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ENGW 3315 Project 2
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March 30, 2022

Mitigating the double-edged sword of technology

As humans have evolved, we have developed technology to help us live longer and easier lives by protecting ourselves from disease, predators, and other hardships. But the technology that gave us the power to improve our lives also gave us the power to destroy them: Industrialization has begun warming the planet and acidifying the oceans, global travel has transformed epidemics into pandemics, and advanced biotechnology has given humans the ability to destroy ourselves on a mass scale. There are also cosmic events such as solar flares, gamma-ray bursts, and asteroids that we remain as vulnerable to as the early humans on the African savannah. Among these issues, climate change speaks with the loudest voice in our society. Our technology is beginning to alter the climate of our planet, and may soon cause irreversible damage. In this paper, we will examine the unintended consequences of human advancement through these technological developments, and assess whether any solutions exist. Our focus is on continuing the advancement of technology while also mitigating the fragility problem. Some questions we aim to answer include: What have we done so far? What can we do in the immediate future? What kinds of long-term solutions have been implemented/proposed? Answering these questions will require an interdisciplinary investigation, involving collaboration across a large spectrum of fields and disciplines.

Human history is littered with technological leaps that have bent our evolution away from the path established over billions of years of life. Advancements such as fire, the wheel, spoken and then written language, agriculture, domestication of animals, metallurgy, and others have slowly but surely cemented our place as the dominant species on this planet. The biggest leap, however, came barely 250 years ago with the Industrial Revolution. The Industrial Revolution transformed every aspect of life, from the way we get around to our knowledge of the universe and our biology. Farmers became factory workers, business owners became unimaginably wealthy titans, and we began to significantly affect the environment of our planet. It took nearly three generations until the first dedicated efforts were made to reverse the polluting effects of the Industrial Revolution (Austin & Macauley, 2001) Since then, we have begun developing cleaner technologies and methods of removing our pollution from the environment, and yet our efforts are not enough. Taking a closer look at the automotive industry helps illustrate this issue with more clarity. While we have made car production cleaner and more efficient, and designed our technologies to be significantly less destructive to the atmosphere, the number of consumers has drastically increased, leading to the rise of a dangerous climate trend (Austin & Macauley, 2001) Additionally, many people prefer driving cars with lower fuel efficiencies and fewer renewable components, which limits the impact of designing more fuel-efficient cars. This trend can be seen in all kinds of manufacturing and energy production industries, and has led to a dismal projection of the success of accords such as the Paris Agreement: “The current round of pledges under the Paris Agreement—if all states fulfill them—could keep warming to within perhaps 2.7°C by the end of this century” (Reynolds, 2019).

This rather dark outlook has led some scientists to consider taking a much more drastic approach: solar geoengineering. Solar geoengineering is a proposed technique to adjust the way the Earth retains and reflects heat in a way that doesn’t involve changing the atmospheric concentration of greenhouse gasses. There are several approaches to this topic, including increasing the albedo of the earth’s atmosphere by injecting aerosols into the stratosphere to scatter and reflect incoming sunlight. Additionally, cirrus cloud thinning has been suggested, as cirrus clouds have been shown to have a warming effect; by preventing cirrus clouds from forming, we could theoretically lower the average earth temperature by up to 1.4 degrees Celsius (Reynolds, 2019)/ These drastic measures, however, are inherently risky. For one, a mistake in any aspect of the approach could lead to too much sunlight being blocked, resulting in catastrophic food shortages and mass extinctions. Additionally, this method serves as more of a stopgap rather than a permanent solution, since it does nothing to help ocean acidification and would likely create regional temperature anomalies. Clearly, the application of this technology would be a last ditch effort to protect humanity from climate change disaster.

A so-called “climate change disaster” is a genuine threat. The World Health Organization predicts that a temperature increase of 1.5°C would lead to “catastrophic health impacts and … millions of climate change-related deaths” ("Climate change and health", 2021). However, the question still remains regarding the best way to mitigate these effects. Since natural gas and the rare metals that make up solar panel circuits are not renewable, constructing wind turbines is expensive, unreliable, and dangerous to wildlife, and nuclear power is incredibly dangerous, it seems as if there are no good solutions to the energy crisis. These are, after all, the most prominent sources of alternative energy. If none of them are good enough, what can we do? There is no one answer to this question. Today, the practiced solution is to use a combination of all energy sources, as the most pressing issue is carbon dioxide pollution. However, further research is certainly needed to find a more permanent solution to the energy crisis that doesn’t put humanity’s future at risk.

