Engineering Change Lab USA

Inspiring **Leaders of Change**

The 2023 Engineering Ideas Institute

Tackling the Challenges Facing Our World Through Scenario Planning & Collaboration

September 25-27, 2023

The 2023 Engineering Ideas Institute – Tackling the Challenges Facing Our World Through Scenario Planning & Collaboration

"Blackout Friday" flashed across cell phone screens throughout the US on a Thursday afternoon in 2033 as the weekly reminder that activities involving all discretionary energy use are to be suspended one day a week. This nationwide blackout was just one of a set of dramatic changes agreed to by society in the wake of a pair of devastating hurricanes that struck Miami in 2031, rendering the surrounding region virtually uninhabitable for the foreseeable future. The resulting society-wide awakening to the escalating threat of climate change and extreme weather events sparked a new, shared commitment to transformation…

In 2033 "abundance" has replaced "chronic shortage" as a descriptor of the engineering community's workforce relative to its needs. A new purpose-driven, diverse cohort of workers from an expanding range of engineering educational experiences combined with new means of leveraging emerging technologies to augment workers within this community drove this surprising outcome over the last decade…

The last decade has witnessed a steady emergence of powerful state, metropolitan area, and regional coalitions across the US in reaction to continued polarization in national politics and an inability of the federal government to get things done. This shift culminated in the 2032 presidential election of a "Great Unifier" along with substantial numbers of new members of Congress drawn from the ranks of successful leaders populating these coalitions. This new alignment of government actors, at federal, regional, state, and local levels sets the stage for significant action to address long-standing societal challenges…

These three narratives capture the opening plot lines of three scenarios of the future, created and explored by participants during the Engineering Change Lab – USA (ECL) 2023 Engineering Ideas Institute, convened in September 2023 at the Colorado Chautauqua in Boulder, Colorado.

The objectives for the 2023 Institute are summarized below.

1 **DEVELOP OUR HABITS OF PAYING ATTENTION TO UNFOLDING TRENDS AND CONDITIONS.**

2 **EXPERIENCE THE ART OF CRAFTING FUTURE SCENARIOS OR "STORIES OF THE FUTURE."**

3 **EXPLORE CRITICAL CHALLENGES FACING THE ENGINEERING COMMUNITY POSED BY ALTERNATIVE FUTURES, INCLUDING INQUIRIES WITH RESPECT TO DIMENSIONS SUCH AS:**

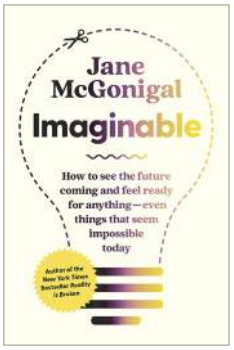
- Emerging technologies
- New practice paradigms for engineering and the engineering workplace of the 21st Century
- Macro-ethical challenges
- Unsticking the engineering pipeline with respect to DEI
- Engineering the unfolding energy transition to "net zero"
- Challenges in climate change resilience and adaptation

4 **BE BETTER PREPARED FOR THE FUTURE THAT DOES UNFOLD AND ENHANCE DECISION-MAKING CAPABILITIES IN THE FACE OF UNCERTAINTY.**

5 **RECOGNIZE SIGNS OF MAJOR SHIFTS EARLY ENOUGH TO TAKE APPROPRIATE ACTION.**

6 **SET THE AGENDA AND IDENTIFY POSSIBLE ACTIONS THAT THE ENGINEERING COMMUNITY CAN TAKE TO INFLUENCE FUTURE EVENTS AND INCREASE ITS CONTRIBUTION TO SOCIETY.**

The work at the Institute followed a process design combining traditional scenario planning elements with a set of concepts for imagining the future explored in Jane McGonigal's book, **Imaginable**. In addition, presentations from seven provocateurs added insights and helped the group move beyond conventional thinking about future possibilities. The diagram provided below illustrates the scenario planning process.



Scenario Planning Roadmap

Define Scope & Time Frame

Research Environmental Scan

Generate Scenarios:

- **Signals of Change**
- **Future Forces**
- **Critical Uncertainties**
- **Constructing Scenarios**

Explore Scenarios:

- **Exploring Individual Scenarios**
- **Analysis Across Scenarios**

Applying Learning

Notes on Scenario Planning

Scenarios are "tools for foresight-discussions and documents whose purpose is not a prediction or a plan, but a change in the mindset of the people who use them."

