AC 2011-1553: NOTE TO SELF: SAVE HUMANITY (A SOCIAL AND CULTURAL HISTORY OF THE "GRAND CHALLENGES"

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Note to Self: Save Humanity (A Social and Cultural History of the "Grand Challenges")

Abstract

The list of engineering "Grand Challenges" lately developed by the National Academy of Engineering enter a long historical tradition of such epically scaled to-do lists, dating back to the profession's origins in the mid-nineteenth century. The mission statements, codes of ethics, and, later, lists of so-called grand challenges that have issued from engineering societies have served the dual function of directing engineers' work and supporting particular cultural roles for these bodies of experts. Almost all such plans, regardless of period or sponsoring body, have also blended highly practical aims of industrial and infrastructural development with more inchoate projects of societal uplift. The Grand Challenges of the NAE, currently playing a formative role in many engineering organizations and research and teaching settings, extend this lineage. Their integration of economic and productive goals with explicit ideals of social and cultural welfare derives from historical precedents described in this paper. This paper indicates how the NAE's definitions of appropriate goals for engineering, generated by arguably the most prestigious engineering body in the nation, organize ideas about engineering in society.

We might bring to the Grand Challenges the type of critical, politically informed analysis that historians have brought to other sites of engineering activity and professionalization, to detect the nature of interests that underlay all such projections of engineering's role in society. Who is served by the development of different technologies, products and infrastructures? Who may be harmed? Most fundamentally, the Grand Challenges proceed from the premise that engineering research, construction, invention, and production are to take precedence over their absence, as befits a body dedicated not to the contraction of such enterprises but to their extension. Yet the interests of sustainability, global health, and other areas of human well-being might be best served in certain cases by just such a turning away from engineering. By making explicit the social and historical assumptions of the NAE's Grand Challenges, and probing the implications of those assumptions for a diverse range of actors and communities, we may pave the way for more thoughtful engagement with the humanistic and democratic potential of engineering.

Introduction

The Grand Challenges lately developed by the National Academy of Engineering with their excited inducements for twenty-first century engineers to "Reengineer the Human Brain," "Make Solar Energy Affordable," "Restore and Improve Urban Infrastructure," "Enhance Virtual Reality," and undertake ten other tasks, enter a long historical tradition of such epically scaled

to-do lists.[1] As early as the 1850s, as the first formal organizations of American engineers took shape, the individuals involved sought to project long-term goals and professional guidelines for their groups. The mission statements, codes of ethics, and, later, lists of so-called grand challenges that have issued from engineering societies and other entities have served the dual function of directing engineers' work and supporting particular cultural roles for these bodies of experts.[2-4] They have spurred countless responses and refinements among engineering subspecialties. Almost all such plans, regardless of period or sponsoring body, have also blended highly practical aims of industrial and infrastructural development and more inchoate projects of societal uplift. As Matthew Wisnioski frames this historical pattern, "By its very nature, engineering is a normative practice," and since at least 1918 designers of engineering curricula have explicitly called for social and humanistic instruction.[4] The Grand Challenges of the NAE, currently playing a formative role in many engineering organizations and research and teaching settings, extend this lineage.[5-8] Their integration of economic and productive goals with explicit ideals of social and cultural welfare derives from historical precedents described in this paper.

Recognizing their historical legacy and avowed contemporary purposes, we may see the Grand Challenges as endowed with particular cultural and sociopolitical power. Although commendations for NAE's efforts and for the list itself are easily found among engineering groups,[5-8] I do not undertake here the complicated labor of demonstrating precisely what impacts such claims may have had on their audiences; that task would require empirical research of another type. Instead, the point of this short paper is to indicate how the NAE's definitions of appropriate goals for engineering, generated by arguably the most prestigious engineering body in the nation, organize ideas about engineering in society.

