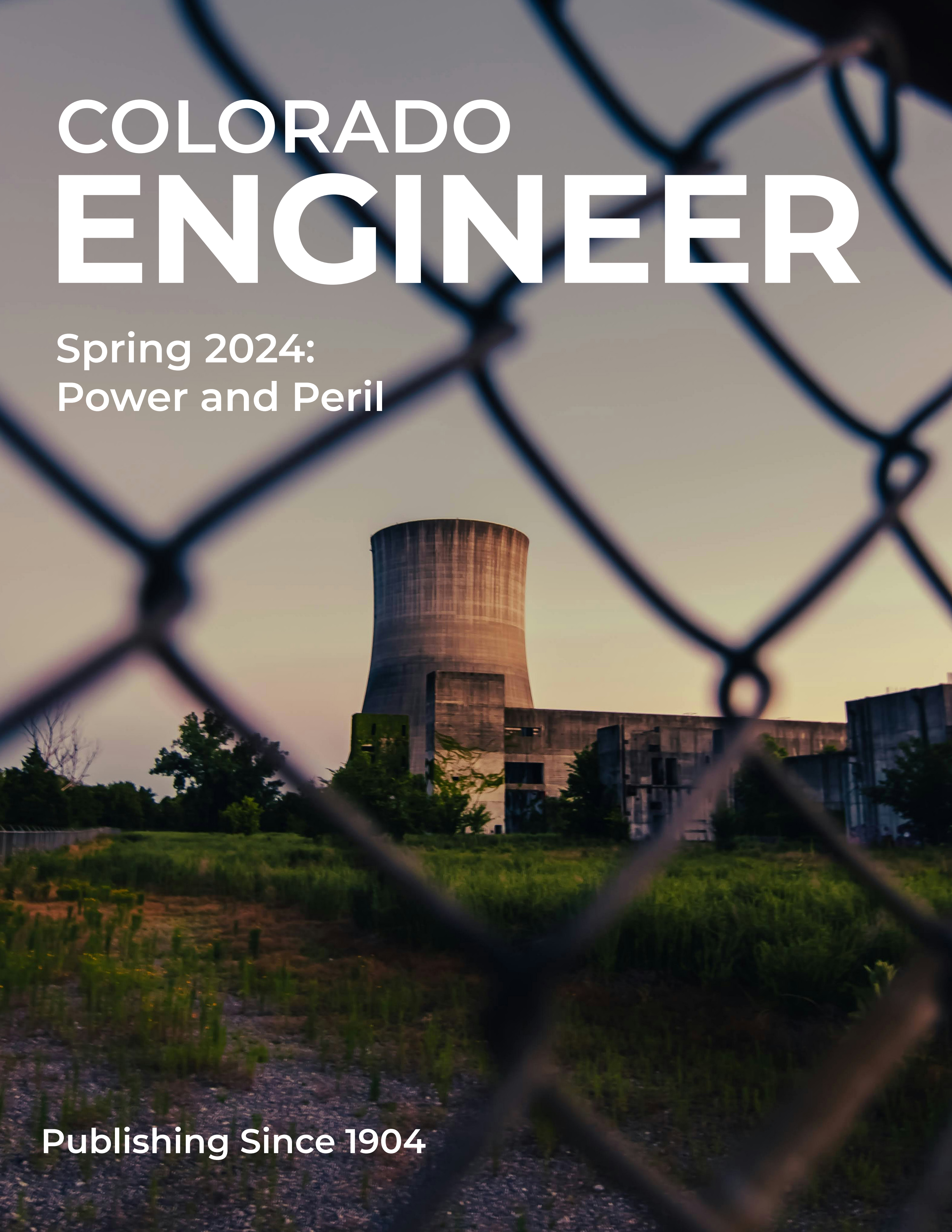
COLORADO ENGINEER

Spring 2024: Power and Peril



Publishing Since 1904

CONTENTS

Opinions expressed within do not necessarily reflect those of the Colorado Engineer (ISSN 0010-1538), its staff, the University of Colorado, or the College of Engineering and Applied Science. The Colorado Engineer is published two to four times per academic year by the students of CU Boulder and is printed by D&K Printing. A yearly domestic subscription to the Colorado Engineer is $10. For a digital copy, or for more information about the magazine and how to subscribe, email: Emily.Adams@colorado.edu.

MEET THE STAFF

Hannah Sanders
Editor-in-Chief
Senior in Architectural Engineering

Aaron Schurman
Design Editor
Junior in Electrical Engineering

Ainsley Cox
Copy Editor
Senior in Information Science

Conor Rowan
Writer
Graduate Student in Aerospace Engineering

Malena Garcia
Writer
Sophomore in Biomedical Engineering

Shreeya Roy
Writer
Freshman in Biomedical Engineering

Aidan Magruder
Writer
Freshman in Biomedical Engineering

Peter Job
Writer
Sophomore in Mechanical Engineering

Zane Perry
Website Manager
Junior in Computer Engineering

Emily Adams
Staff Adviser
Senior Communications Specialist at CU Engineering

Paul Diduch
Faculty Adviser
Professor in Herbst Program of Engineering, Ethics & Society

Alex Priou
Faculty Adviser
Professor in Herbst Program of Engineering, Ethics & Society

The Colorado Engineer has been reporting on the "latest and greatest" from the engineering, science and technology community since 1904. We were there for the Model T, the jet engine, the IBM PC, the iPod — and we will continue to cover the future of human innovation. Today, we operate with a staff of 9 students and three advisers. We publish the magazine biannually, with a readership of over 8,000 individuals, reaching students at the university, researchers, professors and alumni. If you would like to join our staff or have questions and comments, email us at cem@colorado.edu. Alternatively, check out our website at http://https://www.colorado.edu/studentgroups/colorado-engineer/. We always enjoy hearing our readers' feedback!

POWER AND PERIL

Dear readers,

For our magazine staff, this issue was about exploration and taking time to find new perspectives on what we thought we knew. We start this issue with a short story that pushes us to reflect on the limits of progress. What I love most about this short story is that it reminds us that we as a society should be very careful about what we deem worthy of investing in: progress for the sake of progress can be a dangerous thing.

Also in this issue we highlight nuclear energy, diving into the opportunities and challenges nuclear energy presents as we work towards a cleaner energy grid. In addition to presenting fresh ideas on old technology, we discuss new innovations in biomedical engineering and neuromorphic computing. Finally, I share my reflections after speaking with Glen Miller, this semester's guest lecturer for the Herbst Program's Moulakis lecture series on responsible engineering.

This issue serves as a steppingstone in a long tradition of students taking time to inform, explore, start conversations, and reflect. We as a staff are always striving to do better journalism and design. But more importantly, we are always striving to show up. The Colorado Engineer magazine exists because of the people who make it.

I want to thank each and every student who I have worked with in my time on the magazine, Paul Diduch, Alex Priou, Emily Adams, our Board of Directors, and all those who came before me.

If you are reading this, you are a part of our community that we have been building since 1904. Thank you for being intentional enough or curious enough or lucky enough to read this issue; I am so happy you are here.