– Arie DeGeus

Scenario Planning is a tool for imagining possible futures. Although no one can predict the future, it is possible to prepare for it…

1

We will be better prepared if we have considered a range of possible futures, rather than operate under assumptions of an "official future."

2

Strategic decisions will be more likely to produce desired results if they appear to be sound and workable in a variety of alternative futures.

3

Considering plausible alternative futures will increase our strategic agility and prepare us to recognize signs of major changes early enough to take appropriate action.

Participants agreed that an appropriate time frame for the scenario planning at the Institute would be ten years. To set the stage for discussions, participants were asked to consider the major surprises of the last ten years. Participant observations illustrated how we are constantly surprised by developments in the world and how these surprises are often connected.

- COVID-19 pandemic.
- Changes related to diversity / inclusivity efforts.
  - » Substantial amounts of money allocated to diversity / inclusivity programs in universities that have not moved the needle.
  - » Increased emphasis on diversity / inclusivity in corporations.
  - » Recent pushback and politicization of the issue.
- Mental health crisis, amplified by the pandemic and influencing all aspects of society.
- Political polarization, seen in the increasing space between political parties and the rising influence of social media.
- Climate change impacts that are landing faster and harder than projected by science.
- Impacts of AI.
- Lack of trust in institutions such as science and higher education.
- Breakdown of civil discourse and respect.
- Fragility of systems exposed by the pandemic, e.g., supply chains and health care.
- Bounce back of ecological systems during pandemic.
- Rapid consolidation of industries, including engineering.
- Shift from international collaboration (globalism) to nationalism to state-specific interests.

Generating Scenarios – Signals of Change

*"A **signal of change** is a concrete example of how the world could one day be different…It's not a hypothetical possibility. It is happening right now, and it proves that a specific kind of change is possible."*

Imaginable, Jane McGonigal – Chapter 6: Look for Clues

As the first step in generating scenarios, participants were asked to individually reflect on the signals of change they identified as preparation for the Institute. Participants posted their individual signals and then worked as a group to categorize the signals.

Signals of Change

Climate Change - impacts (severe weather, water shortages, wildfire smoke, global climate migration); emissions reduction efforts (increased use of sustainable building materials, electrification of everything, renewable energy adoption in developing countries, decarbonization of industry, adoption of cultivated meat, etc.); and responses (unavailability of insurance in at-risk areas, increase in businesses focused on disaster preparedness, civil disobedience).

Advances in Autonomous Vehicles and Electric Vehicles - increased EV range, charging technologies, etc. as well as emerging public responses (congestion pricing, regulations, etc.).

Space – moon landings, impact of Starlink, space transportation.

Politics – China, Elon Musk, Donald Trump.

Disparities – rising homelessness, opioid epidemic, income inequality.

Economic – inflation and the rising cost of living.

Misinformation / Disinformation – declining trust in institutions, rise of influencers, book wars, anti-woke legislation, mistrust of higher education.

Workforce – impact of unions, push for four-day work week, shortages, turnover (e.g., nursing).

Education – percentage of population that values education, declining enrollment in higher education, student engagement, rise in technicians, changes in educational methods.

Technology – AI impact on jobs, AI regulation and policies, rise of robots, brain-computer interface, utilization of 3-D printing, digital twins, use of Bitcoin.

Biotechnology – sewage monitoring for public health, pain control using nanotechnology, genetic manipulation to increase longevity.

Diversity and Demographics – migration based on political ideology, utilization of foreign-born workforce, diversity in engineering (does it begin to shift?).

Health Care – longevity, self-prescribed and self-administered medical treatments.

