.08 have been observed between several different commercial varieties in barley and maize,” (Singarayer et al., 2009, p. 2). The same paper went on to conclude that, “Because biogeoengineering provides its greatest cooling benefits during summer in many regions closely associated with arable regions, it provides a focused mitigation benefit disproportionate to the modest global average temperature reduction,” (Singarayer et al., 2009, p. 6). Increased reflectivity during solar maximums (summer) results in a higher regional cooling than would otherwise occur. It may be commendable to couple this method of solar radiation management with the implementation of a solar shade. More research is needed – the authors of the paper were unable to conclude whether or not climate variations would still occur if the substitution was enacted only regionally, and not globally.

Overall, ground-based albedo modification does not promise to be a globally effective field. The atmosphere attenuates the effects too strongly for any forcing to be consistent or reliable. However, if coupled with a solar shade from space, the method could prove effective and perhaps more successful on a region-by-region basis, while being reasonably low-cost. More research is needed, but the promise of a shade/albedo coupled mitigation technique may prove highly effective in combating global climate change.

5. The Science of Controlling Earth’s Temperature –

Conclusion

To conclude, a solar shade would be the optimal geoengineering approach for four reasons. The first is that it does not add any particulates to the atmosphere. Stratospheric sulfur injection would mimic a ‘natural’ process, but little is known or reliably modeled about the full effects that such an action would have. To compound upon that, any geoengineering solution, to globally assuage implementation fears, should have an ‘off’ switch. A solar shade has this – shades can be expanded and contracted as needed. Sulfuric injection, cloud seeding, and many other solar forcing techniques do not – once something is in the atmosphere, it is there for its natural lifetime. Thirdly, when a solar shade is put in place, it would be able to be ‘tweaked’ as needed. Less shade? Possible. More shade? Simply launch more shade elements. With methods that inject particles, there is no way to tweak the amount, only increase it. Finally, a solar shade at the L1 point does not contribute to the space debris already prominent in low Earth orbit. Overall, a solar shade is controllable, ‘undoable’, and has maximum effect with zero particle input into an already polluted climate system. Space shades are the future of geoengineering.

#### China says yes, but *only* when they’re equal partners from the onset. Unilateral action is labeled “eco-imperialism” and creates the impetus for geo-conflict.

Edney et al, 13

(\*Kingsley Edney is Lecturer in Politics and International Relations of China in the School of Politics and International Studies at the University of Leeds, \*Jonathan Symons lectures in international relations at Macquarie University, Sydney, “China and the blunt temptations of geo-engineering: the role of solar radiation management in China's strategic response to climate change”, The Pacific Review, 27:3, 307-332, <https://www.tandfonline.com/doi/abs/10.1080/09512748.2013.807865>, July 2, 2013)

*China’s negotiating role: great power or developing world leader?*

China plays a pivotal role in global climate negotiations. Chinese production was responsible for approximately 18 per cent of global emissions in 2008, and this figure is predicted to grow to approximately 33per cent by 2030 (Garnaut 2008: 65). The drivers of China’s negotiating position are complex, sometimes contradictory, and are shaped by diverse processes that work at different levels of governance (national and regional policies can conflict) (Moore 2011: 147–8). Since China’s internal policy-making processes are opaque, analysts often focus on the interests of the CCP. Scott Moore identifies three core CCP interests that are central to climate policy: (1) maintaining an international environment in which China’s place in the international system is secure; (2) preserving stable economic development; and (3) maintaining domestic stability amid rapid economic transformation (Moore 2011: 147–8). China’s acute historical grievances and sensitivity to foreign interference are also relevant to its negotiating stance in that they increase its fear that the developed world, particularly the US, is using climate negotiations to contain China and maintain Western hegemony.

China has made significant progress in its domestic emissions mitigation policies and in its international negotiating stance vis-a-vis climate change ` over the last two decades. Domestically, the first climate policy coordinating body was created in 1990, and subsequent institutional reforms have successively enhanced the influence and effectiveness of bodies responsible for climate governance. In June 2007 a powerful policy group headed by then Premier Wen Jiabao (the National Climate Change Response Leading Small-Group) was created to coordinate government action on climate change. This ‘small-group’ is linked to equivalent bodies that have been established within provincial governments, and is located within the NDRC, which is the highest ranking administrative unit beneath the state council (Held et al. 2011: 22–4). The central government’s capacity to deliver on China’s ambitious energy-intensity pledge (to reduce carbon emissions per unit of GDP by 40–45 per cent from 2005 by 2020) has been enhanced by a parallel consolidation of energy governance. While China is often presented in the Western media as a recalcitrant participant in UNFCCC negotiations and has repeatedly failed to fully implement its own policies and commitments (Foot and Walter 2011: 195), these internal reforms have facilitated a series of shifts in its international stance. Indeed, China’s current non-binding pledge to control emissions is among the most ambitious in the world when measured against ‘business as usual’ (Jotzo 2010). Across the history of UNFCCC negotiations, China has come to embrace flexibility mechanisms (particularly the Clean Development Mechanism (CDM)) that it initially opposed and has shown increasing flexibility around voluntary verification of the emissions pledges that it has adopted (Held et al. 2011: 8).

