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DAKOTA DIGITAL ACADEMY
NORTH DAKOTA UNIVERSITY SYSTEM

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DAKOTA DIGITAL REVIEW

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Introduction to the
DAKOTA DIGITAL ACADEMY

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After our founding last fall, the Dakota Digital Academy continues to gain traction with faculty and administrators across the North Dakota University System (NDUS). Thanks to the vision of Chancellor Mark Hagerott, there is much Dakota Digital Academy activity around designing and developing courses in the digital arena, configuring certificates and programs, creating partnerships and planning events. This activity responds to the need for relevant training and education to serve learners and employers.

We are ambitious and on track to accomplish a great deal in our state. We are committed to fostering access, opportunity, enfranchisement, inclusion and diversity. We believe in collaboration. Among Dakota Digital Academy's challenges is establishing synergy among the diverse NDUS institutions. With two research universities, four regional universities and five colleges, there are considerable differences in orientations, types of expertise and capacities. As well, the Dakota Digital Academy recently entered into agreements with the state's five tribal colleges, which adds significantly to the system's scope. At the Dakota Digital Academy, we view the differences among institutions as sources of opportunities and strengths to celebrate.

The ongoing pandemic is one of the most life- and work-altering events in our history. This coronavirus has forced a large-scale normalization of remote work and school, including mandating how the Dakota Digital Academy as an organization must function. Going forward, if most tasks can be accomplished remotely and most production processes are done by robots, will gender inequality and racism diminish?

North Dakota is a very rural state. The Dakota Digital Academy is committed to location-agnostic operations. As broadband becomes more available and residents adjust to technologies—such as tools for remote collaboration, video conferencing and virtual reality—people may feel that if everyone in their organization is remote, then nobody feels remote.

Dakota Digital Academy's mission is very opportune in our state. There are many people whose jobs are impossible to do from home, and they are now faced with unemployment and a need to reinvent their work lives. For example, about 110,000 restaurants nationwide closed in 2020, leaving many employees without work.

If the future is basically digital, what happens to the people left behind? We see a pressing need for training and education in many areas of computing and cyber sciences, including coding, information technology, cybersecurity and artificial intelligence. Important application areas, such as energy and agriculture, have increasingly become digital enterprises. In terms of programs, the Dakota Digital Academy is actively working beyond cybersecurity and software development into these application areas.

The need for upskilling and retraining is also very real. Dakota Digital Academy is committed to helping meet those needs.

Introduction to DAKOTA DIGITAL REVIEW

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The cartoonist Walt Kelly said it best, "We are confronted with insurmountable opportunities." What sorcerer or ancient magician could have imagined what we take for granted today: video conferencing across continents, texting at 30,000 feet on a jet liner, data mining, robotic surgery. And this is just the beginning. Digital wonders we can't envision yet will delight us and perform seeming miracles for the good of humanity.

As cyber technologies become increasingly ubiquitous, however, their penetration into our personal, family, professional and social lives is accelerating, and their influence is growing. In response, DDA will offer courses in the profound social, ethical, legal and policy implications of the cyber sciences.

To amplify DDA's systemwide approach across 11 colleges and universities, and to engage and educate the general public, DDA now presents Dakota Digital Review, which is being published both in print and online.

Dakota Digital Review will cover the cyber sciences, as well as related legal, political, regulatory, social and ethical issues, and digitization's impact on the humanities and the arts.

In addition to creating opportunities, digital technologies pose serious challenges: cybersecurity hacks by enemy nation states disrupting corporations, government agencies and even, last December, one of the world's largest cybersecurity firms; the massive transfer of power and wealth from small and analogue businesses to Big Tech companies as result of lockdown responses to COVID-19; blatant censorship by Big Tech that threatens free speech and the foundations of democracy; disinformation campaigns and election integrity; privacy and surveillance concerns; artificial intelligence (AI), automation and job loss; rural broadband, especially when students must take classes from home.

Dakota Digital Review is written and edited for the general educated reader. It is vitally important that residents throughout the region—whether working in government or business, or who are retired—become fluent and engaged in cyber sciences and their ramifications.

Articles are written mostly by faculty and students but not to promote their universities. Instead, higher education's intellectual resources are being mobilized statewide to better serve both within and beyond the academy.

Dakota Digital Review aims to elevate discussions and debates about digitization, facilitating better preparation of government and business, parents, students and voters to make crucial decisions about our collective future and about our individual and family lives.

A note of appreciation is due to Jerry Anderson who does the photography, graphic design and layout for Dakota Digital Review. The same is due to Kay Cox who designed and masters the Dakota Digital Academy website (dda.ndus.edu), where access to our courses and this magazine is available.

Digitization & Energy Dependency

The Need for Affordable, Accessible Energy

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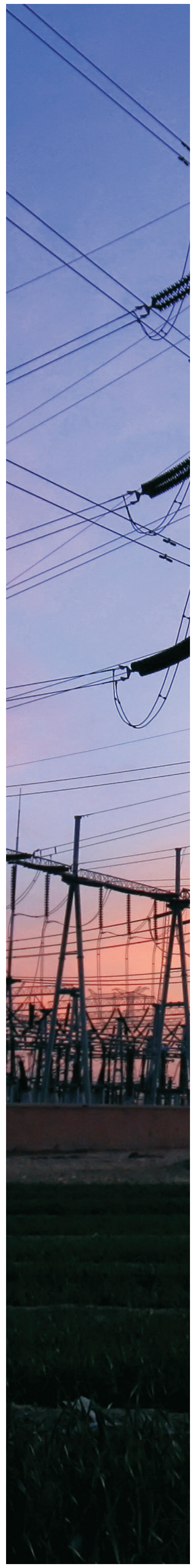
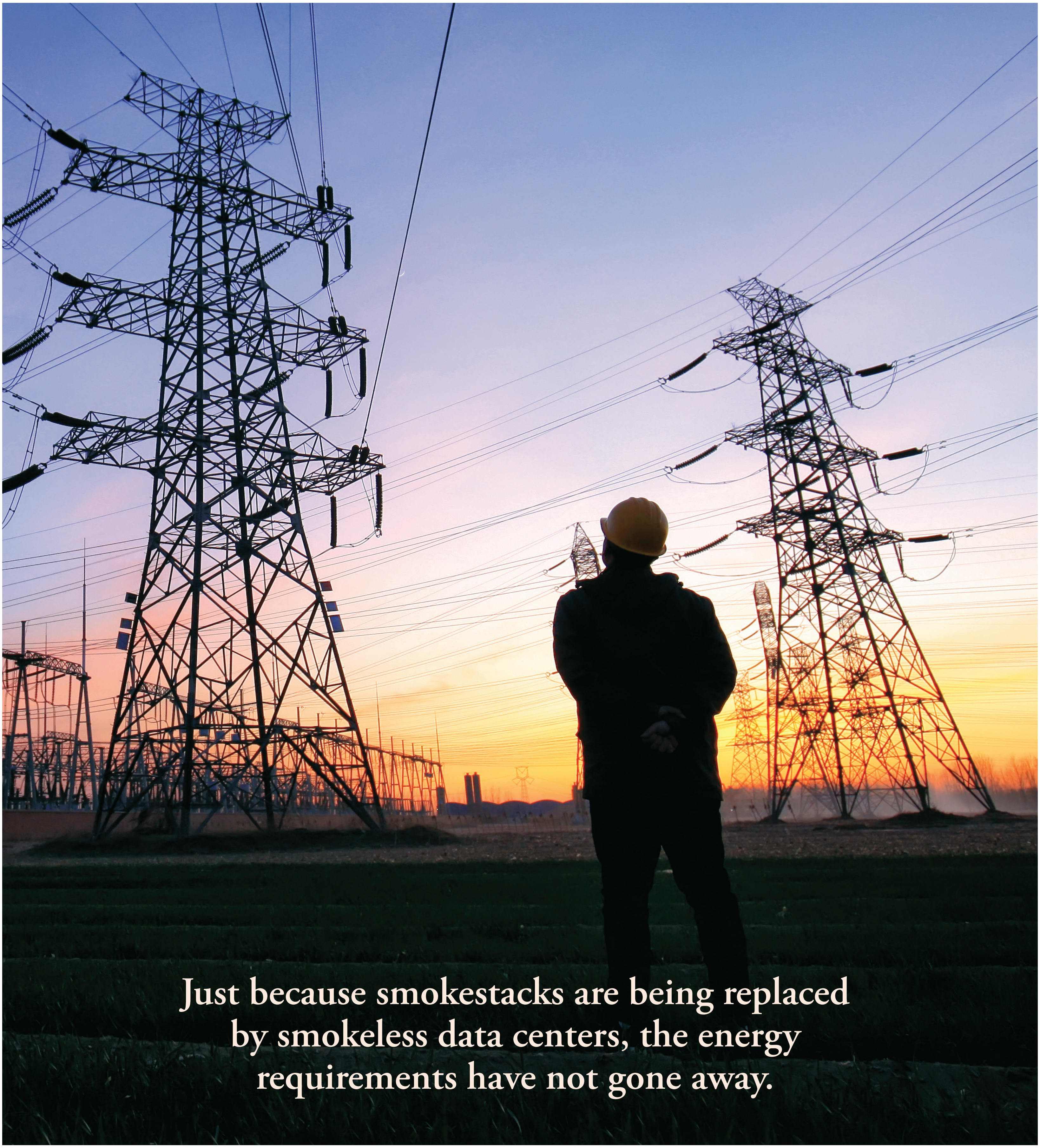
Former Chief Engineer
CGN-25 Dual Reactor Plant

As residents of a top energy producing state, now adapting to the massive digital transformation of our socio-economy, it is important that we understand the role of affordable and accessible energy in creating the digital economy of today and the future. Some people might think that a growing digital economy and increased social interaction through digital media have few if any energy dependencies. But this is not the case. While many readers might be familiar with the story of energy and industrialization in the 19th and 20th centuries, they might be uncertain of the relationship of the triad of energy, information and, in particular, digitization.

While this triad is different than the relationship between energy and industrialization, energy still plays a key role in the 21st century. The share of heavy industry nationwide, replete with smokestacks belching into the atmosphere, has decreased significantly than at its peak in the previous century. Just because smokestacks are being replaced by smokeless data centers, the energy requirements have not gone away. A closer look at the power meter will show the absolutely critical role that accessible and affordable energy plays in economic growth, both in our nation's history and in the future, as we digitize much of our economy and society. Access to affordable and reliable energy will be a key enabler of digital-driven economic growth in North Dakota and our region.




Just because smokestacks are being replaced
by smokeless data centers, the energy
requirements have not gone away.

A brief review of the key role of energy in economic (and military) history helps to place the present and future in context. Energy makes the world go around, quite literally. But also, without access to affordable energy, societies have declined, economies withered and battles were lost. Energy has always been necessary for life. In ancient history, it was agriculture that yielded biomass forms of energy that powered early economies, which relied on mass human (slave) labor and large animals (think: horses and oxen). Those early militaries relied on biomass to power legions of soldiers, cavalry and, at sea, human-powered galley fleets.

Then the forms of energy began to change. Not long after North America was colonized by Europeans, even before the Industrial Revolution, access to non-bio, water energy was key to economic growth. The access to water energy and the power provided via water mills largely determined the location of what would become major cities. A quick glance at the East Coast of the United States reveals that a significant number of the major colonial cities were located on the "fall line," where streams and rivers provided waterpower for grinding mills, and rivers dropped to sea level. Baltimore and Washington, D.C., are great examples of the early role of waterpower. But closer to North Dakota is the example of the Twin Cities. Perhaps only our great grandparents recall that it was the abundance of waterpower of the rivers that led to the explosive growth of Minneapolis and St. Paul. Abundant waterpower drove the massive grain grinding mills, some of which remained water-powered until the 1930s.

But the abundance of energy becomes even more important as our nation industrialized: Increasing amounts of energy rich coal and refined oil powered the first steam ships, and then factories, railroads, Edison power plants, Ford automobiles and eventually aircraft. Affordable, accessible energy literally powered America into the Industrial Age. Moreover, it was American energy supplies—the world's largest oil fields at the time—that proved crucial to victory in the Second World War, when Japan went to war in part over oil fields, and Germany attacked Africa and southern Russia in attempts to obtain more energy supplies.

Today, the world is in the midst of a massive digital transformation of society, including culture, the economy and the military. Some digital enthusiast might argue that the digital world can flourish without a diversified, affordable energy supply and related industries. But theory, history, and recent data prove that reality is quite different. There was indeed a time when scientists and philosophers pondered the relationship between energy and information, and some thought information was "free." In the early 19th century, Nicolas Carnot was among the first to develop concepts of heat (hence the name, Carnot Cycle), which led eventually to theories of what we now call thermodynamics. Scientists understood mechanical energy and work, concluding that total energy (and later mass) could not be destroyed, only converted.

But the conundrum of information was left unresolved. Did it, information, fall under the same rules of thermodynamics? A famous scientist, James Maxwell, who also predicted the existence of radio waves three decades before their discovery, speculated that information existed by magic, or by what became known as "Maxwell's Demon," defying the rules of thermodynamics. But the "demon" of energy-free information did not live long. By the 1920s, as the information machines began to move beyond the human brain to the manual cash register and manual typewriter, to electrical machines powered through transmission lines, scientists proved that information was indeed energy dependent and ruled by the laws of thermodynamics, just like everything else in the universe.

Yet even after theorists proved that information wasn't "magic" or "free," there were many who believed that an information economy would be highly efficient, requiring relatively little energy. Part of this belief was predicated on the idea that computers would remain few in number (one business executive predicted in the 1950s that the U.S. might only need three large main-frame computers; one Navy study predicted that the fleet would only need one ship to carry "the computer"). As late as 1995, leading computer company executives thought the internet was something of a fad. With low expectations as to

Only with a robust energy industry can we have access to affordable, reliable energy, which in turn will allow of us, rich and poor, to be able to enjoy the benefits of a digitizing world.

the number of computers and digital devices, energy would not have been a major factor in a future of advanced digital devices. But our digitizing world is looking very different from these early predictions. Literally trillions of digital machines now exist, and all need power.

In the emerging Digital Age, we can see with our own eyes the massive demands of digital machines on accessible, affordable energy. The almost certain proliferation and growth in numbers of our wonderful digital machines means even more energy consumption, not less. We now observe massive, city block-sized data centers proliferating across the country, which consume megawatt upon megawatt to keep the internet online and accessible. Amazon not only has massive data centers but warehouses full of robots and computers, which also require electrical power as they replace workers who eat biomass. While poker games at one time required no more energy than for the human players to deal a deck of cards, our online games are massive energy consumers. One data point may surprise the reader, reported by the Institut Mines-Télécom in a May 2020 report: "In California, online gambling already consumes more than the power required for electric water heaters, washing machines, dishwashers, clothes dryers and electric stoves."[i]

But on top of general internet traffic, gaming and robots, we can't neglect the rapidly growing energy needs of digital currency. By some estimates, maintaining Bitcoin alone requires a national energy grid. The University of Cambridge Bitcoin Electricity Consumption Index,[ii] according to Quartz magazine, reported that "the global bitcoin network currently consumes more about 80 terawatt-hours of electricity annually, roughly equal to the annual output of 23 coal-fired power plants, or close to what is consumed by the nation of Finland."[iii] And Bitcoin is just one of many digital currencies.

History, theory and now the consumption data prove, beyond a doubt, that access to affordable, reliable energy, preferably from a diversified range of producers, will be essential for our state, region and nation to flourish in the Digital Age. It is imperative that big digital companies, the federal government and the American people come to value and support the energy industry. If energy is too costly, only the wealthy will be able to enjoy our electric-powered digital machines. Only with a robust energy industry can we have access to affordable, reliable energy, which in turn will allow of us, rich and poor, to be able to enjoy the benefits of a digitizing world. ▣

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[i] Fabrice Flipo, "The Worrying Trajectory of Energy Consumption by Digital Technology," Institut Mines-Télécom, May 2, 2020, https://imtech.wp.imt.fr/en/2020/05/28/the-worrying-trajectory-of-energy-consumption-by-digital-technology/.

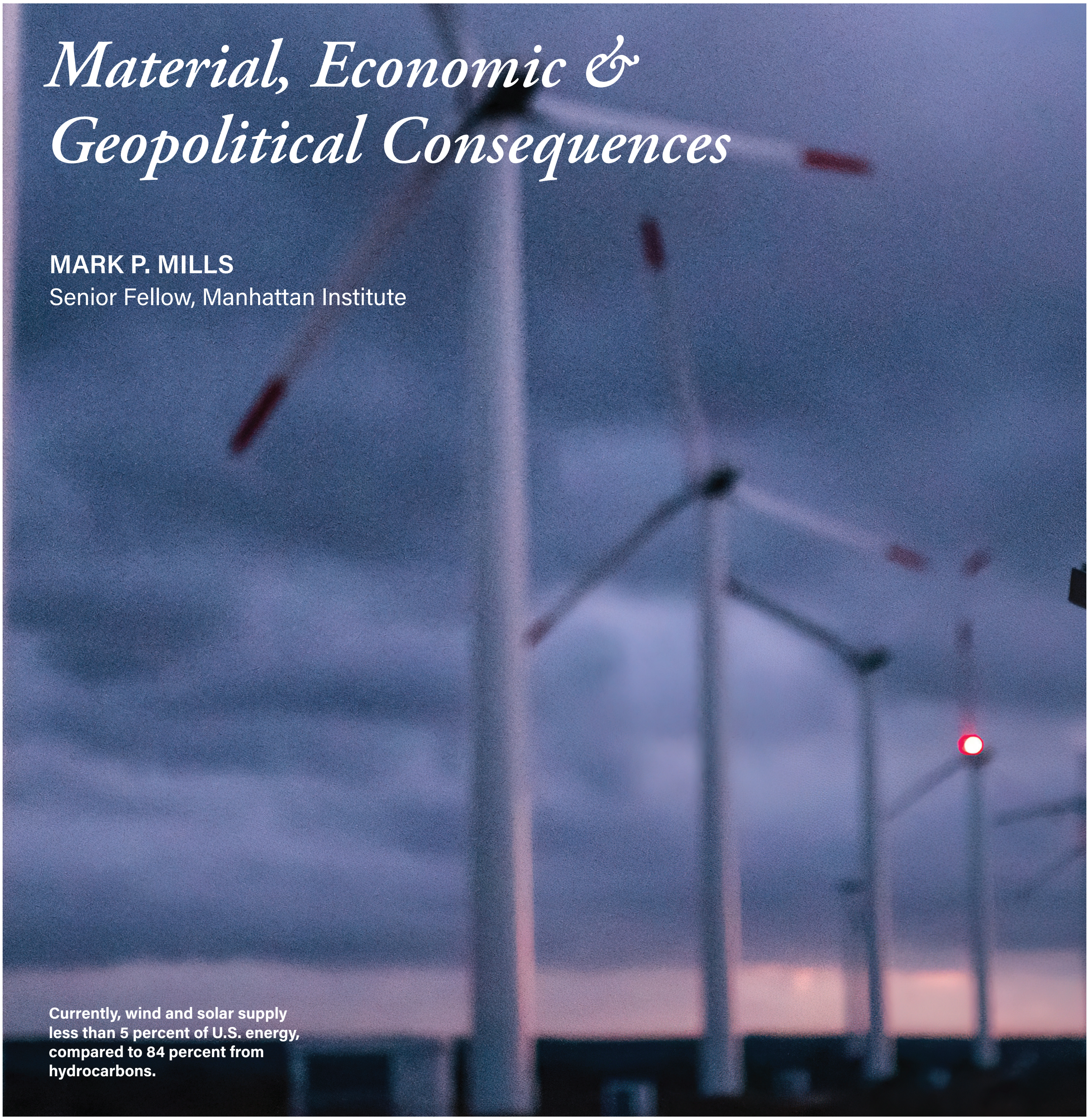
[ii] Cambridge Bitcoin Electricity Consumption Index, https//:cbeci.org.

[iii] Amanda Shendruk and Tim McDonnell, "How Much Energy Does Bitcoin Use?", Quartz magazine, June 25, 2021, https://qz.com/2023032/how-much-energy-does-bitcoin-use.

