Humanistic Engineering: Engineering for the People

Matthew L. Bolton
Department of Engineering Systems and Environment
University of Virginia
Charlottesville, VA 22903 USA

> "The core of the belief in progress is that human values and goals converge in parallel with our increasing knowledge. The twentieth century shows the contrary. Human beings use the power of scientific knowledge to assert and defend the values and goals they already have. New technologies can be used to alleviate suffering and enhance freedom. They can, and will, also be used to wage war and strengthen tyranny."
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> —John Gray [10, p. 106]

The Jetsons was a cartoon that premiered in the 1960s that (ignoring regressive social politics) depicted life in the future with all manner of automation conveniences that eliminate the need for physical labor: robot maids, flying cars, moving sidewalks, and so on. In this future, the main protagonist works a job that, due to the efficiencies offered to him by technological advances, requires him to push a single button up to five times a day, 3 h a day, three days a week. Conversely, the science fiction writer Philip K. Dick (who also published in the 1960s) envisioned a less optimistic future. In the novel *The Three Stigmata of Palmer Eldritch* [1], the world's temperature has become so hot that people cannot go outside during the day unprotected. In Ubik [2], homes are filled with smart devices that require you to pay money every time you want to brew coffee, open the refrigerator, use specific items in the refrigerator, use the bathroom, and open the front door. In any situation in which there is disagreement about the nature of the service provided by the appliances, you must argue the terms of your contract with them. In our current world, technology keeps advancing and promising a better, Jetsons-like future. While it is true that technology is addressing problems and making elements of some people's lives easier, there are aggregate measures that suggest a troubling trajectory that is more akin to the ones envisioned by Dick.

Technology is increasing our productivity, by 140% since 1973 [3]. However, there have not been proportional gains in workers' real wages, which effectively stagnated over the same period [3]. We have seen technology make inroads into nearly every facet of our lives, where the responsible companies have made a significant amount of money by monetizing elements of human life (our interpersonal communications, geographical locations, purchase practices, internet histories, number of walked steps, etc.) that have never before been marketized. However, the majority of the wealth created by these market expansions has not been distributed to the population at large, with the top 1% now holding a historic and increasing proportion of the resources [4]. We are told that technology is democratizing and empowering, but multiple aggregate measures of democracy in the United States have been declining since 2014 [5]. If technology were making us healthier, we would expect significant increases in life expectancy and well-being. However, since 2014 (i.e., even before

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the COVID-19 pandemic), life expectancy in the United States has been declining [6] and the United States is one of only three countries whose social progress index (a measure of citizen quality of life) has fallen since 2011 [63]. If technology were giving us benefits beyond the material, we would expect improvements in happiness. However, United States happiness has been trending down since 1973, with recent declines being highly correlated with the frequency of phone and digital media use [7]. Through technology, we have never been more connected or had more ways of communicating with each other. Despite this, we are also in the midst of a "loneliness epidemic," where associated detrimental health effects are spreading throughout society, especially in older and vulnerable populations [8]. If technology were making us more resilient, the coronavirus response should have been swift and effective. However, we have seen the opposite. In fact, modern industrial engineering technologies like just-in-time production limited the availability of health resources during the crisis [9]. We are supposedly living in a marvelous technological age with capabilities previous generations could not have imagined. But the stark reality is that very little of this technology actually works well. Rather, most modern technology is a nightmare of clicking, waiting, getting into unexpected and confusing states, troubleshooting, finding bugs, working around those bugs, filling out tons of electronic "paperwork," manually transferring and converting information between incompatible systems, and so on. This is to say nothing of the threat of climate change (a problem deeply tied to industrial technology) that, despite scientific consensus since the 1970s, has yet to receive an adequate response.

These are just some of the existential issues we are currently facing. These problems are complex, with critical political, economic, and cultural dimensions. But engineering is undeniably complicit. It created the technology that has undermined the value of labor, enabled the privatization of public resources, funneled wealth and power upward, and sacrificed human well-being for short-term profit.

The net effect is that engineering, often despite the intentions of its practitioners, is contributing to a society that is less fair, less just, less democratic, disempowering, and more precarious. If we do not confront this incoherence and reverse these trends soon, society will likely find itself in a very dark place. However, technology is not inherently opposed to human progress. Given its potential for transformative change, technology can be used to address the underlying problems. As the ones who design technology, engineers control a critical point in determining how technology will affect society and thus have a unique opportunity to make the change. This article explores how the current situation has developed and proposes a reenvisioning of engineering that could reverse these trends and propel society to a better future.

Diagnosing the dysfunction

Several characteristics of engineering technology, practice, and culture contribute to engineering's failure to address the problems from above. We explore them below.

Everything is too complex

For some reason, engineers have decided that everything should be really complex. Complexity can be defined in a number of different ways, but it ultimately describes a condition that is difficult for humans to intellectually manage [11]. Complexity may sometimes be necessitated by the problem being solved or the application domain. However, often it is introduced as part of the design process due to overengineering, the trendiness of current engineering paradigms [e.g., using artificial intelligence (AI) and/or machine learning wherever possible], cost ("it's cheaper to do it in software"), feature creep, or the convenience of "hacky" solutions.