Despite these developments, there are also elements of remarkable continuity in China’s position within UNFCCC negotiations (and indeed, within other environmental negotiations). Rejection of any effort to impose binding emissions limits on the developing world and support for a ‘right to development’ have remained central to China’s position since the first international discussions of climate change in the early 1990s. To this end, China has attempted to maintain a unified and coherent G77 position that emphasizes an uncompromising interpretation of the CBDR norm. Premier Wen summarized this position at Copenhagen in 2009, asserting the West’s ‘unshirkable moral duty’ to provide technological and financial assistance (Wen 2009). At the UNFCCC meeting in Copenhagen in 2009 China demanded that developed countries contribute upwards of 0.5 percent of GDP to developing country mitigation and adaptation. Chinese authorities have forcefully rejected all efforts to soften the interpretation of CBDR; China threatened to cancel Airbus orders in response to Europe’s plan to tax emissions on inbound Chinese aviation, and threatened to release vast quantities of a potent warming agent when the EU sought to exclude certain cheap Chinese emissions credits from the European carbon market.5

A strong G77 position has formed a key plank in China’s efforts to prevent climate change agreements from undermining its economic growth or freedom of action. Yet in recent years this has been complicated by the increasing fragility of the developing world consensus. Some developing states’ vulnerability to climate changes has led them to adopt more flexible positions (Christoff 2010: 652). The growth of China’s economy, GHG emissions and international power has also strained the credibility of its claim to represent the interests of poor countries in global climate negotiations. As China’s emissions have increased, the pressure on it to act responsibly has come not only from developed countries but also from the developing world (Foot and Walter 2011: 201–2). Under these circumstances China might be able to use the prospect of SRM to restore G77 unity, because it could allay the environmental fears of highly vulnerable states while allowing China to maintain a hardline approach to binding emissions limits; this dynamic may prompt China to drive multilateral negotiation of a permissive SRM regime. Regardless of whether China decides to act as a citizen or renegade in multilateral efforts to regulate geo-engineering, precedent suggests it will continue to articulate a developing world position in order to justify its actions and gain international support.

China’s blunt temptations

China’s position in international negotiations does not yet appear to have been influenced by geo-engineering. Indeed, at the 2010 Convention on Biological Diversity conference, which adopted a limited moratorium on some geo-engineering activities, China made no significant contribution to debate. While SRM does not yet appear to be domestically salient, as it gains prominence its contradictory implications for the CCP’s core interests will become increasingly apparent. Chinese policy-makers will no doubt consider various concerns linked to SRM research: that it may undermine international mitigation efforts, cause harm to other states and create vested interests that push for implementation of SRM (Morrow et al. 2009: 3). On the other hand, since climate change causes extreme weather events and threatens agricultural production and water availability, SRM might potentially contribute to China’s domestic stability and economic performance in coming decades. Moreover, since abatement of climate change requires investment in higher cost alternative power sources, if SRM were accepted as a cheap alternative to emissions abatement it might allow simultaneous pursuit of maximum economic growth and social stability.

Internationally, the story is also mixed. Since unilateral pursuit of SRM would likely attract significant international opprobrium and China generally seeks to preserve a stable international environment, it would have reason to prefer that any SRM efforts were brought under multilateral governance. However, SRM is likely to be considered through the prism of China’s fears concerning Western domination, China’s leadership role in the developing world and in the context of the broader Sino-US relationship. If China’s relationship with the US were to become more adversarial, climate change and SRM might contribute to a strategy of delegitimization of the US-led global order (Schweller and Pu 2011) – China could accuse the US of acting in a hegemonic manner irrespective of whether the US sought to restrict or legitimize the use of SRM. The probability that China would deliberately politicize regulation of SRM as part of a delegitimizing ideological assault on Western ecological imperialism is low, but not nonexistent.

It seems unlikely that China would accept any Western-initiated SRM treaty that it perceives either as restricting China’s sovereignty by banning certain actions or as ignoring the views of the developing world by implementing SRM without China’s prior agreement. If North—West unity prevails and states move toward cooperative, permissive regulation of SRM experimentation and implementation it seems probable that China would seek to participate in this endeavour. However, were Chinese scientists not fully involved such a programme might be rejected as ecological imperialism. Conversely, China would be likely to drive G77 efforts to keep the potential of using SRM alive if international momentum moved toward prohibition of SRM.

