The Responsibility of Engineers: Decouple Engineering and Oppression

Walls, Dan

Stanford University, University of British Columbia, & Rensselaer Polytechnic Institute¹

daniel.joseph.walls@gmail.com

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Victor Weisskopf said, “Human existence is based upon two pillars: compassion and knowledge. Compassion without knowledge is ineffective; knowledge without compassion is inhuman.” Unfortunately, a cursory examination of how science and engineering have operated historically reveals a litany of instances where they serve oppression, as neither is inherently “good.” Both exist within the context of societal frameworks and cannot be isolated panaceas for challenges of the day. This article argues that it is the responsibility of engineers and scientists to decouple our work from oppression by considering two existential crises facing life on Earth, climate change and war, from the framework of science in society to identify points of entwinement between engineering, science, and oppression. Recognition of such frameworks may imbue us with the critical conscientiousness and political consciousness necessary to take commensurate action. Accompaniment and dismantlement are proposed as two possible paths out of the coupling of engineering, science, and oppression. Only then will science and engineering contribute to reimagining and remaking the world in an equitable fashion never seen before.

Key Words:

Justice; Do no harm; Climate change; War; Science in society.

¹ This article was first submitted while the author was a doctoral candidate at Stanford University. The author then revised it considerably as a postdoctoral researcher at the University of British Columbia. Final revisions were completed while the author was a postdoctoral researcher at Rensselaer Polytechnic Institute.

Dan Walls is currently a postdoctoral researcher in the Department of Science and Technology Studies at Rensselaer Polytechnic Institute. He is working with Prof. Abby Kinchy on a participatory project to identify and address heavy metal contamination of urban soils in Troy, NY, with city residents through participatory workshops using accessible tools. He trained as a chemical engineer and fluid mechanician, but concerns about justice and the inadequacy of the typical apolitical framing of science and engineering have motivated him to pursue projects focused on environmental health issues where the relevant science remains undone.

INTRODUCTION

Victor Weisskopf stated that “Human existence is based upon two pillars: compassion and knowledge. Compassion without knowledge is ineffective; knowledge without compassion is inhuman” (Weisskopf & Stefan, 1998, p. v), and this sentiment is often reflected in engineering ethical codes through upholding the health and safety of the public. However, the actions of engineers dictate whether their ethical codifications become realizations. Unfortunately, a cursory examination of the history of engineering, and science more broadly, reveals a litany of instances where its development and application serve in the oppression and immiseration of human and nonhuman animals.

A number of authors have reported such instances of harm, including chemical pollution of ecosystems and the life within them, involuntary medical and chemical safety studies, resource extraction, and technological atrocities of war, in a variety of outlets. For context, and with respect to concision, several are mentioned here: a book by Rachel Carson, *Silent Spring*, discussed the widespread consequences of the indiscriminate use of pesticides on ecosystems and the negligence and duplicity of their chemical manufacturers (Carson, 1962); a report by Michael H. Brown, “Love Canal and the Poisoning of America,” detailed the dumping of toxic waste in the Love Canal dump near Niagara Falls and the inaction of the Environmental Protection Agency in stopping polluting companies and compelling them to clean up (Brown, 1979); a book by Javier Auyero and Debora Alejandra Swistun, *Flammable*, documented the lived experiences of the residents in a town on the outskirts of Buenos Aires, surrounded by a highly polluted river and one of the largest petrochemical compounds in Argentina (Auyero & Swistun, 2009); a report by Allen M. Brandt, “Racism and research: The case of the Tuskegee Syphilis Study,” discussed the prevailing, structured racism that allowed the inception and continuation of a forty-year United States government observational study on latent syphilis in Black males and issues of consent (Brandt, 1978); a book by Allen M. Hornblum, *Acres of Skin*, documented the non-therapeutic medical experiments on incarcerated people in Holmesburg Prison and issues of vulnerability and consent (Hornblum, 1998); a journal article by Robert Aronowitz, “‘Screening’ for Prostate Cancer in New York’s Skid Row,” discussed a medical study for prostate cancer on alcoholic men recruited from homeless shelters in New York City and issues of vulnerability and consent (Aronowitz, 2014); a journal article by Peter Singer, “All Animals are Equal,” discussed speciesism and the use of other species for medical experiments as if they were pieces of laboratory equipment as untenable (Singer, 1974); a book by Eduardo Galeano, *Open Veins of Latin America*, surveyed the history of extraction of natural resources from Latin America through European colonialism (Galeano, 1973); books by Edwin P. Hoyt, *Inferno*, and Joe O’Donnell, *Japan 1945*, documented the systematic destruction of Japanese cities by the United States via fire bombing and two atomic bombs (Hoyt, 2000; O’Donnell, 2008); and a newspaper article by Nafeez Ahmed, “How the World Health Organization covered up Iraq’s nuclear nightmare,” discussed the use of depleted uranium munitions alongside the prevalence of congenital birth defects in Iraq (Ahmed, 2013).

In researching and reporting their findings, these authors have enacted “the responsibility of intellectuals to speak the truth and to expose lies” according to Noam Chomsky, who charged intellectuals as “a privileged minority” with “the leisure, the facilities, and the training to seek the truth lying hidden behind the veil of distortion and misrepresentation, ideology and class interest, through which the events of current history are presented” (Chomsky, 1967). Referring to a series of articles by Dwight Macdonald on the responsibilities of peoples, particularly with respect to wars conducted in their names, Chomsky stated that “the responsibilities of intellectuals, then, are much deeper than what Macdonald calls the ‘responsibility of people,’ given the unique privileges that intellectuals enjoy” (ibid.). Staughton Lynd added that being an intellectual has to do “with seeing through this or that posture or mannerism, with being consistent over time, with having the courage to stand alone in relationship to peers and political companions” (Lynd & Grubacic, 2008, p. 59). As there are instances where science and engineering have been implicated directly in producing material harm, one could claim that the responsibilities of engineers and scientists are deeper still than speaking the truth or exposing lies.²

This paper contends that it is the responsibility of engineers and scientists to decouple our work from oppression such that we do no harm, and to challenge historic and contemporary couplings such that past, persisting, and present harm can be redressed. To extricate science and engineering as a tool of oppression requires a framework for how science and engineering function in society, for which we will turn to the field of Science and Technology Studies (STS) in the second section. STS researchers have put forth critiques of technocratic worldviews that uncritically accept technological progress as perpetual and synonymous with improvement in the condition of human and nonhuman animals. Doing so will allow us to enact a broader, richer inquiry that includes cultural, political, and economic questions in order to locate our professions within societal structures and with respect to oppression. In the third and fourth sections, two existential crises facing the prospects of life on Earth, climate change and war, are considered, respectively, to identify points of entwinement between engineering, science, and oppression, and to motivate the importance of rejecting a technocratic framework in favor of a more nuanced approach as suggested in the STS literature in order to do so. The concept of technocracy *as* climate change and *as* war is put forth.³ In the fifth section, connections between climate change and war are discussed briefly. In the sixth section, accompaniment and dismantlement are proposed as pathways for detangling engineering, science, and oppression. In the final section, a conclusion is offered.

²Based on proximity to the cause of harm, engineers and scientists bear a *deeper responsibility* for that harm. As this article is concerned with our work as engineers and scientists with respect to oppression, it will focus on engineers and scientists. This focus is not to suggest an elitist hierarchy of importance where the actions of an “engineer,” “scientist,” or “intellectual” are more valuable than the actions of a “layperson.” On the contrary, throughout this article such technocratic inclinations will be shown to (re)produce harm.

³This is an adaptation of Sora Han’s “image of America as war” (Han, 2006, p. 232).