The detrimental effect of complexity on system safety and stability has been known for decades [12], [13], [14]. Complexity is dangerous because it makes it difficult to identify bugs or design flaws, hard for any engineer to keep the entire system in his or her head, and hard for humans to use the system without making errors. As such, complexity makes every part of the system life cycle (evaluation, design, analysis, implementation, maintenance, and decommission) more difficult. Not surprisingly, complexity was a major factor in large-scale failures such as the Three Mile Island nuclear meltdown and the Bhopal India disaster (where a Union Carbide pesticide plant poisoned roughly 500,000 people due to a catastrophic gas leak). An active research area (which includes much of my own work) attempts to discover engineering solutions that can manage or mitigate the safety problems caused by complexity.

Safety is not the only problem that arises from systems being too complex. Complexity can encourage bad practices by hiding mistakes and incompetence: if nobody can figure out why something is not working, no individual is blamed. Complexity can hide bad intentions, that is, if the system is doing something that designers do not want others to see or notice, this can be hidden inside a complex process. This is a common practice of con artists as well as the financial industry. If you do not want regulators, oversight, competitors, or “marks” to figure out what is actually going on, hide the nefarious behavior in an extremely complex process. Some high-profile examples of this sort of practice can be seen in the iPhone tracking scandal from 2011, [64] where a software update resulted in people’s location being tracked and stored without their permission, as well as the Volkswagen emissions cheating scandal, [65] where the automaker hid a subroutine in onboard software that could detect laboratory emissions tests and alter car performance in response. Finally, complexity is both bad for democracy and the environment. Complexity is antidemocratic because it makes it difficult for people from different walks of life to understand how a system works, learn from it, repair it, or repurpose it [6], [15], [17]. This type of complexity is often deliberate because companies would rather have customers or clients purchase new products or authorized services rather than use self-repair or third-party services, both of which fail to earn profit for the original company. This is bad for the environment because it creates tons of (often high-tech) waste that could have been repaired or otherwise remanufactured.

Good work is too reactive

The above discussion may give the impression that no good engineering work is being done. This is definitely not the case. There is considerable effort in trying to solve societal and technological problems. The issue with such undertakings is that they are reactive. Typically, the engineering effort identifies a specific problem and tries to fix it. Such a reactionary approach does not fundamentally address the underlying systemic issues that are the source of the problem. This means that reactive work too often only serves to prop up broken, poorly conceived, or unethical systems, frequently by adding additional layers of complexity.

For example, many have noticed that machine-learning algorithms, when used in applications like mortgage lending, make recommendations that we would consider sexist or racist. In response, researchers are scrambling to figure out how these biases can be removed from machine-learning methods or from input data [18]. But this reaction is largely missing the point. The purpose of using machine learning in this example is to identify the stereotype of the person applying for a mortgage and, in response, recommend a decision that best suits the profits of the organization. Thus, an algorithm that makes sexist or racist recommendations is actually doing what it is supposed to do. It may well be possible to find methods for removing particular biases from the machine-learning process. However, what is troubling about the original behavior is not just that it makes decisions that offend modern sensibilities, but that the machine-learning approach, by virtue of relying on stereotyping, is inherently inequitable and unjust.

This example also illustrates another problem with reactive work: it lacks vision. Research and developments that view solving problems as their motivation are constrained to a vision of the world that is only iteratively better than the current one, and one that is contextualized in terms of the original, broken system. So, returning to the machine-learning mortgage example, the problem-based reactive approach seeks to remove problematic bias from the algorithm. A more visionary and systemic perspective would attempt to figure out how everybody in society could obtain financing for purchasing a home or (even better) ensuring that everybody has adequate housing.

Too much tech

In situations where engineering work is more genuinely driven by a vision, it is usually done in a very narrow context. What seems to animate most engineers’ vision of the future is cool, shiny tech. In particular, we seem to be driven by a vision of making 1960s, 1970s, 1980s, and 1990s popular science fiction technology a reality. In this light, it makes sense that so much research is shifting toward AI, virtual reality, robotics, exoskeletons, self-driving cars, flying vehicles, and so on. While it is true that these things may help solve some problems, this is not really the point. The point is that the tech is "cool" and makes us feel like we are realizing a vision of the future from our childhoods. While this perspective will certainly have an impact on society, it is a very limited vision. It is one where the world effectively functions the way it does today, but with new toys and more convenience. In the absence of a vision of a better future, and technology specifically designed to realize that future, technology will only serve to perpetuate the status quo, which includes its regressive tendencies.

We do not design things for people

The overemphasis on tech innovation is creating a paradoxical situation where an immense amount of engineering is not designing things for **people**. Rather, products are created to fuel the technological and monetary ambitions of our larger institutions. This is why so much modern work infrastructure (online reimbursement systems, course administration software, electronic medical records) is so difficult to use: it was not designed to help people do their jobs.

In many cases, human concerns, rather than being the point of engineering, are viewed as an impediment to its progress. Autonomy engineers are mounting significant efforts to determine how to make people defer to and "trust" automation. Control theorists view humans as a source of error and instability. Cybersecurity engineers view end users as the "enemy" of security, the equivalent of hackers causing problems. Modern tech companies view humans as sources of data and money and thus any sort of effective human-centered design (which is almost exclusively focused on the consumer space) is meant to extract resources from them as easily (and often as covertly) as possible. But even in this space, devices like mobile phones are supposed to facilitate media consumption and textual communication but make us interact on tiny, smudgy screens with awkward touchscreen keyboards.

Complex technologies that attempt to automate human work have a number of problems that have been recognized for decades [19], [20], [21]: humans often have their roles changed to ones (such as monitoring the automation) that are incompatible with human cognition[1]; automation can be brittle and thus fail in situations unanticipated during design; the human may not be able to track the state of the system, leading to poor situation awareness, mode confusion, disorienting automation surprise, and human errors; humans can become too reliant on automation and use it inappropriately; and humans who cannot determine why the automation is doing what it is doing may distrust it and not use it when it is appropriate. Despite the well-established nature of these problems, they have persisted into modern times [23], [24]. Given the complex and unexplainable nature of emerging autonomous and machine-learning technologies, these issues are expected to get even worse than they were in previous generations [25].