Specifically, I see the fourteen Grand Challenges as framed in such a way as to foreclose inquiry into the challenges' impacts and into the larger sociopolitical character of engineering. This evaluation requires thinking about both the list of fourteen Grand Challenges and the terms in which that selection is justified in the NAE's document , but crucially, my aim is not to bring about a final judgment about either matter. Instead, I hope to encourage debate about the challenges' likely impacts as they are currently configured. However well-intentioned, the NAE's Grand Challenges, as was the case with earlier examples of such lists, forward some ideas of human betterment and not others in the authors' program of "driving the advance of human civilization." With this paper I want to highlight the extremely robust nature of uncritical depictions of engineering over the last 100 years, and the enduring marginality within engineering of voices that do choose to speak critically. My aim is to show that qualifying statements which might alert us to the potential limits of engineering as a force for humanistic reform or to its negative effects on human welfare *do* exist; often side by side with strongly positive statements. However, the sweeping nature of positive claims about engineering, such as those framed in the NAE's Grand Challenge and its historical precedents, help discourage deeply critical assessments of engineering and its products.

Challenging the Challenges

The NAE's Grand Challenges open with a powerful association of engineering with human benefit broadly conceived:

> In each of these broad realms of human concern — sustainability, health, vulnerability, and joy of living — specific grand challenges await engineering solutions. The world's cadre of engineers will seek ways to put knowledge into practice to meet these grand challenges. Applying the rules of reason, the findings of science, the aesthetics of art, and the spark of creative imagination, engineers will continue the tradition of forging a better future.[1]

Throughout the 56-page document, which specifies the need for engineering attention to each of the fourteen challenges, similar formulations assert that scientists and engineers engage in a "great quest for understanding many unanswered questions of nature." Such invocations of the inherently praiseworthy character of American engineering, as it has been practiced both in the past and present, draw on generations of similar rhetoric. A few representative quotes (thousands more are readily found in textbooks, newspapers, speeches and policy documents across the 20th century) reflect this enduring framing of technical enterprise as invariably a welcome contribution to general human welfare. In 1923, a journalist's profile of General Electric president Gerard Swope noted that the American engineer promises "industrial well-being, of creating greater happiness through the wider distribution of nature's gifts and resources, and through a general furtherance of the march of civilization."[9] Prominent civil engineer William Barclay Parsons, then supervisor of subway construction in New York City, told an audience at Columbia University in 1927, that "should our civilization perish, its ruins, if excavated, will disclose that it rested on engineering." [10] General Parsons surely had immediate perhaps careerist reasons to make such claims for his discipline, but not only engineers raised these points. That same year, the editor of *Nation's Business* told readers that the engineer "designs the useful harness for power, conquers the earth and the water under the earth [and] prospers the works of physicist and chemist...." to function as nothing less than "the prodigious servant of mankind."[11] In 1938, the author of the popular text, *Builders of Civilization: The Story of Engineering*, proffered "...an arresting account of the triumph of the modern engineer," who with scientist and inventor does nothing less than "drive back the brute darkness of ignorance by the light of civilization."[12]

UCLA economist Dudley Pegrum in 1944 added a note of historicity to such claims by naturalizing the application of engineering to capitalist culture:

> The resources which constitutes the basis of man's economic life are labor, the gifts of nature, and accumulated wealth. The dominant characteristic of the last two hundred years of western civilization has been the amazing expansion of man's capacity and the consequent growth of population enjoying a standard of living heretofore unknown. The basis of the great change we call industrialization has been the application of physical sciences to the production of economic goods.[13]

This kind of language gained wide resonance. General Motors headed a 1945 magazine ad with the phrase: "Progress More Quickly," assuring readers that its new technical research center in Detroit would "bring about MORE and BETTER THINGS FOR MORE PEOPLE" (original capitalization).[14] Undeniably, wartime had brought a certain urgency to encouraging public faith in American industry and infrastructure, but this was lasting rhetoric about the assured benefits

of engineering beyond the accumulation of corporate profits. In 1948, Gulf Oil promoted the work of its refinery engineers with ads claiming that its engineers were "well aware that there is a 'plus' for everyone in petroleum's progress."[15] Writing in 1950, John Charles Lounsbury Fish opened his treatise on "The Engineering Method" by quoting in full a 1925 presidential address by William Frederick Durand to the American Society of Mechanical Engineers, in which Durand reminded his audience that "we are engineers and as such hold a position of peculiar trust and responsibility in connection with the progress of civilization."[16]