FRAMEWORK TO INVESTIGATE COUPLING OF ENGINEERING AND OPPRESSION

In order to decouple our work as engineers and scientists from oppression, we first must be able to identify and understand the linkages between the two. Here, the field of Science and Technology Studies, where scholars and practitioners have investigated the connections between science, technology, and society, is insightful. STS researchers “have shown that technologies and forms of knowledge always develop in specific social settings and that myriad agents and agencies participate in their production, expression, and travel” (Downey & Zuiderent-Jerak, 2017, p. 224), indicating that our work as engineers and scientists is embedded in and informed by the societies in which we work and the political, economic, and social structures and institutions within those societies. STS researchers have critiqued “the linear model of knowledge creation, diffusion, and utilization” that “pictures science and technologies as produced in a social vacuum by individual human creators who diffuse their creations into the world, where they become facts and technologies that other people use for various purposes” (ibid., p. 224). Thus, their work encourages us to think of “science *in* society,” rather than “science *and* society” (Felt *et al.*, 2013, p. 3-4).

This critique reflects what David A. Banks and Michael Lachney termed the “neutrality problem” in engineering, which places the “moral weight not on the work of engineers but instead the ad hoc uses of engineered artifacts” (Banks & Lachney, 2017, p. 2). Banks and Lachney defined this problem in part based on other engineering educators pointing “to a persistent pedagogical problem that positions the engineering disciplines in apolitical and neutral terms” (ibid., p. 2): an assumed dichotomy between engineering and politics is inherently political (Riley, 2008); militarism has steered engineering education, particularly with respect to “command-and-control problem solving” and relationships with industry (Nieusma & Blue, 2012); the necessity of an engineering ethical principle to be based in social justice and reflect on the historical context of engineering, militarism, and environmental destruction and to end cyclical destruction (Riley & Lambrinidou, 2015); and the frequent involvement of engineers within geoeconomic and geopolitical conflicts (Muscat *et al.*, 2015). Banks and Lachney also noted the limited opportunity for engineers and practitioners to reflect on their roles in perpetuating violence (2017).

Given the framing of science and engineering by STS scholars and practitioners as well as the critiques of neutrality by engineering educators, the possibility of engineering and science producing harm is directly linked to the societal contexts and structures within which scientific and engineering work is undertaken. Thus, the cursory list of harmful outcomes highlighted in the introduction suggests the pervasiveness of racism, sexism, classism, nationalism, militarism, imperialism, and colonialism in our societies, and their influence on our work. If we as engineers and scientists want to live in and contribute toward a just and equitable world, then we need to decouple our professions from oppressive structures in our societies and work to dismantle them. In the next two sections, the critiques of STS scholars and engineering educators are applied to the

crises of climate change and war, respectively, to illustrate the inadequacy of a technocratic approach in producing resolutions, as it (re)produces harm, and to identify points of connection between engineering and oppression.

TECHNOCRACY AS CLIMATE CHANGE

As comprehensively demonstrated by the Intergovernmental Panel on Climate Change (IPCC) in their 2018 special report, “Global Warming of 1.5°C,” climate change is a product of industrial activity, namely through the combustion of fossil fuels, a process that releases greenhouse gases like carbon dioxide, among other emissions, into the atmosphere. The IPCC report amassed measurements of the concentration of carbon dioxide in the atmosphere and oceans, rising temperatures, and rising tides, and made predictions about the viability of life on earth as well as targets and plans for mitigating harm. Mitigation strategies included carbon-neutral energy sources, carbon-offsetting technologies, and geoengineering. The report also called for “transformative systemic change” (ibid., p. 40), “recognizing that many of the impacts of warming up to and beyond 1.5°C... fall disproportionately on the poor and vulnerable” (ibid., p. 31). Thus, the report discredits reductive assessments on climate change solutions such as that proffered by Rex Tillerson: “It’s an engineering problem and there will be an engineering solution” (Associated Press, 2012), which avoids understanding climate change as a product of “engineering solutions” and its effects as mediated by geoeconomics and geopolitics. However, the IPCC report is also derelict in fully assessing the context of the problem, as simple keyword searches of the 630-page document for the words “racism,” “colonialism,” “imperialism,” and “capitalism” reveal zero matches in the body of the text, with “imperialism” and “capitalism” appearing only in the titles of three references. These four keywords were, and largely remain, structural practices of industrialized metropolises. Instead, the IPCC report defined and discussed an “Anthropocene” as if all humans share equal responsibility in causing climate change, rather than rooting it in relation to intensive industrial activity, fossil fuel combustion, and the specific human actors that engage in them.

Bradley C. Parks and J. Timmons Roberts disputed the notion of equal responsibility for climate change with case studies of the submergence of Pacific Island atoll nations and flooding in Honduras and Mozambique that demonstrate that these peoples are among the least responsible, but suffer “worst and first” not only due to geography, but also colonial histories (2006, p. 339). Other authors have also written about extreme weather events and rising sea levels already afflicting certain areas and peoples of the globe with severities modulated by race, class, and colonial relationships, including a collection on Hurricane Katrina, New Orleans, and the Gulf Coast edited by Chester Hartman and Gregory D. Squires (2006), and a collection edited by Laura Weiss, Marisol Lebrón, and Michelle Chase on Hurricanes Irma and Maria and the Caribbean (2018), which included the writing of Hilda Lloréns on Hurricane Maria and Puerto Rico (2018).

The framework put forth by STS scholars and practitioners with respect to science and technology in society suggests that addressing climate change should be deeply informed by the connections between intensive industrial activity and climate change. The IPCC report connected the two as cause and effect, but it simultaneously globalized the responsibility and ignored the historical development of industrialization. Truly, the “tradition of all dead generations weighs like a nightmare on the brains of the living” (Marx, 1852) and a comprehensive analysis of what brought about this moment is indispensable if we are to identify and rectify the causes. In this section, the concept of technocracy as climate change, in that technocratic approaches (re)produce climate change, is put forth by considering the development of intensive industrial activity and entrenchment of fossil fuels in the global economy through the introduction of machines in manufacturing, the rise of fossil fuels as the preferred source of energy for these machines over other sources, the prioritization of economies over workers’ health and rights, and the acquisition of land to extract fossil fuels.

Central to the transition from home craft to industrial production was the introduction of machines. Initially, machines were powered by the exertions of human and nonhuman laborers, with later designs harnessing the power generated through the external action of water wheels and steam engines. Jean-Charles-Léonard Simonde de Sismondi wrote in the early 19th century that “Although the invention of the machine that increases man’s capacity, is a blessing to mankind, it is made into a scourge for the poor by the unjust distribution we make of its benefits” (2004 [1819], p. 13). Here, Sismondi alludes to both machines rendering workers superfluous as well as the enrichment of the machine’s owner by increased production with fewer workers. Later, in the early 20th century, Rosa Luxemburg observed:

A machine will only be considered for use by a capitalist if its costs of production... are less than the wages of the workers replaced by it... [but] [f]rom the standpoint of the social labor process... the use of a machine is economically appropriate if it costs less labor to produce it than the living labor that it saves (2016 [1913], p. 230).

Luxemburg sharpened Sismondi’s observation, juxtaposing two contexts within which a machine could be introduced and the disparate outcomes it would produce, and identifying the tension between labor and capital within a capitalist mode of production. In *Fossil Capital*, Andreas Malm picked up this tension in considering the Industrial Revolution in 19th century England, particularly with respect to the development of the cotton industry (2016). Through his archival research of parliamentary papers and the writings of cotton capitalists, Malm demonstrated that cotton capitalists implemented machines, and particularly machines powered by external action, to not only increase production capacities, but also to break the power of laborers by deskilling tasks to render workers more replaceable, centralizing production to enable the oversight of workers, dictating the pace of manufacturing, and directly rendering some workers dispensable (ibid., p. 121-193). Through their work, Sismondi, Luxemburg, and Malm clearly acknowledged the utility

of the machine while also recognizing that the context in which it is implemented is paramount in translating such technological developments into equitable human benefit. They demonstrated that from the outset, capitalists used machines to profit at the expense of laborers, and this disposition towards inequitable implementation foreshadowed later consequences for the climate.