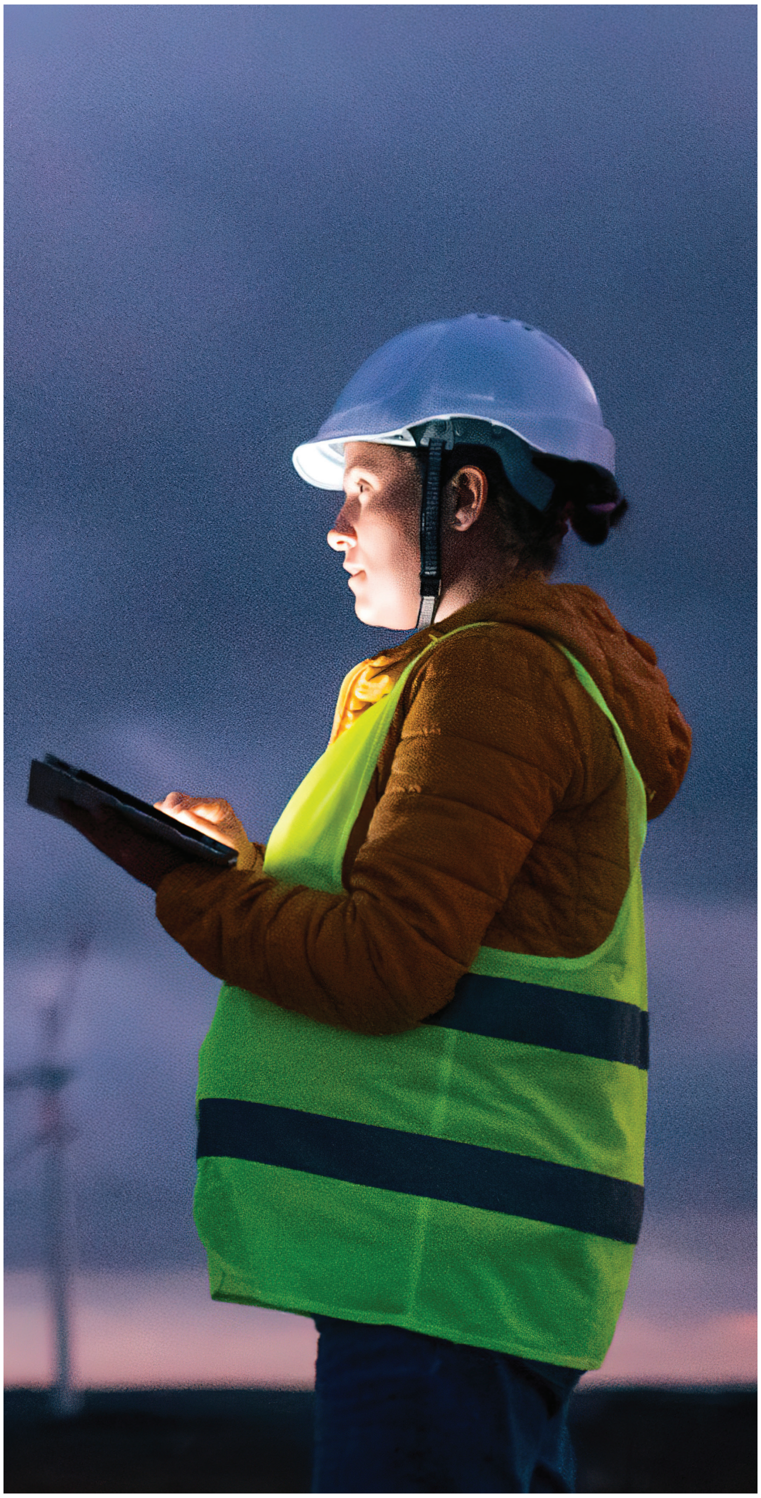
The Hidden Costs of Going Green

Material, Economic & Geopolitical Consequences

MARK P. MILLS
Senior Fellow, Manhattan Institute



Currently, wind and solar supply less than 5 percent of U.S. energy, compared to 84 percent from hydrocarbons.



In February 2021, I testified before committees in both the U.S. House and Senate regarding the costs and consequences of replacing the current level of hydrocarbon energy production with wind, solar energy and batteries. Then, in May, the International Energy Agency (IEA), the world's pre-eminent source of energy information for governments, published a report, "The Role of Critical Minerals in Clean Energy Transitions,"[i] which supports, in extensive detail, my view that this transition cannot be accomplished anytime soon, that it certainly won't be "clean," and that it presents serious geopolitical risks.

To frame my testimony, let me synthesize my introductory remarks to the Congressional committees, which bookend the following presentation.

The increasing use of wind and solar machines is inevitable, even without subsidies, in large measure because of the enormous scale and growth in world demand for energy. Despite significant improvements in energy efficiency in the coming decades, the ongoing digital transformation of society and the economy will alone stimulate more energy demand in America and worldwide—especially in nations with large populations, such as India and Brazil, with fast-growing middle classes that are reaching technological maturity.

Currently, wind and solar supply less than 5 percent of U.S. energy, compared to 84 percent from hydrocarbons. To replace hydrocarbons would entail daunting economic, environmental and geopolitical challenges. While the current federal administration proposes spending $2 trillion on climate programs across seven domains,[ii] restructuring the electric grid alone would require $5 to $6 trillion in wind/solar and battery systems to replace *existing* hydrocarbon generation.[iii]

To accomplish this by 2035 would require a *continuous* construction program at least 600 percent bigger than any *single peak* year for utility construction that has occurred in the U.S., China or Germany over the past half-century.[iv] True this would create jobs. However, since the final product remains unchanged but uses more labor and capital, in economic terms, this is the complete inverse of increasing productivity. And, as is widely acknowledged, raising productivity is the single most important feature of an economy that expands overall wealth for citizens.

On top of that, there would need to be an enormous expansion of the grid if a significant share of cars shifts from oil to electricity.[v] In the end, it bears noting the outcome: ***Even if a "zero carbon" U.S. grid could be built, it would reduce global carbon emissions by less than 6 percent.***[vi]

Grid restructuring and accelerating electric car deployment also means exporting jobs and offshoring environmental consequences. Some 90 percent of solar panels are imported, as are 80 percent of the key components for wind turbines.[vii] Asian companies dominate global battery production and account for 80 percent of all planned factories.[viii] Even if we expand domestic manufacturing, our import dependencies remain for critical energy minerals.

On average, per unit of energy delivered, the quantity of materials extracted from the earth and processed for "clean tech" is 500 to 1,000 percent greater than with hydrocarbons.[ix] And, as it stands today, Chinese firms dominate the production and processing of many critical rare earth elements, and nearly all the growth in mining is expected offshore, increasingly in fragile, biodiverse wilderness areas.[x] More mining can be done in an environmentally responsible way, but so far there's little evidence of support for opening new mines in America.

The Material Cost of "Clean Tech"

The materials extracted from the earth to fabricate everything, including wind turbines, solar panels and batteries (to store grid electricity or power electric vehicles) are typically out of sight, located at remote mine sites and mineral-processing facilities around the world. Those locations matter in terms of geopolitics and supply-chain risks, as well as in general environmental terms and in the accounting of carbon dioxide emissions. The scale of the material demands for building "clean tech" machines is, for many, surprising.

For example, replacing the energy output from a single 100-MW natural gas-fired turbine, itself about the size of a residential house (producing enough electricity for 75,000 homes), requires at least 20 wind turbines, each one about the size of the Washington Monument, occupying some 10 square miles of land.[xi] Building those wind machines consumes enormous quantities of conventional materials, such as concrete, steel and fiberglass, along with less common materials, including "rare earth" elements such as dysprosium. A World Bank study noted what every mining engineer knows: "[T]echnologies assumed to populate the clean energy shift … are in fact significantly more material intensive in their composition than current traditional fossil-fuel-based energy supply systems."[xii] The new IEA report mentioned at the outset makes the same observation.

All forms of renewable energy require roughly comparable—and enormous—quantities of materials in order to build machines that capture nature's flows: sun, wind and water. Wind farms come close to matching hydro dams in material consumption, and solar power requires even more. In all three cases, the largest share of the tonnage is found in the use of conventional materials like concrete, steel and glass. Compared with a natural gas power plant, all three require at least 10 times as many total tons mined, moved and converted into machines to deliver the same quantity of energy.[xiii]

For example, building a *single* 100-MW wind farm—never mind thousands of them—requires some 30,000 tons of iron ore and 50,000 tons of concrete, as well as 900 tons of non-recyclable plastics for the huge blades.[xiv] With solar hardware, the tonnage in cement, steel and glass is 150 percent greater than for wind for the same energy output.[xv]

If episodic sources of energy (wind and solar) are to be used to supply power 24/7, even greater quantities of materials will be required. One needs to build additional machines, roughly two to three times as many, in order to produce and store energy when the sun and wind are available for use at times when they are not. Then there are the additional materials required to build electricity storage. For context, a utility-scale storage system sufficient for the above-noted 100-MW wind farm would entail using at least 10,000 tons of Tesla-class batteries.

The handling and processing of such large quantities of materials entails its own energy costs as well as associated environmental implications. But first, the critical supply-chain issue is not so much the increase in the use of common (though energy-intensive) materials such as concrete and glass. The key challenge for the supply chain and the environment reside with the need for radical increases in the quantities of a wide variety of so-called "energy materials."

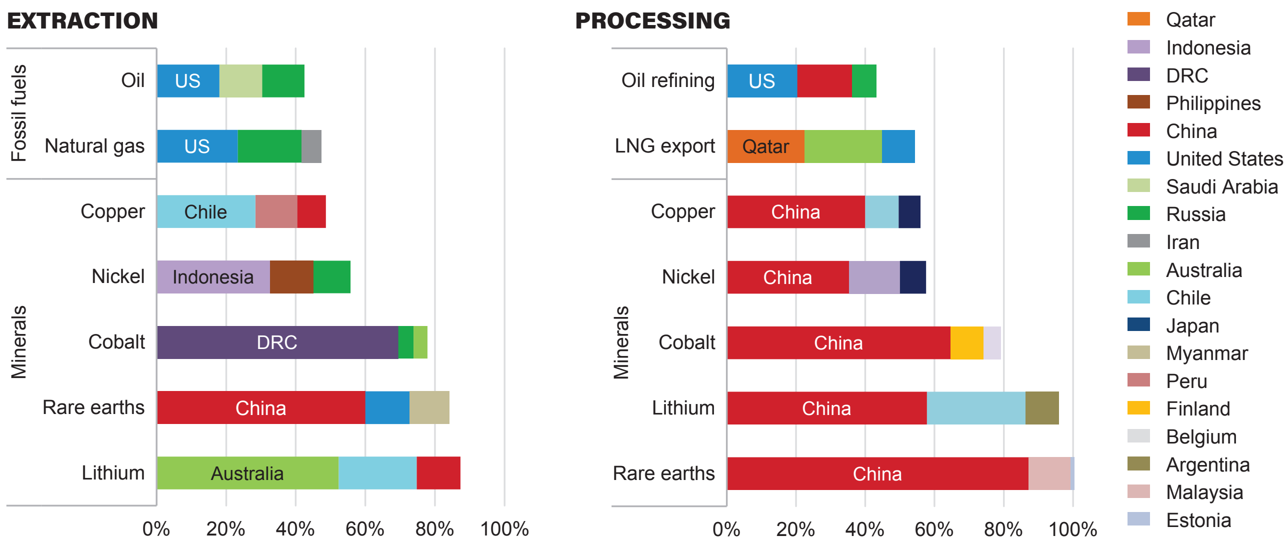
The world currently mines about 7,000 tons per year of neodymium for example, one of numerous key elements used in fabricating the electrical systems for wind turbines. Current clean-energy scenarios imagined by the World Bank (and many others) will require a 1,000 to 4,000 percent increase in the neodymium supply in the coming several decades.[xvi]

Where there are differing underlying assumptions used in various analyses of mineral requirements for green energy, all reach the same range of conclusions. For example, the mining of indium, used in fabricating electricity-generating solar semiconductors, will need to increase as much as 8,000 percent. The mining of cobalt for batteries will need to grow 300 to 800 percent.[xvii] Lithium production, used for electric cars (never mind the grid), will need to rise more than 2,000 percent.[xviii] The Institute for Sustainable Futures at the University of Technology Sydney last year analyzed 14 metals essential to building clean-tech machines, concluding that the supply of elements such as nickel, dysprosium and tellurium will need to increase 200 to 600 percent.[xix]

The implications of such remarkable increases in the demand for energy minerals have not been entirely ignored, at least in Europe. A Dutch government-sponsored study concluded that the Netherlands' green ambitions alone would consume a major share of global minerals. "Exponential growth in [global] renewable energy production capacity," the study noted, "is not possible with present-day technologies and annual metal production."[xx]

Geographic Production of Energy Transition Minerals

Share of top three producing countries in production of selected minerals and fossil fuels, 2019



Notes: LNG = liquefied natural gas;The values for copper processing are for refining operations.
Sources: IEA (2020a); USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020).

Satellite view of Bayan Obo, the world's largest rare earths mine in Baotou, Inner Mongolia, China. Since the late 1990s, China has been responsible for most global extraction and processing, and the Bayan Obo mine accounted for 45 percent of world production in 2005. Previously, California's Mountain Pass Mine was the single biggest rare earths producer and considered one of the world's highest quality deposits. In 2002, the mine suspended operation as China flooded the market with rare earth elements well below market prices. The Mountain Pass Mine resumed operation in January 2018. *Credit: European Space Imaging*

Behind the Scenes: Ore Grades & "Overburden"

The scale of these material demands understates the total tonnage of earth that is necessarily moved and processed, all of which requires the use of energy-consuming machines and processes. Forecasts of future mineral demands focus on counting the quantity of refined, pure elements needed—but not the overall amount of earth that must be dug up, moved and processed.

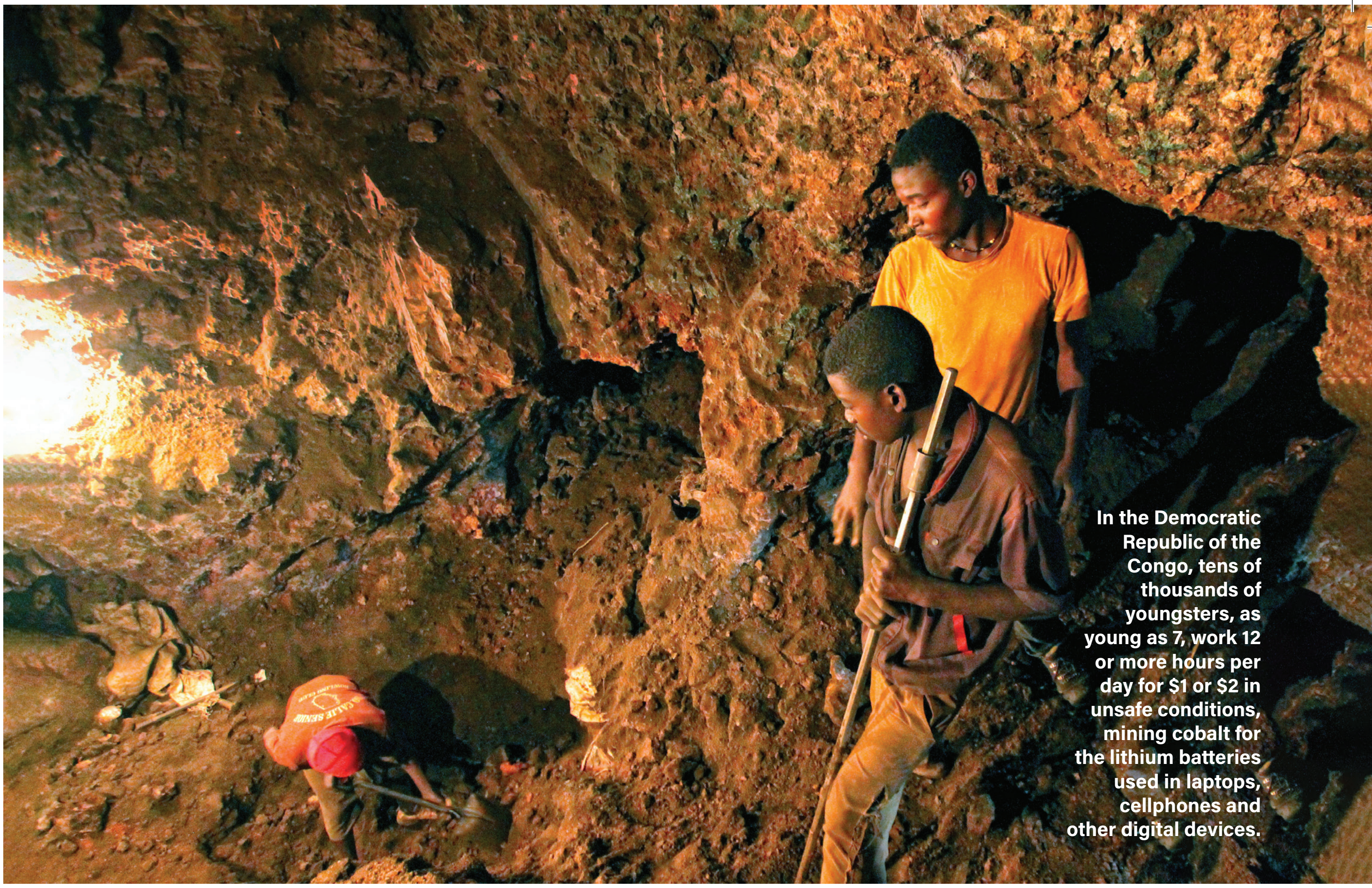
For every ton of a purified element, a far greater tonnage of ore must be physically moved and processed. That is the reality for all elements, expressed by geologists as an ore grade: the percentage of the rock that contains the sought-after element. While ore grades vary widely, copper ores typically contain about a half-percent, by weight, of the element itself: thus, roughly 200 tons of ore are dug up, moved, crushed and processed to get to one ton of copper. For rare earths, some 20 to 160 tons of ore are mined per ton of the element.[xxi] For cobalt, roughly 1,500 tons of ore are mined to get to one ton of the element.

In the calculus of economic and environmental costs, one must also include the so-called overburden—the tons of rocks and dirt that are first removed to get access to the buried mineral-bearing ore. While overburden ratios also vary widely, it is common to see three to seven tons of earth to get access to one ton of ore.[xxii]

For a snapshot of what all this points to regarding the total materials footprint of the green energy path, consider the supply chain for a single electric car battery, which in final form weighs about 1,000 pounds.[xxiii] Providing the refined materials needed to fabricate a single EV battery requires the mining, moving and processing of more than 500,000 pounds of materials somewhere on the planet.[xxiv] That's 20 times more than the 25,000 pounds of petroleum that an internal combustion engine uses over the life of a car.

> *Providing the refined materials needed to fabricate a single EV battery requires the mining, moving and processing of more than 500,000 pounds of materials somewhere on the planet.*

The core issue here for a green energy future is not whether there are enough elements in the earth's crust to meet demand; there are. Most elements are quite abundant, and nearly all are far more common than gold. Obtaining sufficient quantities of nature's elements, at a price that markets can tolerate, is fundamentally determined by the technology and access to the land where they are buried. The latter is mainly about government permissions.



In the Democratic Republic of the Congo, tens of thousands of youngsters, as young as 7, work 12 or more hours per day for $1 or $2 in unsafe conditions, mining cobalt for the lithium batteries used in laptops, cellphones and other digital devices.

However, as the World Bank cautions, the materials implications of a "clean tech" future creates "a new suite of challenges for the sustainable development of minerals and resources."[xxv] Some minerals are difficult to obtain for technical reasons inherent in the geophysics. It is in the underlying physics of extraction and physical chemistry of refinement that we find the realities of unsustainable green energy at the scales that many propose.

Sources of Minerals: Conflicts and Dependencies

The critical, and even vital, roles of specific minerals have long been a concern of some analysts and various government commissions over the years. One can trace a straight line from an electric car to Inner Mongolia's massive Bayan Obo mines (for rare earths) and to mines in the Democratic Republic of Congo (for cobalt in batteries). Both of those regions represent the world's largest supply of rare earths and cobalt, respectively.[xxvi]

Politically troubled Chile has the world's greatest lithium resources, although stable Australia is the world's biggest supplier. Elsewhere in the battery supply chain, Chinese cobalt refiners have quietly gained control over more than 90 percent of the battery industry's cobalt refining, without which the raw cobalt ore is useless.[xxvii]

The Institute for Sustainable Futures cautions that a global gold rush for green minerals to meet ambitious plans could take miners into "some remote wilderness areas [that] have maintained high biodiversity because they haven't yet been disturbed."[xxviii] And then there are the widely reported cases of abuse and child labor in mines in the Congo, where 70 percent of the world's raw cobalt originates.[xxix]

Late in 2019, Apple, Google, Tesla, Dell and Microsoft found themselves accused, in a lawsuit filed in a U.S. federal court, of exploiting child labor in the Congo.[xxx] Similar connections can be made to labor abuses associated with copper, nickel or niobium mines around the word.[xxxi] While there is nothing new about such real or alleged abuses, what is new is the rapid growth and enormous prospective demand for tech's minerals and green energy minerals. The Dodd-Frank Act of 2010 includes reporting requirements on trade in "conflict minerals." A recent Government Accountability Office (GAO) report notes that more than a thousand companies filed conflict minerals disclosures with the Securities and Exchange Commission, per Dodd-Frank.[xxxii]

Automakers building electric cars have joined smartphone makers in such pledges for "ethical sourcing" of minerals.[xxxiii] Car batteries, however, create the biggest demand for "conflict" cobalt.[xxxiv] Companies can make pledges; but unfortunately, the record suggests that there is little correlation between such pledges and the frequency of (claimed) abuses in foreign mines.[xxxv] In addition to moral questions about exporting the environmental and labor challenges of mineral extraction, the strategic challenges of supply chains are a top security concern as well.