Hannah Sanders
Editor-in-Chief

Our CEM Mission

As staff of the Colorado Engineer, our mission is to inform and educate our readers and reflect pride in CU's College of Engineering & Applied Science world-wide.

Our student-led magazine seeks to provide a voice for CU's engineering students while also carrying on the 100-year CEM tradition: by students for students.

A TREADMILL CALLED PROGRESS

Conor Rowan

A short fiction story on the faith that science will bring certainty

Two fundamental discoveries paved the way for this new era of science in the 23rd century: the unification of quantum mechanics with general relativity, and a material understanding of consciousness. Long had physicists struggled to reconcile the strange behavior of matter at atomic scales with the mechanics of large gravitational bodies. Repeated failures to formulate an overarching physical theory had cast doubt on the power and scope of scientific models. Researchers finally triumphed over this stubborn problem with an imaginative new solution facilitated by sophisticated artificial intelligence, ushering in an unprecedented faith in the reach of science. Similarly, understanding how consciousness emerges from vast networks of basic chemical interactions put to rest any lingering notions that it was something immaterial, discrediting once and for all the religious and spiritual groups who stubbornly upheld a distinction between mind and matter. These breakthroughs demonstrated that all phenomena fit comfortably within the purview of scientific knowledge. This new paradigm was called "The Universal Theory." With this new tool in hand, humankind quickly came to a peculiar conclusion: the project of theory development had ended. There were no new fundamental physical laws to discover. But this did not mean there were no problems left to solve.

In the centuries preceding these discoveries, continued technological development had brought companies and governments immense power. New technologies of control, surveillance, persuasion, entertainment, automation, and war continued to disrupt and disorient societies. Regulation was slow to respond, and often inadequate when it did–the problems that technology posed for human societies could not simply be regulated away. Technology changed how people related to society, culture, and nature. It had significant and unpredictable personal and political consequences. Though their effects were often multivalent, these technologies had one clear consequence: it became difficult for individuals and groups to find a firm footing in a world that changed so rapidly. Technological power outpaced humankind's political and philosophical imagination. There was growing concern that the power humankind wielded was not matched by an understanding of its effects. So, in the early years of the 24th century, the focus of research moved definitively away from the development of fundamental theories, to building sophisticated models of large-scale systems. With no new laws to uncover, it was natural to investigate challenging applications of known physical laws. And motivated by the threat of technology's power and caprice, scientists and engineers across the globe teamed up to undertake a modeling project of unprecedented ambition: to build a computational model of the entire world. Such a model would make the future accessible to humanity, and might help avoid cataclysms wrought by unwise political and technological decision-making.

And motivated by the threat of technology's power and caprice, scientists and engineers across the globe teamed up to undertake a modeling project of unprecedented ambition: to build a computational model of the entire world.

With initial conditions which scientists imagined as being measured by future data collection centers all over the world, the Universal Theory would be used to evolve the state of the entire globe in time. Chemistry was a scaled-up version of the mechanics of elementary particles. The behavior of small biological systems could be predicted straightforwardly with an understanding of chemistry, and new understanding of the emergence of consciousness from biological substrates could be used to evolve the behavior of humans in time. The mechanics of groups such as companies and nations could be computed as a straightforward consequence of the agency of individuals. All the necessary theoretical ingredients to construct such a model were in place for the first time, and people were eager to preempt the catastrophic effects of technological prowess. A simulation of this sort could act as a kind of crystal ball, used to help wield power more wisely. It would be a tool not just of scientific interest, but for peace, stability, and human flourishing.

An international effort was undertaken to begin developing the hardware and software infrastructure to carry out the simulation. All the fundamental physical laws which could be used to predict the future were known, but mathematicians, physicists, computer scientists, and engineers needed to collaborate to construct efficient methods of solving these equations in computers. The first obstacle of the project was to construct data collection centers spanning the globe. Measurements of the physical state of the Earth, in addition to extensive census and psychological data, would be used to initialize the simulation. The computational model needed to have a starting point before it could be advanced to predict the future.

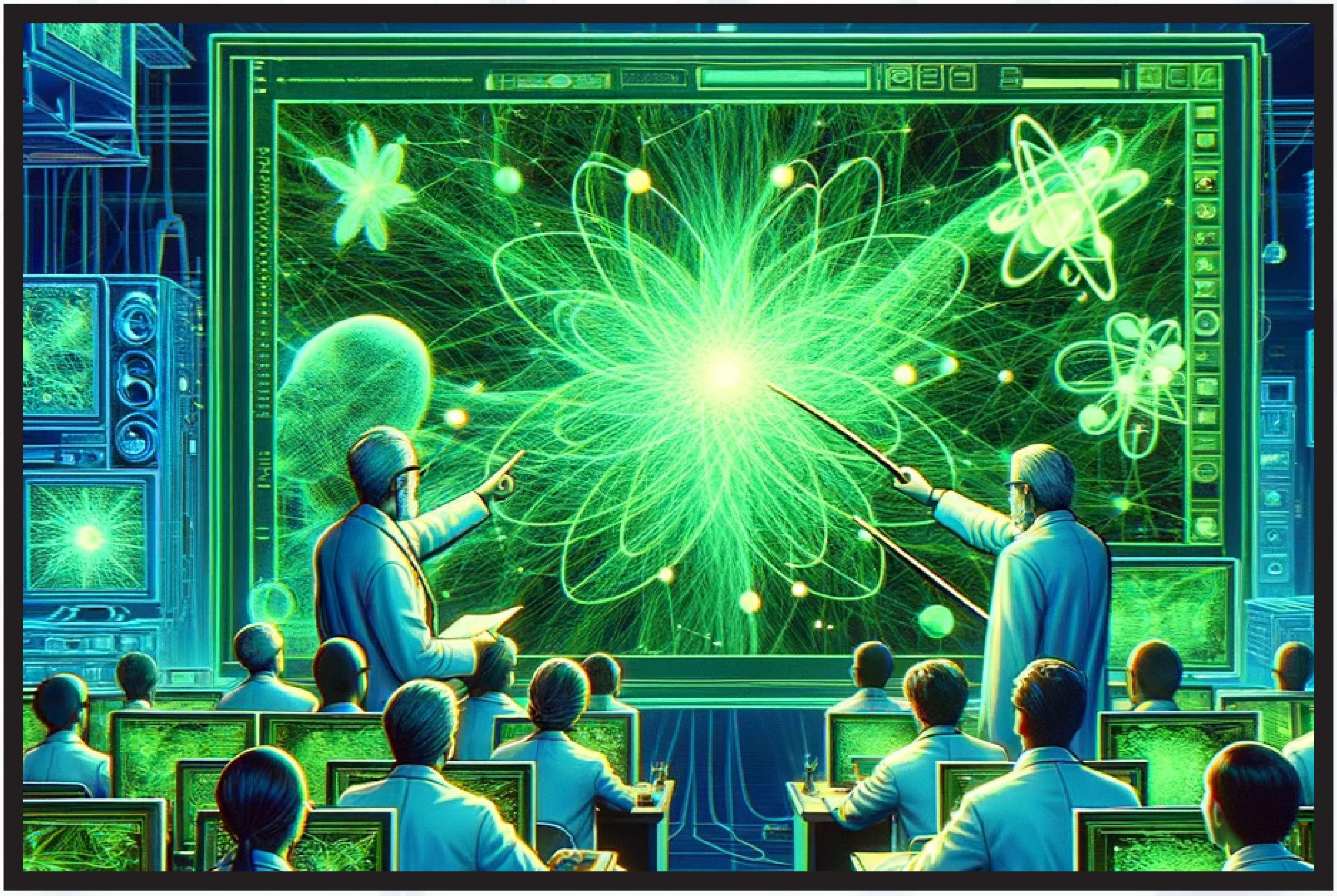
"The Model," as it would come to be called, would be capable of making predictions about any and all aspects of life.