In summary, so long as climate risks appear manageable and reasonably distant, SRM is unlikely to form a major part of China’s climate response. However, if Western efforts to regulate SRM gain greater prominence, China is likely to act to preserve its freedom of action. Were climate impacts to accelerate to the point where rapid preventative action seemed desirable, China might be tempted to implement SRM unilaterally. However, such rapid warming would also reshape the cost-benefit calculations of other states and make multilateral SRM implementation more likely. It would be in the event that China’s perceptions of climate risks diverged significantly from those of Western states, or if politicizing the issue of climate change became part of a broader strategy of delegitimizing US leadership, that renegade SRM action might occur.

We envisage nine potential outcomes, defined by the variables of the stances taken by China (implementing SRM/supporting research/opposing SRM completely) and the majority of the international community (nonregulation/restrictive regulation/regulation authorizing multilateral geoengineering). As has been argued elsewhere, it seems likely that a substantial SRM research programme conducted at a national or international level would inevitably create an influential constituency lobbying for implementation (Morrow et al. 2009: 3). This is because companies, government departments, and individual scientists involved in SRM research would gain financial and reputational benefits from implementation. As a result we anticipate that the most likely outcome is a chronological movement from the bottom left (weak Chinese opposition to SRM coupled with the absence of governance at a global level) to the top right of Table 1 (China supports SRM and participates in international governance that supports cooperative implementation). However, it is also possible that conflict over SRM could arise if China comes to perceive its interests as running counter to international opinion. This conflict could involve either China resisting a Western SRM programme or asserting its right to take unilateral action.

Although geo-engineering has not yet attained sufficient prominence for the CCP to have adopted a public position, we are confident in our claim that the central left side represents the current situation. As international attention to SRM grows, especially through the work of the IPCC on geoengineering in preparing its Fifth Assessment Report, and as funding opportunities for geo-engineering become available to Chinese scientists, in all likelihood China’s interest in and enthusiasm for SRM will increase. China is likely ultimately to embrace SRM if research confirms it could bring economic benefits. If, as we anticipate, the international community also moves toward a cautious, regulated support of SRM, China will probably play a constructive and uncontroversial role in international negotiations. It would only be if the international community opposed SRM, or initiated SRM without Chinese consent, that the potential for China to take destabilizing unilateral action might arise. For these reasons we suggest that international negotiations should avoid framing issues in ways that invite developed/developing world divisions. One example here is the question of whether the ‘L1’ orbit most conducive to some forms of SRM should be open to national appropriation or preserved as the ‘common heritage of mankind’ (Victor 2008: 332).6

More speculatively, we suggest it is possible that China, the G77 and the United States may experience some tensions with the EU over the regulation of SRM. The developing world’s concern to maximize economic growth may rub up against the greater influence of non-instrumental ‘green’ ideologies within leading European states. In this case the position adopted by the United States would be crucial. Were the US to adopt a pro-SRM position, China’s role may replicate the position it has taken to genetically modified foods. Here, China has been content for the US to lead in pushing for international acceptance of a controversial technology. While China has given no indication of any fundamental philosophical objections to genetic modification, and at first embraced these technologies with enthusiasm, it has proceeded increasingly cautiously – granting approval for domestic consumption of GM crops, but not pressing the issue internationally (Falkner 2006). There are multiple contending explanations for the differing positions of the EU, US, and China with respect to GM foods that draw on culture and political economy (Falkner 2007), and we do not presume that a cultural divide over the sanctity of nature would lead to predetermined positions. However, the EU’s economic and political investment in decarbonizing economic activity might potentially produce a political climate that is more resistant to SRM than that of the US.

Conclusion

Some Western scholars have expressed concern that China may already be working on unilateral research and implementation of SRM. Although we cannot discount this possibility, we have found no evidence supporting this contention in published Chinese literature or our discussions with Chinese scientists. In fact, consideration of SRM currently seems to be confined to epistemic communities that are deeply cautious about the possible downsides of deliberate intervention into natural systems. While SRM has only recently come to the attention of Chinese policy-makers and they are yet to give it detailed consideration, we support Victor’s view that China may ultimately embrace SRM. In this context any Western moves towards aggressive research and implementation that do not recruit Chinese scientists and officials as equal partners might prompt Chinese sensitivity to Western domination. Chinese epistemic communities currently seem politically unconstrained and professionally inclined towards participation in international collaboration to build a regulated and transparent international SRM research effort.7 Whether such collaboration does indeed emerge is an unfolding story. We anticipate that current efforts by those responsible for the SRMGI to bring Chinese voices into these international discussions may help to ensure that the issue of geo-engineering is not framed as a conflict between the developed and developing worlds. While there are reasons to fear the possibility of future unilateral action by China, it seems likely that international regulatory and research efforts in which the Chinese state and Chinese scientists are recruited as equal partners offer the best path to forestall such undesirable outcomes.