In many of these endorsements, whether corporate, journalistic, popular, or scholarly, the sheer variety of engineers' contributions invoked by the writers affirmed engineers' value to society. A 1942 book written for young people, part of the "Way of Life Series," describes the products of the civil engineer's labor:

> ...a new sewerage system stem, or a water supply improvement for your own home town. It might be a railroad plunging through forests, deserts, swamps, and mountain, where finally you see the shiny rails leading on and on before the eye. Or canals to make a desert green; dams to harness the white horses in a mountain stream and turn their ageless energy to electricity; a pipeline to bring oil or gas to a large city or seaport.... And the loftily beautiful skyscrapers reaching for the clouds depend for their sturdy assurance on the skill of the civil engineer.[17]

If the scope of engineers' contributions to humanity was wide in such depictions, the origins of engineering were also seen as fortuitously heterogeneous. In 1954, Linton Grintner, preparing his seminal report on engineering education, described the field as resolutely synthetic, applying while transcending the "methods of mathematics, physics, and chemistry" by merging those methods with "engineering art in a professional way to provide for the convenience and welfare of the public."[18]

Five and half decades later, the NAE's Grand Challenges echo Grintner's correction to the popular misapprehension that, "scientists and engineers have distinct job descriptions" when in actuality, the NAE's document explains,

> ....the distinction is blurry, and engineers participate in the scientific process of discovery in many ways. Grand experiments and missions of exploration always need engineering expertise to design the tools, instruments, and systems that make it possible to acquire new knowledge about the physical and biological worlds.[1]

The continuity of historical ideas about engineering with those found in the 2008 Grand Challenges, and the uniform commitment across the decades to a final and positive judgment regarding an entire area of human endeavor, is fascinating to the cultural historian. How can such a sense of assurance possibly have persisted in the face of cultural change? For one thing, we assuredly feel, albeit impressionistically, that in our own lifetimes we have a fuller understanding of human culture than did people of previous generations, that knowledge about our human culture somehow accretes. Otherwise the experience of being "modern" would have no meaning. Much of the language used in essays of 1927 or 1957 feels florid and fusty; how can the ideas expressed not also have changed?

Perhaps more concretely (and defensibly), we might simply observe that in the early 21st century we have the benefit of many counter-arguments that have drawn our attention to the questionable benefits and manifold risks of engineering.[19] These critiques have not obviated messages, such as that of the Grand Challenges, about the collective good inherent in engineering, so we might take a moment to try to understand their origins and impacts to understand why not.

Progress and Critique

Critiques of industrialization issued from nineteenth century American philosophers and critics with the first factories, but during the Great Depression and World War Two these analyses perpetuated. At mid-century it was not just well known figures such as Lewis Mumford and J. Robert Oppenheimer, but also many progressive writers and thinkers who saw science as fueling the "harmful factors and effects" of industrialization and geopolitics, one economist summarizing that "the control and direction of scientific progress should be considered wishful thinking" [20, 21] By the last quarter of the twentieth century, Americans had encountered not only Rachel Carson, but highly organized anti-nuke, back-to-nature, and environmental movements. Influential figures such as Herbert Marcuse, Jacques Ellul and Theodore Rozak supplied a literature on which countless college courses syllabi were based. By 2008, "eco" sensibilities had revitalized in the face of global warming and catastrophic oil spills, with anti-industrial activists, while fewer in number than in Europe, organizing around U.S. meetings of the World Trade Organization and similar bodies felt to be responsible for the worst environmental transgressions and economic inequities of globalizing capitalism.[4, 19] Recent critical studies have also incorporated growing concerns about the privatization of the American university and worrisome exertions of influence by industry on academic scientists.[22, 23]

It is thus apparent that American culture regularly generates doubts about the safety and democratic potential of science and technology, and that for some citizens at least, those activities are no longer imagined to be tethered to a positivist science in ways that once supported unidirectional, entirely upbeat narratives about human ingenuity. [24] Matthew Wisnioski and Rebecca Slayton offer particularly suggestive accounts of experts from within science and engineering who have experienced such doubts.[4, 25] So the historical question for me, in the face of the NAE Grand Challenges, is not how optimism about engineering can persist: engineers today make tremendous contributions to human welfare through both dramatic innovations and the routine work of designing, building, and manufacturing our material reality. Rather, the question is how it is that *unalloyed* praise for engineering can persist, as seems to be the case through much of the Grand Challenges document and as is very much the undertaking's overall impression.