The potential of fossil fuels as a source of energy to power machinery was realized with the advancement of the steam engine; however, the flow of water was the widespread source of power at the time, with intricate reservoir systems and water wheels with large capacities of power designed to propel manufacturing equipment. Malm posed the question of how and why a free source of energy was set aside in favor of first coal, and subsequently other fossil fuels, to the point of their entrenchment in the global economy at our present time. Citing the writings of prominent cotton manufacturers that utilized water power, such as Richard Arkwright and the Ashworth family, as well as Robert Thom, a hydraulic engineer behind many of the reservoir plans, Malm showed that the transition was not for want of power capacity or cost, given the success and potential of factories operating throughout England and Scotland (*ibid.*, p. 96-120). Rather, the shift of the majority of cotton manufacturers to coal-powered steam engines was to eliminate the autonomous power of the water cycle and further subdue the autonomous power of labor through on-demand production; to extricate themselves from cooperative arrangements with competitors for the supply of power and deskill the needs of management for running such a cooperative; and to build factories in burgeoning towns with growing supplies of labor as opposed to the remote countryside (*ibid.*, p. 121-193). Likewise, Robert B. Gordon wrote about the technical complexity and necessary cooperation required to make use of water power through intricate reservoir systems (Gordon, 1985), and Louis C. Hunter investigated the state of water power vis-à-vis steam engines in the United States, drawing similar conclusions to those of Malm for England (Hunter, 1979).

In industrializing England, movements of workers for dignity in the workplace and political representation emerged alongside these developments, such as the Luddites (Hobsbawm, 1952), the Swing Riots (Hobsbawm, 2014), and the Chartist movement and the Plug Plot Riots (Peel, 2013[1968]; Jenkins, 1980; Royle & Lockyer, 1996), among others. These workers movements were concerned with wages, working hours, working conditions, and political representation. A chief concern with respect to working and living conditions was the ever-present smoke that enveloped the factories and the surrounding homes of the workers. Charles Dickens wrote of his fictional Coketown, based on industrial mill towns of Northern England:

in the innermost fortifications of that ugly citadel... Nature was as strongly bricked out as killing airs and gases were bricked in... among the multitude of Coketown, generically called 'the hands'—a race who would have found more favour with some people, if Providence had seen fit to make them only hands (1954 [1854], p. 72).

As a precursor to global climate change, the local generation of noxious smoke produced deleterious health effects for the workers and their families. However, in 1846, the British House of Commons valued continued commerce over the health of these workers, concluding that the “Suppression [of smoke] might materially injure important branches of our national industry” (Malm, 2016, p. 246). This statement echoes more contemporary political positions as well, with corporations and governments largely valuing the economic and political power derived from fossil fuels over the health of workers, the public, and the environment: a report by the *Lancet* Commission on pollution and health concluded that pollution is the largest environmental cause of disease and premature death in the world (Landrigan *et al.*, 2017); a two-part study calculated the early deaths caused by air pollution in 2005 in the United States (Caiazzo *et al.*, 2013; Dedoussi & Barrett, 2014); a study of hydrogen sulfide present at gas wells, the impact on neighbors, and the challenges of inducing regulatory action was reported (Wylie *et al.*, 2017); a study of hydraulic fracturing with respect to infant health in Pennsylvania found evidence for negative health impacts of in utero exposure within 3 kilometers of a fracking site (Currie *et al.*, 2017).

The emergence of coal as an important material for Britain’s *national* industry, as expressed above by its House of Commons, suggests that Britain would have a national interest in securing sources of coal, requiring the possession of land. In *The Village Labourer: 1760-1832*, J. L. Hammond and Barbara Hammond investigated the consequences of enclosure, the national project of converting and consolidating manorial lands previously held as commons by many customary tenants into the private property of a handful of landowners, on the lives of the village poor in England (1913). The Hammonds focused on the agricultural motivations of landowners in consolidating holdings: the derivation of greater earnings from the land through increased yields and rents, at the exclusion of customary tenants. The authors presented a series of parliamentary acts and court decisions in favor of enclosure as well as the resistance of customary tenants in courts of law as well as through direct action in reclaiming enclosures. In *Witches, Witch-Hunting, and Women*, Silvia Federici wrote about the gendered and speciesist aspects of enclosures, “a violent process, causing a profound polarization in what had previously been communities structured by reciprocal bonds,” which disrupted the communal poor relief for widows and the elderly as well as the continuity between animal and human worlds (2018, p. 16). Federici concluded that “we have to think of the enclosures as a broader phenomenon than simply the fencing off of land. We must think of an enclosure of knowledge, of our bodies, and of our relationship to other people and nature” (*ibid.*, p. 21).

In building his argument, Malm cites the work of J. U. Nef in *The Rise of the British Coal Industry* (1932). There, Nef investigated the relationship between coal and enclosures as well as the legal landscape of mineral rights. He wrote that the “enclosure movement, as it develops in the period between 1550 and 1700, should be regarded increasingly not only as a cause for the expansion of the coal industry, but as an effect of it,” (*ibid.*, p. 156) and that “Wherever coal mining became important, it stimulated the movements towards curtailing the rights of customary tenants and even of small freeholders, and towards the enclosure of portions of the wastes,” or common pasture

(ibid., p. 342-343). Nef used the Reformation and the confiscation of Church lands rich in coal as an early seizure of the state that enabled expanded and more industrious extraction of coal than previously undertaken. With regards to customary tenants, Nef stated that they “most often dreaded... that the lord or a concessionnaire would carry on mining operations in his holding, thereby spoiling the crops or interfering with the pasture” (ibid., p. 312) and that “they claimed power to refuse access to minerals beneath their soil, asserting that such access damaged the surface, in which they believed their title to be absolute” (ibid., p. 310). However, he reported a series of court decisions increasingly favorable to owners operating large collieries and increasingly unfavorable to tenants. Nef also reported the resistance of customary tenants to enclosures for coal mining through direct action in tearing down enclosing fences, filling in pits, and absconding with mined coal (ibid., p. 316).

Karl Marx characterized this process of separating peoples from their pre-capitalist mode of living as *ursprünglich Akkumulation*, translated as primitive accumulation or original accumulation, which serves the dual purpose of converting the land and its contents into capital and the people into wage laborers (1867). Rosa Luxemburg extended this analysis to colonial contexts, including settler colonial states like the United States and Canada, writing that “since the primitive social bonds of the indigenous inhabitants constitute the strongest bulwark both of their societies and of the latter’s material basis of existence, what ensues is that capital introduces itself through the systematic, planned destruction and annihilation of any noncapitalist social formation that it encounters” (2016 [1913], p. 267). And lest it be mistaken that primitive accumulation is a concern long past, she added:

This is no longer a question of original accumulation: this is a process that continues to this day... Capital knows no other solution to the problem than violence, which has been a constant method of capital accumulation as a historical process, not merely during its emergence, but also to the present day (ibid., p. 267).

Indeed, extending 106 years from Luxemburg’s present day to ours, we find recent examples in Canada and the United States, made strikingly visible by indigenous-led movements. In Canada, the Idle No More movement emerged in opposition to omnibus Bill C-45 (Jobs and Growth Act):

From the perspective of many indigenous people and communities, the changes contained in Bill C-45 threaten to erode Aboriginal land and treaty rights insofar as they reduce the amount of resource development projects that require environmental assessment; they change the regulations that govern on-reserve leasing in a way that will make it easier for special interests to access First Nation reserve lands for the purposes of economic development and settlement; and they radically curtail environmental protections for lakes and rivers (Coulthard, 2014, p. 160).