The next bottleneck of this project was the immense effort needed to write down and solve the governing equations which could model phenomena from quantum mechanics, to weather events, to revolutionary political movements. "The Model," as it would come to be called, would be capable of making predictions about any and all aspects of life. In fact, it was clear that the future could not be predicted without understanding the seemingly minute details of the present, such as the chemical composition of the soil in Siberia, or the precise way in which a butterfly in Argentina flaps its wings. The equations needed to make sense of these phenomena were derivative of the Universal Theory in one way or another, and could be found spread throughout the scientific literature. But, never had they been synthesized in such a comprehensive way. New and sophisticated algorithms were required to efficiently solve massive systems of equations coming from the Universal Theory describing the evolution of the entire Earth system. Solutions to these systems relied on iterative search procedures, which took an indefinite number of steps to converge. Concerns around computational effort and run time were the final and most serious hurdle The Model needed to overcome.

A computational model of the future required staggering numbers of floating-point operations. Forming and operating on massive matrices approximating the evolution of the Earth system could not be avoided. It was known to mathematicians that there were hard theoretical limits on the extent to which these computations could be eliminated and/or simplified before the computational model failed to reproduce reality. Once the mathematical operations which constituted The Model could not be streamlined any further, it became possible to estimate the amount of computing infrastructure required to run it. But here too, there were hard upper limits on what was possible.

> ***It was believed that the benefits of the ability to predict the future would outweigh the harms of the environmental impacts. Humankind had faith in The Model as a tool for knowledge, and knoledge as emissary of harmony.***

The size of transistors had stopped decreasing, and no new innovations in computing hardware had been introduced for centuries. And humanity's current computing resources were not adequate–thus, the longest phase of the project was one of intensive infrastructure development. High-rise computing centers were built all over the world, and a fleet of computing machinery was sent into orbit. But, hardware could not be positioned arbitrarily far from Earth, as the finite speed of electromagnetic signals limited the ability to synchronize and orchestrate numerical computations. Similarly, the electric currents in chips produce heat, and scientists knew that the heat by-products of the simulation were large enough to measurably increase the temperature of the Earth. After a lengthy and arduous political process, an allowable temperature increase was agreed upon. This limited the number of terrestri-



al computing centers. Though the temperature rise would further destabilize Earth's climate, it was believed that the benefits of the ability to predict the future would outweigh the harms of the environmental impacts. Humankind had faith in The Model as a tool for knowledge, and knowledge as emissary of harmony.

So as the Earth became replete with the machinery of computation, the mathematical structure of The Model was finalized. Thorough and varied studies indicated that the solution methods met accuracy requirements with optimal efficiency. Still, it was not possible to predict the exact computational demands of the model. But scientists were confident that predictions would outpace time itself. Thus, the future would be known. After decades of dedicated effort from universities and governments across the globe, the largest engineering project in human history came to a close. Small tests of The Model had been conducted along the way, but it eventually came time to run a full-scale simulation. Humankind eagerly awaited this deployment as a symbol of freedom from the vagaries of an unpredictable world. And just days before the year 2400, Earth's citizens assiduously tuned in to live broadcasts covering The Model's inaugural use.

> ***Power and certainty do not go hand-in-hand.***

And The Model's predictions agreed with reality, or so reported verification centers stationed all around the globe. But, as if a forgotten God had conspired against humankind, the simulation ran at exactly the speed of time. One second of simulated reality required exactly one second to compute. This trend, baffling in its consistency, continued tirelessly for hours, days, weeks, and months. Hopes for a utopian future free of uncertainty were dashed–reality, though knowable in theory, was indomitable in practice. A simulation which acted only as a mirror to the world was a useless tool. But so it was–the crown jewel of humankind's scientific endeavors had perfectly reproduced what was already in front of them, like a photograph, or a painting. And if anyone were to have gone looking for Wisdom in the artificial reality The Model had created, they would have seen only their own confused face looking back at them, struggling to cope with a world in which power and certainty do not go hand-in-hand.

THE OLD GREEN ENERGY

Aidan Magruder

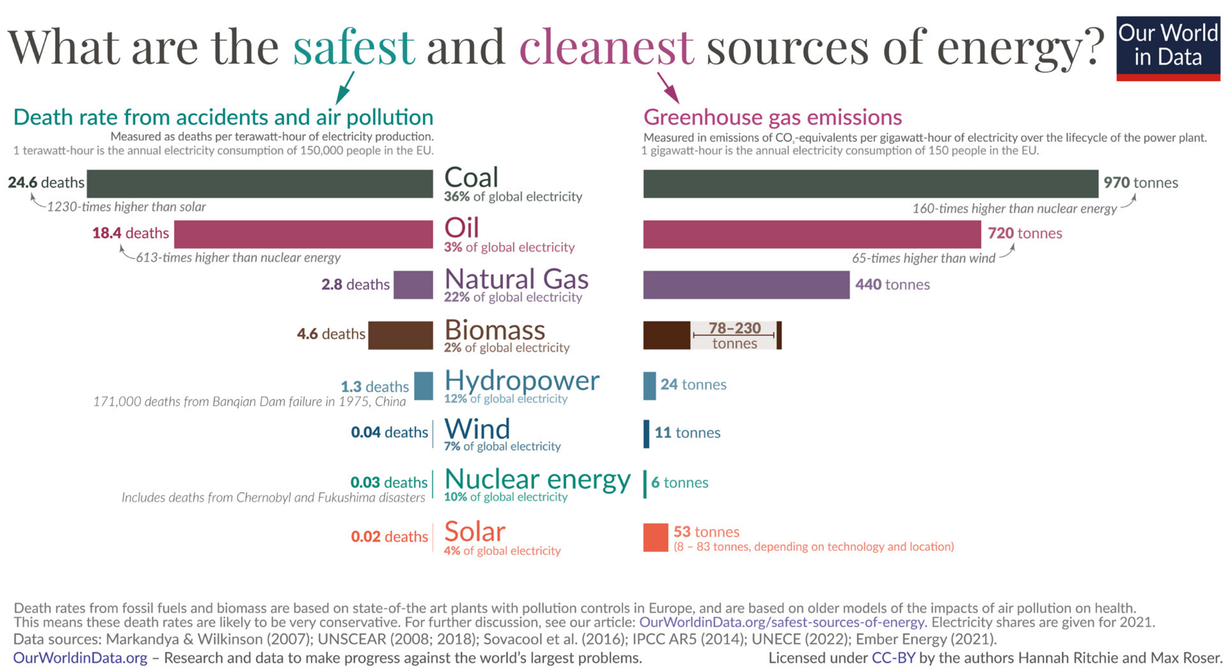
Nuclear power, misconceptions, safety, emissions, and policy

I am willing to live next to a nuclear power plant. In fact, I would like one in my backyard. An understanding of safety, reliability, and the potential this form of energy provides is the primary reason for this belief. I also recognize that this position seems to be wildly ignorant of past nuclear disasters, but the potential of this green energy in the face of our current climate situation is too great to be waved away in fear. To see its potential, a deep dive into its efficacy, safety, and reliability is in order.