Crucially, I am not seeking singular, let alone dismissive, evaluation of the Grand Challenge's intent and/or outcomes. The document has great value to any society that hopes to spread the benefits of health, shelter, and ease of living that technologies can provide. It gathers persuasive arguments for the application of ingenuity, energy, compassion and inclusive impulses towards those ends. Such impulses have always been part of the motivation and function of engineering in the United States. I am instead drawing critical attention to the relative absence in the Grand Challenges of contravening points that might produce genuinely probing engagement with such

aims. I hope to encourage greater openness in our everyday thinking about what engineering has done, historically, and what it can do.[26]

Selective Depictions of American Engineering

First, we may identify ways in which the Grand Challenges point our attention away from flows of power and privilege in technical practice. This occurs in part because the Grand Challenges document does not refer to the complex social conditions of its own creation: who participated in the writing of the document and who did not, and in what capacity. We are provided with a list of names of those who served on the "diverse committee of experts" responsible for the document's content. We are told that they are "some of the most accomplished scientists and engineers of their generation" whose work was then reviewed by "more than 50 subject-matter experts." Some of the names are instantly recognizable as prominent inventors and entrepreneurs, their fame confirming their accomplishments in those particular realms. But we learn nothing of these participants' background in the study of societal impacts of engineering, ideological standpoints, or relative influence on the composition of the document. We know nothing of what counted as valid expertise in the creation of the Grand Challenges, let alone as "worldwide input" from persons or publics deemed to be non-experts by those in charge of the report. [7] Critical engineering studies of the last decade demonstrate that participation in engineering enterprises is largely determined at the major points of entry into engineering, such as public education systems and universities, and professional work settings. These institutions do not yet represent all sectors of our society equally; persons of minority and economically disadvantaged background, and in many instances, women are still underrepresented. It is not clear how or if the production of the Grand Challenges addressed these discriminatory conditions of expertise (for a summary of this scholarship see Brown, Downey and Diogo[26]).

We should draw no simple equivalence between such exclusionary habits and those of earlier generations. We no longer traffic in crudely racialized presumptions about the innate technical talents of different groups, as that evident in the 1927 magazine profile of Gerard Swope, mentioned above. In that piece Swope was said to be identifiable as the perfect "idealistic engineer" in part because he possessed "thin lips often pursed in thought when in repose" and "sharp clean-cut features," both traits invoked in opposition to the facial features thought to signal non-white genetic heritage.[9] However, we do use unexamined criteria (standardized tests, adherence to certain curricular experiences) to judge the talent of aspiring engineering students, and those criteria reassert lines of racial and class differences. [27] And, while we would assuredly not propose today, as did an engineering textbook of 1916, that the engineer must not only be male but also be committed to a "normal family life," homophobia persists in engineering today.[28, 29] Identity constrains opportunity in engineering in many ways. In its claims of definitive knowledge about what constitutes human welfare (the "grand" of "grand challenges" perhaps), uninflected by such issues of identity and inclusion, the NAE's document reifies socially constructed and socially impactful definitions of expertise and "forward edge" technological practice.

Relatedly, despite what I must presume to be sincere concern with the well-being of all who live with the products of engineering, the interests of many non-expert communities are set largely out of view in the very formulation of the fourteen Grand Challenges. They are simply not part

of the "story line" of engineering here.[30] For example, consider the recommendation that engineering fields make it a priority to "Engineer New Medicines." We learn in the NAE document that personalized medicine, building on genetic and genomic techniques, can increasingly base patient treatment on individual biology. This implies an unprecedented precision in medical practice, but in declaring that precision and customization to be the primary goals of bioengineering, this Grand Challenge also empowers researchers' inattention to the collective social conditions that in part determine our health. Variable nutrition, exposure to pollutants, and workplace risks among different communities and similar socially conditioned factors in human health are hidden. Individuals, cast by the Grand Challenges authors as fortunate consumers of medical and pharmaceutical innovation, are not authentically empowered by these developments because they are not given the option of choosing effective preventive strategies.