Specific threats to indigenous sovereignty include the expansion of the Trans Mountain Pipeline project, which the Canadian government purchased from Kinder Morgan, Inc. for C\$4.5 billion, with the finance minister stating “It must be built. It will be built” (Cecco, 2018). Likewise, in the United States, a renewed focus has been placed on domestic fossil fuel production, with government funding advancing unconventional oil and gas exploration and production (Burwen & Flegal, 2013); however, it has not been without controversy. On one hand, academic studies have investigated the environmental and health effects of unconventional methods, such as when living near hydraulic fracturing wells (Vengosh *et al.*, 2014) as well as the asymmetry of information and political influence between fossil fuel companies and the public (Kinchy *et al.*, 2015). And on the other, political movements have emerged in opposition to various oil pipeline projects, notably the indigenous-led NoDAPL movement in opposition to the Dakota Access Pipeline.

The Standing Rock Sioux Tribe, as well as other indigenous and non-indigenous Water Protectors, opposed the route of the Dakota Access Pipeline due to concerns over water contamination and treaty violations (Levin, 2016). In contrast, the construction plan originally routed the pipeline upriver from Bismarck, North Dakota, but was rejected by the Army Corps of Engineers without public involvement in part due to the risk to the city water supply (Dalrymple, 2016). The differing response of the state to these two risks of contaminated water, the first enforced by militarized police and private mercenaries (Brown, Parrish, & Speri, 2017), and the second voided outright prior to construction without public involvement, follows the contours of colonial history in the Americas. In *Our History is the Future*, Nick Estes placed the NoDAPL movement within the longer tradition of indigenous resistance on Turtle Island, particularly with respect to the Oceti Sakowin. Of particular interest to engineers is not only the Army Corps of Engineers involvement with the Dakota Access project, but also their execution of the Pick-Sloan Missouri Basin Program in the mid-20th century that flooded vital river valleys on reservation lands, continuing the erosion of indigenous land bases. In connecting these histories, Estes wrote:

The continuing legacy of the Pick-Sloan dams also thwarts the possibility of a livable future for the Oceti Sakowin and the millions of people who depend on the Missouri River for life. The dams personify settler colonialism—their concrete and rolled earth endowed with the will to disrupt, flood, dispossess, remove, and ultimately eliminate Native society. The Dakota Access Pipeline echoed this process. The full force of the settler state—politicians, police, private security, banks, and private companies—carried out the will of Energy Transfer Partners, the corporation building the \$3.7 billion pipeline that would tunnel under the Missouri River twice, the Mississippi River once, and cross four states (South Dakota, North Dakota, Iowa, and Illinois). Today, their tools are more sophisticated: assault rifles, arrest warrants, rural county jails, felonies, misdemeanors, body armor, armed drones, tear gas, mace, armored Humvees, the National Guard and state patrol, Black Hawk helicopters, Caterpillar earthmovers, and media censorship. But the Water Protectors draw from the history of past Water Protectors who fought to protect the same relative, Mni Sose. While

corporations take on legal personhood under current US law, Water Protectors personify water and enact kinship to the water, the river, enforcing a legal order of their own. If the water, a relative, is not protected, then the river is not free, and neither are its people (2019, p. 255).

Unconventional gas extraction is also prevalent in the Bakken fields: “Clustered constellations of oil flares burning off methane are visible from space at night. ‘What we are dealing with is a death by a thousand cuts’... cancer, asthma, and respiratory diseases” (ibid., p. 33). These histories, through Pick-Sloan, Dakota Access, and sophisticated tools of encroachment and enforcement, directly implicate engineers as fundamental agents of the settler colonial state in perpetuating and amplifying its violence. It is another set of failures in a set of sets of the dichotomy between “technical” and “social,” with engineers as technical decision makers deferring to the organizational logic of settler colonialism (Nieusma & Blue, 2012). Additionally, these histories pose the question of climate change wrought by settler colonialism, through continued dispossession and displacement of indigenous peoples, the extraction of resources, the contamination of air, water, and soil, and the destruction of biodiversity (Daigle, 2018; Whyte *et al.*, 2018). In his book, Estes shared a moment from Standing Rock, where an elder “reminded the younger ones that the tears flowing from their eyes were their ‘ancestors speaking through them,’ and that they were not tears of trauma but of liberation. ‘We survived genocide after genocide’” (2019, p. 131). These instances are telling examples of Rosa Luxemburg’s insight that “political violence is nothing but a vehicle for the economic process” (2016 [1913], pg. 329).

In this section, technocracy was considered *as* climate change, as such thinking fails to understand that “engineering solutions” produced climate change. By replacing a technocratic worldview with the view of engineering and science situated within society, the cause of climate change—intensive industrial activity—and its development was investigated. Conflicts were revealed between the public benefit of a stable, livable climate and growing, vested interests of the fossil-fueled economy, which sit at the intersection of science, capital, and the state. With such an inquiry, the promotion of geoengineering, the “deliberate, large-scale intervention in the climate system designed to counter global warming or offset some of its effects” (Hamilton, 2014, p. 1) by these vested interests becomes perverse and absurd (Long & Scott, 2013). Indeed, Exxon not only understood the science of climate change in 1977 prior to public awareness, but also later spent millions of dollars in promoting misinformation (Hall, 2015). Rather than planning to scale back consumption to meet proposed emissions targets, or directing additional resources and research efforts towards increasing efficiency and renewable energy options, plans of releasing increasing quantities of sulfates into the atmosphere to block incoming solar radiation and other large-scale interventions are contemplated (Hamilton, 2014) in order to not only continue burning fossil fuels, but also to allow continued building, and entrenchment, of fossil infrastructure. Malm commented that “Planning the economy is the ultimate taboo; planning the climate is worthy of close consideration... *It has become easier to imagine deliberate, large-scale intervention in the climate*

system than in capitalism” (2016, p. 388; *my emphasis*). To overcome the climate legacy of industrialization, a broader analysis than a technocratic view allows is required of engineers: the story of climate change is more complex than a technocratic framing where zero emissions technology or climate engineering will provide the solution; more nuanced than an elitist framing where uneducated, recalcitrant, science-denying laypeople are the roadblock. In the next section, we consider technocracy as war, towards which this section has begun to foreshadow.

TECHNOCRACY AS WAR

In their article “Engineering and War,” Dean Nieusma and Ethan Blue examined the deep, lasting influence of militarism on engineering, understanding warfare “as more than bullets flying”: “as an expression of structural inequality, of unequal power relationships,” “a means of naming differences in power, in wealth, and in wellbeing,” and “a strident conceptualization of social conflict as well as the measures taken to ensure or combat its persistence” (2012, p. 54). Here, the concept of technocracy as war will be supported by considering warfare and associated technical advancements as a means to maintain and advance structural inequalities and oppressive relationships. Conflicts revealed in the prior section between capital and labor as well as between (settler colonial) states and (indigenous) peoples foreshadow the content of this section, while also hinting at connections between climate change and war.

The framework put forth by STS scholars and practitioners with respect to science and technology in society suggests that addressing engineering’s contributions to war making should be deeply informed by the influence of militarism and imperialism on engineering. In this section, the concept of technocracy as war, in that technocratic approaches (re)produce warfare, is put forth by considering the relationship between engineering, militarism, and capitalism through the work of Nieusma and Blue, Luxemburg, and others as well as the consideration of a graduate course at Stanford University titled “Hacking 4 Defense,” several examples of military intervention by foreign powers, and the structuring of what is credible knowledge and criticism.