#### Follow-on and delay *ensure* conflict. Getting a global model established early is the only way to prevent conflict over SRM.

Parson, 13

(Edward A. Parson is Dan and Rae Emmett Professor of Environmental Law and Faculty Co-Director of the Emmett Center for Climate Change and the Environment, UCLA, “Climate Engineering in Global Climate Governance: Implications for Participation and Linkage”, *Transnational Environmental Law*, <https://www.uvic.ca/research/centres/globalstudies/assets/docs/publications/parson_TEL_non-US-geoengineering_August-15-2013.pdf>, August 15, 2013)

Yet unilateral pursuit of CE is likely to carry serious risks, which also follow from the same observations about the likely distribution of state capabilities and interests. The ability to develop CE capability, and even to deploy it, will not be limited to the US or to any single state. Other world powers can do it, possibly just as well; and even if some leading state achieves a technological breakthrough—e.g., an approach that is cheaper, safer, or more controllable—less advanced approaches can make similarly large climate perturbations, albeit more crudely. Other states can also assert the same legal arguments for a unilateral right of action. Indeed, states with programs of regional weather modification may be favored in advancing these arguments, due to the blurry line between these activities, which clearly lie within their sovereign authority, and early CE development. With both capabilities and potential justifications broadly distributed, at least among major powers, unilateral pursuit of CE by any world power, including the US, would risk others deciding to do the same; and once any major power decided to pursue this course, attempting to stop them would be difficult and risky.

Moreover, states are likely to perceive strong interests in whether and how other states pursue CE, not just at the deployment stage but also from early unilateral steps to develop capabilities that might make future deployment more likely. As discussed above, the severity of these risks will depend on how states’ future interests in CE are aligned or opposed. But given current uncertainties about CE capabilities and effects, these interests might be subject to some degree of influence. In particular, states’ perceived interests may form in part reactively, in response to early acts by other states that signal either anticipated rivalry or cooperation over CE. Thus, early unilateral acts by a major state— including development of capabilities, secrecy about intentions, or aggressive declaration of rights of action—may induce others to perceive CE as predominantly rivalrous and to pursue similar acts, either because they interpret these acts to indicate hostile or rivalrous intent or because they infer from these acts that it is valuable to have an independent CE capability. Conversely, early signals of cooperation and openness may have the opposite effect, steering others’ perceptions and choices toward cooperation. Given the uncertain and labile nature of future CE capabilities, such cooperative early moves may even influence the direction in which future capabilities are developed, toward those that pose less risk of conflict.

In sum, following a unilateral course in climate engineering—including not just eventual deployment, but also early steps to pursue research and development alone, maintain secrecy about capabilities and results, and reserve unilateral legal rights—is a superficially tempting but dangerous course of action, for the United States and other major powers. States should anticipate and resist these temptations and instead pursue a cooperative approach to CE. Such an approach could start immediately, with informal consultations on research programs, agreement on common standards for transparency, and joint development of assessment frameworks.45 A cooperative approach need not involve universal participation, but could start with only the dozen-odd nations likely to be most interested in developing CE and most able to pursue it unilaterally. It also need not await a comprehensive climate regime. By building cooperation and transparency on CE while the stakes are relatively low, such early cooperation may help build norms for cooperative management of CE, which would then be available to help resolve the more challenging governance problems raised by future proposals for operational interventions.

### 1AC Solar Shield – China

#### The United States and China are locked in a space security dilemma – that makes conflict likely – trust and transparency measures are key to diffuse the crisis

Fabian 19 [Christopher D. Fabian, MA thesis, B.S. from US Air Force Academy, May 2019. "A Neoclassical Realist's Analysis of Sino-U.S. Space Policy." <https://commons.und.edu/cgi/viewcontent.cgi?article=3456&context=theses>]

B. Summary The confluence of current Sino-U.S. relations and the state of space technology creates a structural security dilemma: the United States is excessively reliant on space support to conduct military operations in East Asia, which incentivizes China to pursue the development of technological and tactical innovations to deprive the U.S. of its operational advantage. This development threatens the U.S.’s conventional deterrent threat in the region, undermining strategic relations with key East Asian allies. The U.S. lacks a symmetrical response to China’s ASAT threat and must develop other means of deterrence, increasing the likelihood of horizontal escalation. Simultaneously, the offense-dominance of the space domain results in the lack of first-strike stability. These factors increase the likelihood that space will serve as a flash-point for a regional conflict in East Asia, and attempts to mitigate this threat are unlikely to succeed due to the inherent dual-use of most space technologies. Cognitive biases further worsen this security dilemma. Furthermore, China’s historic “century of humiliation” and rising technonationalism explain its position of losses seeking gains, making Chinese decision makers more likely to take over-weighted risk in order to overturn the existing status quo. Key cultural differences proliferate conflict between the U.S. and China, further altering leaders’ decision calculus and creating an opportunity for self-fulfilling prophesy. Despite this grim prescription, arms race and conflict between the two nations is not inevitable. The implementation of top-down TCBMs designed to build trust and transparency can direct both nations towards a globally optimal outcome.