Again, I do not deny the tremendous benefits to be derived from the development of new medicines. But a "glass-half-full-or-half-empty" framing of these matters forecloses constructive conversation, and those benefits will be limited if we ignore the larger social world in which pharmaceutical and bioengineering innovation occurs. The totalizing claims of the document over all, for the beneficial impacts of engineering, discourage such a heterogeneous intellectual project. Not least worrisome is the elision in this Grand Challenge, however inadvertent, of engineering's role in causing illness. For example, agricultural engineering and food processing techniques of recent decades have introduced contaminants into diets that are now understood to produce cumulative exposure and serious risks.[31] Science and bioengineering reveal those dangers, but these dangers remain offstage in the Grand Challenges, rendered irrelevant in the contemplation of hopeful portrayals of the field.

The idea that bioengineering may be a mixed blessing for humanity, visible when its impacts are viewed through the largest lens, is not a recent development. Even in 1942, V. B. Sullam could write concernedly of Ehrlich's pharmaceutical discoveries in light of globalization:

> A world free from syphilis, from meningitis, from pneumonia...What else could we dream of? But, with tropical diseases held in check new frontiers would be open in Asia, in Africa, in SA, and agriculture would become unprofitable in the OLD World; new and tremendous problems would arise.[20]

But close analysis of such concerns regarding technical enterprise are almost always developed and shared *outside* of engineering disciplines themselves, or compartmentalized within engineering as humanistic or policy *aspects* of technical work, rather than as reflecting conditions that might be generative of engineering work itself (here Riley is extremely helpful[32]). We might consider the Grand Challenge to "Prevent Nuclear Terror" embody this pattern. The document articulates the staggering dangers of nuclear technology falling into the hands of terrorists, but then completely disaggregates that misapplication of nuclear knowledge from the institutional and intellectual developments that give rise to legitimate incarnations of nuclear energy. That is: the Grand Challenges initiative fails to acknowledge that legitimate activities in this case are a precondition for illegitimate activities. American policy makers are currently advocating for the expansion of nuclear power production on the presumption that security is a

surmountable matter; we are not attempting to solve the security problems before proceeding. The Grand Challenges' authors acknowledge that "Ensuring that a nation using nuclear power for energy does not extract plutonium for bomb building is not easy," but the larger framing of how such high-risk situations arise in part through the participation of engineers is not part of the Grand Challenge discussion. While the discussion of another Grand Challenge, "Securing Cyberspace" gives much more attention to shortcomings in technological realms ("The problems are currently more obvious than the potential solutions"), the occupational, institutional and market forces that have brought about that situation and *that may impede its improvement* are not addressed.

The Agency of Engineers

Defining engineering problems in light of such up- and downstream conditions would require a concerted shift in the field; in no engineering job description that I know of are the words "Determine the broadest social and political conditions in which you perform your technological tasks and act accordingly." Such a work requirement sounds absurd to our ears, but that sense of absurdity in fact arises from a culturally specific idea of engineering which can be challenged. Some, if not all, engineers historically involved in humanistic reforms surely had just such a recalibration in mind, despite such impediments as the entrenched instrumentality of the field as powerfully described by Seron and Silbey.[33] The degree to which socially inflected projects such as ABETS' "A through K criteria" actually accomplish these aims is a subject closely related to this paper.