Strategic Dependencies: Old Security Worries Reanimated

Supply-chain worries about critical minerals during World War I prompted Congress to establish, in 1922, the Army and Navy Munitions Board to plan for supply procurement, listing 42 strategic and critical materials. This was followed by the Strategic Materials Act of 1939. By World War II, some 15 critical minerals had been stockpiled, six of which were released and used during the war. The 1939 act has been revised twice, in 1965 and 1979, and amended in 1993 to specify that the purpose of that act was for national defense only.[xxxvi]

As recently as 1990, the U.S. was the world's number-one producer of minerals. It is in seventh place today.[xxxvii] More relevant, as the United States Geological Survey (USGS) has noted, is our strategic dependency on specific critical minerals. In 1954, the U.S. was 100 percent dependent on imports for eight minerals.[xxxviii] Today, the U.S. is 100 percent reliant on imports for 17 minerals and depends on imports for over 50 percent of 28 widely used minerals. China is a significant source for half of those 28 minerals.[xxxix]

The Department of Defense and the Department of Energy (DOE) have issued reports on critical mineral dependencies many times over the decades. In 2010, DOE issued the Critical Materials Strategy; in 2013, DOE formed the Critical Materials Institute, the same year the National Science Foundation launched a critical-materials initiative.[xl] In 2018, USGS identified a list of 35 minerals as critical to security of the nation.[xli]

But decades of warnings about rising mineral dependencies have yielded no significant changes in domestic policies. The reality is that depending on imports for small quantities of minerals used in vital military technologies can be reasonably addressed by building domestic stockpiles, a solution as ancient as mining itself. However, today's massive domestic and global push for clean-tech energy cannot be addressed with small stockpiles. The options are to accept more strategic dependency or to increase domestic mining.[xlii] And both those options have unaccounted for implications for total fuel-cycle carbon dioxide emissions.

Carbon Displacement

The realities of the world mean that using wind, solar and batteries to attempt the wholesale replacement of hydrocarbons over the next few decades would achieve only minor reductions in carbon dioxide emissions. And it would come at enormous environmental, economic and geopolitical costs.

It would result in a tenfold increase in the quantity of materials mined and processed per unit of energy delivered. The U.S. would fall from self-sufficiency in energy production to become a major importer of the critical materials needed to fabricate wind and solar machines and batteries. This would have serious economic consequences in terms of lost businesses and jobs, as well as massive increases in energy costs.

> ***[R]eplacing combustion engines with electrical vehicles in America displaces rather than eliminates global carbon emissions.***

And, rather than reducing carbon emissions significantly, the U.S. would be exporting them offshore. A majority of the manufacturing of battery materials and components, for example, occurs in China, where the electric grid is 60 percent coal-fired. Thus, replacing combustion engines with electrical vehicles in America displaces rather than eliminates global carbon emissions.

[i] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.

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OPINION

Atoms of the World Unite—Or Split

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If transitioning to "green" energy (primarily wind and solar) yields only a 6 percent reduction in global CO2 emissions—as shown in Mark Mill's article, beginning on page 8—how can the U.S., let alone the world, achieve carbon zero?

On May 25, 2021, Mills interviewed Steven E. Koonin, PhD, the author of *Unsettled: What Climate Science Tells Us, What It Doesn't, and Why It Matters* (BonBella Books 2021) as a Manhattan Institute event. Koonin is a science policy leader who served as the Undersecretary for Science in the U.S. Department of Energy during the Obama administration. Previously, Koonin was a professor of theoretical physics at CalTech. From 2004-09, he worked as BP's chief scientist, in charge of long-range strategy, especially regarding alternative and renewable energy. Currently, at New York University, Koonin is a professor with appointments in business, engineering and physics, and serves as the Director of the Center for Urban Science and Progress.

In *Unsettled,* Konnin takes issue, not with the U.S. government's nor the U.N.'s Intergovernmental Panel on Climate Change's climate science, but their efforts—and those of many politicians, activists and journalists—to promote an alarmist narrative. Climate science is not settled, the book shows, and the available data does not support the constant refrain that extreme weather events today or climate catastrophes in the foreseeable future are being caused by human activity. Burning fossil fuels causes some global warming, Koonin agrees, but CO2 (measured in parts per million), he points out, constitutes a tiny part of the climate system, which isn't understood nearly well enough to make accurate predictions. In fact, CO2 levels have only been as low as today's once in the last 500 million years.

Both Mills and Koonin agreed that "green" technologies are far from capable of replacing hydrocarbons. Even if wind and solar energy were sufficient, trillions of dollars in expenditures would have no significant impact on climate change.

Worse, this transition would greatly disempower the U.S. and other nations—massively increasing national debts while lowering GDP (which relies on affordable, reliable energy) and destroying millions of jobs. At the same time, this transition would greatly empower China's rise to world dominance due to control of most of the world's mining and processing of rare earth elements, and because the Chinese government won't be foolish enough to follow suit.

"If the nation really wants to decarbonize its electricity system and run its transportation on electricity as well," said Koonin, who earned a PhD in theoretical physics at MIT, "it's going to have to have [nuclear] fission as an important part of the mix."

Fission produces energy through splitting atoms, as in current nuclear energy plants, submarine reactors and nuclear weapons. Mills noted that "the energy density of nuclear fission" is millions of times greater than hydrocarbons—which are 40 times greater than batteries. The discussion then turned to nuclear fusion, which produces several times more energy than fission by fusing atoms. The first fusion reactors are currently being built, and Koonin said he expects it will take 15 to 25 years before fusion demonstration plants are generating power into the electrical grid. Then commercializing and starting to scale fusion, Mills determined, are about "half a century out … which is typical of big systems." Scaling up nuclear fission would also take several decades.

Not only does nuclear energy offer unlimited energy for humanity, small nuclear reactors are being designed, which could power the Bismarck-Mandan area, for example, for three to five years at very low cost before the fuel needs to be replaced.

The pushback against nuclear energy focuses largely on the highly radioactive material fission produces. But as Koonin pointed out, "We have ways of handling the waste safely and economically. It's not a technical problem; it is a political perception problem." Further, nuclear fusion, when deployed, doesn't produce highly radioactive material.

Many people would be unhappy with hydrocarbons providing most of the world's energy for another half-century—from whenever major nations embark on the nuclear energy transition. However, oil, coal and gas companies are already working on decarbonization.

At the Williston Basin Petroleum Conference in Bismarck in May, Gov. Doug Burgum challenged the state's energy and agricultural industries to achieve net zero carbon emissions by 2030. This was not a mandate but instead, as typical in North Dakota, an ambitious goal to be achieved cooperatively.

The means to carbon zero include carbon capture projects, which store and also provide carbon for enhanced oil recovery and boosting production in the shale oil plays. According to the University of North Dakota's Energy and Environmental Research Center, the state can store up to 250 billion tons of carbon underground. For example, Project Tundra, a $1.1 billion carbon capture initiative, is seeking investments.

Given the hydrocarbon industry's ability to quickly develop efficient technologies that have dramatically lowered fracking costs in the Bakken, Gov. Burgum predicted that North Dakota would become the first carbon-negative state.

Unlike federal goals to reach net-zero emissions by 2050, the governor's challenge maintains oil, coal and gas as central to the state's economy, which will ensure affordable and reliable energy. If this can be done here, then hydrocarbons can be rendered emissions free elsewhere.

This goal is, technologically, far more possible than green energy sources not only replacing hydrocarbons but also accommodating the enormous increase in energy demands that developing countries and ongoing digitization will make—and at carbon zero.

> *This is the fastest and clearest course to becoming carbon negative.*

Alternative and renewable energy sources will certainly hold important but (if reason prevails) minor positions in the nation's energy portfolio. Yes, game-changing scientific breakthroughs are possible but cannot form the basis of strategic planning.

Towards 2050 and beyond, let's split and fuse atoms on the way to the only known way to provide clean, reliable, affordable energy at increasing levels, indefinitely at global scale.

Already, Warren Buffet and Bill Gates are planning to build a small, advanced nuclear reactor in a coal mine that's being phased out in Wyoming. This will be the first Natrium fission reactor, which is sodium cooled, purportedly safer and capable of powering 400,000 homes. As the Guardian reported, Wyoming's governor Mark Gordon said, "This is the fastest and clearest course to becoming carbon negative."

Are Self-Driving Cars Safe?

Challenges in Technology, Trust, AI & Cybersecurity

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On April 17, 2021, a Tesla Model S automobile, equipped with autopilot control, missed a turn and crashed into a tree at high speed, killing both passengers.[i] The vehicle caught fire and the batteries reignited multiple times, making for massive and time-consuming efforts to extinguish the blaze. Each accident involving a vehicle with a significant degree of automation diminishes the collective level of trust in the car and the technologies used for safety and security measures.

Devices and mechanisms, in which physical components and software are integrated, are called cyber-physical systems. Self-driving cars are a prototypical cyber-physical system. Other examples include industrial robots, drones, precision farming machinery, pipelines, and many types of manufacturing and warehousing equipment. Many cyber-physical systems in use and under design and development today operate with considerable autonomy. Many types of integrated sensors, microprocessors, actuators, controllers and communication networks are utilized. Artificial intelligence (AI) methodologies are often employed, including machine learning, which easily leads to people questioning the trustworthiness of cyber-physical systems. There are many concepts related to trustworthiness, including cybersecurity, reputation, risk, reliability, belief, conviction, skepticism and assurance. Actions of betrayal and deception also undermine trust.

We explore the role of trust and cybersecurity as it applies to self-driving cars. Given the prominence in our society of cybersecurity threats, such as stolen identities, fraud, system crashes and disruptions to critical infrastructure, people easily understand that system failures can and do occur in devices, and that hackers could remotely take control of a self-driving car and deliberately cause a mishap or serious accident. With AI systems increasingly replacing human decision-making, there are serious issues concerning whether the control system can successfully match or exceed the effectiveness of human decision-making under all circumstances, especially while autonomous controls are driving on a public roadway.

Below, we present issues regarding trust, cybersecurity and AI that apply to self-driving cars, which are important and of broad interest to society.

Technology in Self-Driving Cars

Multiple technological systems must work together cooperatively to accomplish automated driving. There are many types of sensors needed to detect the conditions surrounding the car and feed data to the control systems. Then actuators, which are devices that respond to incoming sensor information, carry out controls and actions. Both internal and external communication networks provide the means for the devices to coordinate their work.

The technologies used to provide information in the vicinity of the vehicle include Lidar (light detection and ranging), long- and short-range radar, cameras and ultrasound sensors. Lidar uses an infrared beam to determine the distance between the sensor and an object in the vicinity of the car.[ii] These technologies make it possible to map and track positions and speeds of objects, such as traffic signs, vehicles, pedestrians, bicyclists and wildlife.[iii] Lidar enables many functionalities, including lane following and collision avoidance. Image processing and other algorithms classify objects and help the vehicle react appropriately to hazards.

Vehicles utilize both internal and external communication networking. Internal networks employ a bus technology, which provides an electronic backbone that connects many types of devices, with specialized protocols that enable great flexibility for interconnecting the many devices within the vehicle. External connectivity is also essential, for purposes such as receiving software updates; obtaining real-time traffic information from roadside units; providing remote access for remotely monitoring, controlling climate and locking/unlocking the car; and accessing the web.

All these components have failure rates and are vulnerable to malicious intrusions that can jeopardize vehicle performance and compromise safety.

The wreckage of a Tesla sedan that crashed into a police car in Raleigh, NC, in August 2020. The Tesla was in Autopilot mode while the driver watched a movie on a cell-phone. Fortunately, no one was injured. Autopilot mode requires that the driver always pays close attention. The Tesla driver was charged with moving violations.

Trust

Trust is a two-sided social construct involving a trustor and a trustee. Whenever a trustor delegates a task or in some way interacts with a trustee, they make an associated decision about trust. When the trustee is a self-driving car enabled with AI methodologies, a passenger is a trustor who chooses and believes that the car will reliably and safely bring him or her to the destination. While trust refers to a relationship between trustor and trustee, trustworthiness is a property only of the trustee. A self-driving car can be deemed trustworthy if it has high performance levels in terms of categories such as competence, integrity, low risk, high reliability, high ethical standards and predictability.

There have been multiple accidents involving Tesla vehicles.[iv, v, vi] A Tesla car in Autopilot mode (Tesla's self-driving software) is supposed to have a person in the driver's seat ready to take control if needed. However, a recent video and report, released by Consumer Reports, shows that buckling the seatbelt across an empty seat and placing a weighted chain on the steering wheel can fool the vehicle into inferring that the vehicle has a driver in place.[vii] Such reports and continued accidents diminish trust in the technology and raise serious safety and security questions.

Evaluating the trustworthiness of a self-driving vehicle by a trustor is based on evidence. An important source of this evidence is reputation, which concerns reports, impressions and reviews that are available from various sources. Social media and testing laboratories are rife with such reports. Reputation sources are often consulted before people purchase a product online, an approach that readily transfers into evaluating the trustworthiness of a vehicle. It is widely held that repeated good reputation reports build trustworthiness slowly, and bad reports diminish trustworthiness quickly.

Humans are also emotional and complex beings, which means that beliefs, purpose, motivation, integrity, intentions and commitment to outcomes all play a role in trust among people. Trust between humans and a machine differs because behaviors and actions driven by these elements are difficult to program.

Artificial Intelligence (AI)

There is a fundamental question of whether a vehicle operating fully autonomously can possibly function and respond intelligently in all driving situations. Throughout the now long history of designing, developing and deploying higher technology in vehicles, each innovation has been initially met with skepticism and limited trust. A few examples include the automatic transmission, automatic braking, cruise control and electronic stability control. What these ever more sophisticated technologies have in common is that they automatically assist driving and enhance safety and comfort by monitoring and controlling conditions within the driving environment and the actions and performance of the vehicle and the driver. There is a fundamental question of whether it is possible for a vehicle operating fully autonomously to relinquish control to a human driver in standby mode in a meaningful way.

AI refers to the ability of a machine to perform tasks commonly associated with intelligent beings.[viii] AI methodologies are broadly classified into symbolic and sub-symbolic approaches. When applied to self-driving cars, a symbolic approach directly encodes precisely what the vehicle does under a given circumstance. There can be a detailed attempt to utilize available information from sensing devices to drive program code that models intelligent actions.

By contrast, a sub-symbolic approach is based upon developing responses from experience, much as a child learns from being exposed to his or her surroundings. Machine learning is a specific type of sub-symbolic AI that can learn from examples of human behavior and mimic what a person might do. In the race to roll out a reliable and trustworthy self-driving car, automobile manufacturers are developing better and better machine learning methods that can emulate collective human behaviors at their best.

In the march toward fully automated driving, there is a debate regarding whether it is desirable to emulate human decision-making, which is known to often be flawed, or to configure systems that employ AI methodologies that can outperform the best human driver. Elon Musk has stated that a self-driving Tesla might already be smarter than a human driver.

Cybersecurity

Trust and trustworthiness are related to cybersecurity. The well-known cybersecurity triad has dimensions of confidentiality, integrity and authentication. Confidentiality refers to the protection of data and resources from unauthorized access, usage and modification. Integrity refers to the protection of data and resources from unauthorized modification, while also ensuring that the data remains accurate and reliable. Authentication refers to the accessibility of the systems and resources only to authorized users.

Compromise of any of the cybersecurity dimensions erodes trust between a trustor and trustee and diminishes trustworthiness. An autonomous vehicle that is highly vulnerable to a cybersecurity attack will have a low measure of trustworthiness. A malware attack that affects the sensing mechanisms, internal networks, controls, AI functions and computational procedures of the vehicle, while in a full or partial autonomous mode, can easily result in unpredictable and dangerous vehicle actions. Furthermore, intrusive malware often lies dormant and does its damage when a specific trigger occurs, possibly in a coordinated and synchronized way.

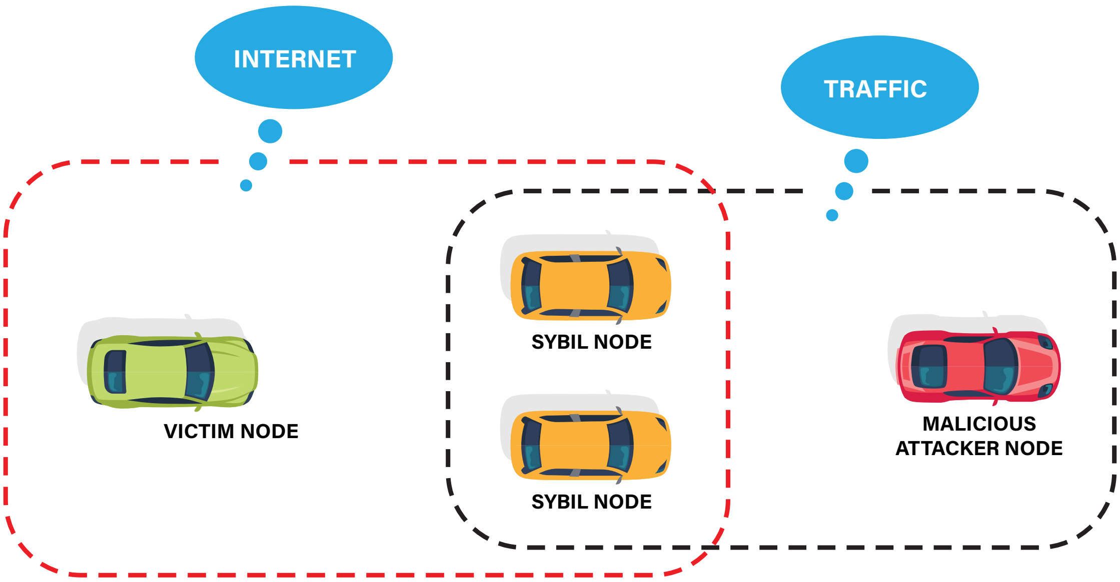
The illustrations on the following pages illustrate several types of attacks to which vehicles are vulnerable, all of which present risks and serve to diminish trust and trustworthiness when they occur.

There are many other types of attacks, but the ones described on the next two pages are quite common.

Most of the attacks threatening autonomous vehicles can be mitigated by the application of intelligent intrusion detection strategies for monitoring and analyzing the data packets exchanged among vehicles and road-side infrastructure. Intrusion detection methodologies are broadly categorized as Anomaly-based Detection and Signature-based Detection. Anomaly-based methods seek out abnormalities in message traffic. Signature-based detection methods are equipped with characteristics of known threat patterns and analyze incoming messages for any matches.

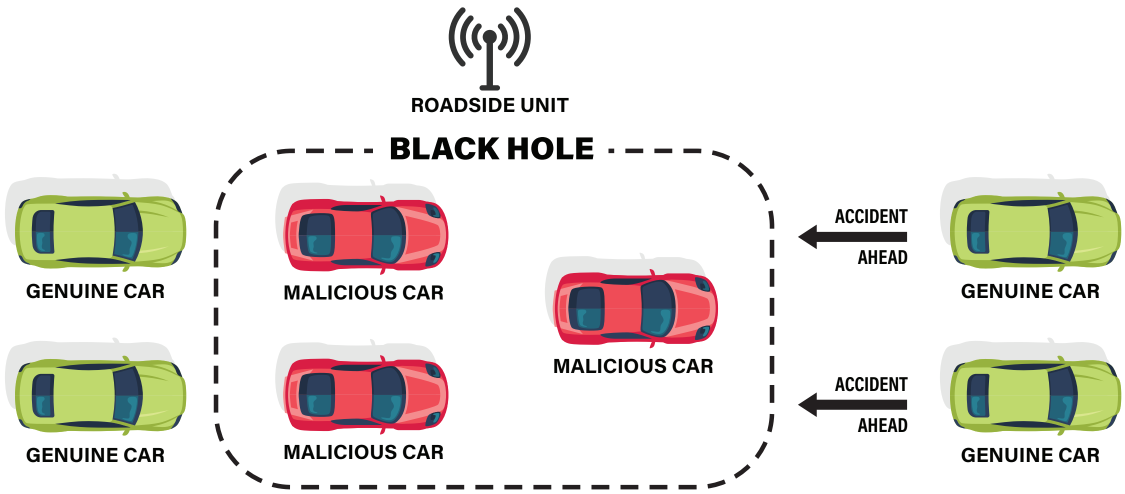
Trust is closely coupled with the public's perceptions of automation. Each accident feeds perceptions that self-driving cars are disastrous and untrustworthy. Details of vehicle-crash statistics, which are available from TeslaDeaths.com, reveal that some accidents occur while the car is in Autopilot mode but are not entirely caused by the automated operation of the vehicle. For example, there were travel conditions that made an accident unavoidable, as well as incidents in which a passenger's intervention—as when a passenger took back control of the vehicle—was the primary cause of an accident.

Social impacts of autonomous systems, on the positive side, include reducing traffic congestion, improving



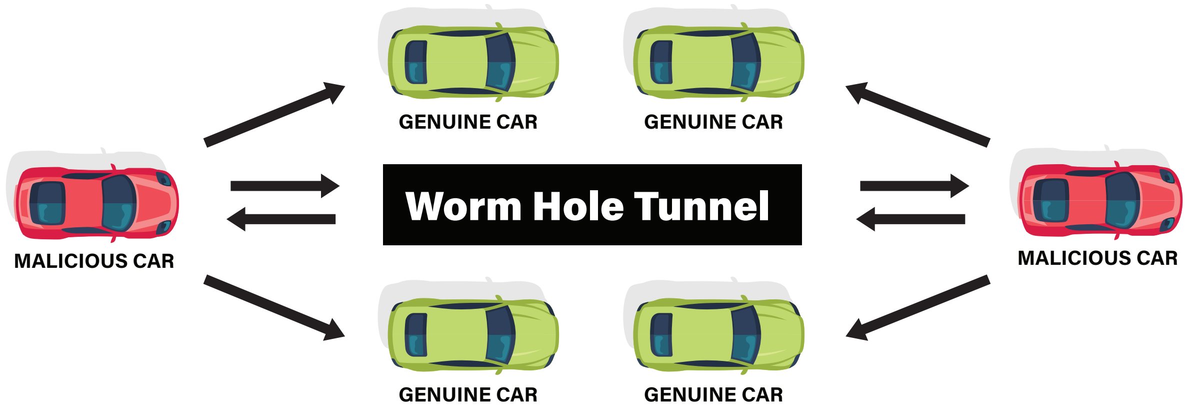
SYBIL ATTACK

Multiple bogus identities of a vehicle are created by a malicious attacker. These bogus identities masquerade as real vehicles communicating with a roadside unit and transmit false messages that report conditions, such as an upcoming accident, road closure or traffic congestion, to other genuine vehicles around them. Such messages damage the reputation of the self-driving vehicles and influence trustworthiness, authentication and the network's availability.