#### Space conflicts go nuclear – the risk is high and there are no breaks on escalation

Grego 15 [LAURA GREGO is a physicist in the Global Security program at UCS. She is an expert in space weapons and security; ballistic missile proliferation; and ballistic missile defense. "Preventing Space War." https://allthingsnuclear.org/lgrego/preventing-space-war]

So says a very good New York Times editorial “Preventing a Space War” this week. Sounds right, if X-Wing fighters come to mind when you think space conflict. But in reality conflict in space is both more likely than one would think and less likely to be so photogenic. Space as a locus of conflict The Pentagon has known that space could be a flash point at least since the late 1990s when it began including satellites and space weapons in earnest as part of its wargames. The early games revealed some surprises. For example, attacking an adversary’s ground-based anti-satellite weapons before they were used could be the “trip wire” that starts a war: in the one of the first war games, an attack on an enemy’s ground-based lasers was meant to defuse a potential conflict and protect space assets, but instead was interpreted as an act of war and initiated hostilities. The games also revealed that disrupting space-based communication and information flow or “blinding” could rapidly escalate a war, eventually leading to nuclear weapon exchange. The war games have continued over the years with increased sophistication, but continue to find that conflicts can rapidly escalate and become global when space weapons are involved, and that even minor opponents can create big problems. The report back from the 2012 game, which included NATO partners, said these insights have become “virtually axiomatic.” Participants in the most recent Schriever war games found that when space weapons were introduced in a regional crisis, it escalated quickly and was difficult to stop from spreading. The compressed timelines, the global as well as dual-use nature of space assets, the difficulty of attribution and seeing what is happening, and the inherent vulnerability of satellites all contribute to this problem. Satellite vulnerability & solutions Satellites are valuable but, at least on an individual basis, physically vulnerable. Vulnerable in that they are relatively fragile, as launch mass is at a premium and so protective armor is too expensive, and a large number of low-earth-orbiting satellites are no farther from the earth’s surface than the distance from Boston to Washington, DC.

#### China’s lack of Cold War experience increases risk of miscalc and nuke war – causes extinction

Fabian 19 [Christopher D. Fabian, MA thesis, B.S. from US Air Force Academy, May 2019. "A Neoclassical Realist's Analysis of Sino-U.S. Space Policy." <https://commons.und.edu/cgi/viewcontent.cgi?article=3456&context=theses>]

Morgan points out that the nature of space deterrence has fundamentally changed since the end of the Cold War. First, a decoupling of space and nuclear warfare has destroyed the tacit red lines that guaranteed an attack on space systems would result in nuclear retaliation.60 Furthermore, technologies have been developed that allow for incremental escalation and non-lethal functional kills of space assets.61 A paradigm is created where escalation is probable, but the extent to which it will happen is unknown. This is a problem for Sino-U.S. space relations because China is a nuclear capable power who believes itself to have achieved nuclear deterrence with the United States, yet does not have the implied strategic understanding that it took the U.S. and the U.S.S.R. four decades to build. The rules of the game have changed, but the danger of nuclear apocalypse is still real and a risk of miscalculation has increased.

#### US-China space weather cooperation creates a foundation of trust and transparency that eases misperceptions and reduces the risk of war

Knipfer 17 [Cody Knipfer is the Technology & Cybersecurity Fellow at Young Professionals in Foreign Policy (YPFP), MA in International Science and Technology Policy from George Washington University's Space Policy Institute, December 7, 2017. “The U.S. and China Need to Start Cooperating in Space.” <https://www.realclearscience.com/articles/2017/12/07/the_us_and_china_need_to_start> \_cooperating\_in\_space\_110479.html]