Engineering lacks values

Finally, the core issue that, I suspect, drives all of the other problems is that engineering lacks values. In my experience, most engineers (and researchers within the field) view engineering knowledge and technology as goods in their own right and that by bringing these into the world, society and the human condition are being advanced.

It does not take much historical searching to find good evidence that science and engineering are not inherently virtuous. The Nazis were able to execute the holocaust as effectively as they did through the use of (then) cutting-edge punched card technology [26]. They were also clearly devoted to advancing the science and technology of industrial operations, nuclear physics, and rocketry to support their authoritarianism and war efforts. The problems outlined at the beginning of this article also make it clear that this is not just a historical anomaly. Thus, it is more accurate to see science and technology as tools that, unless special effort is taken to the contrary, is done to support and advance the goals of society's powerful.

So, if engineering advances are primarily directed by the ideology of society's powerful, then neoliberalism [27] is our driving ideology.

Neoliberalism

While it may sound controversial, there is a general consensus that neoliberalism is the dominant political philosophy in the United States and many other parts of the world. It is the ideology of the World Bank, the International Monetary Fund, the World Trade Organization, the United Nations, the

[1]For example, even for extremely motivated people, visual monitoring performance significantly degrades after approximately 30 min [22].

World Health Organization, the Gates Foundation and has been the guiding philosophy of every U.S. President (both Democrat and Republican) from Ronald Reagan onward [28].

By its nature, neoliberalism is a fluid and shifting perspective, which can make definitions for it difficult. However, the one from Spence [29, p. 3] is concise and comprehensive: Neoliberalism is "the general idea that society works best when the people and the institutions within it work or are shaped to work according to market principles." Stated another way, neoliberalism asserts that competitive marketplaces are the superior method for defining value, where value is meant generally, not just economically. Thus, from a neoliberal perspective, the best products are those that are the most successful in the marketplace. It also means that the people/professionals who have the highest value are those that emerge from the competitive "meritocratic" marketplace with the most prestigious degrees, positions, awards, grants, papers, citations, and so on. This also means that neoliberal adherents hold that markets are a better way of determining what is good and right, better than individual people and better than democratic processes. Note that neoliberalism is not laissez-faire capitalism, though they have many similarities. Neoliberalism is a more general perspective, and one not inherently opposed to large central governments. Quite the contrary, neoliberalism sees the purpose of government to foster markets and thus create value. This is why, for example, the United States has a massive military (by far the biggest on the planet) despite not being attacked domestically since World War II: the military is used to protect and/or open up markets around the world.

This neoliberal ethos leads to specific trends in how our society prioritizes goals and addresses problems. It encourages the deregulation of the private sector to allow it to participate as freely as it can in markets. It encourages the privatization/marketization of things that we used to think of as being public. This is because neoliberal proponents believe that market forces will deliver services better than democratic institutions. Examples of this can be found in the push for charter schools, phone apps (like ride-sharing) that replace public transportation, cities selling off public street parking meters to for-profit entities, or the military hiring private contractors to perform basic services like cooking and cutting hair (things they used to perform internally). Perhaps, the ultimate expression of neoliberalism occurs when something that used to be free becomes marketized. For example, socializing has been marketized through social media so that value can be extracted from our banal communications. As a result, we start treating our friendships as being much more transactional because our communications are part of this marketized space where targeted advertising competes for people's attention.

While neoliberals expound on the virtues of innovation, transformation, entrepreneurship, and disruption, they tend to favor iterative solutions that will not disturb the fundamental functioning of the markets. Furthermore, the solutions that are derived are often very complex and favor the technocratic and technological. In the public sector, this is viewed as good because it minimizes the impact on the market and the complexity makes the professional class (those who have mostly succeeded in the meritocratic marketplace) feel like they are being innovative and best using their unique skills. Nonprofessionals (those who did not achieve the requisite education or credentials) are, in turn, locked out of positions of power. From the private sector's perspective, the new technology helps create intellectual property and complexity creates lock-in, protects trade secrets, and enables the creator to retain control.

The emphasis neoliberalism places on markets frequently lead to situations where the benefits of technology are not fairly distributed. Specifically, a new technology that could have immense societal benefit will likely have significant profit potential. In a market-based system, the creator (or person holding the rights to it) will attempt to maximize the amount of profit that can be gained from the technology. This can make it difficult (or impossible) for people of modest means to afford the technology. A good example of this is the EpiPen. An EpiPen is a medical device that automatically injects a dose of epinephrine into a person. It is the primary treatment for people who experience anaphylaxis, a potentially deadly allergic reaction. In 2009, an EpiPen cost approximately $100. By 2016, the company that owned the technology had raised the price by roughly 500% to $609 [66]. This made the device a substantial expense for those with lower means, potentially forcing them to choose between more immediate needs and the risk of dying from an insect sting or food allergy.

Because labor is one of the biggest expenses in any organization, neoliberalism favors efforts to reduce labor costs wherever possible. This can mean adopting technology and practices that extract the most work out of employees, relocating to cheaper labor markets, replacing labor with automation, or using new business models (such as the ones in the gig economy, which are frequently enabled by technology) to avoid officially hiring employees when human labor is required.