Harry Magdoff wrote that “militarism and imperialism are...major determinants of the form and direction of technological change, of the allocation of resources within a country, and of the allocation of resources between countries” (1978, p. 198). Nieusma and Blue corroborated Magdoff’s statement with one of their own, “Beginning with World War II and persisting through the Cold War, military spending was the literal foundation of the US economy” (2012, p. 52), and extended it to engineering as a whole:

militarism and cultures of warfare have shaped engineering. Sometimes this shaping has been direct and deliberate, but often it has been indirect, in the sorts of ways highlighted by Gramsci [wars of maneuver and of position] and Foucault [discourse]—by bounding the domain of engineering practice, by inflecting assumptions about how problem solving

should proceed, and by structuring what sorts of knowledge are considered to be credible (ibid., p. 56).

Thus, engineers are predominantly trained to perform command-and-control problem solving; that is, a centralized authority defines a problem, in doing so imparting it with the politics and logics of the authority, and hires an engineer to strictly address the technical needs of the authority in addressing its problem. Nieusma and Blue provided the Manhattan Project and then the Sputnik and Apollo projects as examples of “success” with “engineers as highly disciplined, narrowly technical analysts in massive bureaucratic organizations” (ibid., p. 59).

Simultaneously, “internal and external commentators understand engineering as centralized, hierarchical, and... rigid in process” (ibid., p. 58). These commenters include students who may (come to) see engineering as it is—producing “war-built” societies, where bombs and profits are made, and “war-torn” societies, where bullets and lives are expended—and what it could be if grounded in social justice as aptly proposed by Nieusma and Blue, and be left in doubt: in *The Cold War & The University*, Raymond Siever recalled his experience during the Vietnam War as a geology professor and the plight of such students, “who agonized over a career in science while so many people were being killed in the war... [Science students] wanted to be told that science was still a worthwhile thing to do in spite of its misapplication” (1997, p. 166). This “misapplication” was in part a direct application of twenty million gallons of herbicides containing arsenic and dioxin to six million acres of crops and forests, in addition to large quantities of CS gas, napalm, white phosphorous, and high-explosive munitions, as well as mechanized land clearing, as components in the military tactics and strategy of the United States in Indochina against people and the entire ecosystem (Westing *et al.*, 1976).

Militarism is resilient in war-built societies, permeating not just engineering, but all of academia and the society as a whole. Laura Nader, an anthropology professor, wrote with reference to the Cold War that “Colonization of the mind by self-censorship is the most efficient effect of repression or censorious relationships” (1997, p. 142), indicating that academic and professional careers are most easily built by adhering to dominant ideology. Additionally, even in “times of peace,” such as the end of the Cold War, rather than redirecting resources towards constructive ends, the United States sought new outlets for defense budgets, weapons manufacturers, and existing arsenals; namely, dual-use technologies became a focus, military equipment was transferred to local police departments (Wofford, 2014), military technologies were retooled for law enforcement (Thomas, 1994), and sales and exports of arms increased (Pineo & Lumpe, 1996; Rich, 1999). Rosa Luxemburg assigned this resilience to the accumulation of capital possible under militarism, where purchases of military hardware by the state attain

an almost automatic regularity and a capacity for rhythmic growth. The levers regulating this automatic and rhythmic movement of militarist capitalist production are ultimately in

the hands of capital itself through the executive and legislative apparatus of the state, and through the press, whose function is the production of so-called public opinion. This specific sphere of capital accumulation initially seems capable of indefinite expansion (2016 [1913], p. 341).

An example of the persistence, malleability, and revanchism of militarism, imperialism, and capitalism is the introduction and founding of a graduate engineering course, “Hacking 4 Defense,” at Stanford University in 2016. It has since been disseminated to several other universities throughout the United States. The course website indicates that students work in teams to “develop technology solutions to help solve important national security problems,” “learn how to apply the Lean launchpad and Lean Startup principles,” and “take a hands-on approach requiring close engagement with actual military, Department of Defense, and other government agency end-users” (Hacking 4 Defense, 2018), and encourages the reader to “Join the insurgency!” (Hacking 4 Defense, Inc., 2018). Several information sessions are held in advance of the course for U.S. military and government officials to present project ideas, with prospective students required to form teams around one of these projects; although the instructors stated that the class is not specifically about U.S. defense, there seems to be no opportunity to explore partnerships other than what is presented in the initial sessions. The instructors also claimed the class is not political, which stretches the false dichotomy between engineering and politics to absurdity.⁴

The images and words used in advertising the class are also curious, with iconic finger-pointing Uncle Sam posters captioned “I want you” (Contreras, 2017). The command to “join the *insurgency*” and the method of “*hacking* for defense” may be a means to capitalize on the lexicon of Silicon Valley buzzwords, but create interesting connotations. First, the U.S. often claims and insists with “pious rhetoric” that its military operations are characterized as *counterinsurgency*, indicating a defensive response (Chomsky, 1967). Did this class grow weary of touting a fallacy and decide to fully embrace belligerency in foreign policy? Second, both Edward Snowden and Chelsea Manning seem like ideal candidates to pair with project teams in a class titled “*Hacking 4 Defense*,” particularly since the class is not political or specifically about U.S. defense. Third, *iterative* problem solving signals the acceptance and preservation of the continued cyclical pattern of military intervention to subvert others through force, of which historical consequences of such an approach will be discussed shortly.

A proposed function of the course is to curb the “free range [given] to the executive and legislative branches to run our foreign engagements without involving the body politic... [in pursuing]

⁴The author was a doctoral candidate at Stanford University and attended two information sessions in Spring 2017 where these two statements were made.

perpetual wars” since conscription was ended⁵ (Contreras, 2017). This statement is baffling. One, the class is not supposed to be political or about U.S. defense. Two, it ignores the history of the United States as perpetually at war since its founding (Dunbar-Ortiz, 2014). Three, the government partners, which exist within or fall under the purview of the executive branch, participate in the class, presumably without being chided about perpetuating perpetual war. Four, the model of draft and war resisters, who directly resist war by refusing to participate, in ending wars is acknowledged and immediately dismissed without comment. Five, a classroom where students could secure funding for a startup venture and future compensation based on the evaluation of their project, thus earning compensation from warfare without personal risk to life or limb seems more akin to promoting “rhythmic movement of militarist capitalist production,” i.e., profiting through the (facilitation of) deaths of others⁶ (Luxemburg, 2016 [1913], p. 341).

The atomization of student inquiry into purely technical, business-driven channels pressures students to accept the ideological purview of the course and its instructors, precluding a wider set of geopolitical questions necessary to understand complex and historical relations. It is command-and-control problem solving, albeit with a Silicon Valley venture capitalist veneer. It is troubling, though not anomalous, that one of the sites in society purportedly for the pursuit of truth and knowledge for the enrichment of humanity—the university—is (re)directed towards addressing highly confined, predetermined problems constructed for implementation in military interventions.

However, the desire to dominate others does not guarantee domination, regardless of the technologies deployed. In a 1971 essay titled *Counterinsurgency*, Eqbal Ahmad wrote about counterinsurgency as formulated primarily in the United States, but also in Europe and other settler colonial states such as Israel, South Africa, and Canada. He stated that counterinsurgency is a euphemism for counterrevolution, a “product neither of accident nor of ignorance. It serves to conceal the reality of a foreign policy dedicated to combating revolutions abroad and helps to relegate revolutionaries to the status of outlaws. The reduction of a revolution to mere insurgency also constitutes an a priori denial of its legitimacy” (2006 [1971], p. 36-37). Further, the reduction of any military encounter a priori to counter/insurgency avoids inquiry beyond “prediction... [via] more-or-less rigid causation” (Nieusma & Blue, 2012, p. 57). In this sense, Ahmad commented on the ineptitude of rigid causation and command-and-control problem solving, particularly in revolutionary settings:

life begins to manifest itself in forms which are incomprehensible to bureaucrats and social engineers. Wolin and Schaar’s analysis of the “educational bureaucracy” applies admirably

⁵Since 1980, all male U.S. citizens and non-citizen residents must still register with the Selective Service System within thirty days of their eighteenth birthdays, such that a list of eligible draftees exists if conscription were to be reinstated. Several federal programs and benefits require registration.