For the moment, we might note that the embrace of social and political responsibility by engineers might be discouraged to a degree by the somewhat passive or reactive character ascribed to engineers in the Grand Challenges. Despite the authors' repeated appeals to engineers' social values and proactive impulses, in many ways, the status quo comes across in the text as acceptable. Consider the Grand Challenge's endorsement of engineering work on sustainable energy sources:

> Anticipating the continued use of fossil fuels, engineers have explored technological methods of capturing the carbon dioxide produced from fuel burning and sequestering it underground.[1]

Since one of the fourteen challenges is to "Make Solar Energy Affordable," we should not assume that by "anticipating the continued use of fossil fuels" the authors really mean "accepting" that use. And yet, economic context is nonetheless presumed by the authors of the Grand Challenges to determine the value of engineers' research, and thus appropriately to direct that research:

> Engineering solutions for both solar power and nuclear fusion must be feasible not only technologically but also economically when compared with the ongoing use of fossil fuels.

The relative affordability of technologies is accepted as a criteria for meritorious engineering research, but historically, affordability has been judged in industrial societies through the lens of

corporate profit. Cost saving and profit are notoriously conservative forces in capitalistic economic systems, leaving patterns of material privilege (and disadvantage) intact. As Donald MacKenzie and Judy Wajcman put it, "economic shaping is social shaping."[34] The Grand Challenge authors acknowledge that "Engineers' earlier projects have...unexpected or negative impacts," but offer all such caveats with so little contextual analysis that these qualifications lose their power to shape the future of engineering.

This orientation towards social and political neutrality seems, to me, to be incompatible with critical assessment of engineering and thus with genuinely democratic practice. Patronage (sponsorship of innovation and production) is agreed by social scientists to be strongly determinative of the impacts of technology. [22,23] Yet, that element of American engineering is rendered almost entirely opaque in this document. The bald, celebratory rhetoric of pro-capitalist voices in earlier decades simply attributed our quality of life to corporations. In 1944, economist Ludwig von Mises, editorialized that the techniques and products of "Big Business", from "noodles, soap, [and] cigarettes" to "railroads" and "rayon" are characterized by "...an unceasing tend towards improvement." [35] But no such associations, either laudatory or critical, are exposed in the Grand Challenges, as engineering appears in the text to be a service-oriented yet autonomous body of knowledge work. We need not pursue a fully positive or fully negative judgment about the democratic potential of capitalism to question that characterization. Yet, without some frank discussion of the structures of patronage, how can the NAE's aim of fairly and deliberately distributing engineerings' benefits possibly be enacted?

A number of historians and social scientists have lately honed in on the idea that engineers are too often cast, even in their own promotional rhetoric, as "problem solvers" rather than "problem definers." In this way, engineering has limited not only its professional status relative to policy and science fields, but also discouraged practitioners and publics from seeing technological expertise as potentially a politically progressive instrument.[4, 21, 36] However, even that sort of critical analysis may not offset one of the most powerfully conservative features of the Grand Challenges and similar prescriptive projects: The foreclosure of the possibility that engineering may not be the answer to a social or material problem.

It is the patent function of the Grand Challenges to show the role of engineering in meeting the needs of current and future human societies, but the document's logic is totalizing in claiming that those needs "await engineering solutions." Andrew Abbott has shown that professions routinely undertake such self-justifying activities to persuade their audiences of their particular utility.[37] But unlike professions with narrower claims to societal benefit, such as accounting, or with humanistic claims confined to a single area of human experience (however grandiose), such as medicine, engineering often articulates an especially diverse social utility. I do not suggest that we assess the relative contributions of different expert groups to human welfare or even the validity of such claims, both ridiculous exercises that would land us in an infinite regress of criteria-setting and evidence-choosing. Rather, if we are concerned with the impact of knowledge production systems on human welfare, we might learn a great deal by studying the precise means by which bodies of expertise attain their credibility. Historically, observers from Thoreau onward have interrogated the universalizing and self-perpetuating logic of industrialization, by which expectations of economic growth demand technological innovation, which in turn begets more economic growth. Engineering demands more engineering, as Mumford made clear.