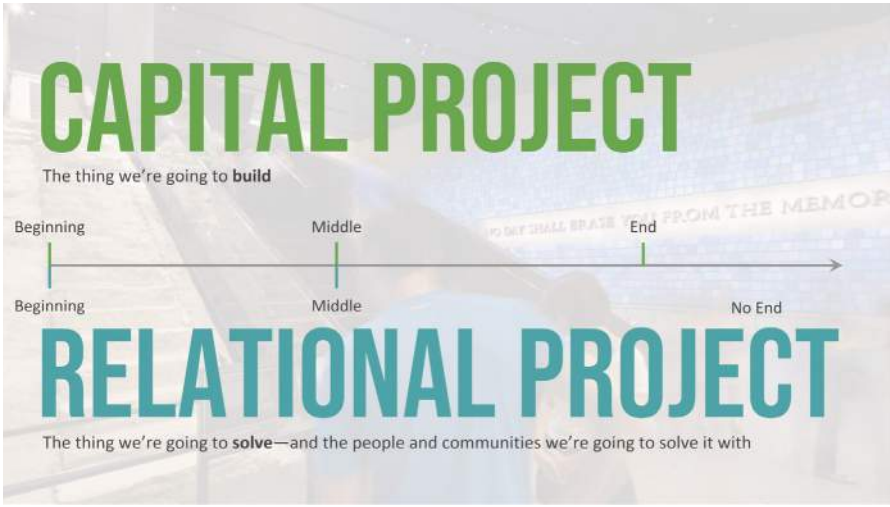

Provocation

Provocation - From Capital Projects to Relational Projects

TOM HENNES

President, Thinc Design

Tom Hennes is a global leader in the field of experiential design. For thirty years, he has led his New York based firm, Thinc, in the development, design, and curation of innovative national and regional museums, World Expo pavilions, national memorials, corporate mobilizations, aquariums, and cultural attractions in the North America, Africa, Europe, and Asia. Notable projects include the National 9/11 Memorial Museum; the Freedom Park, in Pretoria, South Africa; the Sustainability Pavilion for Expo 2020 Dubai, and the reimagined experience for the Empire State Building Observatory.



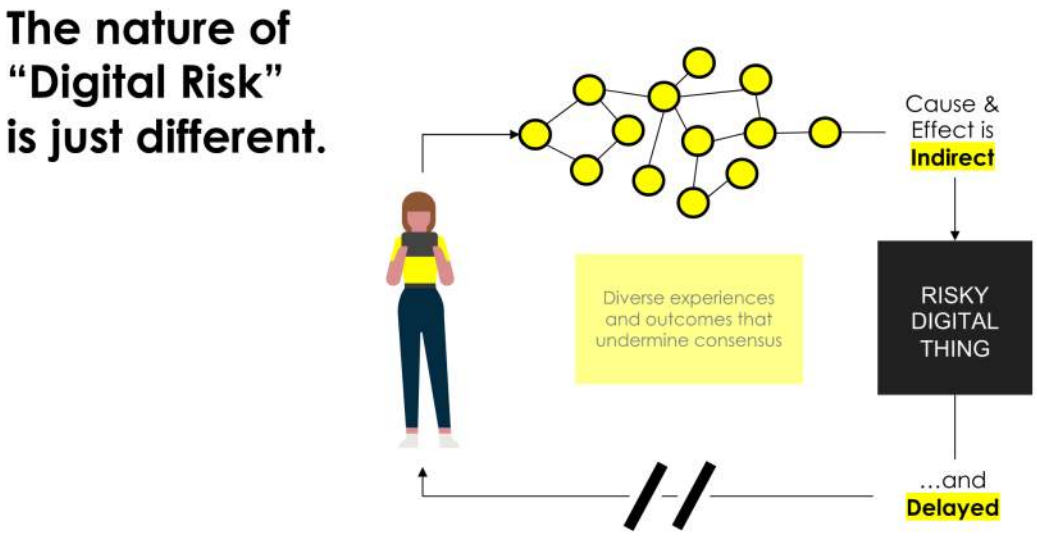
Tom Hennes, founder of Thinc Design, offered his approach to relational design as an important consideration for the future. Using his work on the 9/11 Memorial as an example, Tom described how he views his exhibit design projects with the perspective of a theater. The presence of an audience alters the perceptions of designers.

He described the difference in approach when projects are viewed as "relational projects" as opposed to just "capital projects." The "capital" approach sees projects as the thing we are going to build. The "relational" approach sees projects as "the thing we're going to solve – and the people and communities we're going to solve it with." The relational approach brings meaning to capital projects. He pointed out that designers typically see the relational aspect of projects only in service to the capital aspects. He stressed that we need to turn this logic on its head. The relational approach can help us see how our work can embody the groups we serve and how we can raise awareness.