In addition to the environment, technology has had similar transformative effects on globalization. Just 300 years ago, communication involved writing a letter and sending it via a horse or ship. Letters could take several months to reach their destination, and one could wait a year for a single response. Now, we can communicate instantly with anyone in the world through video calls. Nation-states that once could enact brutalist policies on their people now face the accountability afforded by video recordings and live streams, making it much more difficult to avoid punishment on the world stage. Powered flight allows people and goods to reach their destinations in hours instead of months (Royal Museums Greenwich, 2021), a factor of 20 or more (“Transit and Shipping Time Calculator”, 2022). Suddenly, the entire world is available to us. Every country’s economy has tied itself more closely to global trade, and many have become entirely dependent on it. Why produce goods in one country when it’s cheaper to produce them in another? Global trade, air travel, and digital connection have enabled a massive shift to specialization and reliance on trade (Neufeld, 2020), but this shift has produced tremendous fragility.

While this sort of globalization has benefited consumer life enormously by growing countless economies and giving people access to previously unavailable resources and products, dependence may endanger the livelihoods of people and countries alike. A key example is the blockage of the Suez canal by the Ever Given trade ship, where a simple error led to a 6 day delay in trade costing the global economy almost $10 billion a day (Russon, 2021). While thankfully a crisis was averted, it is an excellent showcase of how a globalized economy can be both a risk and an asset. Had something more permanent occurred, the damage would not have been limited to just one or two countries: any country benefiting from trade across the Suez Canal would also share in the losses, causing widespread economic shockwaves. Holdups on one product could halt production on another, and a break in global trade could cause widespread starvation, people not getting medicine, or fuel for cars running out. Being connected means you can take advantage of other countries' specialization, but also means you are exposed to their weaknesses.

When trying to solve this problem, we are once again faced with the issue of how these sorts of crises can be avoided. A simple solution is simply not putting all the eggs in one basket: diversifying trade routes and production locations ensures that an error with one will not necessarily impact the entire world; however, in today's profit-driven society, there are few instances where companies would intentionally sacrifice income by taking a longer trade route or choosing to manufacture in a more expensive location. There are no true solutions to this issue that have been proposed. Globalization relies on interconnectivity, which is exactly what causes the danger, and the most fitting solution may simply be the antithesis - independence. The world may need to begin searching for the proper medium between the two in order to balance risk and reward, or risk serious economic tragedy upon the next freak accident.

Another byproduct of increased globalization and the easy spread of people and goods is the potential for disease, in the form of pandemics or bioweapons, to spread worldwide and decimate populations and economies. In the past, pandemics such as the plague were extremely lethal – but limited travel between regions of the globe prevented these diseases from spreading worldwide. Nowadays, with enhanced travel and trade, modern pandemics can be more far-reaching than ever.

Naturally occurring pandemics are not the only biological agents driving the potential for mass destruction. For centuries, humans have used their basic understanding of biology to gain advantages during wartime. At first, primitive biowarfare took the form of using dead bodies to spread disease throughout the opponent's cities – in the 1100s, Emperor Barbarossa poisoned water wells with dead bodies in Italy, and in 1346 the Mongol horde used catapults to launch the bodies of plague victims over the walls of Crimean cities (Frischknecht, 2003). As our understanding of biological agents (specifically viruses and bacteria) grew, the uses of bioweapons became more advanced and more destructive. During World War II, the pathogens causing well-known diseases such as anthrax and cholera were abused to weaken enemy troops and cities. In the years following, the USSR developed a bioweapons program that focused on using viruses such as the Ebola and Marburg viruses to cause lethal hemorrhagic fever (Frischknecht, 2003).