What comes to mind when the words "nuclear power" are brought up? A bomb, an unsafe radioactive disaster waiting to happen, an environmental nightmare? I want to challenge these associations. The central issue with writing off nuclear energy because of two public disasters is that it is used as an excuse to prevent new and better nuclear power plant designs from finding funding, despite the hundreds of nuclear power plants that have been operating continuously for nearly 60 years. Nuclear energy is one of the lowest CO_2 emitting forms of power generation and one of the safest alongside wind and solar. Not only does nuclear power generate clean energy but it also provides substantial amounts of energy for relatively low costs post plant construction.

In 2022 alone, nuclear reactors across the globe provided over 2545 terawatt hours of energy, energy that is produced without greenhouse gas emissions. An amount of energy like this is equivalent to the energy needed to launch a space shuttle through the atmosphere 458 times. Additionally, while nuclear provides 10% of energy globally, it provides 26% of all clean energy produced. In the context of the sheer number of alternative power generation sites, nuclear power's output is astounding considering only 438 reactors were active in 2022, compared to thousands of solar and wind sites across the globe. The pure power output of nuclear power compared to its fuel usage eclipses that of other traditional power plants. Nuclear energy relies on energetically dense fuel which is both easily obtained and refined and can run for extended periods of time before needing to be replaced. On average a single nuclear fuel cell can run continuously for 18 months without needing to be replaced. Nuclear power's unique energy density allows for cost and energy efficient power generation that is reliable and has longevity. The power nuclear provides meets base load, is consistent, and can rise to meet consumer demands.

Another common concern about nuclear power is its potential health risks. While radiation is nothing to be laughed at for its potential to cause serious harm to humans and animals, the number of deaths per terawatt hour of energy produced for nuclear power is 0.03, this includes deaths due to accidents as well as pollution. In comparison to other energy sources such as coal (24.6 deaths/tWh) and oil (18.4 deaths/tWh) nuclear power is incredibly safe. Nuclear power generation, as measured by deaths/tWh, is the second safest form of power generation behind solar power. This is no accident, nuclear energy has been designed to be safe and effective, not only in times of regular operation but also in times of disaster.



Not only is nuclear significantly safer than most other forms of power generation, it is also the cleanest form of energy. Over the life cycle of a nuclear plant, a single plant will produce 3 tonnes of CO_2. This may not seem impressive until the timeline is put into perspective: a nuclear power plant can operate continuously for up to 40 years. Compared to an average solar power site which produces 5 tonnes of CO_2, or a hydroelectric plant which produces 34 tonnes of CO_2, nuclear power continues to provide reliable, consistent, and long-lasting power generation without significant emissions. Not only does nuclear power provide the cleanest form of power generation, but it also provides useful isotopes for both medical and industrial use, meaning its expended fuel is not just waste. All these factors and more are why it is so important to continue to build and operate our nuclear power plants.

When we as a civilization fail to renew our investments in nuclear energy, we actively work against climate goals and our ability to become a society independent of fossil fuel power generation. We see this result in countries like Germany, which has taken all of their nuclear power plants offline. As an effect of this policy decision, Germany increased its consumption of both natural gas and coal with the German government even investing billions of dollars into new gas power plants. Germany is an example of policy creating increasingly adverse effects for our planet as they move to more renewables while cutting out nuclear and still using energy sources that are actively working against climate goals. Contrast this policy to France's, whose 58 nuclear reactors contribute 65-70% of their country's energy. France's continued effort to provide clean nuclear energy led to significant cuts to their coal and natural gas consumption and allowed them to remain one of Europe's top energy exporters and continues to move to a carbon-neutral society.

When nuclear power is prevented from operating, or expanding with new plant construction, like it is in Germany, we actively work against the goals of a climate focused society. We turn to old sources like gas and coal to supply power when other renewables are unable to produce consistently. Our instinct, counterintuitively, turns to renewables like hydro and solar that actively produce more carbon through generation and construction on a much shorter life cycle. Our society turns away from decades of safe nuclear plant operation and consistency. Nuclear power's sheer reliability in the face of disasters is ignored. Nuclear is scorned even when power runs low, and we need a source that is always running. We turn a blind eye to our most efficient and effective form of power generation.

Ultimately, nuclear continues to prove its mettle in the ring of power generation, consistently outperforming both renewables and fossil fuels in both safety and consistency; defying the misconceptions and providing safe, clean, and lasting energy for generations to come. The energy of the future is already here, and its name is nuclear.

MICROBUBBLES WITH MASSIVE POTENTIAL

Shreeya Roy

Microbubbles acoustic sensitivity has to potential to cure

Researchers are doing the opposite of "going big" when it comes to cutting-edge biomedical technologies. A large emphasis is placed on microscopic technologies, especially microbubbles, extremely small gas-filled bubbles. Current research is focusing on using microbubbles for medical imaging, targeted drug delivery, and gene delivery. Microbubbles can be controlled by ultrasound waves, and this unique property can make them incredibly applicable in a vast range of biomedical sciences.

Once formed, microbubbles respond to waves and can be manipulated by different frequencies of sound and pulsate between small and large sizes. This process of moving a microbubble to a state of oscillating sizes by using waves is known as acoustic cavitation.

Stable activation of microbubbles has been used to promote the opening of the blood brain barrier in rats and to detect bleeding in the gastrointestinal system. The cavitation of a microbubble can also encourage small molecules from the bloodstream to enter tissue, which is particularly useful in targeted drug delivery. Another application of acoustic cavitation is within targeted delivery of drugs. In this process of acoustic oscillation, the microbubbles oscillate inertially, and grow with each oscillation until they rupture.