These are valid fears, but a cooperative venture with China need not be expensive, high-profile, or entail significant transfers of US technology and expertise. Joint ventures, such as monitoring climate change, studying space weather, or tracking near-Earth asteroids, could be done through non-sensitive means such as sharing already-collected data and analysis. More tangible cooperation could be as simple as flying scientific instruments on each other’s satellites – an option that, because of the generally benign nature of these instruments, minimizes the security risk of “dual-use” technology sharing. In addition to the scientific benefits they’d provide, these partnerships would help create meaningful patterns of interaction that lower barriers to transparent information exchange – and may pave the way to future cooperation on higher-profile efforts. There is utility in the practice of exchanging information. Space cooperation allows partners to learn and acclimate to each other’s decision-making processes, institutional cultures, and standard operating procedures. This gradually builds trust in each other’s intentions, or at the very least eases misconceptions about how the other thinks. This is vital in the case of China, which is [seen by many](https://defensesystems.com/articles/2016/06/07/us-china-space-counterspace.aspx) in the national security community as the United States’ greatest threat in space. By helping policymakers and security leaders decipher China’s intended use of dual-use space technologies, cooperation in any form would limit American suspicion and possible miscalculation as China uses these technologies. Cooperation between our two countries would also signal, and over time establish, growing mutual confidence. Earning this perspective of presumed good intention would serve to far better mitigate military escalation in space during times of tension on Earth than what the current status quo offers. Ultimately, policymakers need to look at the reality of the situation: in space, China isn’t going away. They are and will be as integral an actor in setting outer space’s future norms as our current-day allies. During the Cold War, despite stark differences in ideology and values and regardless of their active development of anti-satellite weapons, the United States pursued space cooperation with the Soviet Union because of this recognition. Today, the United States should do the same with China. Cooperation can be preconditioned on transparency and tempered in expectations. It can be as simple as sharing data and establishing space agency-to-space agency dialogue. It needn’t begin with a giant leap, but rather small steps. For a peaceful coexistence with China in space, small steps are far better than none at all.

#### US-China space trust-building and cooperation steers China away from future ASAT development and testing

Ressler 09 [Aaron R. Ressler, Major, USAF, AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY, April 2009. “ADVANCING SINO-U.S. SPACE COOPERATION.” https://apps.dtic.mil/dtic/tr/fulltext/u2/a539619.pdf]

After reviewing Chinese counterspace capabilities and possible motivations, the question at hand, again, is how can the U.S. make ASAT operations less attractive for China? To not do anything is an option since China broke no laws or treaties.24 But what if China were to pursue continued and even more aggressive ASAT testing? Then there is always the option of multilateral treaties that could be designed to prevent or limit the weaponization of space. While this may appear to be an attractive option, a treaty of this sort could go against the 2006 U.S. National Space Policy which states that the U.S. intends to maintain its freedom to act in space.25 U.S.-China space cooperation could be the ideal answer to deter Chinese counterspace testing and operations without significantly tying the hands of the U.S. with regard to maintaining freedom of action in space. The idea here is gaining a partner versus a competitor. Despite improvement in diplomatic and economic relationships between the U.S. and China, there has been very little initiative from the U.S. in entering into cooperative efforts with China in space activities. In fact, it was reported by Michael Griffin, the National Aeronautics and Space Administration’s (NASA) current administrator, that the Bush administration failed to approve an “overture to China for a cooperative U.S.-China space mission” in late 2008.26 Opening the doors toward increased cooperation with China in the space endeavor could present some attractive benefits. First and foremost, communication would improve between the two countries on space matters which would be essential in ultimately preventing further uncoordinated direct-ascent ASAT type activities. Currently, there is essentially no dialogue between the U.S. and China regarding military space issues.27 Another advantage of space cooperation is cost. The U.S. and China share similar goals, like returning to the Moon and eventually pursuing a manned mission to Mars. Space is expensive, so why not share resources and capabilities in the pursuit of such activities?

#### China will test ASATs now – that creates debris fields that spark nuclear miscalculation

Beauchamp 14 [Zack Beauchamp, editor for Vox, citing a study done by Micah Zenko, senior fellow with the Center for Preventive Action at the Council on Foreign Relations, April 21, 2014. “How space trash could start a nuclear war.” https://www.vox.com/2014/4/21/5625246/space-war-china-north-korea-iran]

