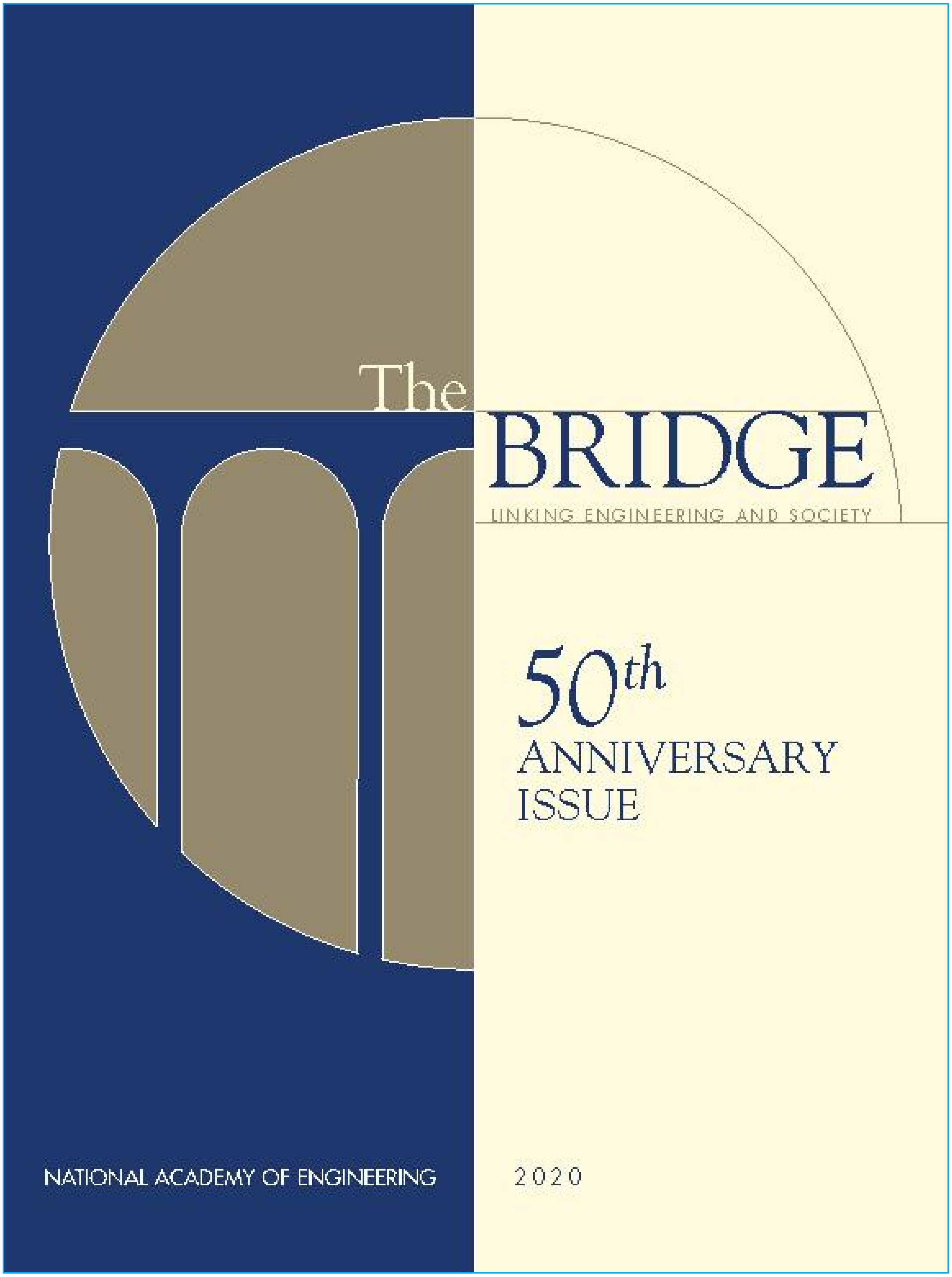

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The Bridge: 50th Anniversary Issue

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This special issue celebrates the 50th year of publication of the NAE's flagship quarterly with 50 essays looking forward to the next 50 years of innovation in engineering. How will engineering contribute in areas as diverse as space travel, fashion, lasers, solar energy, peace, vaccine development, and equity? The diverse authors and topics give readers much to think about! We are posting selected articles each week to give readers time to savor the array of thoughtful and thought-provoking essays in this very special issue. Check the website every Monday!