In modern-day development of bioweapons, the hot topic is gain of function (GOF) research. GOF research entails modifying the transmissibility or virulence of pathogens. This is often done for beneficial research to better understand the pathology and spread of the associated diseases; in the wrong hands, however, malevolent development has the potential to lead to the next generation of biological weapons of mass destruction. An ethical analysis of GOF research written in 2016 by Michael Selgelid examines some concerns regarding the usage of this research. Before the outbreak of COVID-19, the most controversial use of GOF research was seen in the creation of a highly pathogenic avian flu virus, H5N1. It was transmissible via airborne pathways between ferrets, which purportedly are the closest model to human transmissions (Selgelid, 2016). There were concerns regarding the uncensored publishing of this research, which could act as instructions for bioterrorists or foreign powers to create a lethal influenza pandemic among humans. Nevertheless, the research was published publicly in its completely uncensored version (Herfst et al., 2012). Two years after this controversy, the Obama administration put a pause on funding for GOF research. The administration was being cautious about the double-edged use of this research saying that the pause in funding was targeting research that "may be reasonably anticipated to confer attributes … such that the virus would have enhanced pathogenicity and/or transmissibility in mammals via the respiratory route" (Obama White House Administration, 2014). Another concern brought up in the Selgelid analysis, which was written prior to the beginning of the COVID-19 pandemic, is "that a devastating pandemic could potentially result from a laboratory accident involving an especially dangerous pathogen created via GOFR" (Selgelid, 2016).

Turning now to look at GOF research within the context of the COVID-19 pandemic, we can see the double-edged nature of advancements in biological research. Although the true origins of the COVID-19 pandemic are unclear, according to a New York Times article there are shaky-at-best allegations that it began with GOF research in the Wuhan Lab in China (Zimmer, 2021). Regardless of whether or not this specific pandemic was caused by GOF research, it is not difficult to imagine that the possibility for an incident involving GOF research to cause a pandemic exists. Opponents of GOF research would look at the effects of this COVID-19 pandemic as an example of the world's inability to handle a globally spreading disease and would point out the dangers of a true GOF designed pandemic on our clearly unprepared world. Those in favor of GOF research might take the stance that our lack of preparation and inability to handle this pandemic is evidence that we need to be doing more research into the pathology of disease and that controlled and contained GOF research is the best way to understand possible pandemics (Imperiale, 2020). Put simply, this is yet another example of a difficult balancing act where there are both benefits and drawbacks of our advancements and research. Identifying the level of research that provides the most benefits without risking devastating consequences remains a challenge to this day.

Now that several examples of the double-edged nature of technological advancements have been examined, the next logical step is identifying possible solutions to the problem. Ideally, solutions would reduce the fragility of the human race while sacrificing as few benefits of our technology as possible. There are two main categories that solutions would fall under. First, some solutions aim to prevent disaster. The difficulty with these types of solutions is that it is impossible for a single solution to effectively remedy all of our weaknesses that have arisen as a result of advancing technology. For example, if we attempted to resolve global warming by covering the Sahara Desert with solar panels, how does that do anything to combat our weakness to pandemics or biowarfare? It's possible that this solution would even make the problem of globalization worse – is putting so much of the world's power generation in one spot a good idea?

Clearly, each area of our technological advancements must be investigated on a case-by-case basis. There is no end-all-be-all solution; it will take a combined effort from scientists and governments across the world to safeguard our species against the vulnerabilities that we face. An incredibly idealistic starting point to address only the problems mentioned thus far in this examination might take the following form: 1) Reduce reliance on oil and fossil fuels for global power production. Turn to more sustainable forms of energy production such as nuclear, solar, hydro, or geothermal. 2) Establish new trade routes, potentially via a network of man-made canals, such that there is less dependence on the operation of single ports and canals for global trade. 3) Increase funding globally for research into vaccines, medications, and understanding of pandemics. The human race must be better prepared when the next global pandemic strikes. 4) Global agreements to stop the research and development of bioweapons and nuclear weapons. Both can decimate populations, and in a worst-case scenario could wipe out a large swathe of the human species.