Provocation - Challenges Related to Digital Technologies at Scale

MARTIN RYAN
Venture Strategy & Development, ServiceNow

I live at the cross-section of foresight/strategy/innovation/technology and design. I have learned that our instincts and conventional wisdom often lead us astray, and the momentum generated from what has made us successful in the past can feel unstoppable. But when we approach change and innovation with the humility and discipline needed to see the whole system, intervene only where it matters, and find the creative confidence to tell new, compelling stories about the future, we can break through. These days, you can find me at ServiceNow working on its corporate vision and venture strategy.



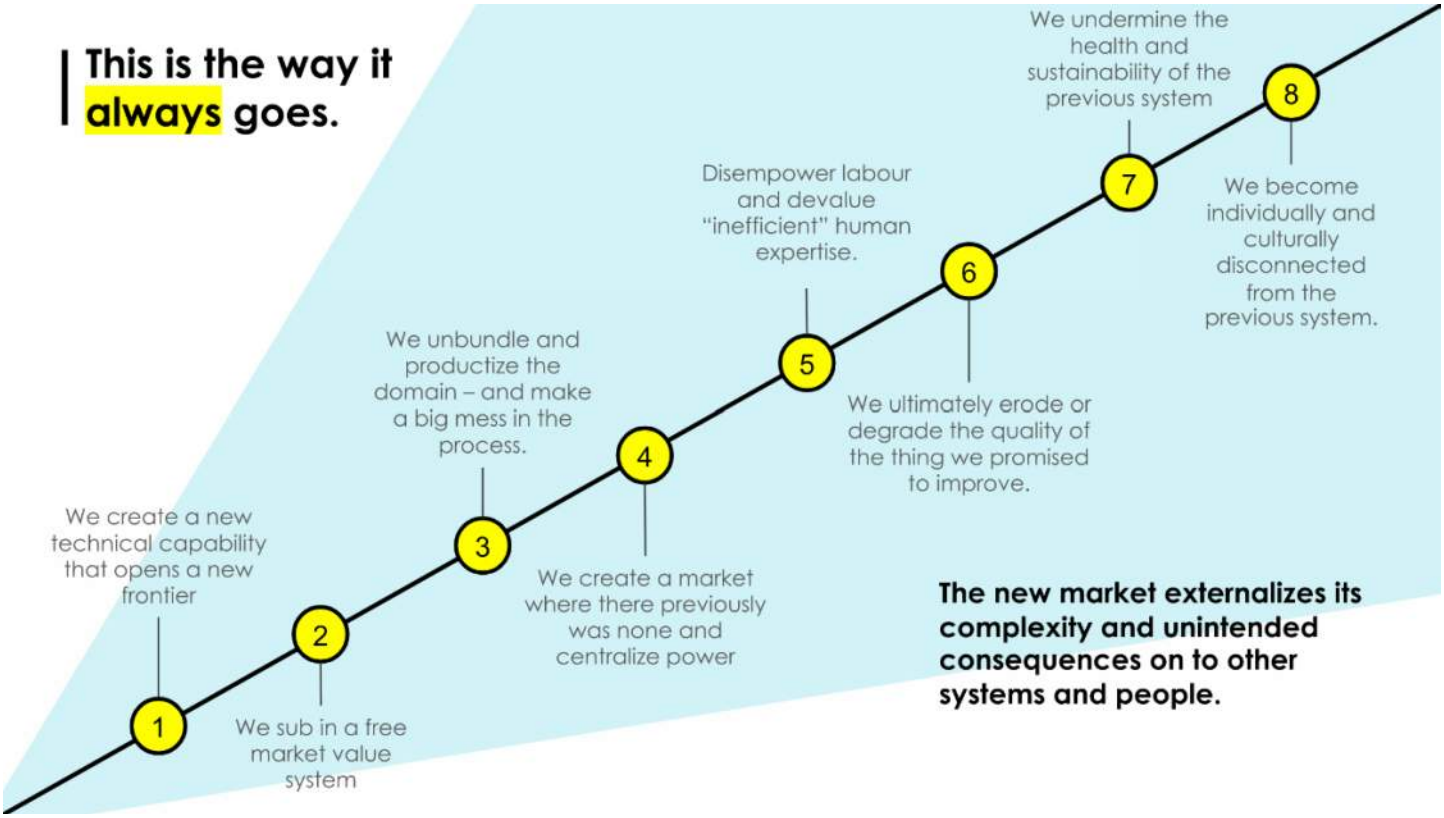
Martin Ryan's provocation addressed the future implications of the social/cultural aspects of AI and emerging digital technologies. He described our struggle to relate to the risks of digital tech at scale.