President's Perspective: Unintended Consequences

MONDAY, JANUARY 11, 2021

AUTHOR: JOHN L. ANDERSON

John L. Anderson, President, NAE

In theory there is no difference between theory and practice, while in practice there is.[1]

The intention to "do good" is not always realized in the engineering of artifacts, processes, and systems. Innovations have led to many improvements in health, security, and quality of life, but in some cases there have been serious unintended consequences.

A current example of the double-edged sword of technology is social media. While global society has benefited from connectedness and instantaneous communication, malevolent activities such as terrorism and cyber-bullying have proliferated. With any new technology there is a potential for both good and bad uses, and sometimes there is collateral damage that is difficult to predict.

One source of unintended consequences lies in design flaws. As **Henry Petroski** notes, "Everything designed by human beings is potentially flawed."[2] This is especially relevant to designs involving human-machine interactions or the way the designed artifact interacts with the environment. As an example of the latter problem, Petroski cites the unintended consequences of buildings designed with polished stainless-steel façades, which reflect sunlight in a harmful way into adjacent buildings. While such flaws can usually be corrected after the fact, they result in lost time, money, and often credibility.

Some unintended consequences have lasting effects. Thomas Midgley is credited with the development of two important innovations in the first half of the 20th century that were initially beneficial to society but later proved detrimental to human health and the planet's sustainability.[3],[4] The first was tetraethyl lead (TEL), a compound he and colleagues discovered that greatly reduces "engine knock" and improves fuel efficiency. TEL was so successful commercially that it spawned a new company, Ethyl. Although it was known that lead is toxic to animals, the US Bureau of Mines concluded that the product could be manufactured in a way safe for the workers. Unfortunately, little thought was given to the build-up of lead in the environment resulting from vehicle exhaust fumes. Most Americans who were tested showed elevated levels of lead in their blood after the introduction of TEL, and by the 1980s leaded gasoline was phased out of production.[4]

Midgley's second invention was dichlordifluoro-methane (Freon), the first commercial CFC, which replaced other refrigerants such as ammonia. The chemical inertness and lack of toxicity made Freon an ideal substitute for other, corrosive and toxic refrigerants, and it also found use as a gas carrier in spray cans. At a meeting of the American Chemical Society in 1930, Midgley made a dramatic demonstration of the safety of Freon by inhaling the gas and then exhaling over a lighted candle to extinguish the flame, thus demonstrating its inertness (noncombustibility) and lack of toxicity (Midgley lived).[4] Freon looked like a win-win for all, until CFCs were implicated in thinning the planet's ozone layer.[5]

These and other examples demonstrate that engineers should seriously consider potential impacts of a design or invention on individuals, society, and nature. The connection between engineering and society should be tighter than it is. Could a new technology cause harm to segments of the population and widen the gap between the haves and have-nots? Is there racial or ethnic bias in the algorithms we are developing for artificial intelligence and automated systems? Could a new product damage the environment, or negatively affect the way humans interact?

Some unintended consequences are foreseeable. In retrospect, it should have taken little imagination to realize that curved, reflective surfaces concentrate light and heat. Yet the famed architect Rafael Viñoly designed two buildings that created what some called "death rays" across public spaces under certain conditions, resulting in costly remediations.[6]

As we look to the future, engineers should accept responsibility for incorporating the consideration of possible unintended consequences into their work and seeking to minimize the possibility of their occurrence. The National Academy of Engineering will contribute in at least two ways. The NAE Program Office has a new initiative on Cultural, Ethical, Social, and Environmental Responsibility in engineering (CESER); one of its goals is to focus on avoiding the unintended consequences of engineering innovation. And the NAE annual meeting will feature a special lecture on engineering and society.

Because engineers want to improve society through technology, we must first understand both the needs and the vulnerabilities of society, including the sustainability of our planet.

It is not enough to state the obvious: any new technology can result in harmful effects or be put to bad uses. Our responsibility as engineers is to anticipate and minimize these unintended consequences.

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[1] Brewster B. 1881. Quoted in the Yale Literary Magazine 47(416):202.

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[3] Leslie SW. 1980. Thomas Midgley and the politics of industrial research. Business History Review 54(4):480–503.

[4] McNeill JR. 2000. Something New Under the Sun: An Environmental History of the Twentieth-Century World. New York: W.W. Norton & Company.

[5] Molina MJ, Rowland FS. 1974. Stratospheric sink for chlorofluoromethanes: Chlorine atom-catalysed destruction of ozone. Nature 249:810–12.

[6] Taylor-Foster J. 2013. Seven architectural sins committed around the world. ArchDaily, Sep 13.

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