With this insight into neoliberalism, it makes sense that most of the current trends in research are being pushed so aggressively. Robotics is a major priority because it will enable us to reduce dependence on human labor. Autonomous systems are of interest for the same reason, but also because they can open up new markets and accelerate privatization. Autonomous driving is a particularly illustrative example. For those that need to commute, autonomous driving will help create new markets to fill people's transit time: media consumption, online shopping, and location-targeted data collection and advertising. Companies pushing it are also seeking to replace public transportation and car ownership by making everybody dependent on them for individualized rides.[2]

AI is perhaps the best example of neoliberalism's interest in engineering because it seeks to create automation capable of doing "knowledge work" that could previously only be done by people. In cases where the technology is not yet ready, the general trend is to use AI as a surveillance and enforcement tool to ensure people are working as "effectively" as possible.

Higher education is also seeing the influence of neoliberalism. The last couple of decades have seen the rise of for-profit colleges and universities promising training in tech-centric jobs. Across higher education, there is a big push toward online offerings. This is concerning because it has the potential to devalue the role of the instructor: why do we need so many professors and universities when one person can teach to an unlimited audience? We are also seeing continual efforts to get more people into science, technology, engineering, and mathematics (STEM) (to the detriment of the humanities) and/or to teach everybody to code. While it is certainly important to give people an understanding of the technology that impacts our lives, these efforts are more concerned with vocation than actual education. As such, these initiatives also come with a dark side: creating a surplus of STEM labor. If anybody can do low-level STEM labor, why would a company hire an expensive, first-world worker? It will be much cheaper to hire somebody in the developing world, especially in a country where there are fewer worker rights.

Not surprisingly, under the neoliberalism of the last several decades, scientific research has gotten more cutthroat, competitive, and austere, with more and more researchers competing for resources that are not growing at a proportional rate.

Is this the future we want?

I cannot speak for anybody else, but I do not like the trajectory that we are on. As an engineer, I did not pursue this career so that the fruits of my intellectual effort could help marketize every element of human society and interaction. I did not become an engineer because I wanted to help concentrate wealth and resources upward. I did not become an engineer because I wanted to help our military maintain and grow economic imperialism. I did not become an engineer because I wanted to help powerful forces extract as many resources as possible from human labor or undercut its value with automation. I did not become an engineer so that I could turn a blind eye to the environmental catastrophe that is being driven by the continued industrialization of society. I did not become an engineer because I wanted to help prop up the current, broken infrastructure by putting out its fires. I became an engineer because I believe in the ability of science, reason, technology, and hard work to create a more fair and just society and to enable people to live better, more satisfying lives.

I recognize that other engineers may not have the same motivations that I do. I also think that it has been easy for engineers to look the other way as the value of blue-collar work was undercut using their advances. This is because such developments did not directly impact them. But pragmatically, we are living through a time where (through AI, online education, and the exporting of STEM labor to cheaper markets) we can see the forces coming for our livelihoods.

[2]A vision of transportation that is extremely bad for the environment [30].

If you agree with me that we are on a very dangerous path, then it is imperative that we start addressing the situation now. Fortunately, we engineers, at least currently, do have leverage. This is because powerful organizations currently depend on us to perform fundamental research, design technologies, and educate the workforce they depend on. I am proposing that we wield this power by reforming engineering around a concept I am calling humanistic engineering, a new approach that will give engineers the knowledge and skills they will need to drive society in a better direction.

Humanistic Engineering

If you accept that a lack of values is at the root of why engineering has failed to address the problems described in the introduction, then we need to adopt a value system to guide our work. **We need values!**

Humanism offers a source of (hopefully) noncontroversial values. Humanism is a philosophy that puts paramount importance on the common good and solving human problems rationally. Thus, I am proposing the creation of humanistic engineering, a value-driven approach where **all engineering** should be done with the explicit purpose of improving people's lives and advancing humanistic goals. In particular, humanistic engineering offers a vision of the future in which human advancement through science and technology are realized: a world where everybody (regardless of demographic or socioeconomic status) benefits from technological advances; a world where people are able to fulfill their societal contribution through a minimum amount of labor every week; a world where people can use their free time for entertainment, education, personal advancement, creative enterprises, scientific research, entrepreneurship, or community development; a world where the technology in people's lives actually enables and facilitates these enterprises; a world where everybody can gain ownership of new technologies to help advance their lives and extracurricular activities; a world where technology is open and accessible so that everybody can learn from it, contribute to it, and build upon it; a world where all technologies are both beneficial to the environment and sustainable; and, finally, a world where people are empowered by their technology and societal infrastructure to make change and come together collectively to confront powerful interests that are holding humanity back.

This last point is a critical component of humanistic engineering. Humanistic engineering expressly adopts a model of power to give engineers and the larger population the ability to drive society in humanistic directions. As such, humanistic engineering seeks to create technology, construct infrastructure, and deliver education that supports the empowerment of individuals; democratization of technology, the workplace, and organizations; and collective action.

This vision of the future and theory of power inform the core principles of humanistic engineering as well as the strategy for broadly realizing it. Both of these topics are discussed next.

Core principles of humanistic engineering

The specific goals of humanistic engineering projects will vary and evolve over time. I have identified five core principles that, together, should provide a comprehensive value system for ensuring that these goals are pursued with a common set of humanistic values.

Principle 1: All engineering should be human centered

To ensure that engineering projects are being done with the explicit purpose of advancing humanistic goals and improving people's lives, all engineering should be human centered. That is, all engineering projects should be designed to facilitate the needs and goals of the people that must interact with the products or are affected by them. If an engineering decision cannot be justified on the grounds that they are directly benefitting the people impacted by them, or are at least inconsequential to them, then the decision is likely serving a purpose that is antihumanistic and should be discarded.