As an example of this struggle, he compared the risks of the aviation industry to the risks of digital technologies. In the early years of the aviation industry, the risks were clear. Frequent crashes were a reminder to the public of these risks. Cause and effect were direct and immediate. The desire to minimize risks drove the need for regulation with the result that air travel now is incredibly safe. Digital risk is different. Cause and effect are indirect and delayed. This undermines the ability to develop consensus around regulation. This phenomenon tends to worsen as the complexity of the digital technology increases.

According to Ryan, people generally suffer from risk blindness with respect to digital technologies. Social media took advantage of this blind spot, becoming embedded in society within just a few years of its introduction. This type of rapid adoption, now being experienced with AI, has amplified our collective failure to acknowledge risks and develop effective regulation of emerging technologies. One of the consequences of this blindness is the documented negative impact of social media on children.

Provocation - Emerging Digital Technologies: Future Implications of Social/Cultural Aspects continued

Ryan described "the way it always goes" with product development in free markets (see exhibit). He cited factory farms as a non-digital example of this process. The "productization" of food production has come with many negative impacts, such as a decline in overall health, negative impacts on communities, and negative impacts on the environment. With the rapid, unregulated growth of digital technologies such as AI, he warned that we are, in a sense, "productizing" ourselves.



Ryan stated his belief that we are still in control of digital technologies, but as we become increasingly dependent on these types of technologies, there may come a point when human control collapses. He cited 2019 research from Gartner that this loss of control will come with both short-term and long-term social impacts, including emotional, behavioral, and functional disorders.

In concluding his provocation, Ryan emphasized the options that are available to improve our toxic relationship with technology. He stressed the need to learn from our past mistakes, to scale more of what we want (such as dialogue that results in effective regulation), and to bet on ourselves.

Provocation - Emerging Digital Technologies: Future Implications of Social/Cultural Aspects continued

A few directions worth exploring....

LEARN FROM OUR MISTAKES

We need to **lower the barriers to ethical inquiry** at work

We needs new ways of **modeling the objectives an unintended consequences** of digital system at scale

SACLE MORE OF WHAT WE WANT

We need to build systems that **bias the values and objectives we need** to survive

Build **new systems for democratic dialogue that scale** and can better negotiate policy at local, national and global scales

BET ON OURSELVES

Work to balance the power of new digital capabilities between labour and capital

Prioritize community and human interaction in the design of our physical world to counterbalance our digital one

Generating Scenarios - Future Forces

"A future force is a significant trend or phenomenon that's likely to make a disruptive or transformative impact on society…It usually starts off as a small signal of change - and then picks up strength over a period of months, years, or decades."

Imaginable, Jane McGonigal – Chapter 7: Choose Your Future Forces

As the second step in generating scenarios, participants looked at future forces, the external trends, dynamics, or factors that are likely to affect our lives and the work of the engineering community within the scenario planning time frame. Working individually and then in small groups, participants developed a comprehensive list of future forces and then prioritized the list. The list of future forces included below is in order from highest to lowest priority with those shown in the boxes judged to be most important in exploring possible futures for the engineering community.

Future Forces

Climate change. Reaching the tipping point.	Disparities / Inequality. Income inequality and access to AI and other digital technologies.	Change in priorities of our work – more purpose driven. Prevalent in younger generations.	AI – positive or negative or both?
More emphasis on work-life balance. Overlap with remote work.	Political polarization.	Depletion of water resources.	Fragility of technology. Cyber security threats.