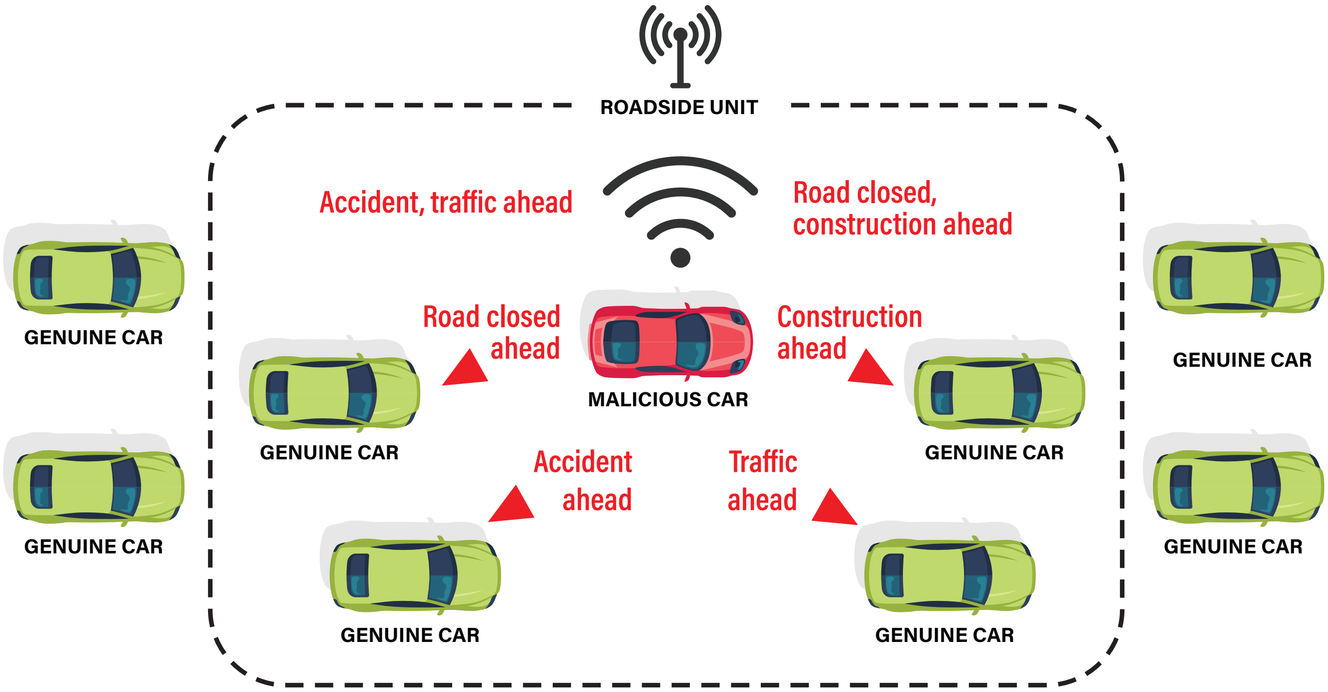
BLACK HOLE ATTACK

A group of malicious vehicles joins the legitimate network and form a black hole that gathers information from surrounding genuine cars about conditions, such as traffic congestion, accidents and road closures. These malicious vehicles then refuse to forward the information to other genuine vehicles, effectively destroying important information. Black hole attacks disrupt the efficiency and ability of the vehicular ad hoc networks to pass along important information about roadway conditions, traffic congestions and accidents to other vehicles.



WORM HOLE ATTACK

Two malicious vehicles form a wormhole by creating a private tunnel message route between them and broadcasting a shorter route to the destination. As a result, when the malicious vehicles receive a request over the network, they modify or falsify it, impacting all three elements of the cybersecurity triad and potentially creating unsafe conditions.



DENIAL-OF-SERVICE ATTACK

A malicious vehicle disables communications among vehicles and network infrastructure by broadcasting a massive pool of message traffic that overwhelms capacity. A victimized vehicle will not receive important information about conditions—such as road closures, accidents and construction zones, leading them into incorrect decisions, which could cause serious accidents.

safety, making many human tasks easier and more convenient, and creating new jobs. On the negative side, jobs such as truck driving, one of the most common occupations, could be eliminated. Also, knowing that vehicles can be wirelessly hacked from a distance reduces trust. In July 2020, cybersecurity researchers Charlie Miller and Chris Valasek hacked into a Jeep Cherokee's Uconnect computer from more than 10 miles away. Once they wirelessly gained control, they were able to access dashboard functions, brakes, transmission and steering.[ix]

There have been instances in which human drivers—and not to mention, pedestrians and bicyclists—have tricked the internal mechanics of self-driving vehicles, causing them to crash. Last but not the least, even when vehicle manufacturers employ white-hat hackers to decode every possible hacking attack to help build a secure vehicle, there are still very smart hackers out there capable of finding that one loophole vulnerable to a hack, which can lead to a crash.

TeslaDeaths.com maintains and presents a comprehensive record of all fatalities caused by Tesla, including crash data on the geographic locations of accidents and instances where Autopilot was engaged prior to accidents, as well as crash analysis and the claims made by Tesla officials. As of May 2021, six of the 181 reported Tesla deaths were Autopilot fatalities.[x] In August, the National Highway Traffic Safety Administration launched an investigation into Tesla's Autopilot driving system.

To some extent, car drivers are actors within social settings. Characteristics that are fundamentally human, such as mercy and empathy, can influence their behaviors and actions during a crisis. In contrast, the programming and controls of a self-driving car are unlikely to have comparable characteristics, even if training is done with emulation based upon real human responses. Accidents and crash reports, involving vehicles driven in autonomous mode, reveal that an autonomous vehicle is not capable of mercy, which evokes an instinctive fear and antagonism undermining trust. Major questions remain concerning the best course of action for a car under autonomous control to follow in difficult circumstances, especially if available information is incomplete, uncertain or biased.

Promotions of autonomous vehicle technology by the automobile manufactures paint a positive picture of self-driving cars, depicting them as robust, trustworthy, economical and congestion alleviating. This article provides a service by describing and increasing awareness of a myriad of trust and trustworthiness issues and challenges surrounding self-driving cars. While acknowledging the benefits of automated vehicles, this article points out sources of risk that can undermine trust and illustrates the need for further advances and maturing of the technologies, particularly in supporting intelligent decision-making.

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Precision Agriculture

The Future in Farming and Ranching

As the state's land-grant university, NDSU has a unique role to play in precision agriculture.

Recently, Dakota Digital Review (DDR) interviewed Greg Lardy, Vice President for Agricultural Affairs at NDSU, about precision agriculture and the future of food production. As well, Lardy serves as the Dean of the College of Agriculture, Food Systems and Natural Resources and the Director of the North Dakota Agricultural Experimental Station, both at NDSU, and also as the Director of NDSU Extension.

DDR: What is precision agriculture?

VP Lardy: Precision agriculture, broadly defined, is a more precise management of crops, livestock and other agricultural processes through the use of various techniques that require substantial data to support decision-making processes. Ultimately, the goal is to more efficiently and effectively manage agricultural operations to improve sustainability, conserve natural resources and enhance profitability.

DDR: How much interest is there in precision agriculture in the agricultural community?

VP Lardy: It's a major interest area for almost everyone involved in agriculture at the moment. They may not express it in terms of "precision agriculture," but interest in the farming and ranching community about techniques that will allow them to better manage their operations is substantial. Precision agriculture means different things to different people, depending on what segment of agriculture with which you are involved. In the farming world, a lot of the interest is associated with some sort of machinery application.

Greg Lardy,
Vice President for
Agricultural Affairs at NDSU,
at the Central Grasslands Research
Extension Center in Streeter, ND.
Credit: Jerry Anderson

In the livestock sector, the interest is really in breeding and genetics, with genomic-associated means of animal selection (genomic-enhanced EPDs [expected progeny differences]). Also, interest is significant in the area of individual animal management. Collection of data on individual animals (for example, health or feed consumption data) helps livestock producers provide more customized nutrition and care for livestock.

DDR: Give us some examples of current precision agriculture applications.

VP Lardy: Most major equipment manufacturers are using computer geospatial applications to control tractors, planters and combines already. The onboard computer is controlling the speed of operations; monitoring seeding rates, fertility applications and chemical application rates; and communicating with other machines in the field.

Through GPS linkages, many machines are equipped with features such as autosteer, which helps move the tractor or combine down the field by using satellite positioning to reduce the amount of overlap in a field. These functions ultimately save the farmer money, as well as reduce operator fatigue, which can help improve safety.

In the livestock sector, cattle producers are selecting animals based on what we call "genomic-enhanced EPDs." This gives the rancher or livestock producer additional information about the type of progeny that a bull is expected to produce when mated with a particular cow. It gives ranchers a tool to more precisely predict the outcome of mating decisions. A huge amount of data goes into the computations necessary to develop these EPDs.

DDR: How is rural broadband service linked with precision agriculture?

VP Lardy: Many of these applications require substantial use of data of some sort. It might be data from machines, such as planters or combines, or other applications, such as sprayers overlaid with soil maps, or other geospatial applications. These are data-intensive operations, so access to sufficient bandwidth is going to be critical for our farming and ranching operations.

This is especially true for applications that are going to involve real-time decision-making in field operations. For instance, if we expect a machine to sense or monitor specific conditions in the field and then make a change in real time, rural connectivity is critical.

In addition, rural broadband and sufficient connectivity are becoming a critical component of rural health care, veterinary medicine, teaching and learning, telework and other basic services. If we expect rural places to be places where people can live and work, broadband connectivity is going to be critical to attracting and retaining a workforce, providing adequate health care and developing learning platforms for K-12 education, as well as further education for the broader population. Luckily, North Dakota is ahead of most states with respect to rural broadband and connectivity.

DDR: What are some of the challenges associated with precision agriculture?

VP Lardy: Because precision agriculture is directly linked to computers and computing power, the challenges largely revolve around the typical computer problems described in many other industries. Things such as data storage, data security, cloud analytics and data management, as well as data access, are just a few of the challenges.

Questions about who owns the data are also part of the dialogue. Farm machinery is collecting data as part of routine fieldwork in many applications now. Most equipment companies have policies in place, related to data access and ownership, stipulating that the farmer owns the data and that farmers can share their data with their professional management team or others whom the farmers designate.

Precision agriculture data present some unique geopolitical challenges for equipment manufacturers as well. For example, manufacturers might find themselves selling equipment to foreign governments that have different philosophies or policies related to data ownership than we have in the U.S.

The sheer volume of collected data also presents some unique challenges. Movement of large volumes of data to and from the cloud requires adequate connectivity. The data storage for these applications can be problematic and quite costly.

DDR: How far away are we from the totally autonomous farm?

VP Lardy: If you are talking about a farm with only robots and no people, we are a substantial amount of time away from that yet. We probably will measure this timeframe in decades. But if you are talking about having driverless tractors or other field implements doing autonomous operations of some sort in the field, we are getting very close.

We have a few hurdles that we need to get past, related to the technology. A driverless tractor is one thing, but we also need to remember that the tractor is almost always pulling some sort of field implement, such as a planter or tillage tool, which means the system also needs to be monitoring what is going on with the tool the tractor is pulling. This presents some unique challenges with monitoring, sensing and adjusting what the implement is doing.

In addition, we have a few regulatory and policy-related items that need to be addressed regarding autonomous operation. These regulatory and policy issues are probably most acute when it comes to movement of autonomous farm equipment on roadways. Currently, we do not have an adequate regulatory framework for these sorts of applications.

Because the tractor is such a utilitarian piece of equipment on a farm, we won't see cabless tractors for a while. On a farm, a tractor performs many functions that will be difficult to fully automate and run autonomously. For example, the tractor might be equipped with a loader for moving materials on and off a truck, or it might have other equipment driven by the PTO (power take-off). These functions will be much more difficult to run in a fully autonomous fashion, because a substantial amount of human sensing, adjusting and acting happens when these sorts of equipment are used with a tractor.

DDR: What is the future of precision agriculture?

VP Lardy: The future will involve more and more applications that are, what is termed, "sense and act." In other words, a sensor will collect some sort of data (it might be soil fertility, moisture conditions or some other parameter) and then implement a solution or act in a manner that requires some sort of computation before implementing a solution in the field.

This requires data to be uploaded from the sensors at the farm to a cloud application. The data then undergoes some sort of computation in the cloud, and then the solution is downloaded back to the machine for implementation of the final solution, as the machine moves about the field. To do this in real time will require better connectivity across the rural landscape than what currently exists in most locations.

Obviously, this is a data-intensive operation that requires adequate connectivity, cloud storage and data security, and the resolution of all sorts of other "computer" issues. Consequently, tractors and combines are no longer going to be just "mechanical machines" but instead will be complex mechanical machines with sophisticated computer technology as an integral part of the machine. This already is happening in many applications in North America.

Additional applications will include more and more work with sensors of some sort. These sensors are going to be part of the internet of things. They might be moisture meters in grain storage facilities to monitor optimal storage conditions, or some sort of device that monitors the feed intake of livestock, or other sensors that can monitor various aspects of animal health and then provide information or recommendations to the farmer or rancher.

We also are moving rapidly to systems that manage individual plants. In the past, a field of corn was managed as a field, maybe 40 or 80 or 160 acres. A farmer might plant 30,000 to 40,000 corn plants per acre. In the past, that field would be planted to a single variety, be fertilized with the same fertility recommendations throughout the entire field, and the entire field would have the same recommendation for weed control. In the future, when we think of these applications, we are envisioning systems that actually manage each of these plants individually.

As an example, the farmer would be working with a solution that chooses a specific plant variety for a small piece of the field (maybe as small as a square meter). On that quarter section (160 acres), you might be managing 4.8 million to 6.4 million plants.

NDSU … carries out programming in precision agriculture that helps farmers and ranchers to be more efficient, conserve natural resources and be more economically viable in the long term.

Several different varieties of corn or soybeans would be planted in this field, which would be specifically chosen based on soil type, yield potential or other parameters. Each plant would have an individual prescription for fertility and weed control, which also depends on soil type and expected yield. This gets to be a pretty complicated set of data to even envision, much less manage.

Livestock producers are also moving to individual animal management. For instance, on dairy or swine farms, the cows and sows are receiving a specialized ration and feeding regime that depends on productivity and expected production. Monitors and sensors track activity (much like pedometers), as well as feed consumption, water intake and other parameters, all in an effort to more appropriately manage the individual.

DDR: What is NDSU doing in the world of precision agriculture?

VP Lardy: As the state's land-grant university, NDSU has a unique role to play in precision agriculture. Being a land-grant university means that NDSU has, as part of its mission, a role in teaching, research and extension services. I'll mention what we are doing in each of these areas briefly.

Teaching: NDSU recently launched one of the first undergraduate degrees in Precision Agriculture, and our first student graduated from the program in May 2021. Enrollment in the major is growing rapidly, and we've seen a lot of interest from employers in hiring students trained in this field. Many employers in agricultural disciplines are looking for graduates who understand basic agricultural principles, such as agronomy or soil science, but who also have training and experience with data analysis, data management and analytical tools that use data to drive recommendations or decision-making.

Research: NDSU, through the North Dakota Agricultural Experiment Station, has a major research thrust in precision agriculture. This effort is multidisciplinary and includes work with sensors and robotics, imagery and drones, as well as work that links disciplines related to production and utilization of agricultural commodities and food. The work includes strategic partnerships with governmental agencies, industry and commodity groups.

One of the areas we are really seeing the "big data" function come into play in research is in our plant and animal breeding programs. Our scientists deal with huge volumes of data, and it will just get bigger as we incorporate more genomic data into the selection procedures. The volume of data that is being handled is growing rapidly, so access to better data storage, analytics and security is going to become increasingly important. Using genomic information allows our scientists to select better varieties more rapidly, which speeds up the selection process and helps ensure that the variety is going to be better suited for our growing conditions.

Extension: NDSU, through NDSU Extension, carries out programming in the area of precision agriculture that helps farmers and ranchers utilize precision agriculture to be more efficient, conserve natural resources and be more economically viable in the long term. These efforts include educational programs that highlight technology applications, as well as provide solutions for some of the more complex problems in agriculture.

Precision agriculture, in its many forms, is becoming increasingly important to farmers and ranchers in North Dakota. It is a complex and rapidly evolving field that makes it very exciting for our students, faculty and stakeholders. We are happy to play a role in shaping the future. Ultimately, the synergy of our teaching, research and extension services mission delivers a product that will help address challenges associated with land use, resource allocation, food security and economic sustainability, not only for farmers and ranchers but also for consumers.

Facebook vs Free Markets & Innovation

Examining a Regulatory Capture Power Move

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Photo credit www.thoughtcatalog.com

Facebook wants new internet regulations. And they haven't been shy about saying so. The company has put out at least three sleek, well-produced ads calling for new internet regulation. The ads direct viewers to a website Facebook operates that has more details on their preferred regulations.[i]

As an economist, I get suspicious whenever I hear a large corporation calling for regulation. Some might see these ads as evidence that Facebook is being socially responsible. Even though regulations might be costly for them, they want regulations that they believe will serve the public interest. But regulations don't always serve the public interest. Too often, they instead serve incumbent businesses. How? Regulations often make it costlier to enter an industry, which protects the current big players from competition.

Economists call this *regulatory capture.* George J. Stigler, a Nobel laureate in economics, explained that "every industry or occupation that has enough political power to utilize the state will seek to control entry."[ii]

On their website, Facebook points out that they have "tripled our security and safety teams to more than 35,000 people and built new privacy tools." They have also "expanded our efforts to fight voting misinformation, removed 100+ networks of coordinated inauthentic behavior globally and launched a Voting Information Center." They boast that they "take down millions of fake accounts every day and collaborate with experts and authorities to reduce misinformation."[iii]

In other words, they are already investing large amounts of resources in efforts that new regulations could make mandatory for all. They know that they can profitably run a business while complying with the new standards they would like regulators to impose. But a new startup may not have the resources to comply with such regulators. They would likely not be able to hire thousands of people to work on security, privacy and election integrity issues. Yet such new entrants might still offer value to internet users, and that value creation could be stifled by new regulations.

Facebook emphasizes that the last piece of legislation comprehensively regulating the internet was passed in 1996. After showing some of the *many* things that have happened online since, a woman in one Facebook ad asks, "If the internet has come a long way in the last 25 years, shouldn't internet regulations too?"

But the simple regulatory framework established in 1996 is part of *why* the internet has come a long way. The 1996 law Facebook is referencing is presumably the Telecommunications Act of 1996. As Adam Thierer explains in *Permissionless Innovation*, this law "notably avoided regulating the Internet like analog-era communications and media technologies."[iv] In particular, Section 230 of this 1996 law meant that companies that host digital platforms would not face costly liability for the actions of their users. This allowed for companies to host user-generated content without fear of costly legal reprisals. "Today's vibrant Internet ecosystem likely would not exist without Section 230," Thierer argues.[v]

Subsequent laws and policies maintained a similarly laissez-faire approach. For example, in 1998 "Congress enacted the Internet Tax Freedom Act, which blocked all levels of government in the United States from imposing discriminatory taxes on the internet."[vi] The executive branch also embraced a laissez-faire approach in 1997 by issuing "The Framework for Global Electronic Commerce." This framework recommended private sector leadership and advocated limited governmental involvement that would "support and enforce a predictable, minimalist, consistent and simple legal environment for commerce."[vii]

Digital entrepreneurs had the freedom to experiment and try things out. Even when a platform such as MySpace seemed like a monopoly, new entrants like Facebook and Twitter could try out new ideas and ultimately displace the old winners. Facebook's ads show some of the numerous changes and advancements that have happened online since 1996. But the truth is that these changes were possible precisely because the policy framework established in the late 1990s was simple and allowed entrepreneurial experimentation.

If new regulations raise the cost of starting new online ventures and experimenting with new approaches, then consumers and internet users will lose out on exciting new opportunities. This may benefit incumbent firms like Facebook, as they would be protected from competition. But it will hurt everyone else. If we want the next 25 years online to be as exciting and innovative as the last 25 years, any new regulations should have simple, predictable rules that let new entrants innovate. ▣

[i] The website, which features the ads as well as more details on Facebook's preferred regulatory reforms, can be found at https://about.fb.com/regulations.

[ii] Stigler, George J. "The Theory of Economic Regulation." The Bell Journal of Economics and Management Science, vol. 2, no. 1, 1971, pp. 3–21. JSTOR, www.jstor.org/stable/3003160. Accessed on April 8, 2021.

[iii] https://about.fb.com/regulations/ Accessed on April 8, 2021.