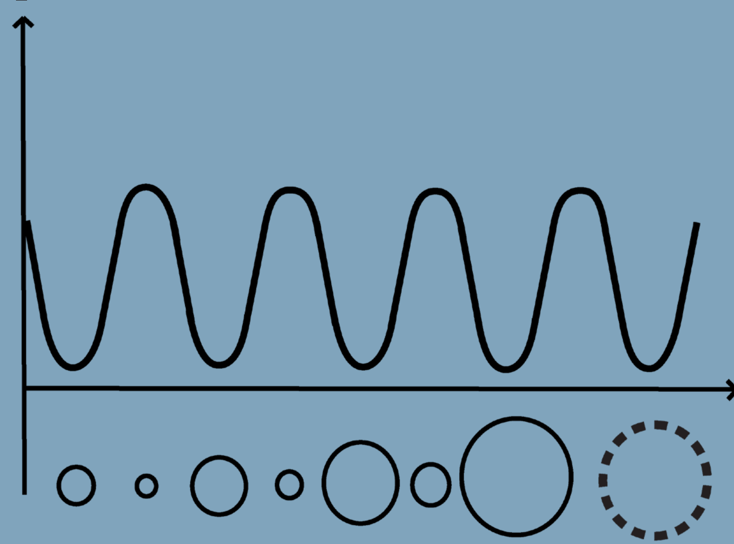
However, when the microbubbles rupture, they release a large amount of energy, which can damage nearby tissue. If the frequency of the ultrasound wave that is necessary to cause rupture can be reduced, then negative side effects can be mitigated. A team of researchers from the University of Colorado Boulder worked to find ways to decrease the frequency needed for rupture. Their research primarily focused on investigating how PL-HMSNs (Phospholipid-coated, Hydrophobically Modified Silica Nanoparticles) in water react to cavitation as a function of particle concentration and lipid composition.

One major finding of this study was that increasing the particle concentration allows the microbubble to be cavitated at lower acoustic thresholds.

They tested this hypothesis with a variety of different lipids and found that the acoustic threshold required for cavitation could be decreased by increasing particle concentration from 25 to 200 μg/mL. They also found that longer lipid tail lengths assist in reducing the cavitation threshold.

While cavitation of microbubbles can have strong positive impacts on biomedical technologies, the high energy of rupture can have negative off-target effects on surrounding cells. Looking into how to reduce cavitation thresholds has the potential to significantly reduce these detrimental impacts. Utilizing microbubble technology could unlock a host of treatments for a variety of diseases. Microbubbles can help address Parkinson's disease, diabetes, Alzheimer's, and cancer. While there are still imperfections in this technology, their vast range of applications make it an extremely valuable investment for future research.

"Microbubbles respond to waves and can be manipulated by different frequencies of sound and pulsate between small and large sizes."



The figure above depicts microbubbles growing with each each acoustic oscillation cycle until

A MOUNTAIN OF NUCLEAR WASTE

Peter Job

Engineering problems in nuclear energy

Since the Industrial Revolution, we have primarily relied on fossil fuels for power, but what was once the dawn of a new era could spell the end of life as we know it today. Fossil fuels are a limited resource, and, as a Stanford study from 2019 suggests, we could run out of oil by 2052, gas by 2060, and coal by 2090 , which is within many of our lifetimes. Perhaps more urgent than running out of fuel is the issue of global warming, which has already contributed to ice at the pole melting, leading to higher ocean levels and flooding. Extreme temperatures, wildfires, and even hurricanes are becoming more frequent and more deadly due to global warming. Continuing to burn fossil fuels and release greenhouse gases into the atmosphere will further worsen heat waves, flooding, droughts, crop yields, and coral reef die-off.

A Greener Alternative

Considering the scarcity and dangers of fossil fuels, we need an alternative; nuclear energy looks promising. As John Kennedy, a U.S Senator for Louisiana, explains, "Wisdom and data suggest that America needs an all-of-the-above approach to energy, one that includes renewables, fossil fuels, and nuclear energy." Using known reserves, we have enough uranium to supply 100 years of power at current demand, and future technological improvements could utilize the uranium in the world's oceans, which could supply thousands or tens of thousands of years of energy. Nuclear energy also does not have CO_2 as a biproduct, so it could act as a good "bridge solution" while we find ways to further develop storage solutions for renewable sources of energy. The International Energy Agency (IEA) agrees that achieving net zero emissions globally will be more difficult without nuclear power, so nuclear plays a vital role in powering the future.

A Necessary Biproduct

The clean power that nuclear energy provides does not come free, however. Creating energy from nuclear fuel necessarily produces radioactive waste. The United States alone has 85,000 metric tons of nuclear waste, which is increasing at a rate of 2,000 metric tons per year. The most dangerous of this waste is designated high-level waste (HLW), composed of spent fuel that remains thermally hot, highly radioactive, and potentially harmful to humans and the environment for hundreds of thousands of years. Though we have permanent storage methods for low- and mid-level wastes, will still don't have a permanent solution for managing HLW. As a result, HLW is left on site at nuclear power plants with nowhere to go.

Current Disposal and Storage Methods

The disposal of HLW requires specific care. Some ideas for permanent solutions are absurd – involving burial in ice sheets or projection into space – but the international consensus for a permanent solution is burial in an underground repository. These repositories contain several barriers, so they will still contain the waste should any individual barrier fail. The stable physical waste form, the waste container, and the chosen site itself each provide an additional layer of security, protecting the environment from the nuclear waste and vice versa. Due to its intense heat, HLW needs to be cooled in pools for at least five years before it can be transported, but these pools are reaching capacity, and the solution has just been to cram more spent fuel into pools. This increases the potential risk in the case of a meltdown.

In Fukushima, spent fuel rods posed a risk of further damage, sitting in pools without a proper containment vessel.

> ***"Wisdom and data suggest that America needs an all-of-the-above approach to energy, one that includes renewables, fossil fuels, and nuclear energy."***

Luckily, the hydrogen explosions were not close enough to the pools to cause any significant damage, but overcrowded pools pose a massive risk of making a catastrophic event much worse. After being cooled, HLW is moved to dry cask storage, which provides additional layers of protection: a sealed metal cylinder enclosed within a metal or concrete outer shell. Dry casks are designed to be able to resist earthquakes, projectiles, tornadoes, floods, temperature extremes, and other scenarios, but they were not designed nor intended to be a permanent solution.Now, the question remains: can dry casks stand the test of time? Corrosion poses a very real risk, especially near the sea. If corrosion sets into the weld joints of steal casks, the materials may crack and fail, and sea-salt aerosols can accelerate this process.Leaching additional radioactivity into the environment with failed dry casks can have devastating consequences that could be avoided entirely if nuclear waste were kept far from the sea and other additional environmental factors by storing it underground.

Efforts Towards a Solution

Finland is currently on track to have the world's first permanent HLW disposal site, where an elevator and robotic vehicles will take waste 430 meters undergrown and 420 meters below sea level. The United States has planned to build a repository as well, but since Congress passed the Nuclear Waste Policy act in 1982, over 40 years ago, there is not even one in construction. Yucca Mountain Nevada was selected as the site for this repository in 1987, but all plans were cancelled by the US in 2010. In 2013, since no repository was under construction, the Department of Energy was ordered to cease collecting fees for the Nuclear Waste Fund (amounting to over $30 billion) and federal funding was eliminated in 2015. This leaves us with no long-term plan and no funding for the storage of nuclear waste in the United States.