- Misinformation / disinformation. Engineering community's role as trusted advisor is at risk.
- Changing demographics. Population explosion in sub-Saharan Africa v. aging population and declines in the rest of the world.
- Global migration.
- Urbanization.
- Access to inexpensive solar and wind energy.
- Growing global divide in educational opportunities.
- Questioning of the efficacy of capitalism. Pushback from younger generations.
- Increase in authoritarianism.
- Increased sensitivity to the value of human life.
- Lack of understanding by the public of the role of engineering.
- Engineering culture slow to adapt to broader cultural shifts.
- Rising human resistance to change. Applies to AI regulation, climate change, public health, etc.
- Geopolitical conflict. War in Ukraine.
- Autonomous vehicles.
- Increase in populism.
- Food insecurity.
- Bio-medical breakthroughs. Development of RNA vaccinations.
- Advances in materials, e.g., living concrete that absorbs CO2.
- Potential for innovation and entrepreneurship.
- Global movements, such as Greta Thunberg's youth climate change movement.


Provocation

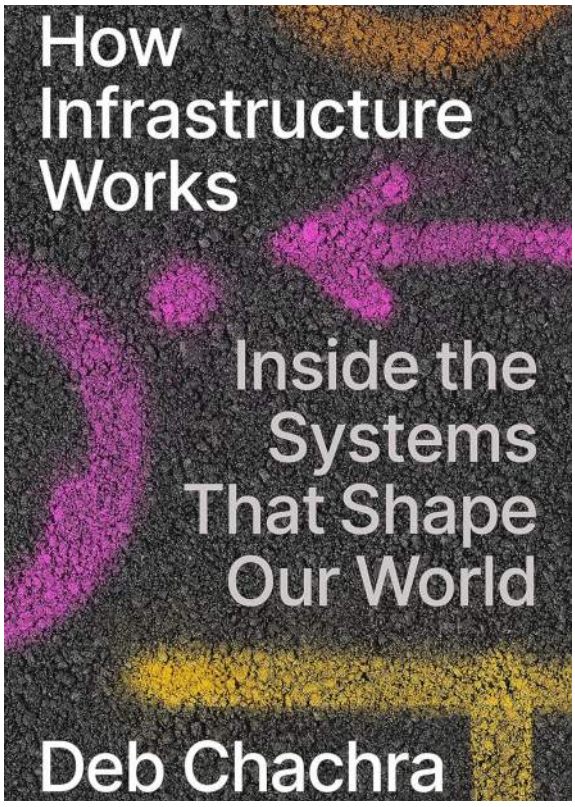
Provocation - Shifting Our Energy Mindset from Scarcity to Abundance

DEBBIE CHACHRA
President of Engineering, Olin College of Engineering

Deb Chachra is a professor at Olin College of Engineering and the author of HOW INFRASTRUCTURE WORKS: INSIDE THE SYSTEMS THAT SHAPE OUR WORLD (Riverhead, October 2023, supported by the Sloan Foundation). Her research interests include the engineering student experience (for which she received an NSF CAREER award), equity and inclusion, and the intersection of technology and culture. She speaks, writes, and consults widely in these fields. Prior to Olin, she held a postdoctoral fellowship at MIT, and she earned her PhD in materials science and bioengineering from the University of Toronto.

According to Debbie Chachra society is experiencing a phase change with respect to energy, de-coupling from our historical reliance on fossil fuels, that we dig up and burn, and transitioning to renewables that ultimately source from the sun. This phase change also involves a societal mind-shift moving from "scarcity" to "abundance."

Chachra's provocation to participants was to consider how we build collective systems in the future that offer equal access to energy to everyone.



The supply of fossil fuels has always been limited (by stocks accumulated over eons), while the flow of renewables from the sun is virtually unlimited. In her just-published book, How Infrastructure Works , Chachra notes that our "estimate of civilizational energy usage to meet the needs of every human on Earth is about 0.04 percent of the incident solar radiation (which also powers the movement of wind and water on the planet).

This potentially infinite energy source will be coupled with finite supplies of materials (and closed material loops), causing the need to fundamentally rethink how we extract, refine, use, and reuse material resources.

This shift is being driven by our need to address climate change, but it also creates a virtuous cycle where the individual agency derived from a new collective, renewable energy infrastructure will reinforce our ability and willingness to address not only climate change, but other societal challenges.