Panic in the skies! "The threats to U.S. space assets are significant and growing," according to a new report from the Council on Foreign Relations, which warns that there's a real chance of breaching conflict's final frontier. This isn't idle fearmongering. The report makes a not-crazy case that efforts by China and other powers to limit America's total military dominance of space could accidentally destroy an American satellite, inadvertently convincing the US that war was coming and prompting retaliation on Earth. Its author, Micah Zenko, has [made a name](http://www.theamericanconservative.com/articles/the-anti-warrior/) for himself in report-after-report downplaying the threat to the United States from China, terrorists, and, really, [most things](http://blogs.cfr.org/zenko/2012/02/23/clear-and-present-safety-the-united-states-is-more-secure-than-washington-thinks/). So that fact that Zenko is this [concerned about space](http://www.cfr.org/space/dangerous-space-incidents/p32790?sp_mid=45655631&sp_rid=emFjay5iZWF1Y2hhbXBAZ21haWwuY29tS0) should tell you something. The basic dynamic is simple: the US controls space and its opponents don't. Of all the money spent on space by all countries combined, America [spends](http://www.cfr.org/space/dangerous-space-incidents/p32790?sp_mid=45655631&sp_rid=emFjay5iZWF1Y2hhbXBAZ21haWwuY29tS0) 75 percent. It also owns 43 percent of all satellites. It uses that huge satellite network for, among other things, all sorts of military spying and coordination purposes. At one point, the Bush Administration [mused openly](http://www.armscontrol.org/act/2004_11/Krepon) about putting actual weapons pointed at Earth in space. Countries who might hypothetically fight a war with the United States hate that space dominance, which gives the US a real strategic edge. Some have [developed](http://www.stimson.org/images/uploads/Anti-satellite_Weapons.pdf) anti-satellite (ASAT) weapons, usually missiles that shoot into space. Zenko thinks ASAT weapons are really dangerous, particularly those owned by China, North Korea, and Iran. The threat comes from both deliberate use and the risk of a misunderstanding that could spiral out of control. The "greatest threat to international space security," in Zenko's view, is a Chinese accident. China is [seriously investing](http://america.aljazeera.com/articles/2014/4/16/china-s-presidentxiurgesgreatermilitaryuseofspace.html) in ASAT weaponry, which it has tested by blowing up old satellites in low earth orbit, one of the places place where satellites live. These explosions create debris, which can travel tens of thousands of miles per hour and shred up other satellites and spacecraft. If debris from a Chinese test destroys a US military satellite, the US could mistake it as a preemptive strike against its space capabilities — some of which are [designed](http://www.pbs.org/wgbh/nova/military/nuclear-false-alarms.html) to detect nuclear missile launches. If the US thinks China is trying to take out its ability to detect a nuclear launch, things could get very bad, very quickly. Accidents aren't the only concern. Zenko also worries about intentional space attacks, either during peacetime or a crisis. Here, Iran and North Korea are probably bigger threats, though their ASAT capabilities are far from proven. North Korea has a pattern of crazy military moves designed to extort concessions from South Korea and the West; it could extend that behavior to space. Iran, according to Zenko, "already views space as a legitimate arena in which to contest US military power." He worries that Iran might fire missiles into space "during a major crisis, especially if it believes war is imminent — an assessment that could have self-fulfilling consequences." But even if none of these scenarios for war are likely, preparing and testing for space war is intrinsically dangerous. Space debris don't discriminate between military and non-military satellites; the more ASAT testing there is, the more hazardous space travel becomes for everyone. As satellites become increasingly important to the economy and scientific research, even preparation for space war becomes deadly.

### 1AC Solar Shield – Solvency

#### The plan would deploy a solar shield to the L-1 point – that prevents solar storms and would modulate solar radiation, solving warming

Pelton 16 [Dr. Joseph N. Pelton, Research Professor, Institute for Applied Space Research, George Washington University; former Chairman of the Board, Dean, International Space University; former Director, Graduate Telecommunications Program and Center for Advanced Research in Telecommunications, University of Colorado at Boulder; former Director, Strategy Policy and Executive Assistant to Director General, Intelsat. Director, Project Share. Vice Chairman, Arthur C. Clarke Foundation and Executive Director, Clarke Institute for Telecommunication and Information (CITI). Member, International Academy of Astronautics, 2016. “Our changing world and the mounting risk of a calamitous solar storm.” https://room.eu.com/article/our-changing-world-and-the-mounting-risk-of-a-calamitous-solar-storm]