Repository Controversy

But why was this project abandoned? One major fear is potential groundwater contamination. A 1996 study discovered that water had migrated from the surface to the depth of the repository in less than 50 years, much lower than the 1000-year predicted travel time. Hydrology guidelines state that "groundwater travel time to the accessible environment of less than 1000 years shall be grounds for disqualification," but the Nuclear Regulatory Commission, using conservative assumptions and assuming failure of multiple barriers, discovered that the estimated peak radiological dose would be 1.3 mrem (millirem, a common unit of radiation) from groundwater, a small fraction of the current background radiation dose of 600 mrem per year in the United States. Since geological repositories have not yet stood the test of time, there is feal of potential unforeseen consequences. Radioactive waste could potentially give off much higher levels of heat or corrode barriers more quickly than expected, posing a risk to the environment, but nature already has precedents for geological disposal.

Two billion years ago, in what is now Gabon in West Africa, several spontaneous nuclear reactions occurred in a vein of uranium ore, continuing for 500,000 years before finally dying away. These natural nuclear reactors produced the same high-level wastes present in manmade nuclear reactors, including over five tons of fission products and 1.5 tons of plutonium, but this all remained contained and safely decayed into non-radioactive elements without any human intervention. This offers evidence that nuclear waste will not continuously corrode rock and wreak havoc on the environment if kept safely underground. Another concern is that geological repositories, in their current form, prevent recovery of waste. France desires a "reversible" disposal process since waste could prove to be valuable if future discoveries find new uses for spent fuel. For this same reason, Switzerland, Canada, Japan, and the US require retrievability in any disposal plan, and this could be incredibly difficult if waste is sealed in a permanent repository. Nuclear waste may be useful in the future, but currently it only poses risks to humans and the environment, the safety of which should be our utmost priority.

> ***Regardless of whether nuclear is here to stay or not, it will be the responsibility of engineers to make sure we have the technology to handle our current mountain of nuclear waste.***

Urgency of a Solution – Our Role as Engineers

40 years have already gone by without any significant progress in building a repository, so how can we expect to solve this problem now? The answer is engineers. Yucca Mountain may never become a geological repository, but there is room for progress in the nuclear energy field. One opportunity presents itself in the form of education grants. In a press release this February, the NRC committed to awarding 22 education grants to 16 academic institutions to support nuclear science and engineering fields, amounting to $8.2 million total. This is a sign of future progress in this field for engineers, which will make building a geological repository possible.

Proper transport casks need to be developed, the physical repository needs to be designed, and additional safety measures should be added to every step of the process. Engineers can redesign casks to be more resistant to corrosion, providing us with more time to find a solution. They can also design repositories where nuclear waste could be retrieved in the future should the need for them arise, which would help repositories seem more appealing to other countries that require retrievability in any disposal plan.

Nuclear energy appears to be on the rise again. Georgia is currently constructing the first new nuclear unit the US has seen in over 30 years. Many plants in Japan are coming back online after being shut down following fears from Fukushima. Coal power plants can also be converted to nuclear, another issue that requires dedicated engineers and will be better for our environment in the end. All of this could be an excellent opportunity to move towards greener energy, but regardless of whether nuclear is here to stay or not, it will be the responsibility of engineers to make sure we have the technology to handle our current mountain of nuclear waste.

EMPOWERING INNOVATION

Hannah Sanders

CU's Wind Team in final stage of NREL competition

CU Wind team is pushing the needle forward on renewable energy through their participation in the National Renewable Energy Laboratory's (NREL) annual Collegiate Wind Competition and community engagement efforts. The mission of the competition is to "fast-track new ideas and accelerate the clean energy revolution through training, team building, and mentoring, connecting innovators and entrepreneurs to America's national laboratories and the private sector", and prepare participants to be innovators in the green energy transition.

NREL put out a report in 2021 exploring the feasibility of offshore wind generation in the Great Lakes. The prompt for this year's Collegiate Wind Competition draws inspiration from this report, challenging students to undertake the project development and design of a small-scale offshore wind turbine farm in the Great Lakes. The competition is broken down into three distinct tasks: designing and building a functioning turbine, developing a hypothetical wind farm in the Great Lakes, and lastly, to create a community for wind energy. To learn more about the CU Team's work, we spoke with environmental engineers Daniel Sherry and Julia Gentile on the Great Lakes project development subteam.

Daniel Sherry notes that what makes the competition so exciting is that the stakes matter much more than winning,"the way that I think of it is they're seeing if we have

A Wind Club meeting where students competed in a turbine design challenge

any other ideas that their researchers haven't thought of… [with the competition] there's a lot more minds working on this really difficult problem. And hopefully at least one of us can come up with something that'll help it move forward."

One of the challenges of designing for energy production, in contrast to the design of other renewable systems like solar and geothermal, is that wind energy is highly variable. The capacity available for generation varies greatly between locations based on weather, wind patterns, and consistency.

The team touring the NREL campus

> **“There’s a lot more minds working on this really difficult problem. And hopefully at least one of us can come up with something that’ll help it move forward.”**

Julia Gentile believes that variability is what makes the project so engaging, “It’s fun. There’s more of a challenge with wind than the other sources of renewable energy.” Beyond the variability of wind energy, there are several other factors that make this turbine and wind farm design competition so challenging. Supply chain issues, installation logistics for turbines (both on land and offshore), land acquisition, and impacts to adjacent properties add another layer of complexity to the design problem.

“There’s just so many variables that have to come together and it’s just super satisfying when they hopefully do,” said Sherry.

A meeting of the design team.

To tackle such a complex design challenge, the team relies on the specialization of each team member. The student group has a mix of mechanical, environmental, and electrical engineers. Team members bring their respective expertise to their role- be it designing transmission lines or energy policy-which helps to facilitate knowledge sharing within the partnership and division of labor. “Having background diversity is so important for this competition and I think that’s pretty reflective of industry as well,” Gentile said.

To advance in the competition, the team is evaluated not only on their turbine and wind farm design, but also on their ability to develop a community for wind energy. The club on campus connects students to professionals, internship and job opportunities, and hosts events like jeopardy, and hands-on mini turbine competitions. Team members bring their time and expertise to support KidWind, a project by the U.S. Department of Energy to get children excited about renewable energy through interactive workshops. The team’s podcast, Get Blown Away, is produced on campus and shares important conversations in and around Wind Energy. Recently the podcast hosted Colorado State Senator Chris Hanson to talk about where Colorado is headed with renewables.

The CU Boulder community is cheering out the team as they prepare for the third and final phase of the competition, where they will compete at the CLEANPOWER Conference and Exhibition in Minneapolis May 5th through May 9th.

TAKING UP THE MANTEL

Hannah Sanders

Responsible engineering to guide us through what regulation cannot

On March 19, CU Engineering's Herbst program for Engineering, Ethics, and Society hosted Glen Miller for their Moulakis Lecture Series for Responsible Engineering. Glen Miller is an Instructional Professor in the Department of Philosophy at Texas A&M University with a background in chemical engineering.