[iv] Thierer, Adam D. *Permissionless Innovation: The Continuing Case for Comprehensive Technological Freedom, Revised and Expanded Edition*. Arlington, VA: Mercatus Center at George Mason University, p. 14.

[v] Ibid, Thierer, p. 14.

[vi] Ibid. Thierer, p. 15.

[vii] Ibid, Thierer, p. 15.

Complex Maya Computations

Math, Time, Astronomy & Hieroglyphs

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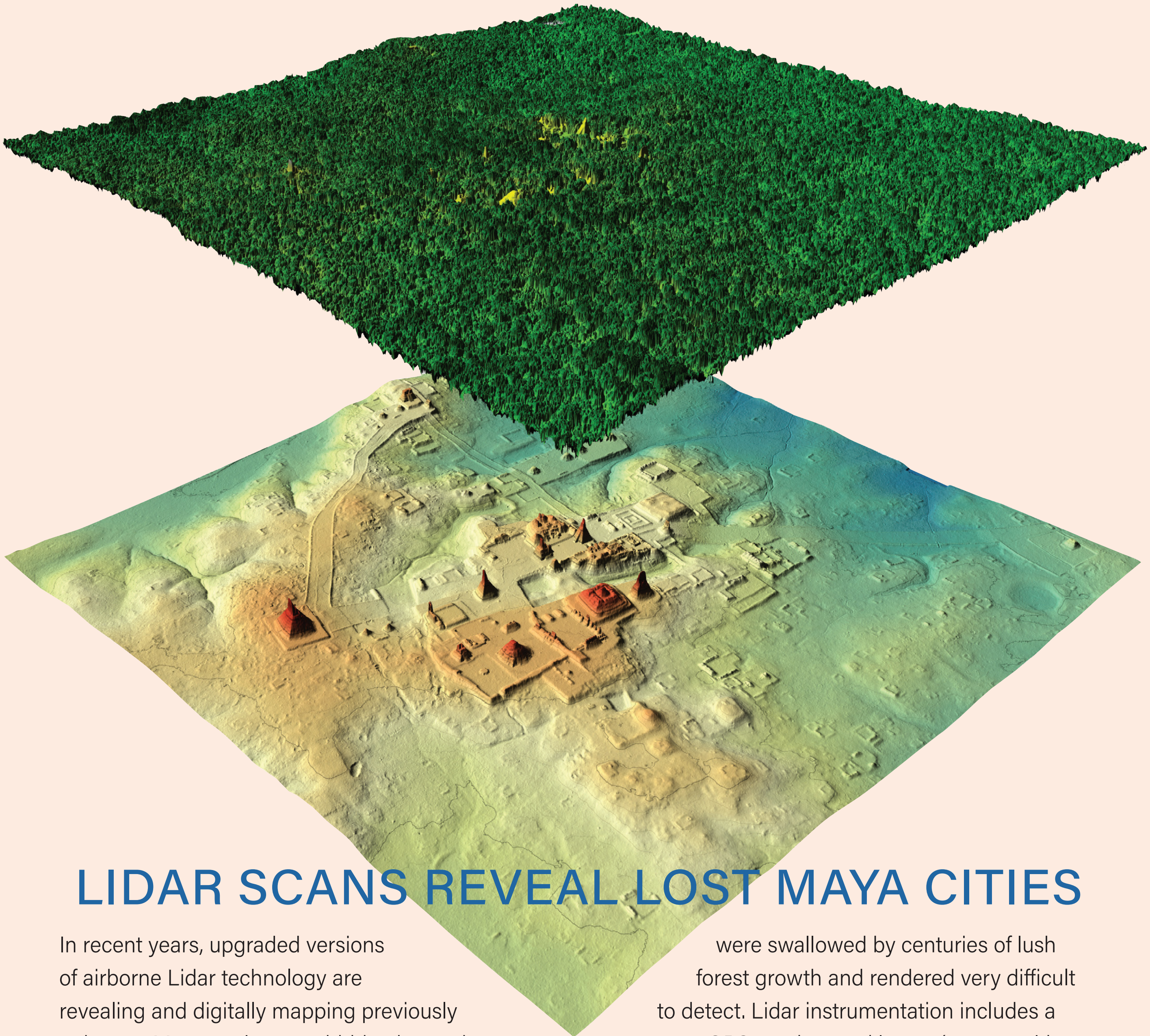
Ancient peoples and places might seem far removed from the world of computers, the internet and other modern technology, but we share more with our human ancestors than not.

When we think about the Maya people—whose earliest settlements date back to at least 1800 BCE—of southern Mexico, Guatemala, Honduras and Belize as occupying a world of grand pyramids and religious rituals, those associations are certainly true. However, the ancient Maya were also fascinated by mathematics and observations of the natural world, calculating the positions of the stars and planets. Although the Maya did not have digital technology, the precise calculations they undertook are precursors to today's world of scientific computing.

Maya Calendar

The ancient Maya calendar is intriguing and enigmatic because it is one of the most complex systems for marking time ever developed. The calendar consists of several cycles, usually referred to as "counts," that overlap. A 365-day solar year is called the *Haab'* and a set of 260 days is called a *Tzolk'in.* (The pronunciation of Maya words can be approximated by sounding out the words phonetically in English, with a glottal stop where the apostrophes are located.) Because these sets of days vary in length, their beginnings only align with each other once every 52 years. This is called the "calendar round," and each time it occurs it becomes a defacto marker of cultural change over time, similar to how Americans think about the passing of centuries. Although Maya people today primarily use the Gregorian calendar, as does most of the world, the calendar round remains in use in Guatemala as a secondary way of tracking the passage of time.

The Maya calendar consists of multiple time cycles, represented as rings in this sculpture on display at the National Museum of the American Indian. The innermost ring contains the numbers from one to 13. The middle ring contains 20 names for the days, each of which is called a *K'in.* The 13 numbers in the innermost ring are each paired with the 20 days from middle ring to create the *Tzolk'in cycle* (260 days). The outermost ring contains the names of groups of 20 days, each of which is called a *Winal.* A set of 18 *Winals* constitutes a *Tun* (360 days).



LIDAR SCANS REVEAL LOST MAYA CITIES

In recent years, upgraded versions of airborne Lidar technology are revealing and digitally mapping previously unknown Maya settlements hidden beneath thick jungle canopies. Lidar is also used to create precise 3-D maps of previously discovered sites, such as Tikal—an ancient Maya city in the Petén region of northern Guatemala—shown in the graphic above. Lidar (light detection and ranging) is "a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the earth," according to the American Geosciences Institute website. "These light pulses—combined with other data recorded by the airborne system—generate precise, three-dimensional information about the shape of the Earth and its surface characteristics." Remnants of Maya cities were swallowed by centuries of lush forest growth and rendered very difficult to detect. Lidar instrumentation includes a scanner, GPS receiver and lasers (some multi-channel laser systems fire up to a combined 900,000 times per second), which are mounted on an airplane, helicopter or drone. Both Lidar's precision and speed are game changers for archeology. "For example, at the Maya site of Caracol in Belize, it took archaeologists 20 years on foot to survey just nine square kilometers," Andrew Moller and Juan C. Fernandez Diaz reported Lidar Magazine in April 2019. "Using airborne Lidar, 200 square kilometers were mapped in as little as six days, with greater resolution than that accomplished on foot."

Image created by Dr. Juan C Fernandez-Diaz from airborne Lidar data collected by NCALM for the Pacunam Lidar Initiative (PLI) in 2019.

Making matters a bit more complicated, there is also a second calendrical system, which is overlaid on top of the calendar round, called the "long count." It is a way of marking the number of days since creation, 4 *Ahaw,* 8 *Kumk'u* (August 11, 3114 BCE in the Gregorian calendar). In modern Western systems of counting, we primarily use base ten—probably derived in prehistory from the number of fingers on our hands. Computer scientists, of course, are also familiar with counting in binary for circuitry-level computer science and hexadecimal for digital computation. The Maya, however, mostly used base 20 for their calendrical computations—probably derived in prehistory from the number of fingers plus toes.

In this system, a day is called a *K'in*, a set of 20 *K'ins* is a *Winal*, a set of 18 *Winals* is *Tun*, a set of 20 *Tuns* is a *K'atun*, a set of 20 *K'atuns* is a *B'ak'tun*, a set of 20 *B'ak'tuns* is a *Piktun*, a set of a 20 *Piktuns* is a *Kalabtun*, a set of 20 *Kalabtuns* is a *K'inchiltun*, and a set of 20 *K'inchiltuns* is a *Alautun*. Within traditional Maya thinking, each time that one of these cycles resets is a time of transition in the world, with the more infrequent cycles signaling ever-more significant changes. An example of this thinking, which spilled over into popular culture, occurred before December 21, 2012, when a *B'ak'tun* turned over, and a faction of the public assumed that an apocalypse was about to occur.

Dresden Codex

The technology that the Maya used to complete the complex calculations needed for understanding the calendar was simple—paper books with data tables—but its usefulness was profound. Tragically, after the conquest of Mexico by the Spanish during the 16th century, most Maya books were destroyed. Indeed, only four survived this purge. The rest were burned, along with much of the indigenous art, which had been deemed heretical by Franciscan missionaries.

One of the surviving books, the Dresden Codex, is filled with data tables used to calculate the movements of the planet Venus, as well as solar and lunar eclipses. This accordion-folded book was made from beaten tree bark and coated with a thin layer of stucco to make the surface smooth for writing. Unfolded, the

Spanish colonizers burned images of Maya gods and books, as dramatically drawn by Diego Muñoz Camargo—the son of a conquistador who became a translator, author and businessman. The drawing was completed around 1585 CE and included in the Codex Tlaxcala—a book that describes the history of the Tlaxcaltec people of Mexico. The manuscript is in the collection of the University of Glasgow, and the illustration is on folio 13.

78-page document stretches for 3.7 meters. It is a proto-scientific record that intersperses fantastical animals and plants with numerical data.

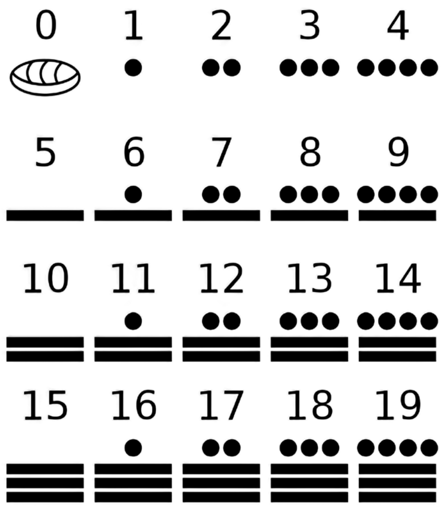
Although the numerical form is different than what Americans are familiar with—we use Arabic numerals that originated in the Middle East and North Africa during the Middle Ages—we can begin to intuit the intent of the book with just a small amount of knowledge of Maya math.

Numbers as Dots & Bars

The Maya numerical system for recording numbers is based on tallies of dots and bars, and its digits function somewhat like Roman numerals. In this system, a dot indicates one and a bar indicates five. Zero is indicated by a shape that looks like a football or a flower blossom.

This is particularly notable historically, as zero is a difficult concept for people to intellectually grasp. It was not understood in the Western world until

The Dresden Codex, made in about 1200 CE, contains complex data tables used to calculate eclipses and the movements of Venus. Depictions of Maya scribes show them using brushes. Unfortunately, such writing tools have not been recovered archaeologically—likely because they were made from natural materials that decayed—but they were likely made from rabbit or other animal hair attached to a reed. The manuscript is in the collection of the Saxon State Library.



Maya numerals were based on tallies of dots and bars. A dot equals one, and a bar equals five. Because the positional notational system is base 20, there are never more than four dots and three bars used together.

the 13th century when Fibonacci introduced it to Europe with the other Arabic numerals that we still use today. It is a positional system in base 20, so the largest set of digits in a single position is three bars and four dots, which tallies to 19. With this basic understanding of the notational system, the Dresden Codex starts to make sense.

Codebreaking Maya Hieroglyphs

The Maya language is alive and well today in oral form—there are about six million native speakers and 30 dialects—but sadly the tradition of writing in Maya hieroglyphs was lost during the colonial era. The book burning, paired with the suppression of the indigenous political system and religion, meant that knowledge of Maya hieroglyphs did not last through the end of the 18th century and had been mostly forgotten long before.

This story has a happy ending, however, as today we can once again read the words of ancient Maya people. The mathematical data in the Dresden Codex and modern codebreaking proved to be the keys for recovering this system of communication.

The decipherment of the Dresden Codex is intertwined with its history of ownership, and it is one of the most important Maya documents ever

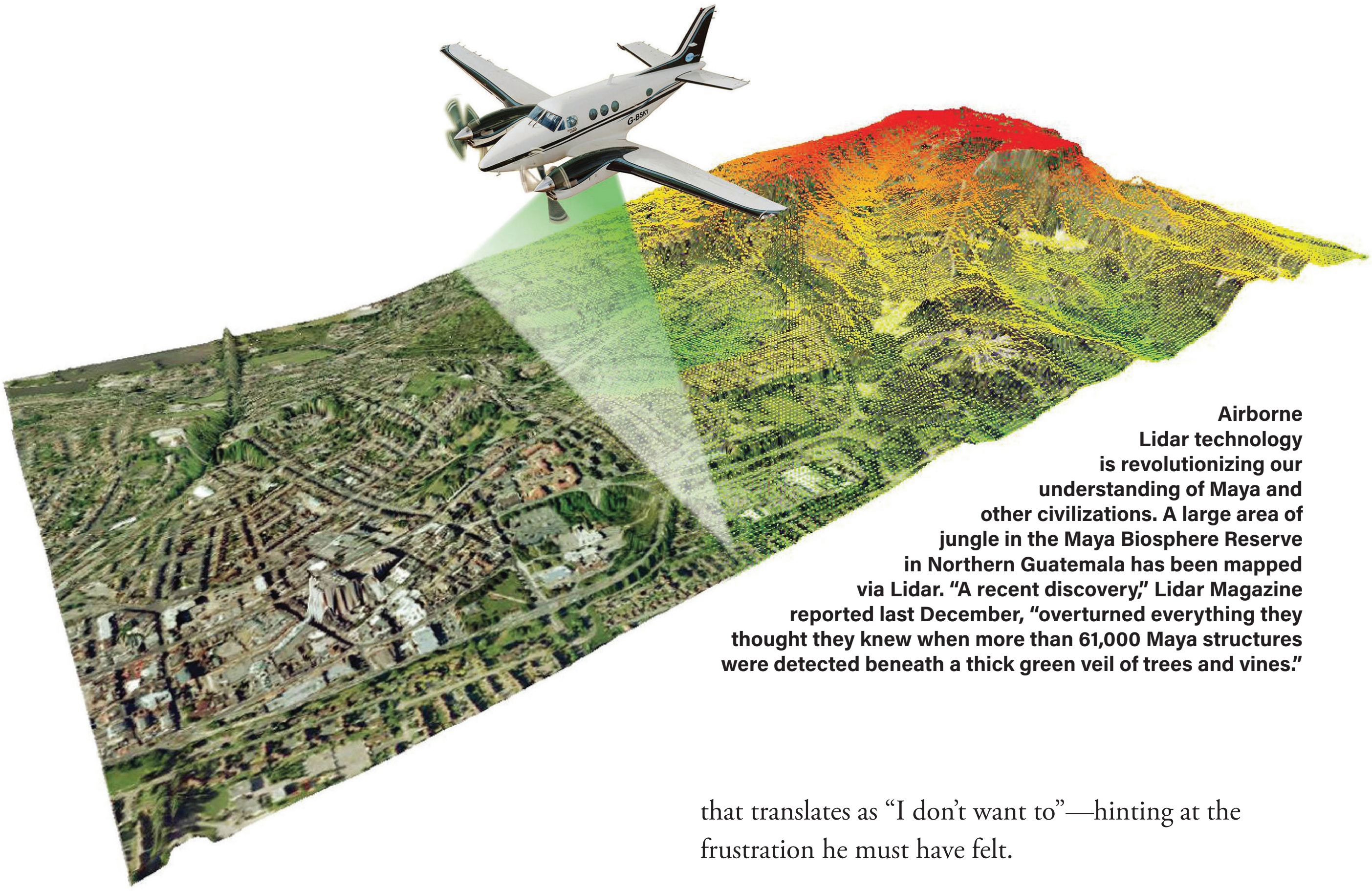
scrutinized by scholars. The early history of the codex is poorly understood, but it was likely created 900 or more years ago near the city of Chichen Itza in Mexico. It was perhaps sent to Europe by Hernan Cortes as a cultural curiosity during the conquest of Mexico, about 500 years ago, then passed down through private collections until it entered the Royal Library at Dresden in 1744 CE.

The great scientist Alexander von Humboldt studied the Dresden Codex and then published several pages of the codex in his *magnum opus* on the Americas in 1811. This volume has been part of scholarly discourse ever since. The first person to understand that the dots and bars represent numbers was the eccentric intellectual Constantine Rafinesque, who published his ideas in 1832. By the late 19th century, a full facsimile of the book was published by the librarian Ernst Förstemann, who was able to decipher the numerical and calendrical information.

Scholars struggled to decode the broader set of Maya hieroglyphs for decades until linguists imagined themselves to be codebreakers. This was perhaps unsurprising, given that the *zeitgeist* of the 20th century celebrated decryption, epitomized by the work of the computer's inventor, Alan Turing. His decipherment of German top-secret messages during World War II, which had been encrypted with the Enigma machine, helped the Allies to win the war.

The key to "codebreaking" the Maya script was accomplished with a document that functioned like the Rosetta Stone for deciphering Egyptian hieroglyphs. In 1566 CE, Diego de Landa, a Franciscan friar, wrote a

A Maya scribe interpreted the Spanish alphabet in hieroglyphs for Diego de Landa, OFM, which functioned as a Rosetta Stone for deciphering ancient Maya. For more information, please see Landa's *Relación de las cosas de Yucatán* in the Further Reading, below.



Airborne Lidar technology is revolutionizing our understanding of Maya and other civilizations. A large area of jungle in the Maya Biosphere Reserve in Northern Guatemala has been mapped via Lidar. "A recent discovery," Lidar Magazine reported last December, "overturned everything they thought they knew when more than 61,000 Maya structures were detected beneath a thick green veil of trees and vines."

mistaken explanation of how Maya hieroglyphs worked. He asked a Maya scribe to write hieroglyphs that corresponded to the Spanish alphabet. This task, however, was impossible because the Maya system of writing uses symbols for syllables that represent the sounds of consonants and vowels together, while written Spanish pairs letters together to evoke such sounds.

The Maya scribe, nonetheless, tried to do as he was asked, and the result was a list of hieroglyphs that referred to Maya words that sound similar to the names of the letters of the alphabet in Spanish. For example, the letter "B" in Spanish and the Maya word for road are both pronounced "beh." The hieroglyph for a road in Maya consists of a picture of a foot on a pathway, which is what the scribe drew next to the letter "B." This alphabet was used over the course of the 20th century as a starting point to decode the ancient writing. Amusingly, in addition to the alphabet, the scribe infamously wrote a phrase on Landa's manuscript that translates as "I don't want to"—hinting at the frustration he must have felt.

Using Landa's manuscript as a starting point, a community of scholars, which included Michael Coe, Yuri Knorozov, Simon Martin, Peter Mathews, Tatiana Proskouriakoff, Linda Schele and J. Eric Thompson, analyzed the glyphs with an approach that is similar to solving cryptograms or breaking ciphers. The result is that most of the glyphs have now been decoded, and we can once again understand the world of the ancient Maya peoples in their own words. Their writing includes royal genealogy, records of warfare and even poetic language. When a ruler died, for example, we know that the Maya said that the person's "white flowery breath" was gone.

Maya Digital Redux

The ancient Maya world may seem distant from us in the 21st century, when we intentionally encrypt and decode so much data, but we can be grateful that the work of scholars who use modern technology can enable us to understand the data and mindsets of the past. As we look to the future of research on the Maya, it is clear that using technology is now an important strategy to enhance our understanding of these people. Greg Reddick, a software engineer, has created software to convert dates between the Maya and Gregorian calendars. Also, the Foundation for the Advancement of Mesoamerican Studies has organized the Mesoamerican Language Texts Digitization Project to make materials for research readily available online.