Principle 2: All engineering products should be accessible and inclusive

Engineering advances that offer advantages or new capabilities are truly beneficial to humanity only if those advances are available to everybody. Thus, all engineering products should be accessible and inclusive. Note here that accessible and inclusive are being used as broadly as possible. This means that engineered products should be accessible and inclusive in the traditional sense, making technologies and services available to disabled and minoritized populations. It also means that engineering products should be available to people irrespective of socioeconomic class. We can build all of the luxury, green transportation options, or medical treatments we want, but they will not see a significant societal benefit unless they are available to everybody.

Principle 3: All engineering efforts should be sustainable

If engineering is to make lasting contributions without negatively affecting future generations, all engineering efforts must be sustainable. This means ensuring that they are, at the absolute minimum, doing no harm to the environment. Ideally, projects should be reversing the environmental damages committed by older industrial technology. Of course, sustainability is concerned with more than just the environment. Thus, engineering projects must also account for economic sustainability to ensure the long-term stability and viability of developments. They should also be socially sustainable to facilitate community commitment and civic responsibility.

Principle 4: All engineering products should be democratic

Technology that is needlessly complex or discourages people from engaging with it except in ways intended by the designer is discouraging creativity, negatively affecting learning, and ultimately reducing participation in science and engineering. Thus, all engineered technology should be democratic. It should be designed in a way that enables or even encourages people to engage with it, repair it, or modify it for their own ends.

Principle 5: All engineering products should be empowering

Finally, any engineering products that cede power from individuals to a more powerful organization (like corporations and governments) are inherently antihumanistic. Because technology should serve to give people power and control over their lives, all engineered products should be empowering. Note that empowerment can happen at both the individual level (e.g., through education or ownership of a product) but can also relate to people with common interests coming together to exert influence towards collective ambitions.

Realizing humanistic engineering

On its face, it seems ridiculous that humanistic engineering is not the way that engineering is currently done. But as it is, humanistic engineering would constitute a major transformation. It is my intent for humanistic engineering to be the dominant engineering paradigm. Achieving this will require a significant multidisciplinary effort with advances in research, education, and service dimensions.

Research

Foundational work exists for the first four humanistic engineering principles. Human–computer interaction (HCI) and human factors engineering have done essential work related to how to design and engineering systems from end-user and worker perspectives. Both human factors and HCI, as well as subareas in architecture and art, have made developments in inclusive design, which relates to accessibility and inclusivity. Sustainability has become a subemphasis within a number of engineering disciplines. Finally, elements of democracy in engineering have roots in established concepts such as the right to repair, remanufacturing, and open source. While many of these areas still require basic research, a major challenge will be to discover how the associated core principles can be integrated across engineering so that engineers of any discipline can account for them in their efforts.

The core principle that has no precedent in the current engineering canon is empowerment. As such, basic research is needed in this area to define models and measures for understanding and predicting individual and collective power. Luckily, this is a domain where there is substantial social science and humanities research from which to pull inspiration.

Education

Education will be critical to the success of humanistic engineering. I propose that humanistic engineering become a core component of all engineering education, one that should be emphasized throughout course and research work, no matter one's area of concentration. It is through education, training, and supervised research that students will be introduced to the concepts and learn how to account for the fundamental principles in engineering efforts. This will also allow basic and integrative research to be performed. With the requisite training and knowledge, humanistic engineers will be able to take their training and disseminate their influence to universities and institutions once they are employed.

An extremely important dimension of humanistic engineering education, and one that is in line with humanistic engineering's theory of power, will focus on giving students practical skills for affecting change. This is essential because educating engineers in humanistic principles and simply putting them out into a world that is incompatible with them will not, on its own, be effective. This is because the vast majority of engineers work for large organizations and merely teaching engineers how to be conscious of humanistic issues puts the onus of change on the individual. This places engineers in potentially conflicted and precarious situations. If individual engineers encounter an ethical dilemma in the workplace and make their concerns heard (or refuse to participate), they risk being fired or subjected to other forms of retribution. This generally leaves them with two options, quitting in protest or keeping quiet and shouldering the ethical burden. To avoid this problem, humanistic engineering education will instruct students on ways that engineers can use legal, institutional, and collective power. This will give them the means to help ensure that their projects and institutions are adhering to humanistic principles while protecting individuals from retaliation.

This will include, for example, teaching students about whistleblowing, strategies for employing it, and associated legal protections. For engineers working in companies, students will be taught how to organize and form unions with their fellow engineers and workers. This will enable engineers to collectively bargain with management to ensure the results of their labor are headed in humanistic directions. Finally, for engineers interested in pursuing entrepreneurship, the education will teach them about alternative business models and managerial practices that will help make businesses more democratic and thus align with the values and needs of their workforce. For example, workers' self-directed enterprises are a form of cooperative where workers both own and manage their companies [31]. By giving workers a democratic say in and responsibility for the actions of their organization, such companies will produce a variety of benefits. There will be reductions in income inequality because workers will determine how resources are distributed. Worker health will improve because employees will be able to better dictate their work terms and there will be reductions in stress due to improved job security. Productivity and product quality will increase because workers will be more invested in the outcome of their work and thus incentivized to use the expertise they build on the job to improve products and processes. Finally, such an organization will behave more ethically because it will be more responsive to its employees' values (not just the ones demanded by the marketplace). To illustrate this last point, consider a company that manufactures chemicals. If this company is a workers' self-directed enterprise, then it will be less likely to dispose of its hazardous waste in the local community's drinking water, even if doing so is legal and more profitable than alternatives. This is because the employees will inevitably live in the affected community and have to answer for the company's behavior to their family, friends, and neighbors.