Through his teaching and research, Miller helps people to understand and thrive in an evolving sociotechnical world. In particular, his work focuses on engineering ethics as it relates to artificial intelligence (AI) and cyberethics.

The lecture provided students with the opportunity to learn from Miller's expertise on what responsible engineering is today and how they can embody it moving forward in their careers.

Miller provided students with a philosophical background on why it is useful to understand the role of engineers through a "sociotechnical" understanding of the world, and then illuminated how this understanding allows us to see the limits of regulatory bodies. Miller's talk culminated with a call to action, emphasizing the importance of individual responsibility over passive reliance on regulatory bodies. And that shifting emphasis in this way will help us close today's widening gap between public interest and engineering design.

Miller's argument is grounded on concepts from a variation of phenomenology, a philosophical approach that attempts to describe reality from the lens of human consciousness. Postphenomenology, originally developed by Don Ihde, blends elements of phenomenology and American pragmatism together. It is also referred to as the "philosophy of mediation" because it treats technology as an active participant in our reality as humans, thereby mediating our experiences. Technology mediates, standing between us and our acts in the world and our experiences of it, as a sort of active participant.

Using this view of what technology does, we are led, argues Miller, to conceive of our collective relation to technology as "socio-technical," and to look at the assemblages of people and things as sociotechnical systems. Miller's lecture at CU by using a "socio-technical" lens to consider the impacts of the work that engineers do. Using the socio-technical lens makes us more sensitive to the various ways that any given person, device, or machine is not isolated, but has a complex relation to makers, users, and other systems, including the cultural and natural environments.

Miller highlights that one of the reasons there is such a gray area on ethics in engineering today is that much of the innovation today is proprietary, and regulatory agencies can't keep up.

"The easiest argument for the legitimacy of regulation (which is restriction of freedom of action by some group of people) is that there is public interest involved.…Most of the work computer scientists do is proprietary: no one ever directly experiences what's done by it, and so it's not as easy to see that there's a clear public interest in regulating what's happening in a private corporation," said Miller.

Often where public interest is not obvious, there is limited scrutiny of whether the technology (product, software, design, service) has a net positive impact on the public, or whether adequate checks are in place to prevent harm to the public. Here is where a sociotechnical approach is useful, because it allows us to understand that a threat to the public can include something like (intentional or not) perpetuation of misinformation, algorithmic bias that degrades mental health among users, and other harms less tangible than say data leaks or the selling of personal data. When we see technology as participants in, or co-creators of our reality, then we can shift the conversation to "is it legal?" to "does this work enhance the world we live in enough to justify its existence?"

Professions like civil and architectural engineering have long had strict regulations from the government, as infrastructure (roads, bridges) and building design (homes, hospitals) clearly directly affects the public. For professions like computer science and computer engineering (social media app development, internet infrastructures, AI development, software development, etc.), where products are often privately developed and used, the public interest is less clear, and regulation often more limited.

KEY TAKEAWAYS: HOW CAN WE BETTER EMBODY RESPONSIBLE ENGINEERING?

Think in terms of sociotechnical systems

Taking this mindset ensures that we treat our designs in a vacuum, and critically consider the impacts our projects and products will have on the human experience. This view is more holistic than, say, just using impact metrics such as carbon emissions, manufacturing energy intensity, percent waste, etc.

Develop a multifaceted identity as an engineer through professional societies.

Participating in professional engineering societies not only encourages lifelong learning, but also exposes you to engineering practices outside of your company, and provides one with a network to benchmark one's company culture, reporting practices, and embodiment of engineering ethics.

Practice reflection and informed imagination.

Constant reflection and broadening our mindset to include new possible methods gets us out of the dangerous mindset of "this is just how it is done" or "this is how it's always been".

Keep questioning

One should always be asking themselves,"what is responsible engineering today?" as the sociotechnical landscape is always evolving, and with it the nature and weight of the engineer's duty to the public.

If we can agree that much of engineering falls under "public interest", and that regulatory bodies do not have the manpower or expertise to effectively regulate such a growing and diverse field, then a simple solution reveals itself: more responsibility may fall to the engineer.

> "The old adversarial model of regulation, doesn't seem to hold anymore. And I think ultimately what that does is to put more responsibility on the engineer."

"That's a pretty new mindset for regulation, and I think it opens up some some problems for engineers that they're not aware of, that the regulatory state has changed. They may think the regulator will be there to keep them from their mistakes or to provide a backstop against what they're trying to do. I don't think that's there anymore, the old adversarial model- at least partially adversarial model- of regulation, doesn't seem to hold anymore. And I think ultimately what that does is to put more responsibility on the engineer."

Miller left students with four key takeaways.Three out of the four points - think in terms of socio-technical systems, practice reflection and informed imagination, and keep questioning- depend on critical reflection on the individual level. The fourth point-Develop a multifaceted identity as an engineer outside of your company through professional societies- points to community building as a way to become a more responsible engineer.

CU's College of Engineering orients students to their professional obligations by introducing them to the relevant associations and codes of ethics. It also sponsors programs like Herbst and Engineering Leadership that actively cultivate the critical perspectives, personal ethics, and broader awareness that our students need and that companies are looking for.

NEUROMORPHIC COMPUTING

Malena Garcia

An attempt to digitize the brain

Many technology and engineering concepts that exist today are modeled after the human body or nature. For example, Swiss electrical engineer George de Mestral developed Velcro on the basis of burrs found on his clothes and his dog after hunting. Japanese engineer Eiji Nakatsu was able to reduce train noise by modeling the bullet train after the beak of kingfisher birds.

Then there is the example of the tardigrade, commonly referred to as a "water bear", that has the remarkable ability to survive for numerous years in extreme conditions. These eight-legged microanimals inhabit aquatic environments. When these microanimals are removed from water, even after they dry out for as long as 100 years, they have the ability to come back to life by self-rehydrating. They survive this hibernation cycle by coating their DNA and proteins in a protective sugar called trehalose, which moves into the cells and replaces lost water. Biotechnology companies have studied these "water bears" and adapted this process to protect live vaccines by coating the vaccine in a sugar film that can be stored at room temperature. This allows for vaccines to be shipped to various locations without the need of refrigeration. It also makes supplying vaccines to third world countries more cost-effective and easier to transport without the need of bulky freezer containers.