Perhaps most significantly, airborne Lidar technology (described in the graphic on page 34) is revolutionizing our understanding of the Maya and other civilizations, especially if their cities and other remnants were engulfed by jungle. Previously, estimates of Maya populations were low enough that experts concluded that their sociopolitical complexity was likewise modest. Recent discoveries of massive numbers of structures in northern Guatemala, including homes and temples, along with "a complex system of raised roads and causeways enabling travel between urban centers, reservoirs, irrigation and terracing," indicate a far more sophisticated culture and society with perhaps millions of residents. ◘

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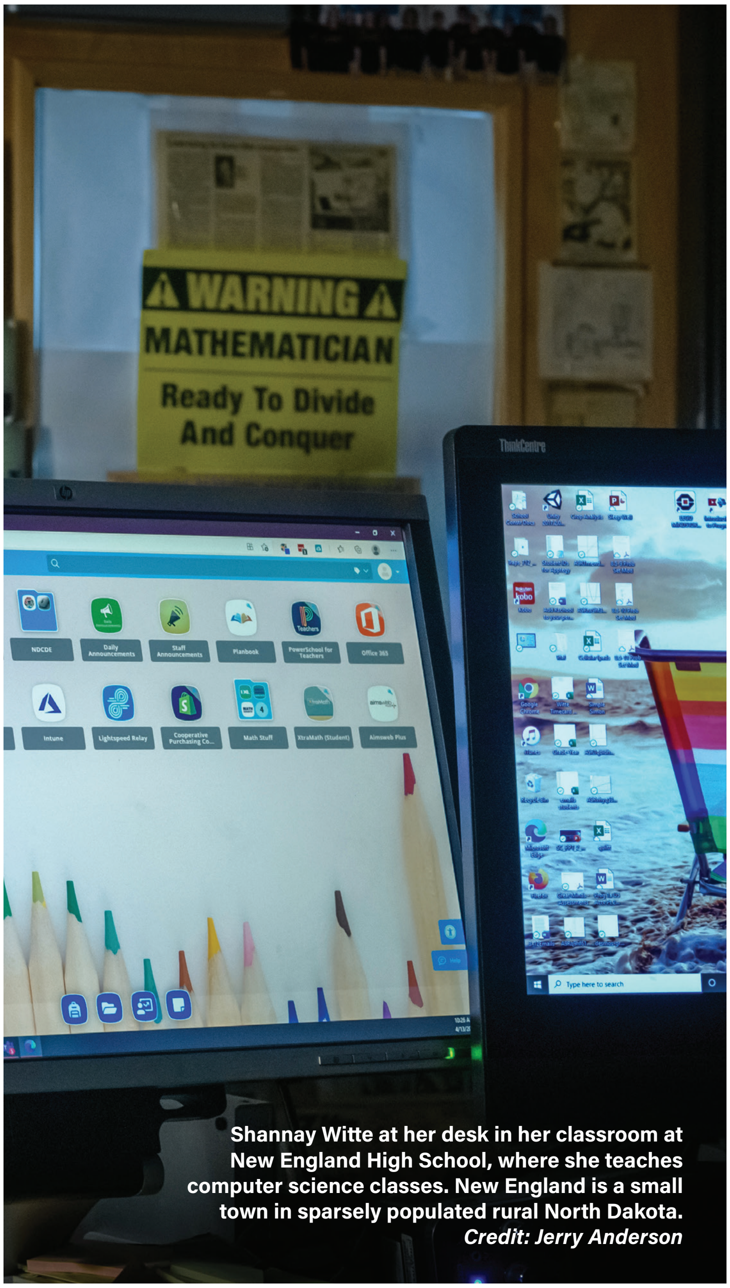
Witte & (Digital)Wisdom

The Benefits & Challenges of Online Education

MATTHEW LONN, EdD
Director, North Dakota Center
for Distance Education



Shannay Witte at her desk in her classroom at New England High School, where she teaches computer science classes. New England is a small town in sparsely populated rural North Dakota. ***Credit: Jerry Anderson***

Unlike many teachers, Shannay Witte was well prepared to deal with online instruction during the COVID-19 pandemic. Many K-12 peers struggled to quickly master online instruction, often leading to inconsistent and inadequate student learning experiences nationwide. Through decades in the classroom and teaching remotely with North Dakota's Center for Distance Education (CDE), Witte developed a digital skillset that enabled her students to continue excelling regardless of the medium of instruction.

Witte grew up on a farm near New England, North Dakota, a small city of 600 residents in sparsely populated southwestern North Dakota. She attended the city's eponymous elementary and high school. Aspiring to become a teacher, Witte moved to Fargo to study at North Dakota State University (NDSU) in 1984. Since majoring in computer science as a K-12 educator was not an option at the time, she majored in Family and Consumer Science (FACS) with minors in Math and Computer Science.

After graduating, Witte married her high-school sweetheart and moved back to the New England area to teach at the same school where they met. Eventually, they took over her husband's family small-grains farm, which typically means any grain that can be made into flour or pressed for oil. For the Witte family, this meant growing wheat, flax and canola. The family farm is located a few miles out of town. At the height of their operations, they farmed thousands of acres. The land was initially homesteaded by the Wittes in the late 1800s.

In 1989, Witte began her education career at New England, teaching computer science and middle-school math, and later took over the FACS teaching duties. In addition, she was and still is the full-time technology coordinator for K-12 in New England, with all grades in one building. For nearly 20 years, she focused on developing her teaching skills, being a parent, helping the family farm be profitable and managing the New England creamery. Witte and her husband raised two children. Her son Alex now works in Fargo, North Dakota, in behavioral health and her daughter Stephanie works in Dickinson, North Dakota, in childcare.

From Salad to Distance Ed

On a summer evening in 2009, Witte was peeling cucumbers in her farmhouse kitchen. The table was covered with the day's edition of the Dickinson Press. As the peelings piled onto the newsprint, Witte noticed an advertisement for a part-time computer science teacher with North Dakota's Center for Distance Education (CDE). The advertised position afforded Witte the ability to flex her schedule as needed. She could work with students online and still maintain her full-time teaching position at New England while also working on the family farm. Witte applied the next day.

CDE is North Dakota's only state-funded distance learning school. It was founded as a correspondence school in 1935 during the height of the Great Depression when many students, especially in rural areas, needed alternative learning opportunities as they worked long hours struggling to keep their family farms viable.

CDE's mission remains providing quality learning opportunities to students regardless of location, today via online platforms. When Witte was interviewed by CDE's director in 2009, course enrollments (an enrollment means one student in one course) had declined by 90 percent, from 9,500 to about 1,000 over the previous five years. CDE's core customers throughout the 1990s and early 2000s were out-of-state students in rural areas. However, CDE's once-popular print correspondence courses were no longer in demand as other state schools developed online courses.

CDE needed strategic and cultural change. In fact, the state governor's office considered closing the agency but decided there were serious unmet educational needs statewide. In rural areas, teacher shortages and lack of robust course offerings persisted as problems with no apparent viable solutions. A quality distance learning program held potential to alleviate these concerns.

A new director, Alan Peterson, PhD, was hired for the 2010-11 academic year, at the same time as the state legislature increased funding. This enabled the agency to decrease in-state student tuition and onboard hundreds of additional quality online courses from providers nationwide. High teaching standards for online education were defined clearly, and the agency committed to become fully online, with no print correspondence courses, by 2015. These initiatives focused CDE's mission on meeting the needs of North Dakota students first.

By the 2013-14 school year, enrollments surpassed 4,500, and the in-state proportion increased to 70 percent. By the 2019-20 school year, just before the pandemic, there were 5,500 enrollments, 80 percent of which were in-state.

In the summer of 2019, Peterson retired, and I was hired to replace him. I grew up in rural Princeton, Minnesota, and moved to Bismarck, North Dakota, to earn a BA in Social Behavioral Sciences at the University of Mary. Then, for almost 10 years, I taught social studies in grades 9-12 at Red Wing Public High School in Red Wing, Minnesota, as well as coaching football and track. In 2013, my family and I moved to Fargo when I was hired as CDE's assistant principal. I learned much under Dr. Peterson, as I earned my masters and doctoral degrees in Educational Leadership, and then accepted the challenge of becoming CDE's next director. My time at CDE helped me reframe how technology can be leveraged in education to provide students with learning experiences that offer greater choice and control over what a student wants to learn and when they learn it.

My first task as CDE's new assistant principal was to get to know CDE's part time adjunct teachers. Supervising CDE's adjunct teacher pool would become my main responsibility. Witte stood out as an exemplar teacher because of her targeted feedback with students and her high level of engagement with her colleagues at CDE.

From Classroom Instructor to Online Facilitator

Witte quickly realized that working at CDE differed significantly from teaching in a traditional classroom. First, students work at their own pace. There are no synchronously taught lessons to larger groups of students meeting together at one time. Second, the online courses are all predesigned and prebuilt online, eliminating the need for daily lesson planning and lectures. Instead, teachers provide detailed feedback to students when they submit work and communicate via multiple mediums, including a Learning Management System, phone, email, text and video conferencing.

This facilitator instruction model enabled Witte to teach a wide range of Information Technology courses, including Middle- and High-School Coding, Game Design, Robotics, AP Computer Science, Computer Programming and Cybersecurity. To date, she has worked online with almost 1,100 students from across North Dakota, as well as from California, Alaska, Germany and South Africa.

Witte soon learned that working with students online from a distance doesn't prevent building strong relationships. Currently, Emelia Thielman, a 16-year-old homeschooled student in Fargo, is taking the second semester of CDE's Advanced Placement (AP) Computer Science course with Witte as instructor. In phone and electronic interviews, Emelia said she has always enjoyed math and working with computers, but the first semester of AP Computer Science challenged her. Yet, "I found it be an extremely rewarding experience when you finish a computer program, and it works like it is supposed to," Emelia said. "Mrs. Witte is great to work with. She is always quick to help with questions and provides extra resources for learning and studying."

Emelia already has completed 23 of the 22 credits required for graduation in North Dakota, but she still considers herself a high school junior. She looks forward to majoring in forestry or a related field in college.

To help instructors conduct successful academic interventions with students struggling with

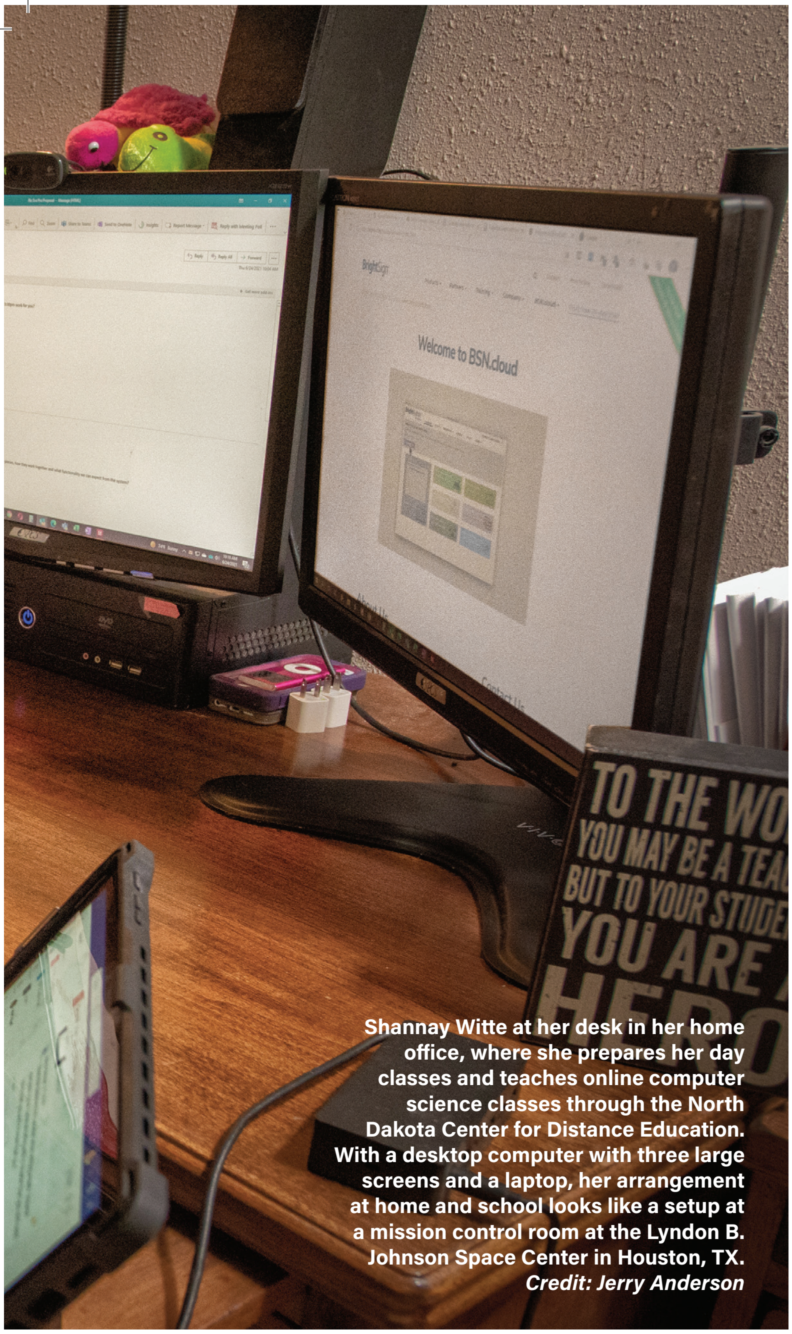
Shannay Witte walking with her husband Keith on their small-grains farm near New England, ND. Shannay and Keith were high school sweethearts who married in June 1989. ***Credit: Jerry Anderson***

coursework, CDE developed the Targeted Academic Progress (TAP) form, which creates a repository for each student with information about learning preferences, previous interventions and student feedback after course completion. TAP enables CDE teachers to collaborate regarding what works best for each student, essentially creating a digital version of a Professional Learning Community. The TAP form has played a crucial role in helping increase CDE's successful course completion rates from 54 to 85.9 percent over the last decade. This equals the average completion rate for similar state-hosted virtual academies, according to the Virtual Learning Leadership Alliance.

Online Education During the Pandemic

In the year before the pandemic, Witte taught FACS, math and computer science at the New England Public School, while also serving as the full-time technology coordinator. In the evenings via CDE, she helped students master competencies in computer science, cybersecurity, coding, robotics and game design.

Then, as spring 2020 approached, the new norm for educators nationwide became "distance learning." On March 15, Governor Doug Burgum ended in-person learning for the state's K-12 schools for the rest of



Shannay Witte at her desk in her home office, where she prepares her day classes and teaches online computer science classes through the North Dakota Center for Distance Education. With a desktop computer with three large screens and a laptop, her arrangement at home and school looks like a setup at a mission control room at the Lyndon B. Johnson Space Center in Houston, TX. ***Credit: Jerry Anderson***

the academic year. However, within weeks, schools were expected to reopen with a distance learning plan approved by North Dakota's Department of Public Instruction.

"Many teachers across the country were asked to be online instructors, and they were not well prepared," Witte observed. "It was this variability in teacher preparedness that at least partially led to large inconsistencies in a student's digital experience throughout the pandemic." Many classroom teachers had little to no experience working with online education and almost instantly had to build engaging lessons with interactive content and live virtual meetings.

In New England, there was no coordinated effort to adopt the same Learning Management System when the pandemic hit. As in many school districts, teachers utilized Schoology, Seesaw, Class Dojo, Google Classroom, Canvas and others, which created confusion and logistical issues with students and their parents.

In the fall of 2020, most students across the country started the school year from home via Zoom and other platforms. New England elementary and high school, however, were fully open. Still, all public schools statewide were required to provide a full-time virtual option for students. According to Witte, only about a dozen of more than 300 students in New England chose to learn virtually.

The pandemic, however, was a key factor that helped convince New England's education authorities to adopt a 1:1 device policy for students. Every student in grades K-12 is now equipped with a digital device—an iPad for grades K-2 and a small laptop for grades 3-12—to enable both distance learning and hybrid (which blends face-to-face classroom and remote instruction) and distance learning more easily.

"[Digital] devices are really important learning tools for all students," Witte said, "but students and teachers need to be taught how to use them as educational tools." The key objective is student mastery of competencies. But the challenge is how to leverage new technologies to help students learn key concepts and then demonstrate mastery of skills. The first hurdle is laying a foundation so that students can access the required course content remotely. This requires that teachers first move course content onto a Learning Management System. However, many teachers are not trained to do so. Prior to the pandemic, Witte had already started moving her course materials onto the Teams Learning Management System for her New England students. As soon as COVID-19 precipitated school closures, Witte helped her New England peers learn how to utilize technology for remote learning and hybrid learning scenarios.

CDE & COVID-19

During the 2020-21 school year, CDE almost doubled in-state course enrollments from the previous year to 10,200. Core subjects such as English and math increased about 325 percent from the previous school year. Enrollment increases in CDE's computer education courses were not quite as significant, but Witte's classes grew by 180 percent.

The biggest challenge for Witte and other CDE instructors was dealing with the surge of students who had not taken an online course before. CDE's research shows that first-time online learners pose the greatest risk of not successfully completing their courses. During the 2020-21 school year, almost 70 percent of CDE enrollments were new online learners. Helping these students often requires longer work hours, increased frequency of communication and different mediums to address even basic online course navigation questions.

For those organizations already providing online distance learning, such as CDE, the COVID-19 pandemic tested capacity and enrollment processes. Other vital components, such as digital curriculum, online teaching methods and technology infrastructure, were already in place. For Witte, being consistently exposed to an online teaching model had provided her with years of experience that at least partially transferred to distance scenarios now playing out in schools across the country.

What many traditional K-12 teachers discovered was that the shift to distance or hybrid learning did not just require them to learn about Learning Management Systems and virtual meeting platforms. Many of the methods that classroom teachers had been using for decades—such as large group lecture, non-verbal feedback cues and student questioning—were suddenly no longer applicable for students learning virtually, since they could progress through content at their own pace.

Students now experience an environment in which traditional barriers, such as seat time and classroom bells, are removed. Also, no longer do teachers remind students about daily lesson objectives, upcoming quizzes or homework assignments. Many of these common stabilizing factors for students are not part of online education, sometimes causing confusion and frustration.

For two decades, educational innovators have been promising a revolution in education via digital delivery and the implementation of adaptive, intelligent software programs. Some educators conclude that the pandemic exposed the weaknesses of potential digital innovations in education. Other experts argue that the pandemic exposed the drawbacks of the traditional classroom. For teachers like Witte, the way forward involves the best of both online and face-to-face instruction.

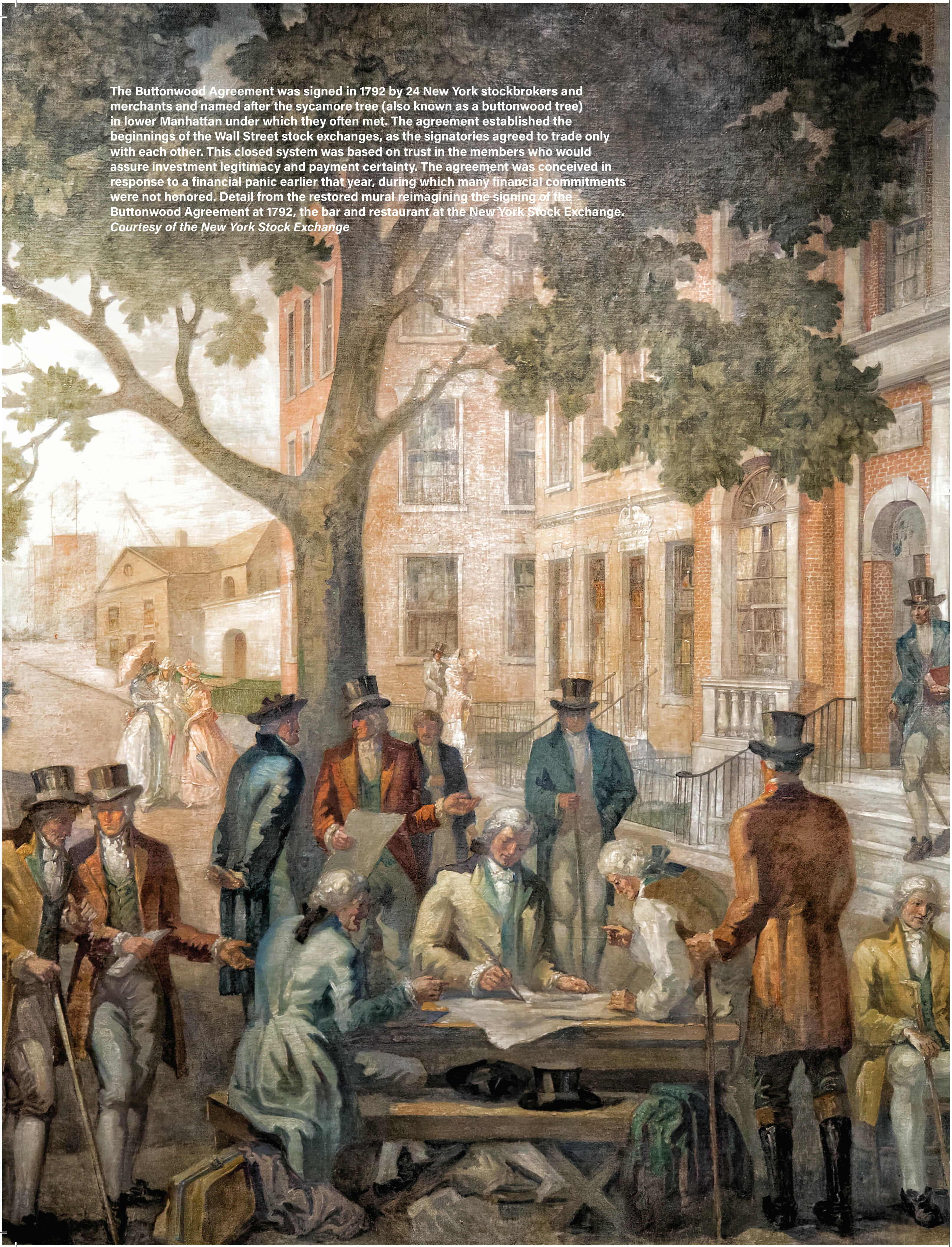
Benefits & Challenges of Digital Education

We are now at a watershed moment where we can implement positive change that would really benefit students. Most notably, the pandemic provided a catalyst for accelerating educational choice and control for students and their parents, enabling them to leverage new digital technologies. This has been developing gradually over the last decade and is now becoming the norm. Often for the first time, parents and students are realizing that there is reliable technology and infrastructure in place to enable access to increasing inventories of available courses and to enable control over each child's pace of study.