If recent events and past government policies are anything to go by, it seems unlikely that these solutions could be implemented on a global scale in time to prevent disaster. This brings us to the second type of possible solution. These solutions are intended to be drastic responses to a potential apocalyptic disaster. If the worst comes to worst and there is global nuclear war, a lethal pandemic, a massive food shortage, or extreme irreversible damage to our climate, how can humans survive? These are the types of solutions often seen in science fiction films – but those fictional movies are based on possibilities from our real world. Is it realistic to pursue space travel with the ultimate goal of colonization of another planet? Could some form of population control be necessary to combat a food shortage? The answers to these questions are well outside the scope of this examination, but one thing remains clear – something must be done to knock humans off our current trajectory to inevitable disaster.

Annotated Bibliography

Austin, D., & Macauley, M. K. (2016, July 28). *Cutting through environmental issues: Technology as a double-edged sword*. Brookings. Retrieved March 2, 2022, from https://www.brookings.edu/articles/cutting-through-environmental-issues-technology-as-a-double-edged-sword/

This article explores the 'double-edged' nature of technology from an environmental standpoint, talking about the massive increases in wealth caused by the industrial revolution while also exploring the environmental damage it caused. It moves on to the efforts being made to bring this pollution under control, and shows that we have in fact reduced our per capita rate of pollution through things like increasing the fuel efficiency of cars and setting air quality standards for cities. The article then moves on to energy production, explaining the energy efficiency gains that technology has provided us, but showing that even with these gains aggregate pollution is still increasing. The article continues to give examples in several environmental areas where technology has been used to mitigate damage caused by technology.

This article will be extremely useful to our paper because it focuses on one of our main topics and provides great detail on both sides of the technological coin.

Grant, E., & Yung, J. (2021). The double-edged sword of global integration: Robustness, fragility, and contagion in the international firm Network. *Journal of Applied Econometrics*, *36*(6), 760–783. https://doi.org/10.1002/jae.2839

Selgelid, M. J. (2016). Gain-of-function research: Ethical analysis. *Science and Engineering Ethics*, *22*(4), 923–964. https://doi.org/10.1007/s11948-016-9810-1

This article centers around the ethics of gain-of-function research, which is research on how viruses can gain transmissibility. Interestingly, this article was written in 2016, well before the COVID pandemic. It talks about the US government's caution

regarding this type of research, with the Obama administration pausing funding and calling for a ‘deliberative board’ for any future grants. This decision was made in response to several biosafety incidents with anthrax, smallpox, and H5N1. This article is especially interesting post-COVID because it does an incredible job outlining the dangers of GOFR and even mentions the SARS class of viruses by name. The article then goes on to explore potential ethical frameworks around such research and decision-making criteria for researchers and funds.

Herfst, S., Schrauwen, E. J., Linster, M., Chutinimitkul, S., de Wit, E., Munster, V. J., Sorrell, E. M., Bestebroer, T. M., Burke, D. F., Smith, D. J., Rimmelzwaan, G. F., Osterhaus, A. D., & Fouchier, R. A. (2012). Airborne transmission of influenza A/H5N1 virus between ferrets. *Science*, *336*(6088), 1534–1541. https://doi.org/10.1126/science.1213362

This paper is the controversial research into ferret H5N1 influenza virus. Ferrets are the closest model to human transmission and this paper provides details into how gain-of-function could transform this deadly virus into one transmissible by humans. In our paper, it is used as an example of GOF research that could potentially result in the loss of human lives.

Frischknecht, F. (2003). The history of biological warfare. *EMBO Reports*, *4*(S1). https://doi.org/10.1038/sj.embor.embor849

This paper is an examination into the history of how biowarfare has evolved along with the evolution of our technology. Starting with the use of dead bodies to contaminate water in the 1300s and going all the way to GOF Ebola viruses in modern-day research, it outlines the timeline of biological warfare. We use it in this paper to paint a picture of the growing elegance and lethality of biological warfare as our technology develops.