Community building and service

As discussed previously, a goal of humanistic engineering is to reduce the risk to individuals trying to make larger and significantly more powerful, organizations behave humanistically. Thus, there is a real need for supportive and protective infrastructure. Fortunately, there are existing organizations that could serve this purpose. Most engineers belong to professional organizations: collective groups (which usually charge dues from membership) with the purpose of advancing particular professions. Such organizations do perform a number of good services including networking opportunities, scientific dissemination (through publications and conferences), and (in some cases) lobbying. However, these professional societies could do much more to help engineers navigate power differentials. For example, they could provide legal aid to support whistleblowers and/or help engineers who are standing up for humanistic principles or facing retribution for doing so. They could provide unemployment and job placement services to help those that lose or leave their jobs. They could use their collective weight and visibility to pressure organizations that are behaving anti-humanistically. They could use their influence to institute standards as well as author and lobby for legislation that will advance humanistic engineering perspectives, goals, and worker protections.

Finally (if necessary), they could organize strikes across disciplines to apply pressure in egregious situations.

In the short term, these sorts of efforts should be instituted within individual societies. In the long term, however, there is a significant need for a broader engineering professional society specifically charged with establishing a standard humanistic engineering code of conduct. This organization would coordinate efforts across the more specialized professional societies as needed. This would enable the exertion of more force in responses to humanistic problems.

Additional benefits

Besides the aforementioned benefits, centering engineering around humanistic principles also has the potential to address other significant problems.

Improved creativity

Despite the current emphasis on STEM education and research, we have been seeing significant declines in the rate of scientific innovation [32], [33], with increased complexity being cited as a critical factor in the slowdown [32]. Interestingly, a loss of creativity is a common, broad criticism of neoliberalism [34]. This is because the inherent complexity of everything, the pervasiveness of seemly intractable institutions, and the established market success of previous products limits people's ability to imagine alternatives.

Thus, humanistic engineering, by stepping outside of the neoliberalism perspective, has the potential to spur creativity. By focusing on systemic problems and humanistic goals, rather than technological or reactive incrementalism, new solutions and unique technologies will be developed. Innovation and creativity will also be spurred by the fact that humanistic engineering will inherently require the incorporation of new concepts from the liberal arts and humanities.

Increased entrepreneurship

Neoliberal proponents espouse the importance of entrepreneurship in driving innovation, improving people's material conditions, and growing the economy. However, under neoliberalism, entrepreneurship has been declining for more than a decade, even in the high-tech sector [35]. This seeming paradox actually makes sense in light of the complex, techcentric, technocratic, and market-based solutions favored by neoliberalism. By making products unnecessarily complex and technological, companies make it harder to develop secondary entrepreneurial markets for service, repair, modification, or remanufacture. If the original company has significant influence, they may encourage laws or adopt policies that make it illegal or a violation of warranty to do these things. Often, companies will create unique tools to perform repairs that they only make available to authorized parties or people paying them for service agreements. Finally, due to economic deregulation, any large company that perceives a new entrepreneurial effort as a threat can use its superior resources and influence within the marketplace to drive the newcomer out of business. For example, a company could refuse to do business with a customer that uses or stocks a competitor's product.

Good examples of this phenomenon can be found in the automobile industry. There used to be significant market demand for independent automobile mechanics. However, today, it is a dying industry. This is primarily due to the ever-increasing complexity of automobiles and the expense of specialized and computerized tools. Furthermore, the auto industry has been actively fighting so-called "right to repair" laws, even going so far as to release television commercials implying that allowing independent mechanics to work on cars will lead to sexual assault [67]. Other examples can be found in the tech and medical industries [68]. In the latter case, it can be very dangerous to make it difficult for customers to repair equipment that might be necessary for responding to a health crisis (such as a respirator during a respiratory infection pandemic).

By encouraging scientific creativity, we would expect humanistic engineering to push entrepreneurship in new directions. By enabling democracy in engineered products, we also expect it to encourage a host of third-party industries to grow around major innovations. Thus, humanistic engineering should stimulate entrepreneurship and facilitate its associated benefits.

Diversity

While not explicitly represented in the core principles, humanistic engineering should have a positive impact on diversity in engineering. There are several reasons for this. First, diversity and improved social outcomes are compatible with humanistic engineering's second and fourth core principles from above. Second, in STEM areas that engage with human issues more directly (like medicine), gender disparities have been closed much more effectively than they have been in engineering [36]. Thus, I suspect that a major part of the problem engineering has with diversity is a direct result of its lack of humanism. Beyond this, underrepresented minority populations have disproportionately been on the sharp end of all of the damaging trends highlighted in the introduction. Given the role that technology has played in these outcomes, it would make sense that these groups would not inherently see engineering as an uplifting or positive force in their communities. Furthermore, there have been studies that have shown that a higher percentage of minorities (as compared to nonminorities) pursue STEM for the purpose of affecting social change [37] and that the "narrow focus on decontextualized science" [38] often discourages them once they have enrolled [38], [39]. This suggests that aligning engineering with humanistic pursuits will help recruit and retain unrepresented populations. Third, humanistic engineering specifically encourages worker and population empowerment, especially as it relates to unionization and collective action. Evidence shows that labor unions have positive effects on diversity and reduce discrimination: union membership decreases racial resentment among white workers [40]; minorities often join unions explicitly for protection from discrimination [41]; and union membership generally reduces racial and gender wage gaps [41], [42], [43]. This actually makes a fair amount of sense. Unions are based on the idea that people with different backgrounds and perspectives come together in solidarity based on shared goals and interests. This ultimately helps break down barriers by giving common ground to people that may otherwise have trouble relating to each other.