⁶One project team has raised \$34 million in funding since the completion of the Spring 2016 course (Hacking 4 Defense, 2018).

to the counterinsurgency experts: “The bureaucratic search for ‘understanding’ does not begin in wonder, but in the reduction of the world to the ordinary and manageable. In order to deal with the world in the cognitive mode, the world must first be approached as an exercise in ‘problem-solving.’” Finding the solution implies devising the right techniques, hence “reality is parsed into an ensemble of discrete though related parts, and each part is assigned to the expert specially assigned to deal with that part” (2006 [1971], p. 55).

The work of Wolin and Schaar, Ahmad, and Nieusma and Blue call into question the approaches advanced by courses such as “Hacking 4 Defense.” In evaluating the two sets of claims, a brief turn to two historical examples, Algeria and Vietnam, and two contemporary examples, Afghanistan and Iraq, of the military intervention of foreign powers is illustrative.

In another essay by Ahmad, *How to Tell When the Rebels Have Won*, he discussed the Algerian Revolution, drawing particular attention to the fact that, at the time that Charles de Gaulle negotiated independence with Algeria’s revolutionary leaders, France had crushed Algeria militarily. “France faced a sullen Algerian population that it had conquered but could not rule. The FLN [Algerian National Liberation Front] was defeated in the field, but it continued to outadminister and ‘illegitimize’ the French” (2006 [1965], p. 16).

In *Kill Anything That Moves*, Nick Turse investigated U.S. military actions in Vietnam, particularly with respect to war crimes and the indiscriminate killing of Vietnamese in the south of Vietnam, noting that “the nature of investigating war crimes in Vietnam [is] I’d thought that I was looking for a needle in a haystack; what I found was a veritable haystack of needles” (2013, p. 21). Turse characterized the U.S. military as pursuing “technowar,” having “turned war making into a thoroughly corporatized, quantitatively oriented system” that combined technological and economic power with managerial practices, such that “the war machine [functioned] as smoothly and predictably as an assembly line” (ibid., p. 14). He also cited top U.S. military officials, including William Westmoreland, as referring to the importance of Vietnam as a laboratory for testing new military equipment, weapons, and tactics, some of which were alluded to by Raymond Siever and documented by Arthur H. Westing, as noted above. “That such military power might not prevail against poorly armed guerrillas in an agrarian country seemed inconceivable” (ibid., p. 78). Turse noted that as the war continued, “the Pentagon... decided to simply pursue technowar ever more intensely” (ibid., p. 78). Ahmad wrote of the genocidal direction in such situations:

Increasing reliance on technological-attritive methods marks the shift of counterrevolutionary foreign intervention in a genocidal direction. When a revolutionary war has been definitively lost—when the moral isolation and illegitimacy of the client regime become total and perceptibly irreversible, when even a prolonged and massive foreign intervention fails to break the “enemy’s” will to resist but produces widespread antiwar sentiments at home, when draftees become restive and resistant, when the protracted war

becomes bad for business and begins to contribute to the dual pressures of inflation and recession—then a great power caught in counterrevolutionary operations is left with only two alternatives. One is to negotiate withdrawal as de Gaulle did in Algeria. The other is to continue the war and subsequently create a quasi-permanent occupation of the belligerent country, at a cost acceptable to the people at home but costly to the “insurgents” abroad (2006 [1971], p. 40).

The U.S. withdrew from Vietnam on April 30, 1975, after an estimated “3.8 million violent war deaths, combatant and civilian” (Turse, 2013, p. 13). Ahmad noted that of the many similarities between Algeria and Vietnam, one difference is very troubling, and the “Hacking 4 Defense” class bears witness to it:

The former [Algeria] marked the end of France’s involvement in counterinsurgency; its exponents ended up in prison or oblivion. The latter [Vietnam] appears to have been a testing ground and training area rather than the terminal point for American counterrevolution. Its practitioners attend conferences and join public forums to discuss the “lessons” of Vietnam... indications that the “lessons” of Vietnam have reinforced the most barbaric and destructive components of counterinsurgency (2006 [1971], p. 61).

As indicated, the U.S. has been applying the “lessons” of Vietnam around the world, most recently in Afghanistan (since October 7, 2001) and Iraq (since March 19, 2003). Jairus Grove wrote about these two protracted occupations through the assemblage of the improvised explosive device (IED), a common weapon used in both locations against U.S. occupation forces. In 2006, the Joint Improvised Explosive Device Defeat Organization (JIEDDO) was formalized as a type of Manhattan Project. Grove, however, stated that defeating the IED was nonsensical:

The problem is that an IED is a real thing that has changed the course of two major wars, but it is not one or any particular thing. An IED exemplifies what Morton (2013, 44) calls “a strange irreductionist situation in which an object is reducible neither to its parts nor to its whole” (2016, p. 333).

The IED is a condition of possibility present in almost all of contemporary life. IEDs are native inhabitants of a world of global relations and things that hover on the edge between tool and weapon... no proper names, no essential identity, or even consistent components. IEDs are the weaponization of the throbbing refuse, commerce, surplus, violence, rage, instant communication, population density, and accelerating innovation in contemporary global life (ibid., p. 336).

Thus, the IED is difficult to categorize, either in whole or in parts, and resists reduction to something ordinary and manageable. Between 2006 and 2012, when IEDs accounted for two-thirds of U.S. casualties between Afghanistan and Iraq, JIEDDO spent \$23.3 billion in its efforts to

combat IEDs without much to show for it. Grove noted a particular series of modifications and countermodifications regarding the IED in the summer of 2005 in Afghanistan: the U.S. spent \$3 billion widening and paving roads to prevent the burial of IEDs under roadways. IEDs were then modified to propel molten copper slugs at high velocities up to 100 yards, triggered by the heat emitted by convoys. U.S. occupation forces then hung toasters from booms extended in front of their vehicles, prompting IEDs to be re-aimed by a few feet to compensate. U.S. occupation forces then deployed sophisticated heat decoys and jammers. IEDs were then modified to be triggered by the jammers. In other scenarios where areas would be swept for IEDs, pressure sensitive triggers constructed from wooden boxes and having no metal parts would be deployed to trigger multiple IEDs simultaneously (*ibid.*, p. 345-346). Grove described these (re)actions of warring opponents frustrating one another “while setting conditions of possibility for each other,” capable of producing differentiation, but not progress (*ibid.*, p. 333).

Between 2006 and 2012 when JIEDDO spent \$23.3 billion combatting IEDs, 53,997 IEDs were deployed in Afghanistan, which Grove estimated as costing \$14.4 million. He concluded that “The new ‘Manhattan Project’ failed” (*ibid.*, p. 338), with the U.S. accepting limited withdrawal from Iraq and Afghanistan at the time.