Today the space agencies around the world and the UN Committee on the Peaceful Uses of Outer Space (COPOUS), especially through its Long Term Sustainability of Space Activities initiative, are addressing cosmic threats from asteroids and comets, but have essentially said, ‘There is nothing we can do to protect Earth from solar radiation and perhaps even less from coronal mass ejections. It is up to agencies like Homeland Security [in the US] to address recovery from such a major solar-triggered disaster since we can do nothing.’ The basis of this article is simply to argue that this is not true. There is technology that we could deploy at Lagrangian Point 1 (L-1) that could potentially do the following: Create an artificial Van Allen ‘electro-magnetic shield’ that could protect Earth against a major solar coronal mass ejection that could otherwise have a crippling impact on the global economy and risk injury, illness or death to perhaps millions of people. Create a modulation system for solar radiation that could help slow or reduce climate change due to the source of energy that heats our planet and controls our climate. In creating a large magnetic shield system, we could also design-in solar power satellites that could beam back clean energy to Earth that could assist with the financing of the solar shield system. Finally, the structure that is designed could also be multi-functional in concept and become an effective way-station for efficient transportation to other points in the Solar System such as the Moon, Mars, or asteroids. The advantage of such a way-station is that the low gravitational pull at L-1 is such that highly efficient electrical propulsion systems could be used for travel from L-1 to any point in the Solar System. This article is therefore about how such an innovative mega-structure could be designed to save the human species and Earth as we know it today. That is not to say this is something easy or inexpensive to build. It could be on a par, for example, with the cost of the International Space Station (ISS). There are many issues to be addressed and considered before launching into such an ambitious project. Not the least of these would be who would design and build it, and who would control its operation. This could conceivably be a commercial global space industry consortium, but its operation would almost certainly have to be under some form of reliable and international authority that would guarantee the responsible on-going operation of such a key international space infrastructure. The design of the ISS was far from easy. There were at least a dozen different concepts and, despite a reduction in size and performance capabilities, the price rose to around US$200 billion if the costs of all of the participating entities are included. US investment was an estimated US$140 billion. A mega-structure that could be deployed at L-1 would not be some sort of scientific toy for international space cooperation - this would be a device to save Earth and would be of enormous economic value over the long term. Further it could be designed to have dual functions - a power generating system or way-station for low cost transportation to the Moon and Mars. The key to the basic generic design will be lightweight electromagnetically charged structures that may be a combination of gossamer and inflatable structures. NASA’s Innovative Advanced Concept studies have examined the feasibility of electrostatically inflated membrane structures (EIMS) to create systems to protect astronauts in orbit from cosmic radiation. It seems quite possible to create a cluster of such inflatable structures with a magnetic field charge level of perhaps 1 or 2 tesla (or 10,000 to 20,000 gauss) to create a solar shield system against not only radiation but coronal mass ejection ions as well. The figure (right) is from the NASA-NIC study on protecting astronauts in space from solar radiation. The logical extension of this study would be to devise an architecture of a network of a number of these structures that could be combined to create an effective solar shield system. A combination of scores of these electro-magnetic force fields that could slow and divert solar radiation and ions from a powerful CME seems entirely possible. The idea would be to strategically locate this ‘magnetic solar screen’ in the L-1 position between Earth and the Sun. This screen could be maintained in position using an ion propulsion system powered from a solar array. Further, at a location that is 1.5 million km from Earth the structure would not have to be super-large to protect Earth. The creation of a structure with an overall magnetic field of 2 tesla (or 20,000 gauss) would only require the development power sources that could be easily generated by solar arrays. The accompanying chart (below) indicates the magnetic field levels of various applications. Such a magnetic solar shield structure could provide protection against massive solar storms and could also even modulate solar radiation to protect against severe climate change. This extension in thinking from the NASA NIC studies seems only a logical next step with regard to how such technology might be usefully applied. Clearly there are many scientific and engineering questions still to be addressed. Would gossamer structures be sufficiently durable or would more substantial inflatable structures such as those Bigelow Aerospace is using in its inflatable commercial space stations be a more suitable material? Would solar cell arrays, solar concentrators, or nuclear or radio isotope or other forms of power sources be optimum for the design to created the necessary magnetic fields? There are also fundamental engineering design questions regarding whether this design could be further enhanced to use part of this overall structure as a sort of space transport way-station for transitioning from chemically fuelled rocket launchers to much more efficient electric ion propulsion systems that could fly on to the Moon and Mars? The parallel question is whether the overall solar screen system could also be designed to create a large scale solar power satellite station that could beam clean energy back to Earth 24 hours a day, seven days a week when the unit was not being deployed to save the Earth from a massive solar storm, modulating solar radiation to reduce climate change and overheating of the atmosphere? It is more than a little thrilling to think of an invention that could literally save the world. One of my forebears, Lester Allen Pelton, who is in the Inventor’s Hall of Fame, not only first conceived the Pelton Water Wheel but extended the technology to invent the world’s first hydro-electric turbine - a fundamental technology that provides electric power around the world today. In his honour, I hope that the Pelton Space Shield and Transport Terminal (PSSTT) can help us reimagine what we can do to save Earth, save the human race, and power our future. When someone says to be me, “Psstt, what did you do with your life?”, someday I can say I helped the International Space University, space engineers and the world’s space agencies to start thinking about inventing, building and deploying PSSTT. In the past few years ‘new space’ companies and initiatives like the XPrize, SpaceShipOne, SpaceX, Skybox, O3b, ViaSat, Blue Origin, Stratolaunch/Viking, Virgin Galactic, etc. have embraced disruptive new space technology and reinvented the innovative nature of outer space enterprise. It could now be the turn of space agencies to show their innovative side and take the lead in planetary defence. For too long space agencies have had too little within their portfolio and mission plans that include programmes to save Earth and deploy space systems that can provide protection from asteroids, comets, solar radiation and solar ionic eruptions. It seems to me that it is time to re-examine the prime mission of space agencies. The prime strategic agendas of space agencies have been on cruise control for too long and need to be disruptive. Nobel Laureate Joseph Stiiglitz recently addressed the leadership of the Organization of Economic Cooperation and Development (OECD) and suggested that a new economic activity for our scientists and engineers should be ‘Planetary Defence’. It is time for those leading our space agencies to consider what technologies they might conceive and implement to save Earth and the human race. To put not too fine a point on it, now is the time for them to start doing their truly core mission - ‘Save Earth’.