In this light, humanistic engineering should both facilitate diversity within engineering and help correct discriminatory practices and outcomes across society.

Relationship to other areas of study

Elements of humanistic engineering do have precedence in engineering and design practice. This section serves to explore these connections and explain why humanistic engineering is different and why it adds necessary perspective.

HCI and human factors engineering

HCI, and human factors engineering have all made, to some extent, contributions to human-centered engineering and accessibility. HCI is, by its nature, primarily concerned with humans interacting with computers. As such, HCI largely serves the advancement and adoption of computation, not humanistic goals. Thus, when human goals and computational advancement are aligned, HCI can indeed be a humanistic undertaking. However, as we have already discussed, the technology focus generally makes such alignment difficult. Human factors engineering (my primary research discipline) is probably the closest conceptually to humanistic engineering, but with a very narrow scope. Human factors engineering is principally focused on engineering safe and effective human work. This means that human factors emphasizes the engineering of things in a human-centered way in so much that it helps people do their jobs. This inherently limits the scope of the goals that are considered and often aligns human factors engineers with management: human-centered engineering is worthwhile if it contributes to a more profitable workplace [44].[3] Importantly, both areas are marginal subdisciplines whose influence on most engineering projects only comes near the end of the design phase, when the human-centered perspective will have minimal impact on the overall project. Humanistic engineering makes human-centeredness central to **all** engineering. This is fundamentally different because it increases the scope of human-centered practice and, thus, will help ensure that a broader set of human goals are accounted for at all steps in the engineering process.

Humanitarian engineering

Humanitarian engineering [46] is a multidisciplinary application area of engineering focused on improving the condition of disadvantaged populations, particularly in response to disasters in the developing world. Humanitarian engineering falls into what I previously classified as reactive research: genuinely noble pursuits that iteratively address problems without fixing systemic causes.

[3] Safety has historically shown that it is both profitable and supported by labor [45], thus safety is an area where human factors aligns with labor, but largely for coincidental reasons.

Additionally, as an application area, humanitarian engineering is not a comprehensive reformulation of engineering the way humanistic engineering is. Humanitarian efforts will definitely be part of humanistic engineering. However, these will be conducted as part of a larger framework that attempts to correct the deep systematic problems that produced the disparities. It will also do so while avoiding the destructive implications of economic imperialism that can accompany humanitarianism.

Engineering ethics and engineering justice

Ethics has long been a part of the engineering canon. It has been a requirement of ABET accreditation since 1997 [47] and organizations like the National Society of Professional Engineers (NSPE) have adopted codes of ethics [69]. Engineering justice [48] is an education initiative that seeks to connect engineering to social justice. Both are synergistic with humanistic engineering in that all seek to broaden the perspective of engineers to include societal concerns. However, humanistic engineering is different. It expands the scope of all engineering disciplines to encompass its core principles. Furthermore, humanistic engineering is a fundamental reformulation of the discipline, not an "add-on" like both engineering ethics and justice. Additionally, despite its legacy, engineering ethics has clearly been insufficient to address the problems discussed in the introduction. There are several potential reasons for this. First, even within the established ethical codes, there are possible conflicts. Within the NSPE code, engineers are expected to both "hold paramount the safety, health, and welfare of the public" and "act for each employer or client as faithful agents or trustees." This can result in a dilemma where an engineer must choose between professional obligation and the welfare of the public. Second, engineering ethics does something that humanistic engineering explicitly seeks to avoid: putting the responsibility of organizational ethical behavior on the individual. That is, if an engineer encounters an ethical dilemma with a project, it is his or her personal responsibility to do something about it. In the NSPE code, an engineer is instructed to report up the chain of authority (the client organization, governing bodies, law enforcement, etc.) if the organization is doing something unethical. This puts the individual engineer in a very precarious situation where he/she/they can choose to either keep quiet or potentially face retribution for speaking out. In fact, there is good evidence that this relationship between engineers and employers suppresses ethical behavior in practice.

A survey of UC San Diego undergraduates found that power differentials between employees and employers were a major concern and compromise for socially conscious engineers on the job market [49]. Similarly, a survey of University of Colorado graduates found that engineers who left the profession were more likely to say they wanted a job with an "ability to contribute to society" [50]. Because engineering justice is based on the same education strategy as ethics, we expect it to have similar shortcomings. Humanistic engineering addresses the deficiencies of these areas by adopting a democratic model of power and training engineers to wield it for ethical and humanistic ends. Furthermore, by democratically empowering people with technology, humanistic engineering gives the population the power to drive society in ethical directions, taking the further burden off of individual engineers and citizens.

Design

Within the design discipline, there have been a number of advances that include human-, environmental-, and value-focused principles in products. For example, user-centered and human-centered design attempt to account for the end user and human goals [51]. Recent developments extend these concepts beyond humans to account for the environment and value frameworks [52], [53], [54]. Concepts related to worker power have also played a key role in computer-supported cooperative work and participatory design, both concerning themselves with determining how to have people work democratically towards shared goals [55], [56]. The latter specifically focuses on the importance of end-user participation in the design process and has strong roots in the Scandinavian labor movement. Universal design [57] seeks to create artifacts that are accessible and inclusive to as many people as possible. Finally, value-sensitive design [58] is an approach that incorporates stakeholder values into the design process.