It's important to temper this with Witte's observation that digital devices, educational software and learning platforms, although important learning tools, are still just tools. They must be continuously evaluated regarding how they facilitate student learning.

Digitization doesn't replace or diminish the fundamental reality that students learn most when there is a caring adult involved in the process. The teacher-student bond is vital for learning, and digital platforms risk failure when human engagement is missing. What prepared Witte to be an effective teacher during the pandemic was both her technological expertise and her well-honed ability to build positive, lasting relationships with students in the classroom and online. The result is students who are well equipped with the academic skills and knowledge they need to be successful.

Emilia Theilman, a 16-year-old homeschooled student, completing work on her laptop for the Advanced Placement (AP) Computer Science course, which Witte teaches through the North Dakota Center for Distance Education. In the equivalent of her junior year, Emilia—who lives in Fargo, ND, about 315 miles away from Shannay Witte—has already earned enough credits to graduate high school and is taking AP courses to earn college credit. *Credit: Jerry Anderson*



The Buttonwood Agreement was signed in 1792 by 24 New York stockbrokers and merchants and named after the sycamore tree (also known as a buttonwood tree) in lower Manhattan under which they often met. The agreement established the beginnings of the Wall Street stock exchanges, as the signatories agreed to trade only with each other. This closed system was based on trust in the members who would assure investment legitimacy and payment certainty. The agreement was conceived in response to a financial panic earlier that year, during which many financial commitments were not honored. Detail from the restored mural reimagining the signing of the Buttonwood Agreement at 1792, the bar and restaurant at the New York Stock Exchange.
Courtesy of the New York Stock Exchange

GameStop or Stopping the Game?

Retail Davids vs. Wall Street Goliaths

FARIZ HUSEYNOV, PHD
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"O wonder! How many ingenuous investors are there! How courageous mankind is! O brave new markets That has such retail investors in't." – *The Tempest (of Markets)*

If, as above, we paraphrase Miranda's words to her father, Prospero, in Shakespeare's "The Tempest," perhaps we would conjure the story of Vladislav Tenev and Baiju Bhatt, the founders of Robinhood Markets, Inc. In 2008, Tenev earned a bachelor's degree in mathematics from Stanford University, and Bhatt, whom he met there, finished a master's degree in mathematics. A year later, Tenev and Bhatt decided to start a trading company and moved to New York City.

Their first venture failed. For their second company, Chronos Research, Tenev and Bhatt created and marketed algorithmic trading software for automated transactions. "[H]edge funds and banks were using our software to place millions of transactions per day, and the portfolios they came up with were … incredibly rich," said Tenev.[i] The duo "realized that big Wall Street firms paid effectively nothing to trade stocks, while most Americans were charged commission for every trade."[ii]

Disrupting Nottingham

Tenev and Bhatt saw an opportunity to make their sophisticated software, which was powering large investment firms, available to retail consumers. In 2013, they founded Robinhood to enable the little guys to invest in stock markets and trade other financial assets directly, without the wealth management industry making decisions for them—and without having to pay transaction fees. Not only were brokerage firms charging small investors $7 to $10 per trade, but they also required a deposit of $500 to $5,000 to open an account, which Robinhood waived.

robinhood

Robinhood was the first to leverage digital technology for maximum accessibility with an app, enabling ordinary people to participate in our financial system from their smart phones. Today, Robinhood has over 13 million customers, more than half of whom trade daily. This forced most brokerage firms to offer commission-free trading, which greatly increased public access to financial markets.

In so doing, Robinhood disrupted the century-old tradition of the minimum commission rule that, in 1894, the governing committee of the New York Stock Exchange (NYSE) called "the fundamental principle of the Exchange … on its strict adherence hangs the financial welfare and the life of the Institution itself."[iii]

From Buttonwood to Vanguard

Originally, investing and brokerage firms were not meant for everyone. About 230 years ago, 24 brokers met under a buttonwood tree on Wall Street in New York City to make an agreement on the commission rates they would charge each other when trading Revolutionary War bonds and stocks from the First Bank of the United States. Today, that one-page "Buttonwood Agreement" (things were much simpler in those days) is considered the NYSE's founding document and one of the most important financial records in American history. Trading was executed face-to-face and limited to this group of investors.

After Samuel Morse invented the telegraph in 1844, information was communicated remotely, which increased the number of potential investors. However, most Americans invested in land and commodities, such as gold, until the early 20th century. Then rising poverty and double-digit inflation provided motivation to put money into stock markets. Starting in 1913, the inflation rate (the change in the Consumer Price Index) was calculated and published monthly. Consumers not only felt the depreciation of the dollar in their pockets, but they could also read about it in newspapers and other publications.

When an economic depression hit in 1920-21, people started looking for alternative ways of accumulating wealth and often chose to invest in stock markets. Certainly, stock traders and brokerage firms made their best efforts to encourage them. Success stories of capital gains and speculation increased the number of individual traders. In 1929, more than 1.5 million customers had accounts with America's 29 stock exchanges.[iv]

Nearly 600,000 families were trading on margin, which means investing their own plus borrowed money. But the more these families relied on capital gains to increase their wealth, the less able they were to pay off these loans in case of a downturn in stock prices.

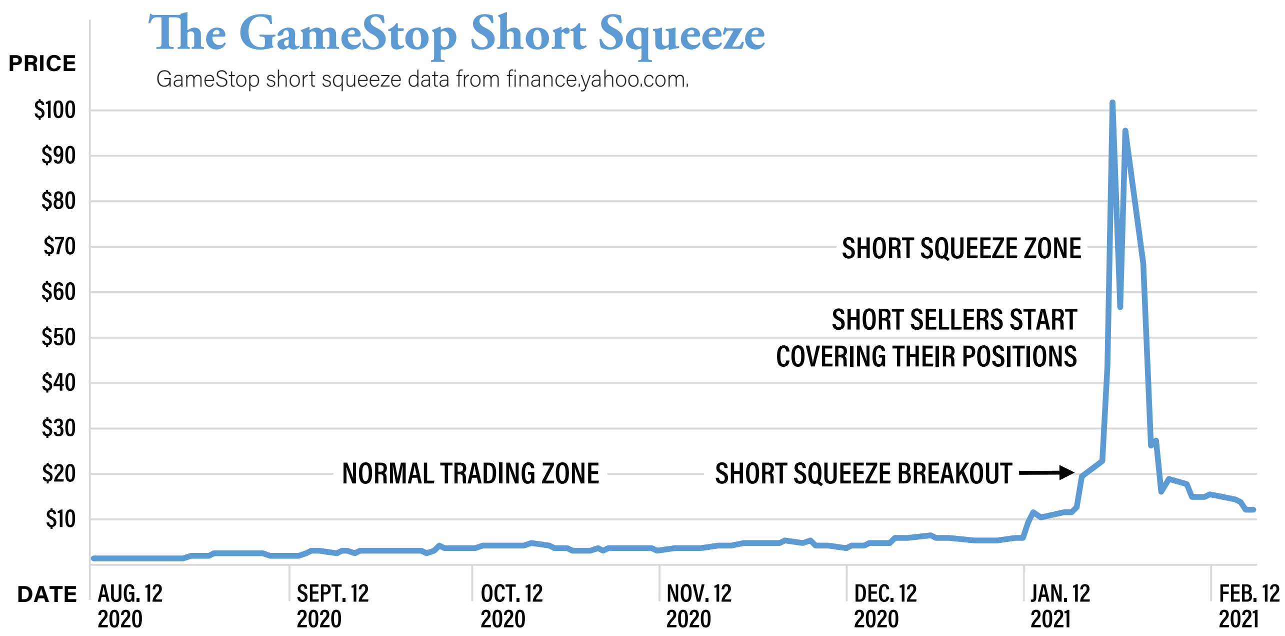
As well, the growing number of investment trusts made investing more accessible and attractive.

Then the bitter experience of the 1929 Great Crash, which initiated the Great Depression, drove retail investors away from the markets until 1975, when investing in broader stock markets became available as the legendary John Bogle founded Vanguard 500, the first Index Fund. The United States Revenue Act of 1978 established 401(k) tax policies, encouraging saving and investing to benefit at least from compound interest. While these advancements made investing in overall markets and funds easier, in order to draw retail investors to individual stocks, brokerage firms needed to develop tools directly targeting them.

E(lectronic)*TRADE

The "game changer" came in 1992 from E*TRADE, which adopted a "direct-to-consumer" strategy and offered online brokerage services to ordinary Americans.[v] Within three years, the information revolution was well underway with "multimedia PCs, which bundled sound, video and—particularly important for E*Trade—modems into relatively inexpensive and easy to install packages."[vi] The mass proliferation of digital technologies greatly increased the customer base for online trading. E*TRADE opened its website in 1995, which soon accounted for 13 percent of company sales.

By the beginning of new millennium, there were 13 million online brokerage accounts nationwide, with four million Americans trading stocks actively online—still paying transaction fees—representing 25 percent of all retail stock trades and about 15 percent of the trading volume on the NYSE and NASDAQ (a stock exchange created in 1971 by the National



Association of Securities Dealers, which originally stood for the National Association of Securities Dealers Automated Quotations).[vii]

According to the Yankee Group IC,[viii] the top three reasons retail investors embraced digital technological disruption and traded online were low transaction fees, access to online research and convenience.

Similarly, in recent years, millennial and Gen Z retail investors prefer Robinhood for providing a mobile phone app to do all this for free. These generations also shifted their focus from funds to individual stocks such that, according to Bank of International Settlements (BIS) reports, retail investors' holdings of individual stocks increased 100 to 200 percent. To turn a profit, Robinhood makes money by receiving rebates from brokers on order flows and by offering loans and cash management services to their clients.

Retail investors are assumed to be "noise traders"—driven by rumors such as postings on Reddit—lacking the ability to fairly price financial assets. Nobel Prize winner Milton Friedman argued that these "mistaken investors"[ix] cannot survive in financial markets because they will buy high, sell low and eventually lose their wealth. However, we do not know how long it will take for this to happen. Noise traders tend to remain bullish (expecting prices to go higher) and extend their demands for longer time periods, which will lead them to take more risks.

Subsequent studies showed that if noise traders dominate the market over rational investors, they can increase their wealth consistently by betting against more informed traders. To accomplish this, however, they must bear greater risk tolerance and, as prices go up and their wealth grows, they tend to bet more in order to gain more, thereby compounding risk.

GameStop

Robinhood's retail investors might be called noise traders, but they are not necessarily less knowledgeable, since they access online educational platforms, such as Coursera, and share knowledge with peers through digital forums. Dismissing retail investors as temporary noise might cost sophisticated investors dearly. The story of GameStop and similar stocks, such as AMC, teaches valuable lessons.

Thousands of GameStop retail investors became fired up by a narrative that if the stock price rose to a certain price point, it could only go higher. The origins of the frenzy date back to mid-2019 when some retail investors shared Reddit posts about how GameStop's stock price could increase sharply because the stock was heavily shorted. They called it "an epic short squeeze," a phenomenon that involves going against short sellers (bearish investors who are betting on stock prices going down).

Short sellers try to sell high first and buy low later, while posting equity to protect their brokers, who facilitate short selling by borrowing shares from other institutional investors until short sellers cover their positions. If the stock price falls, they are the winners. But if the stock price rises, short sellers will have to buy back shares to curb their losses. Then as they buy more shares, the stock price pushes even higher, which will require them to buy more shares—forcing them to slide into an endless spiral of loss. If a stock is heavily shorted, short sellers get into deep trouble when they try to buy shares to cover their losses, and no investor is willing to sell since they believe in the stock's potential upside. Worse, short sellers also have to cover the loans they took to buy stock.

Groups of retail investors who were following heavily shorted stocks (as a percentage of total tradable shares) realized that GameStop topped the list. They knew if they pushed GameStop's price beyond a threshold, the short squeeze would begin. Then if no one was willing to sell GameStop, the price would skyrocket—not because the market believed higher prices were the fair valuation based on fundamentals, but mostly because of pressure put on short sellers to buy.

The short squeeze happened in two phases. First, in September 2020, Ryan Cohen, a successful entrepreneur, disclosed he held an almost 10 percent stake in GameStop. Secondly, Cohen's firm announced that it was getting more involved with GameStop in order to "produce the best results for all shareholders."[x] At the same time, retail investors, who were waiting for a catalyst event, which would materially impact the price of a heavily shorted stock, started communicating through online posts about GameStop and drove up the stock price. Other investors, who also saw GameStop as one of the most heavily shorted stocks at the time, thought this was a once-in-a-lifetime short-squeeze opportunity and bought the stock. During the business week of January 25, 2021, GameStop was the most heavily traded stock—proving that small investors, driven by conviction, can drive the stock market.

When this began, the price for GameStop was in single digits. By January 15, the price jumped to $15, and on January 25, it surged past $100. As a result, Melvin Capital, a hedge fund that had shorted more than 100 percent of the stock—up to 140 percent, which can happen temporarily since many brokers keep borrowing stocks from various institutional investors, such as pension funds and insurance companies—was in deep trouble and had to close their position**.** This entailed buying back GameStop shares at a loss of $3.75 billion, which was 30 percent of the total hedge fund. Melvin Capital's woes were tracked by retail investors who generated more than 40,000 Reddit posts**.**

Digital Gamma Squeeze

Robinhood and other digital platforms provide access to financial markets for retail investors, who gather and share information and then sometimes (as with GameStop) act together for the specific purpose of getting rich quick by going against institutional investors. Not only were these retail investors trading in stock markets, they were also increasing their bets in the options markets. Options require more sophisticated knowledge, but apparently that was not an issue for retail investors suffering from Covid-induced boredom. They could easily educate themselves online about complex securities.

In a nutshell, options give investors a right to purchase or sell underlying assets. Buying a call option on GameStop shares, for example, secures the price for a defined period of time. Then if buyers choose to exercise their purchase rights, sellers must buy shares—even if the price has increased—to hedge risks.

Some investors purchased GameStop call options, and as the stock price rose, options sellers had to buy more shares at higher prices, which pushed the price even higher, creating what is called the "gamma squeeze": the combined short squeeze and options squeeze. This drove GameStop up to $430 per share.

Not surprisingly, the gamma squeeze was characterized in the media as "a populist revolt by small-time investors against big hedge funds."[xi]

Robinhood

As indicated in the graph above, tweets on January 27 by Elon Musk, Tesla's CEO, dramatically accelerated GameStop buying. By the next day, Robinhood was forced to halt GameStop trading on its platform. Later, on February 18, Robinhood's CEO, was summoned to testify before the U.S. House Committee on Financial Services. "[T]rading restrictions were necessary to allow us to continue to meet the clearinghouse deposit requirements that we pay to support customer trading on our platform," Tenev explained.[xii] Despite immense technological advancements in online trading, the settlement process in stock trading takes two days—only one day less than previously—during which customers can't cash out.

Many investors traded on margin, which means they borrowed money to invest, thereby increasing Robinhood's settlement risk. To cover this, Robinhood was required to place a deposit using its own funds until the trade "settled." On January 28, Robinhood had a deposit deficit of about $3 billion. Even though the National Security Clearing Corporation, a clearing agency registered with the Securities and Exchange Commission, waived some of the excess capital obligations, the required total was too high for Robinhood to allow GameStop trading to continue.

A day later, however, Robinhood received enough capital commitments from its investors to lift the trading restrictions, after which the share price fluctuated sharply as many investors tried to capitalize on market volatility.

Then on April 19, GameStop's CEO announced he was stepping down, which paved the way for entrepreneur Ryan Cohen to cement his control over GameStop by adding more allies to the company's board of directors. On April 8, GameStop announced that Cohen would become company chairman.[xiii]

Piggly Wiggly

Did GameStop's retail investors accomplish something unique in stock market trading? Not really. Even though some investors might not have heard about the short squeeze previously, it is not a new phenomenon. In fact, the first famous short squeeze was organized not by investors but an entrepreneur.

In 1916, Clarence Saunders founded Piggly Wiggly, the first self-serving grocery store—the model that's ubiquitous today—in Memphis, Tennessee. Now there are more than 530 stores in 17 states, according to the company's website. When asked why he picked such an odd name for his stores (the website reports), Saunders replied, "So people will ask that very question."

By 1922, Piggly Wiggly was growing rapidly with 1,200 stores nationwide. The company's stock had gone public and was listed on the NYSE. Saunders served as president and become very wealthy. After several grocery franchises (not Piggly Wiggly) went bankrupt, some Wall Street traders decided to short Piggly Wiggly stock and make a quick, lucrative profit. Saunders became enraged and decide to "break Wall Street" by orchestrating the first David vs Goliath short squeeze.

Saunders took out a loan for $10 million (almost $155 million today) and started buying Piggly Wiggly stock from the market. Within a week, he owned half of the outstanding shares and the price went up by 50 percent. Soon he owned 99 percent of the stock and Wall Street became alarmed, realizing that Saunders was cornering the market. He was in a position to squeeze short sellers, since they would have to buy from him, and he could name the price. Short sellers were facing huge losses.

Previous cornering strategies had been executed by major insiders, such as Cornelius Vanderbilt and Jay Gould. But, for Wall Streeters, Saunders was a country hick, an outsider who was trying to teach Wall Street a lesson. This could not be tolerated.

A photo of the interior of the original Piggly Wiggly store in Memphis, TN, taken in 1918, two years after it opened as the first self-service grocery store. ***Source: Library of Congress***

Short sellers complained to the NYSE, which set its own trading rules—the U.S. Securities and Exchange Commission had not yet been established. Not surprisingly, the NYSE (whose governing committee members were Wall Street insiders) changed its rules to suspend Piggly Wiggly trading indefinitely when the stock price peaked at $124.

This caused the stock price to drop, and Saunders couldn't repay the $10 million loan, which was far larger than the declining worth of his shares. He resigned as president and was forced into bankruptcy.

Digitization's Many vs the Established Few

Saunders was alone in his short squeeze, which contrasts greatly with the GameStop version. Today's digital tools enable thousands of retail investors to join forces and create havoc in financial markets.

The efficient markets hypothesis (a dominant financial theory stating that share prices—and markets overall—reflect all the relevant information) assumes that when investors deviate from rationality, it's a random, not interdependent, phenomenon.

Recently, we have often seen this assumption disproven. According to CNBC**,** one in five GEN Z and Millennial investors use online Reddit forums to drive financial decisions.[xiv] This community effect can impact markets too significantly to easily be dismissed, even if retail investors make irrational trades or suffer from confirmation bias. Real-time transfers of knowledge among retail investors strengthen them against more sophisticated institutional investors, such as hedge funds. Seasoned Wall Street investors might not be calling them "mistaken investors" anymore.

Retail investors don't just bet their own money, they also borrow funds. This enables them to increase market leverage, which, according to a report by the Bank of International Settlements,[xv] has reached greater levels than during the dot-com bubble. Options allow retail investors to further increase their leverage.

Stopping or Elevating the Game?

The retail investor-GameStop phenomenon has not gone unnoticed among conventional stock market giants. On May 1, Warren Buffett and his business partner Charlie Munger spoke at Berkshire Hathaway Inc.'s annual meeting, during which they criticized Robinhood for attracting and supporting retail investors in making casino-like bets via options. "The gambling impulse is very strong in people worldwide, and occasionally it gets an enormous shove," Buffett said. "It creates its own reality for a while, and nobody tells you when the clock is going to strike 12, and it all turns to pumpkins and mice." [xvi]

"If the last year has taught us anything," responded Jacqueline Ortiz, Robinhood's Head of Public Policy Communications, in a blog post,[xvii] "it is that people are tired of the Warren Buffetts and Charlie Mungers of the world acting like they are the only oracles of investing. And at Robinhood, we're not going to sit back while they disparage everyday people for taking control of their financial lives."

Giving ordinary people free access to financial markets has a significant value. Their savings flow to companies that invest and create jobs across the country. They get a chance to increase their wealth and reach financial goals. They also have the opportunity to become tech savvy while managing their wealth.

However, these all come with significant risks. Buffet and Munger are right that impulsive, poorly informed investment decisions reap "pumpkins and mice" far more often than Cinderella's golden carriage. These investors can drive stock markets in unpredictable ways, which makes big investors and investment firms quake. Their reactions to the GameStop saga indicate they would like to stop the small-guy investment game on platforms they don't control, such as Robinhood. However, according to The Wall Street Journal, major Wall Street firms are now "combing through the internet forms of Reddit" and others "in search of trade opportunities."

The horse is out of the proverbial barn. Digital access to online trading is already available to anyone with a computer or smart phone. It can't be stopped.

Instead, to mitigate risk to both retail investors and the big guys, we need to invest in comprehensive financial literacy programs, which also develop competency in digital trading tools, at the high school and college levels. This can be done both in the classroom and via online courses, which should be available to everyone. Elevating knowledge and skills always yield significant dividends.

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HAVE YOU MET
THE NEW BOSS?

Would Regulation Prevent AI From Becoming an Evil Overlord?