Obama White House Administration. (2014, October 17). *Doing Diligence to Assess the Risks and Benefits of Life Sciences Gain-of-Function Research*. White House Archives.

https://obamawhitehouse.archives.gov/blog/2014/10/17/doing-diligence-assess-risks-and-benefits-life-sciences-gain-function-research

Zimmer, C. (2021, June 20). Fight Over Covid's Origins Renews Debate on Risks of Lab Work. *The New York Times*. https://www.nytimes.com/2021/06/20/science/covid-lab-leak-wuhan.html

In this article from the New York Times, an allegation is made that the COVID-19 pandemic was a result of GOF research gone awry. It also provides insight into the then-current debate over GOF research that arose from this allegation. Although more recent evidence suggests that this claim was mostly unfounded, we nonetheless use this article to indicate that a pandemic arising from GOF research is well within the realm of possibility while simultaneously connecting our examination to a current topic.

Imperiale, M. J., & Casadevall, A. (2020). Rethinking gain-of-function experiments in the context of the COVID-19 pandemic. *MBio*, *11*(4). https://doi.org/10.1128/mbio.01868-20

This paper provides a meta-analysis of current arguments for and against GOF research. We use it to exemplify the double-edged nature of GOF and other types of biological research. There are advantages that can be found from even the most risky research, so we must find the correct level of risk to accept to get the most benefit.

Climate change and health. Who.int. (2021). Retrieved 31 March 2022, from https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

The greenhouse effect traps the energy from the sun without our atmosphere. Extra greenhouse gasses in the atmosphere can exaggerate this effect, and trap too much energy near the Earth's surface, causing warming that we recognize as global warming / climate change. Research has shown that this global warming is primarily caused by increased greenhouse gasses produced by humans. Greenhouse gasses let light through the atmosphere, but prevent heat from escaping. In order to mitigate deaths and minimize health impacts, experts say that heating must be limited to within 1.5°C. Global increases in temperature can lead to extreme weather events

and flooding, causing catastrophic property damage and death, and melting ice caps and glaciers are starting to melt, causing a rise in sea level across the globe.

This article will be useful for our paper because it details the risks of increasing temperatures, as well as giving useful figures about how much temperature change is too much, and what issues we can expect to see.

Reynolds, J. (2019). *Solar geoengineering to reduce climate change: a review of governance proposals | Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences. Retrieved 31 March 2022, from https://royalsocietypublishing.org/doi/full/10.1098/rspa.2019.0255.

This article, published under Mathematical, Physical, and Engineering Sciences on Royal Society Publishing, proposes the topic of solar geoengineering as a potential stopgap for climate change. It outlines several possible methods of solar geoengineering, including increasing the albedo of the earth's atmosphere and cirrus cloud thinning. These methods are alternatives to existing climate change solutions, and were proposed due to studies that show that humanity is not on track to prevent dangerous temperature levels with current methods. The article heavily discusses potential risks and (lack of) governance around the topic, as well as how the risks merit much more attention than has been given to the topic.

Russon, M. (2021). *The cost of the Suez Canal blockage*. BBC News. Retrieved 31 March 2022, from https://www.bbc.com/news/business-56559073.

This article gives detailed information about the blockage of the Suez Canal by the Ever Given cargo ship. It speaks to the efforts to free the ship, the size of the ship itself, and most importantly, the estimated loss in trade value by ships that were rerouted or unable to reach their destination. It also discusses the extent of the businesses that were affected by the blockage.

This article will be useful for our paper because it will help to illuminate some of the challenges of living in a globalized world. In this example, it shows how one person/country's mistake can lead to devastating consequences across countless industries, negatively impacting many countries.

Royal Museums Greenwich. (2012, November 8). *18th century sailing times between the English Channel and the coast of america: How long did it take?* Royal Museums Greenwich. Retrieved March 30, 2022, from https://www.rmg.co.uk/stories/blog/library-archive/18th-century-sailing-times-between-english-channel-coast-america-how

Museum article detailing the length of a transatlantic crossing in the 18th century.

Freightos. (2022, March 9). *Transit & Shipping Time Calculator*. Freightos. Retrieved March 30, 2022, from https://www.freightos.com/freight-resources/transit-time-calculator/

This article outlines the average sea and air freight times for the modern-day.

Neufeld, D. (2020, November 18). *Mapped: The top export in every country*. Visual Capitalist. Retrieved March 30, 2022, from https://www.visualcapitalist.com/mapped-top-export-in-every-country/

This article contains information on global exports by country along with great visualizations. It contains blurbs describing why some countries' top exports are what they are.