All of these developments have clear roles to play in humanistic engineering. However, there are important limitations. In particular, design focuses almost exclusively on what the technology will be like, not how it will be realized. Both the what and the how are accounted for in engineering. As previously stated, how a design is made to work will be critical to the democratization and empowerment capabilities of technology. Thus, humanistic engineering adds critical considerations. Furthermore, many cooperative, democratic, and inclusive design principles are rooted in stakeholder analysis. This is meant to ensure that different perspectives are represented. This is also common practice in business, where the market-driven values of neoliberalism dominate. A good example of how this can manifest as a limitation is seen in value-sensitive design, where no specific commitment to a set of values is made [59]. As such, making money or dominating a market can be treated as values along with (or instead of) other, more humanistic principles. Thus, by attempting to specifically combat neoliberal influence in technology development, humanistic engineering makes a novel contribution.

Potential criticisms

As with any transformative idea, I expect people to be skeptical and critical of humanistic engineering. What follows are some likely criticisms, along with responses to them.

Problems outlined are bigger than engineering

One argument I have encountered when discussing the ideas in this article with colleagues is that the problems I have identified are bigger than engineering. This particular argument, is, I fear, rooted in a desire for engineers to avoid responsibility for the fact that technology has not accomplished the benefits it has promised. Engineering is the discipline that translates scientific developments into society. If science and technology are the instruments of human progress that engineers claim they are, then engineering is particularly well suited to take the lead in ensuring that the promised benefits are actually realized. That said, humanistic engineering is, prima facie, a multidisciplinary undertaking and any other disciplines that want to contribute are welcome.

Values/politics should stay out of science and engineering

The other concern colleagues have raised with me is that some individuals may not share humanistic values. Also, given the political nature of the labor power emphasis of humanistic engineering, I expect objections on the grounds that science should avoid politicization. There are two problems with these arguments. First, engineering already claims that it serves to advance the human condition. Because this ambition is not actually a fundamental part of the engineering process, reality produces divergent results. In this context, humanistic engineering is attempting to clarify the values that engineering should be pursuing (a distillation of what is already claimed), while giving it the actual ability to adhere to them. Second, I hope it is now clear, that in the absence of engineers asserting their values through their work, their work will serve the values of other powerful societal interests. Thus, there is no neutral position. Engineering work will always support ideological and political perspectives. Humanistic engineering offers us the ability to take agency over the values asserted by our work so that it can be used for real good.

All of this is not to say that humanistic engineering supports indoctrination. Should any engineers choose to forgo upholding the standards of humanistic engineering, there will be no enforcement that strips them of credentials, blacklists them from the profession, or otherwise "cancels" them. Such practices are authoritarian and run contrary to humanistic engineering's perspectives on democracy and empowerment. There are, and likely always will be, enormous opportunities for those who choose to forgo civic responsibility to support the interests of the moneyed and powerful. Humanistic engineering will simply give those of us who wish to take a different course more opportunities to do so.

Closing remarks

Over the last few years, there has been a significant increase in labor organizing. This applies not just to the working class, but also to tech and gig economy workers. Worker organization, unionization, and strike efforts have occurred at Kickstarter, Instacart, Amazon, Google, and Uber as well as with public education teachers, auto workers, Starbucks baristas, and even university graduate teaching assistants. In fact, 2018 saw the most workers involved in strikes since 1986, 2019 had more labor work stoppages than any other year in the last decade, and 2021 saw the initiation of 16 major work stoppages [60], [61], [62].

All of this is to say that there is a clear desire in the engineering community and a larger labor force for education, tools, and infrastructure for democratic organizing and action. Thus, humanistic engineering would likely be positively received by engineers and the public.

I recognize that humanistic engineering is potentially controversial and could run up against very powerful moneyed and political interests. We, engineers, need to decide who we work for. Are we courtiers and sycophants for the powerful or do we serve humanity more broadly? Doing the right thing is noble not because it is easy, but because it is hard and requires personal risk and sacrifice. That said, we engineers do have power. Our countries are dependent on the economic growth and stability facilitated by the technology that we discover and design. Those of us in education train the workforce that designs the technology. We (at least for now) are difficult to replace because of the extensive, technical, specialized training required to be a successful engineer. Because we currently hold these positions, we collectively have the ability to negotiate the terms under which we deliver our services.

Ultimately, I am looking for like-minded people and organizations who are interested in working to make humanistic engineering a reality. With contemporary engineering emphasizing robotics and AI, more skilled works will be automated away, labor reductions will continue to concentrate wealth upward, and people's lives will be more surveilled and monetized. Humanistic engineering is genuinely transformative and convergent and will give engineers the skills and infrastructure to address these pathologies, push engineering in creative directions, empower the populous, and achieve a happier, healthier, fairer, and more democratic future. ■

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Matthew L. Bolton is an associate professor at the Department of Engineering Systems and Environment, University of Virginia, Charlottesville, VA, USA. His research focuses on the use of human performance modeling and formal methods in the design and analysis of safety-critical systems. Bolton has a PhD in systems engineering from the University of Virginia. He is a Senior Member of IEEE.

■ Direct questions and comments about this article to Matthew L. Bolton, Department of Engineering Systems and Environment, University of Virginia, Charlottesville, VA 22903 USA; mlb4b@virginia.edu.