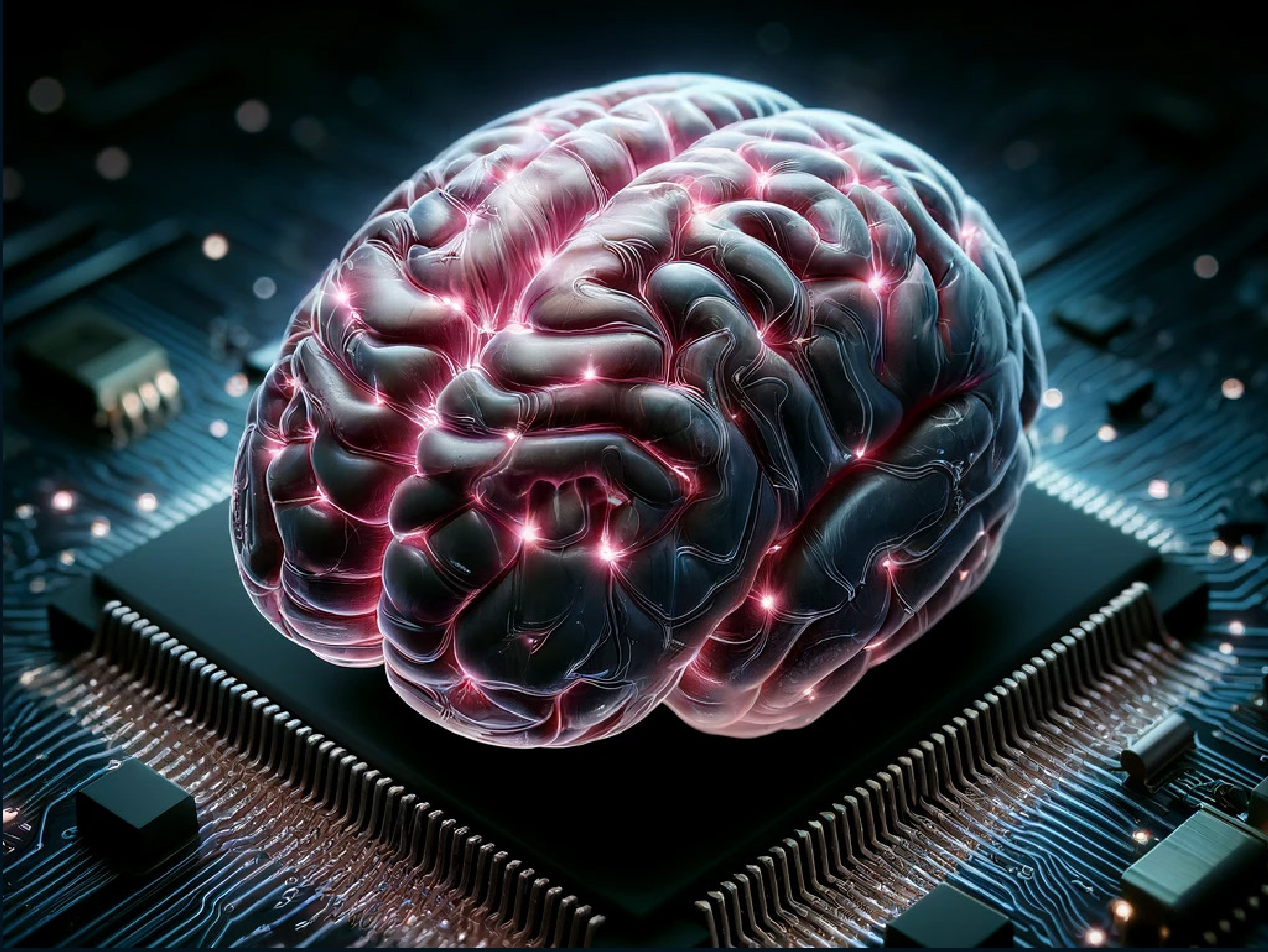
Another example of an engineering concept modeled after nature is neuromorphic computing. This method of computer engineering is directly inspired by the human brain. The human brain, as an organic model, remains the pinnacle of efficiency and power in processor design, serving as a benchmark for advancing computational capabilities. The systems in a neuromorphic computing model mimic the parallel processing of neurons and synapses which is far more efficient than traditional computers that use the von Neumann architecture (which separates memory and computing through binary code). Binary, utilizing only two digits (0 and 1), serves as the underlying language enabling traditional computers to process data, perform calculations, store information, and communicate with other devices. Compared to the human brain that operates in parallel, binary code tends to be linear and serial in function.

Neuromorphic computers process and store data together on each individual neuron, while von Neumann computers have separate areas for each. This is called parallel processing, which allows many tasks to occur simultaneously. When a neuromorphic computer "thinks," it can make different connections that layer on top of each other, using less storage for each individual piece of data.

Currently, these computers are only available to experts at universities, billion-dollar companies and government-funded research labs. Even with the assistance of artificial intelligence, machine learning and computer science backgrounds, operating a neuromorphic computer requires extensive knowledge in different subjects including neuroscience and physics.

While working on a neuromorphic computer, researchers at the Australian Institute of Physics used silver wires at one thousandth of a human hair that randomly arranged themselves in a form like the neural network in humans. Not to be confused with artificial intelligence, the silver wires display "brain-like" behaviors in response to electrical signals. External electrical signals cause changes in how electricity is transmitted at the points where nanowires intersect, all of which mirror biological synapses.

Image Citation : Prakash, C, et al (2023). Computing of neuromorphic materials



The researchers also discovered that these networks respond and adapt quickly to changing signals, proving to be very useful in artificial intelligence modeling and computing. An important distinction is that artificial intelligence learns through "batch-based" process learning, which requires access to high amounts of memory and requires that the system iterates and trains itself multiple times to learn. A key quality of neuromorphic computing is that these human-like networks process data continuously and only needs to review the data once to be stored.

Neuromorphic computers are modeled after the neocortex in the brain, where sensory perception, language and spatial reasoning occur. The neocortex consists of neurons and synapses that instantaneously carry information from the brain to the rest of the body. This is the process that tells your hand to move quickly if you touch a hot stove. This process is so fast and efficient that it is nearly impossible to replicate. Neuromorphic computers attempt to mirror this process by forming "spiking neural networks." In an article published by Built-In about neuromorphic computing, they state,

> ***"A spiking neural network is the hardware version of an artificial neural network which is a series of algorithms run on a regular computer that mimics the logic of how a human brain thinks."***

Spiking neurons are essentially storage units that hold data similar to how biological neurons hold information. These neurons are connected through artificial synaptic networks that transfer electrical signals back and forth. Spiking neural networks only compute in response to spikes, which means only a few of a system's neurons use power while the rest stay idle. These spiking neural networks have proven to be more energy efficient than quantum computers and von Neumann computers.

Neuromorphic computing stands at the forefront of computer engineering, drawing inspiration from the remarkable efficiency and adaptability of the human brain. By mimicking the parallel processing capabilities of neurons and synapses, these systems promise to revolutionize computing power. The adaptability of neuromorphic computing holds potential for addressing challenges in various domains, from online artificial intelligence to energy-efficient computing. By leveraging spiking neural networks and artificial synaptic networks, these systems offer a pathway toward faster processing speeds, enhanced pattern recognition capabilities, and more efficient learning mechanisms, as compared to traditional computing architectures.

As we continue to explore the possibilities of neuromorphic computing based on nature's designs, we stand poised to unlock new frontiers in technology, driving innovation and advancing our understanding of intelligent systems.

The Colorado Engineer
University of Colorado Boulder
UCB 422
Boulder, CO 80309

Engineering & Applied Science
UNIVERSITY OF COLORADO **BOULDER**

Nonprofit Org.
U.S. Postage
PAID
Boulder, CO
Permit No. 156