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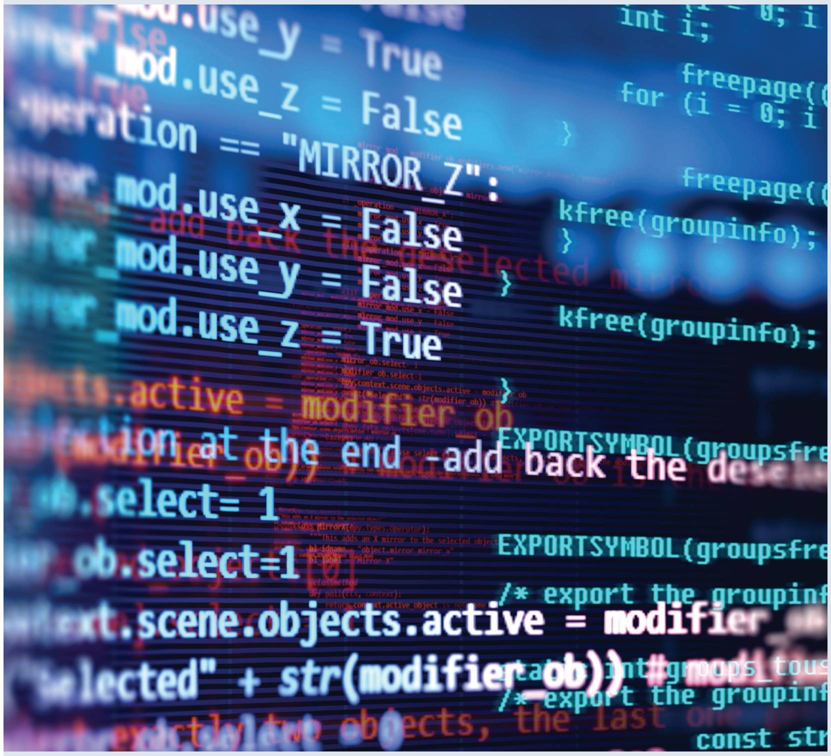
Some people are, perhaps, afraid that heavily armed artificially intelligent robots[i] might take over the world and enslave us—or they might even exterminate humanity.[ii] Due to these and other concerns, tech-industry billionaire Elon Musk, late physicist Stephen Hawking and a growing number of computer scientists say that artificial intelligence (AI) technology needs to be regulated[iii] to manage the risks.[iv] Amazon CEO Jeff Bezos and Microsoft founder Bill Gates, despite his earlier more relaxed position on AI,[v] have both raised concerns[vi] about AI weapons systems.

Because of these and related concerns, there have been a number of calls to regulate AI. Some policy makers have suggested regulating it as a "tool with applications,"[vii] while others have proposed regulating its use in particular sectors of the economy on a use-by-use basis.[viii] The Federal Trade Commission (FTC) has released guidelines reminding AI developers and users that AI has to play by FTC and other federal rules, including those regarding accuracy, non-deception, truthfulness and non-discrimination.[ix]

More extreme proposals have called on regulators and system operators to "starve" AI to prevent it from becoming "a social and cultural H-bomb" that could "deprive us of our liberty, power autocracies and genocides, program our behavior, turn us into human machines and, ultimately, turn us into slaves."[x] Rob Towes, a venture capitalist and journalist, has even called for the creation of a new federal AI regulating agency.[xi]

AI, though, is already subject to numerous regulations (as the FTC aptly notes). Regulating its decision-making processing—because of what it might determine or recommend—is inherently problematic. While AI likely doesn't have constitutional free-speech rights, the designers and developers of the systems clearly do. Regulating AI's output is arguably constitutionally prohibited prior restraint on developers' speech, irrespective of what the AI may recommend or how these recommendations may be utilized.



■ What is Artificial Intelligence?

Artificial intelligence systems are a type of software that uses computer algorithms to make decisions. Multiple types of artificial intelligence exist. Some model the emergent decision-making patterns of insects and other animals, in which powerful decision-making emerges from the combination of many small-scale decisions. Other researchers use machine learning, in which the system performs analysis or prediction and learns from the results, either by comparing them to the right answer, as part of a training process, or by observing what happens in response to the implementation of training processes.

■ Regulation of AI as Regulation of Speech

We don't regulate human thought or speech in the United States, but groups concerned with preventing AIs from advancing beyond human control and ensuring equitable AI decision-making have advocated regulating the decision-making processes and outputs of AI systems. While human speech is protected by the First Amendment to the U.S. Constitution, it is not clear that the speech of an AI system would be protected. One could argue that the broad language of the First Amendment ("Congress shall make no law abridging the freedom of speech") applies to non-human speech. Or, since an AI program's source code is the developer's speech, and the outputs generated by the AI system are an extension of the developer's code speech, these should be protected on the basis of preventing restraint on the developer's (human) free speech rights. However, there is no clear precedent for these arguments as yet.

In fact, some proposed regulations are dangerously close to suggesting the regulation of human thought. This is particularly true when the AI is advising only its developers or operators of its conclusions and not speaking to a larger audience. Moreover, researchers and businesses are already subject to existing rules, regulations and laws designed to protect public safety. Imposing further limitations risks reducing the potential for innovation with AI systems or limiting these benefits to only the large firms that are skilled at navigating governmental regulations without necessarily actually solving any real problems.

How Is AI Regulated Now?

While the term "artificial intelligence" may conjure fantastical images of human-like robots, most people have encountered AI before. It helps us find similar products while shopping,[xii] offers movie and TV recommendations,[xiii] and helps us search for websites.[xiv] It can also grade student writing,[xv] provide personalized tutoring[xvi] and even help the TSA detect objects carried through airport security scanners.[xvii]

In each case, AI makes tasks easier for humans. But even as AI frees people from doing this work, it still bases its actions on human decisions and goals about what action to take or where to search, and what to look for.

In areas like these and many others, AI has the potential to do far greater good than harm—if used properly—and additional regulations are not needed to make sure this happens. There are already laws on the books of nations, states and municipalities governing civil and criminal liabilities for harmful actions. Autonomous drones, for example, must obey FAA regulations, while a self-driving car's AI must obey regular traffic laws to operate on public roadways.

Existing laws also cover what happens if a robot injures or kills a person. If the injury is accidental, the robot's programmer or operator isn't criminally responsible[xviii] but could face civil consequences. While lawmakers and regulators might need to refine responsibility for the actions of AI systems as technology advances, creating regulations beyond those that already exist could prohibit or slow the development of capabilities that would be overwhelmingly beneficial.

Potential Risks from Artificial Intelligence

It may seem reasonable to worry about researchers developing very advanced artificial intelligence systems that can operate entirely outside human control.[xix] A common thought experiment deals with a self-driving car forced to make a decision[xx] about whether to run over a child who just stepped into the road or veer off into a guardrail, injuring the car's occupants and perhaps even those in another vehicle.

Musk and Hawking, among others, worry that hyper-capable AI systems, no longer limited to a single set of tasks, such as controlling a self-driving car, might decide it doesn't need humans anymore. It might even look at human stewardship of the planet, interpersonal conflicts, theft, fraud and frequent wars, and decide that the world would be better without people.[xxi] Science fiction author Isaac Asimov tried to address this potential by proposing three laws[xxii] limiting robot decision-making: Robots cannot injure humans or allow them "to come to harm." They must also obey humans—unless this would harm humans—and protect themselves, as long as this doesn't harm humans or ignore an order.

But Asimov himself knew the three laws were not enough.[xxiii] And they don't reflect the complexity of human values. What constitutes "harm" is an example: Should a robot protect humanity from suffering related to overpopulation? Or should it protect the individual freedom to make personal reproductive decisions? Or might it identify something humans wouldn't even readily think of—and decide to protect us against it?

Humans have already wrestled with these questions in our non-artificial intelligences. There are numerous restrictions on freedom in this and all other societies. Rather than regulating what AI systems can and can't do, it would be better to develop them with—or teach them human ethics and values,[xxiv] like parents do with human children.

However, just as not every human society's values are the same, we can expect that AI systems made by different groups might have different values. If AIs are developed in the shadows by zealots or criminal organizations that flout regulations, it will almost certainly be these organizations' values that they embody.

Artificial Intelligence Benefits

People benefit from AI everyday. They get product recommendations from Amazon, search results from Google or Microsoft's Bing and even AI-targeted marketing from numerous companies. AI systems look for network attackers, detect fraudulent credit card and bank transactions, and even keep airports and national borders safe. But this is just the beginning. AI-controlled robots could assist law enforcement in responding to human gunmen. Current police efforts must focus on preventing officers from being injured, but robots could step into harm's way,[xxv] potentially changing the outcomes of cases such as the shooting of an armed college student at Georgia Tech[xxvi] or an unarmed high school student in Austin.[xxvii]

Intelligent robots can help humans in other ways, too. They can perform repetitive tasks, such as processing sensor data[xxviii] during which human boredom might cause mistakes. They can limit human exposure to dangerous materials and dangerous situations, such as decontaminating a nuclear reactor[xxix] or working in areas humans can't go. In general, AI robots can provide humans with more time to pursue what they define as happiness by freeing them from having to do other work.

AI Is Going to Happen—Here?

Many discussions of U.S. regulations seem to presume that American laws can restrict or prevent AI development. However, this is demonstrably not the case. While the U.S. has led the world in the development of key computing technologies and several of the world's largest software companies[xxx]—Microsoft, Google, Oracle, IBM, Apple and Adobe—are American firms, the U.S. is not the only place where AI is being developed. Russian president Vladimir Putin has heralded AI as "the future, not only for Russia, but for all humankind."[xxxi] In September 2017, he went as far as to tell Russian students that the nation that "becomes the leader in this sphere will become the ruler of the world."[xxxii]

With Russia and other nations embracing AI,[xxxiii] nations that don't innovate in AI technologies—or worse, those that actually restrict its development—run the risk of falling behind and not being able to compete with the countries that promote AI development.[xxxiv] Advanced AIs can create advantages for a nation's businesses and its defense. Nations without AI or with less mature AI systems might be placed at a severe disadvantage and forced to buy systems with whatever capabilities the more advanced nations are willing to let their firms sell to other countries. While the state of nations after the introduction of AI is inherently unclear, one thing is apparent: restricting AI development in the U.S. won't stop it from being developed. In fact, this may make it far more likely that the eventual winning AI systems won't respect our societal values, because they have been developed by another country or group that doesn't share them.

AI Transparency

Despite the benefits that AI provides, and those that it is poised to provide, AI is far from perfect. AI makes mistakes. Computing systems can incorrectly take a spurious correlation as causality. They have been shown to disadvantage members of minorities and other groups. Academic Virginia Eubanks charged that some systems are responsible for "automating inequity" in a book by this name,[xxxv] while another academic, Safiya Umoja Noble, termed some systems as "algorithms of oppression"[xxxvi] in another eponymous volume. Improving the underlying learning technologies and how these algorithms are trained is critical to preventing these and other issues.

What is even more problematic, however, is that AI's mistakes are very hard to detect. Some systems can't explain or justify how they made a recommendation or decision. Others can explain decisions in general terms but not justify them specifically. Yet others can explain general rules and trends but not specific decisions. A new sub-discipline has arisen, called eXplanable AI (XAI), to try to develop new AI techniques that are better understood by humans and to develop upgrades

AI systems have the potential to change how humans do just about everything. Scientists, engineers, programmers and entrepreneurs need time to develop the technologies—and deliver their benefits.

that attempt to better explain existing techniques.[xxxvii] Efforts in this area are critical to human trust in AI systems and AI's long-term viability. Many of these efforts are being driven by academia, not corporate AI developers. The development of XAI techniques is exactly why we need to encourage more innovation by a broader community, not less by a small group that is well positioned to navigate extensive government bureaucracy.

Notably, the FTC discusses the need for transparency in their guidance.[xxxviii] They point out that an issue with a health care AI system was discovered by independent researchers who were able to source data from an academic hospital—not the AI developer or its users. Transparency won't just help identify issues so they can be fixed, though, it can also demonstrate that systems are making good decisions and not exhibiting bias, if this is the case, and provide a defense for spurious claims against properly functioning systems' developers and operators.

Who Does Regulation Really Protect?

Achieving most of these benefits will require a lot more research and development. Regulations that make it more expensive to develop AIs or prevent certain uses might delay or forestall those efforts. This is particularly true for small businesses and individuals—key drivers of new technologies—who are not as well equipped to deal with regulation compliance as larger companies.

In fact, the biggest beneficiary of AI regulation may be large companies that are used to dealing with it, because startups will have a harder time competing in a regulated environment. Even ambiguity regarding regulation and what aspects of AI are regulated may be problematic, as it may cause people to avoid innovation to avoid risking inadvertent ensnarement by vague regulations and potential penalties.

Humanity faced a similar set of issues in the early days of the internet. But the United States actively avoided regulating the internet to avoid stunting its early growth.[xxxix] Elon Musk's PayPal and numerous other businesses helped build the modern online world while subject only to regular human-scale rules, like those preventing theft and fraud. Similarly, no special rules were rolled out to govern early software businesses, such as Microsoft, in their burgeoning years, that have gone on to become industry titans.

AI systems have the potential to change how humans do just about everything. Scientists, engineers, programmers and entrepreneurs need time to develop the technologies—and deliver their benefits. To achieve maximum benefit, their work should be free from concern that some AIs might be banned, and from the delays and costs associated with new AI-specific regulations. The bigger risk is that if we don't develop these technologies domestically, they may be developed abroad, and we will have little or no knowledge about how they work and little or no say over their operations.

On the other hand, regulations regarding business conduct, including the conduct of AIs employed by businesses already exist. If gaps exist in these regulations that allow otherwise regulated conduct performed by an AI to slip through, an obvious solution is to patch the holes and fix them. Knee-jerk regulations that ban until we know it's safe, on the other hand, will provide little benefit, in the long term, and might have severe repercussions.

This is not to say that there isn't a role for government. Agencies, such as the FTC, have a part to play in keeping the market for AI technologies honest, non-deceptive and fair, and for ensuring that users of AI systems are similarly honest, non-deceptive and fair in their practices.

There is also an important legislative role. In fact, perhaps the most important AI government regulation would be for Congress to prevent states and municipalities creating a hodgepodge of local laws that may result in a confusing marketplace with increased compliance costs and a need for modified products from jurisdiction to jurisdiction. Because most AI products would have the potential for widespread use across state lines, AI development is inherently interstate commerce and would fall under federal preemption doctrine (under the authority of the Constitution's Commerce Clause) if a federal law prohibiting state and municipal regulation was passed.

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Mark P. Mills is a Manhattan Institute Senior Fellow, a Faculty Fellow in the McCormick School of Engineering at Northwestern University and a cofounding partner at Cottonwood Venture Partners, focused on digital energy technologies. Mills is a regular contributor to Forbes.com and writes for numerous publications, including City Journal, The Wall Street Journal, USA Today and Real Clear. Early in Mills's career, he was an experimental physicist and development engineer in the fields of microprocessors, fiber optics and missile guidance. Mills served in the White House Science Office under President Ronald Reagan and later co-authored a tech investment newsletter. He is the author of *Digital Cathedrals* and *Work in the Age Robots.* In 2016, Mills was awarded the American Energy Society's Energy Writer of the Year. On October 19, 2021, Encounter Books will publish Mills' latest book, *The Cloud Revolution: How the Convergence of New Technologies Will Unleash the Next Economic Boom and A Roaring 2020s.*

Kendall E. Nygard, PhD, is the Director of the Dakota Digital Academy and Emeritus Professor of Computer Science at NDSU, where he joined the faculty in 1977 and served as department chair for 12 years. His many accomplishments include operations research at the Naval Postgraduate School and two research fellowships in logistics and unmanned air vehicles at the Air Force Research Lab. In 2013-14, he had the distinctive honor of serving as a Jefferson Science Fellow and Senior Science Advisor at the U.S. Agency for International Development and the State Department in Washington, DC. He has served as a major advisor for 184 MS and 26 PhD students at NDSU and is published widely in his field. He has secured over 50 grants and contracts from federal agencies. Nygard's research areas involve optimization methods, data analytics and artificial intelligence with applications to cybersecurity, energy, drones, networks, transportation modeling and trustworthy systems.

Travis Nygard, PhD, is an Associate Professor of Art History at Ripon College. He earned a PhD in the History of Art and Architecture, a PhD in Cultural Studies and an MA in the History of Art and Architecture, all from the University of Pittsburgh. He earned a BA in Art History from Gustavus Adolphus College. He is fascinated by intellectual and cultural history, and his scholarship focuses on both ancient Maya and modern Midwestern art. Professor Nygard's career began as an intern at the Memorial Union Gallery at NDSU; he has published pedagogical research with faculty and graduate students in the Department of Computer Science at NDSU. Professor Nygard coedited *Landscapes of the Itza: Archaeology and Art History at Chichen Itza and Neighboring Sites* (University Press of Florida, 2018), in which he coauthored "To Face or to Flee from the Foe: Women in Warfare at Chichen Itza." With a research team at NDSU, Professor Nygard wrote "Social Sensitivity Correlations with the Effectiveness of Team Process Performance: An Empirical Study," published in the Proceedings of the 8th International Conference on Computing Educational Research (2012).

Aakanksha Rastogi, PhD, earned an MS and PhD in Software Engineering at NDSU. She has six years of industry experience in software development and quality assurance. Currently, she works as a senior software engineer at a medical devices company. Dr. Rastogi has expertise and research interests in visualization methodologies, cybersecurity, machine learning and threats to autonomous systems, such as self-driving cars. She has published several conference proceedings and journal articles in notable publications, such as IJCA (International Journal of Computer Applications), ISCA (International Society for Computers and their Applications), CATA (International Conference on Computers and Their Applications) and the 2017 World Congress in Computer Science, Computer Engineering & Applied Computing. Dr. Rastogi co-authored a book chapter in *Advances in CyberSecurity Management,* published by Springer. She has volunteered in staffing summer workshops in cybersecurity for middle and high school girls.

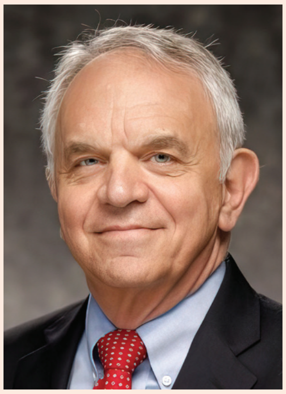
Jeremy Straub, PhD, is an Assistant Professor in the NDSU Department of Computer Science and a NDSU Challey Institute Faculty Fellow. His research spans a continuum from autonomous technology development to technology commercialization to asking questions of technology-use ethics, and national and international policy. Dr. Straub has published more than 60 articles in academic journals and more than 100 peer-reviewed conference papers. He serves on multiple editorial boards and conference committees. Dr. Straub is also the lead inventor on two U.S. patents and a member of multiple technical societies.

New Books From Our Contributors

Robert H. Latiff, PhD
Maj. Gen. (Ret.) USAF

Article in DDR Issue 1:

Closer to the Robo-Rubicon:
Robots, Autonomy and the Future (or Maybe Not) of You



Mark P. Mills
Senior Fellow,
Manhattan Institute

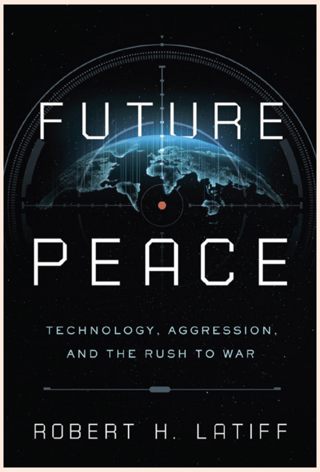
Articles in DDR Issues 1 & 2:

Robophobia: Work in the Age of Robots

The Hidden Costs of Going Green

Robert Latiff urges extreme caution in the adoption of new weapons technology and makes an impassioned plea for peace as a military officer who spent his career preparing for war.

Today's militaries are increasingly reliant on highly networked autonomous systems, artificial intelligence, and advanced weapons that were previously the domain of science fiction writers. In a world where these complex technologies clash with escalating international tensions, what can we do to decrease the chances of war? In ***Future Peace***, the eagerly awaited sequel to *Future War,* Robert H. Latiff questions our overreliance on technology and examines the pressure-cooker scenario created by the growing animosity between the United States and its adversaries, our globally deployed and thinly stretched military, the capacity for advanced technology to catalyze violence, and the American public's lack of familiarity with these topics.



Publication Date: March 1, 2022

Future Peace describes the many provocations to violence, how technologies are abetting those urges, and explores what can be done to mitigate not only dangerous human behaviors but also dangerous technical behaviors as well.

The conventional wisdom on how technology will change the future is wrong. Mark Mills lays out a radically different and optimistic vision for what's really coming.

According to Mills in ***The Cloud Revolution,*** a convergence of technologies will drive an economic boom over the coming decade. It will come not from any single big invention, but from the confluence of radical advances in three primary technology domains: microprocessors, materials and machines. Microprocessors are increasingly embedded in everything. Materials, from which everything is built, are emerging with novel, almost magical capabilities. And machines, which make and move all manner of stuff, are undergoing a complementary transformation. Accelerating and enabling all of this is the Cloud, history's biggest infrastructure, which is itself based on the building blocks of next-generation microprocessors and artificial intelligence.

Publication Date: October 19, 2021

We have wrung much magic from the technologies that fueled the last long boom. But the convergence now underway will ignite the 2020s. And this time, unlike any previous historical epoch, we have the Cloud amplifying everything. The next boom starts now.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