Through this brief turn to two historical and two contemporary examples in considering the claims of courses such as “Hacking 4 Defense” against those of Wolin and Schaar, Ahmad, and Nieuwsma and Blue, it is apparent that rigid causation and command-and-control problem solving are incapable of producing anything but death and destruction “at a cost acceptable to the people at home but costly to the ‘insurgents’ abroad” (Ahmad, 2006 [1971], p. 40). However, the persistence of militarism, imperialism, and cultures of warfare is in part due to resistance to criticism. With respect to U.S. foreign policy, Noam Chomsky wrote of the distinction drawn between “responsible criticism” and “sentimental, emotional, hysterical criticism” by government officials and policy experts closing ranks:

The “hysterical critics” are to be identified, apparently, by their irrational refusal to accept one fundamental political axiom, namely that the United States has the right to extend its power and control without limit, insofar as is feasible. Responsible criticism does not challenge this assumption, but argues, rather, that we probably can’t “get away with it” at this particular time and place (1967).

This structuring of what criticism is credible reflects the statement of Nieuwsma and Blue on the indirect shaping of engineering by militarism and cultures of warfare, structuring what sorts of knowledge, *and, in turn, criticism*, are considered credible. In order to produce such structures, Nieuwsma and Blue referred to Foucault’s development of discourse, recognizing that “experts” were required to produce “expert” knowledge through the pursuit of specific fields of study. Again,

with respect to U.S. foreign policy, Chomsky commented on the role of experts with attention to his comments on criticism:

is “expertise” applicable—that is, is there a body of theory and of relevant information, not in the public domain, that can be applied to the analysis of foreign policy or that demonstrates the correctness of present actions in some way that psychologists, mathematicians, chemists, and philosophers are incapable of comprehending?... American aggressiveness, however it may be masked in pious rhetoric, is a dominant force in world affairs and must be analyzed in terms of its causes and motives... To the extent that “expert knowledge” is applied to world affairs, it is surely appropriate—for a person of any integrity, quite necessary—to question its quality and the goals it serves (ibid.).

Chomsky reasonably concluded with respect to elitist hierarchies of experts: “There is no body of theory or significant body of relevant information, beyond the comprehension of the layman, which makes policy immune from criticism” (ibid.).

In this section, technocracy was considered *as* war. By investigating the persistent historical relationship between engineering, militarism, and capitalism through the work of Nieusma and Blue, Luxemburg, Ahmad, Chomsky, and others, as well as the case study of the course “Hacking 4 Defense,” such technocratic tendencies were shown to perpetuate cyclical warfare in an attempt to subvert others through force. The bonds between engineering and the abject destruction of life are intolerable and considering questions of a political and historical character revealed various interests that profit from these linkages. To Rosa Luxemburg, these connections were clear; she wrote of World War I during her imprisonment for antiwar organizing in Germany:

For the first time, the destructive beasts that have been loosed by capitalist Europe over all other parts of the world have sprung, with one awful leap, into the midst of the European nations... Here capitalism reveals its death’s head, here it betrays that it has sacrificed its historic right of existence, that its rule is no longer compatible with the progress of humanity (Liebknecht, Luxemburg, & Mehring, 1918, p. 125).

If we as scientists and engineers are to refuse this destruction and realign our profession, we must consider inquiries of a political, economic, and historical character, and soberly assess the structuring of our professions and the intent and actual use of our work. In the next section, connections between climate change and war are considered briefly.

CLIMATE CHANGE AS WAR AND WAR AS CLIMATE CHANGE: RELATIONSHIPS OF DOMINATION

As the prior two sections both proposed the concepts of technocracy *as* climate change and *as* war, respectively, it suggests the direct associations of climate change as war and war as climate change to discern their mutual reinforcement. Indeed, some connections are already evident from above.

Briefly, climate change often impacts those least responsible “worst and first,” both with respect to humans not societally engaged in intensive industrial activity and resource extraction, as well as nonhumans, a material assault by a set of humans on everything else. War often incorporates ecological destruction as an explicit military tactic, as with the U.S. military in Indochina during the Vietnam War as well as a century earlier on the Great Plains with the extermination of the buffalo (Dunbar-Ortiz, 2014, p. 142-143). Both wars and climate change reshape landscapes and ecosystems, supplanting existing relationships of reciprocity among living and nonliving in those places with new relationships of domination.

Thus, relationships of domination undergird both climate change and war. Through the work of Luxemburg, Marx, and others, this article has implicated capitalism (as well as imperialism and militarism), with engineering as a tool, as a driving force behind both existential crises. Indeed, “Under [capitalism], anything subject to natural limitations appears as inherently scarce. Capital is insatiable. It needs more than nature has; it needs infinitely more” (Mies, Bennholdt-Thomsen, & von Werlhof, 1988, p. 101). However, capitalism is not the only source of structures of domination, and its end is necessary but not sufficient in ending relationships of domination. Other sources of domination have been explored, such as racism, sexism, and colonialism, alongside capitalism by Angela Davis in *Women, Race, and Class* (1983), Maria Mies, Veronika Bennholdt-Thomsen, and Claudia von Werlhof in *Women: The Last Colony* (1988), Cedric Robinson in *Black Marxism* (2000 [1983]), Glen Coulthard in *Red Skin, White Masks* (2014), and others. Further, a simple example will suffice to reveal another tendency towards domination that engineering and science are acutely susceptible: the meme “fully automated luxury gay space communism” seems beautiful, but the labor-free blissful existence also seems divorced from material realities, implicitly anthropocentric, assuming relationships of domination with nature rather than relationships of reciprocity. This elaboration is not a slight against queerness, space, communism, imagining possible futures, memes, or even necessarily automation, luxuries, and “fully automated luxury gay space communism,” but a reminder that relationships of reciprocity between humans and nonhuman animals, and the living and nonliving, rather than relationships of domination, need to guide the consideration and pursuit of those possibilities. This point is particularly important for engineers, who through our work materially inflect our surroundings and the relationships within them. In the next section, pathways out of the entanglement of engineering, science, and oppression are discussed with this in mind.

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PATHWAYS OUT? ACCOMPANIMENT AND DISMANTLEMENT

For good reason, engineering educators such as Donna Riley, Dean Nieuwma, and Ethan Blue have focused on changing paradigms within engineering, convincingly arguing that engineering should be grounded in social justice, with its critical attentiveness to social power imbalances and material inequities. These efforts to restructure, or “undiscipline” as Nieuwma and Blue wrote, engineering is critical. Additionally, in this article the importance of grounding engineering in explicit anticapitalism and eschewing relationships of domination was advanced. Equally critical to these framings, however, is their translation into action by engineers. Here, accompaniment and dismantlement are put forth as possible approaches for engineers to undertake.

Staughton Lynd defined accompaniment as

simply the idea of walking side by side with another on a common journey. The idea is that when a university-trained person undertakes to walk beside someone rich in experience but lacking formal skills, each contributes something vital to the process. “Accompaniment” thus understood presupposes, not uncritical deference, but equality (Lynd & Grubacic, 2008, p. 176-177).

He came to know accompaniment through his own experiences following a desire to “unselfconsciously [offer] a service of unquestioned usefulness” (ibid., p. 51), the writings of Archbishop Óscar Romero of El Salvador, and conversations with Father Uriel Molina of Nicaragua. Two examples of accompaniment that he described will be illustrative. The first concerned the emergence of the Zapatistas:

a small Marxist sect gave up their academic affiliations in Mexico City and moved to the Lacandón jungle in Chiapas. There they “accompanied” indigenous Mayan communities for the next ten years, until, on January 1, 1994, all concerned were ready to make a public appearance... the Marxists from Mexico City learned more from the Mayans than the Mayans learned from the Marxists... all these ideological elements had to be discussed and re-discussed, practiced and practiced again. The emerging synthesis could not have been created in a university library (ibid., p. 64).