Again, while engineering has surely improved the quality of life for countless individuals in industrialized societies, obscuring this self-perpetuating logic cannot be consistent with thoroughly progressive social ideologies; hence the problem with setting "engineering challenges" in the first place...they are predetermined to necessitate more engineering. Consider in this regard the NAE Grand Challenge centered most clearly on America's built environment, a call to "Renew and Rebuild the Infrastructure"

Happily, in articulating this challenge, the authors do not uncritically call for the replacement of existing structures. Instead, they highlight the creation of new facilities, such as "hubs" that may support the addition of mass transit, bikes or walking to existing road systems. Yet the document stops short of casting roads as part of the problem so that we may entertain the possibility that fewer built structure in these settings would be better. Certainly, no larger point about the sometimes unsustainable or undemocratic nature of American civil engineering projects is introduced. Nowhere are we asked to think about the legal and policy structures that continue to facilitate the construction of, say, new roadways and suburban developments, long after the ill effects of such sprawl, on both the environment and urban communities left behind, came to light. Pro-automobile, pro-development, and even pro-business ideologies that balk in principle at limiting any private enterprise in this country will mitigate against engineering work on such "hubs" even at the funding and design stage, let alone at the technical research and construction stages. As in many portions of the document, mention of "various policies and political barriers" to changes in the aims of engineers is confined here to a single sentence included after and apart from other points, rather than treated as integral, pervasive forces in the built environment. "Political forces" must be marshaled in order for engineers to work effectively, we read, but engineering itself is cast by extension as something other than a political force.

Conclusions

Since this discussion raises doubts about the efficacy of what is clearly a well intentioned project, it is worth repeating that on every page of the Grand Challenges, welcome developments in health, shelter, mobility, labor saving devices, and national security as well as likely directions for further such improvements are instantly recognizable to us. The suggestive point here, however, might be in those last words: "*to us.*" How would people of other cultures read this document? Or, persons living in economically disadvantaged American communities that have historically born the costs, rather than benefits, of the nation's industrial or infrastructural development? The universalizing tone of the Grand Challenges, implying that there are better and worse material projects in which humans might engage but that all humans share the same material interests, is unfortunate. Technological developments that enhance aspects of my life may bring costs to others: my inexpensive household heating comes from the use of coal obtained through moutaintop-removal mining, a process that has caused incalculable environmental and community harm in the communities of Appalachia. My ability to purchase inexpensive household appliances derives not only from the genius of inventors, materials experts, and process engineers, but from the low wages of factory workers in other parts of the globe.

The alternative to relentless positivity is not negativity, but criticality, or openness of inquiry. The categorization of certain problems as engineering problems might be shifted in helpful ways here. If the Grand Challenges project advocates for the control of chemical weapons, for example, it might also ask what is *not* remedied when chemical warfare is indeed foiled by nano-engineered detection devices: The sources of geopolitical conflict that give rise to the weapons in the first place. With such a wide lens, defense spending might be reconfigured to include economic development in troubled nations, perhaps through U.S.-led innovation in health and water distribution technologies, say. Or, we might ask: What is not fixed when American cars run on renewable fuels? The economic system that deprives those who do not own cars of proximity to jobs, healthy food, and pleasant communities, and its reification in a road-based infrastructure. Why roads at all, we might ask anew. We need to put the work of engineers (and our expectations of their work) on the broadest stage to assess its meaning for human society; flattery gets us nowhere, literally.

These reorganizations of "problems" and "solutions" involve taxonomic change, questions about where engineering begins and ends. These are asked by historians, sociologists and policy makers working in the loosely defined field of Science and Technology Studies, but also by those who write about economic equity, environmental history, labor history, and many other subject areas in which engineered structures and systems have had an impact. Activists, as noted above, have also asked these questions as they contend with perceived challenges to health, sustainability, and quality of life in the U.S. and global settings. This paper emerges not from a belief that the authors of the Grand Challenges hold some particular ideological position about health, sustainability, energy production, or any of the geopolitical matters surrounding these areas of human enterprise. Rather, it derives from a powerful sense that the well intentioned authors and promoters of these 21st Century Grand Challenges are operating at a distance from the critical scholarship in which those fields engage.[19] The document fails to engage with the important historical finding that technical knowledge is *necessary* in order for technical expertise to improve human welfare, but *not sufficient*, as historian of urban technology Scott Gabriel Knowles has put it.[38] The Grand Challenges help us set priorities; some projects are more worthwhile than others, without organizing our work we cannot make headway. But questioning the definition of what counts as headway may be the most important challenge of all.

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