The second concerned the Student Nonviolent Coordinating Committee (SNCC) and the Freedom Summer. Volunteers, largely from universities and cities in the North and West of the United States, joined SNCC in Mississippi for ten weeks in the summer of 1964 to counter systematic disenfranchisement of Black people with a coordinated voter registration drive to register as many Black voters as possible, as well as building the Mississippi Freedom Democratic Party. The creation of Freedom Schools and Libraries also emerged during the Freedom Summer, providing alternatives to segregated and underfunded facilities, and even simply access in some cases.

Although these are examples of accompaniment by political theorists, political organizers, and broadly college students, and may seem like large endeavors, Lynd noted how accompaniment starts from a simple beginning: “People will need you, and over time, as you offer a useful service trust and friendship will emerge of themselves” (ibid., p. 59). Who are engineers and scientists to accompany? There is no shortage of people suffering adverse health effects due to pollution across the world, as reported by the *Lancet* Commission (Landrigan *et al.*, 2017), who are trying to make sense of their situations and live healthy, dignified lives (Auyero & Swistun, 2009; Kinchy *et al.*, 2015; Wylie *et al.*, 2017). As engineers and scientists bear responsibility for pollution from chemical manufacturing, fossil fuel, nuclear fuel, and precious metal extraction and use, this seems like a logical entry point.

A compelling example of accompaniment is detailed in *Refining Expertise*, where Gwen Ottinger delved into the environmental justice campaigns of two citizens groups in Louisiana, Concerned Citizens of Norco and Concerned Citizens of New Sarpy, against refiners adjacent to their towns, Shell/ and Orion/Valero, respectively, to address issues of environmental health (2013). While Ottinger and her interlocutors do not use the word accompaniment, the citizens groups were aided by the Louisiana Bucket Brigade, a New Orleans-based environmental health and justice nonprofit organization that assisted with air quality measurements, and the Tulane Environmental Law Clinic, a legal clinic operated by the Tulane Law School concerned with state and federal environmental law that brought a lawsuit on behalf of Concerned Citizens of New Sarpy. Even as accompaniment is a straightforward concept, the campaign in New Sarpy illustrates that simply connecting citizens with legal and scientific support does not in itself pave the path to environmental justice. Ottinger convincingly described the terrain upon which the campaigns were conducted as neoliberal, in which industrial and regulatory actors sought to channel the campaigns’ challenges to the scientific authority of the refineries and its engineers with respect to the citizens’ environmental health concerns into dialogue between representatives of the refineries and representatives of the communities, without regulators and without activist allies such as the Louisiana Bucket Brigade and the Tulane Environmental Law Clinic.

Dialogue was structured through community advisory and community-industry panels, which, Ottinger wrote, functioned

To shore up expert authority against attempts to democratize scientific knowledge. It satisfies demands for egalitarianism, for civility, for reason around contentious issues of pollution and health in fenceline communities. Yet it does so by bracketing out the situated, experiential knowledge that represents the most serious challenge to experts’ ways of knowing, and that democratizers are particularly keen on seeing become a systemic part of environmental decision making. In the neoliberal guise of dialogue, deliberation thus becomes a resource for the reassertion and maintenance of expert authority over questions of the environmental and health impacts of industrial emissions (2013, p. 128).

She also engaged corporate social responsibility as a means for technical industries to deflect challenges to their technical authority while making concessions to grievances neatly partitioned as “social concerns.” Throughout the text, Ottinger deliberates on how to best structure critiques and campaigns such that they make use of corporate concessions while also challenging the scientific authority claimed by polluting industries to advance environmental justice concerns. These are questions that engineers and scientists who enact accompaniment will need to consider.

Other entry points for accompaniment arise when considering dismantlement. Dismantlement is the act of depriving or stripping of apparatus, defenses, disassembling or pulling down, taking apart. As we often conceptualize our contributions as creating something new, disassembling an engineering or scientific artifact is often viewed as a means to more intricately know that artifact in parts and whole, to then be reassembled, rather than as the primary purpose to dissolve the artifact. However, given the relationships of domination that have structured engineering and science, and its materialization in engineering and scientific artifacts, dismantlement is an opening for engineers and scientists to take up in decoupling our (past) work from oppression.⁷

With respect to enacting dismantlement through accompaniment, two examples are revealing. First, the peaceful direct-action campaign of Catholic Workers Jessica Reznicek and Ruby Montoya in damaging infrastructure of the Dakota Access Pipeline between November 2016 and May 2017 (Reznicek & Montoya, 2017). During its construction, Reznicek and Montoya used tires and gasoline-soaked rags to burn valve sites, their associated electrical units, and heavy equipment along the pipeline in Iowa and South Dakota. They also used an oxyacetylene cutting torch to pierce valves along the pipeline. In early May 2017, while attempting to pierce a valve with an oxyacetylene torch, they discovered that oil was already flowing through the pipe and concluded their campaign. And second, the direct action of Aki Ra in disarming landmines throughout Cambodia since the 1990s (Cambodia Landmine Museum, n.d.). Aki Ra returned to the villages throughout Cambodia where he had planted landmines as a child soldier, removing and defusing them by hand. He created the Cambodia Landmine Museum to tell the story of landmines in Cambodia and to care for children harmed by landmines, and poverty more generally.

Jessica Reznicek, Ruby Montoya, and Aki Ra showed that the technical character of the infrastructures that they confront did not preclude their campaigns, but it does set constraints. Reznicek and Montoya curtailed their campaign when oil began to flow through the pipeline, as further actions would have resulted in oil spills. Ra can disarm mines by hand with simple tools, but at great personal risk. Engineers and scientists designed pipelines and landmines, as well as fossil fuel and nuclear power plants and their associated infrastructures for extraction and transportation, chemical manufacturing facilities, and conventional, biological, chemical, and

⁷Here, relationships of domination, the structured violence enacted by those relationships and their artifacts, and their dissolution are the focus, rather than seeking definitions of violence or nonviolence as in Banks and Lachney (2017).

nuclear weapons, bearing the responsibility of their creation and ultimately resultant harm. In enacting dismantlement alongside accompaniment, in trust, friendship, and solidarity with the people affected “worst and first” by climate change, warfare, imperialism, colonialism, and other forms of violence of capital and the state, we can accept that responsibility and bear the burden of the risks associated with decommissioning and dismantling artifacts forged from relationships of domination: swords to ploughshares. Further, an order of operations for dismantlement is likely to emerge. For example, there are many weapons in the world, and members of the aforementioned SNCC and the Zapatistas armed themselves in self-defense against anti-Black and anti-Indigenous violence by state and non-state actors. They should not be expected to dismantle their arms before states, militias, paramilitaries, or otherwise white supremacists.⁸

A CONCLUSION

The interplay amongst climate change, science, war, and engineering reveals intersections of political, economic, and ideological forces within society that impose themselves upon developments in science and engineering. This recognition may imbue us with the critical conscientiousness and political consciousness necessary to take commensurate action through challenging, dismantling, and reconstructing: with grounding engineering in social justice, anticapitalism, and relationships of reciprocity, and proliferating the concept of *science in society* from Science, Technology, and Society studies; with disarming landmines and biological, chemical, and nuclear weapons; with redirecting pipeline infrastructure from oil consumption to transporting clean water and sanitation. Only then will science and engineering contribute to reimagining and remaking the world in an equitable fashion never seen before. Walter Benjamin wrote that “Marx says that revolutions are the locomotive of world history. But perhaps it is quite otherwise. Perhaps revolutions are an attempt by the passengers on this train – namely, the human race – to activate the emergency brake” (Löwy & Turner, 2016, p. 66).

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⁸This statement should not be confused as support of the second amendment of the U.S. Constitution, which Roxanne Dunbar-Ortiz has shown to be grounded in the settler colonial white supremacist logics of anti-Indigeneity and anti-Blackness (2014).

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