Chachra noted that the economics of renewable energy are fundamentally different than fossil fuels. There are no incremental costs for renewable energy, and renewable energy is decentralized. Unlimited, distributed renewable energy can give agency to and raise the standard of living for previously energy-starved segments of society who couldn't afford the cost of fossil fuels and the expense of building infrastructure to supply that form of energy.

Provocation - Defending Civilization: Engineering in a Time of Existential Digital and Climate Risks

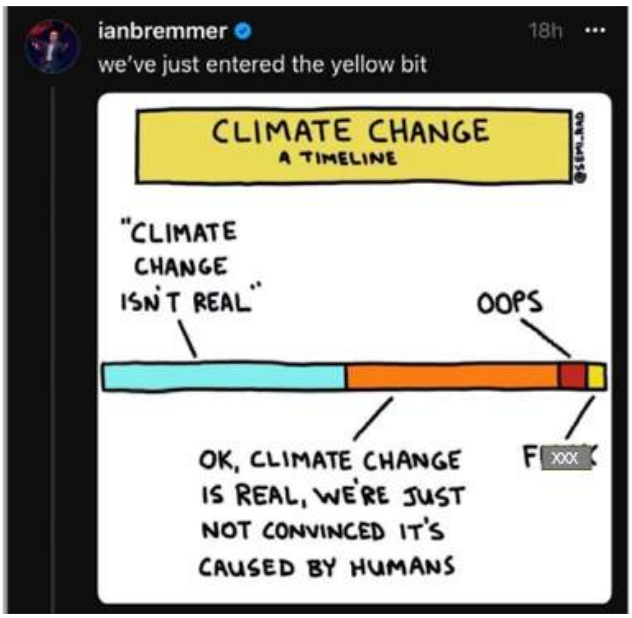
ANDREW BOCHMAN

Senior Grid Strategist-Defender, Department of Energy / Idaho National Lab

Andy provides strategic guidance on topics at the intersection of grid security and climate resilience to INL leadership as well as senior U.S. and international government and industry leaders. A frequent speaker, writer, and trainer, in 2021 he published Countering Cyber Sabotage: Introducing Consequence-based Cyber-Informed Engineering (Taylor & Francis). An Atlantic Council non-resident senior fellow, Andy recently published "A Heat Dome Hits Virginia," which portrays the national and global impacts of a prolonged extreme heat event in northern Virginia (Security Management, 2022).

Andy Bochman challenged participants to consider existential risks such as grid security and climate resilience in future scenarios. Bochman illustrated the urgency of these challenges with a climate change timeline. According to Bochman, we have moved into the acceptance of the reality of climate change, even though there is still some resistance.

Bochman described the mission of the engineering community as defending civilization through designing, building, and protecting infrastructure.



Provocation - Climate Change: A Timeline continued

He proposed two problem areas that must be addressed to fulfill this mission. The first of these is climate. Bochman highlighted the challenges posed by climate change – too much heat and fire; too little heat (unexpected freezes); too much water (floods), not enough water (drought), storms with higher velocity winds; and melting permafrost. He stated that our electrical grid and our cities are not ready for these challenges.

Provocation - Climate Change: A Timeline continued

The second problem area includes cyber security and AI. Business systems and infrastructure systems face cyber security risks that will be amplified by AI.

Click here for a summary of Andy Bochman's provocation.

Bochman highlighted the commonalities between these two risk areas. One is that they are exceedingly difficult to regulate. Cybersecurity and climate resilience are almost impossible to measure. Humans are not proactive with respect to future risk, including for these two areas.

He highlighted the value of investments in resilience. The consensus of the insurance industry is that every dollar spent on resilience produces between $6 and $11 of benefits through reduction of business interruption and recovery costs.

Bochman concluded by stressing that the engineering standard of care must adapt to address these challenges. The argument that catastrophic events are unprecedented, record setting, totally unforeseeable, or historic will not work in the future.

Generating Scenarios - Mapping Critical Uncertainties

As the next step in generating scenarios, participants examined **critical uncertainties**, the events, whose outcomes are uncertain, that will significantly affect the signals of change and future forces that are of most concern for the future scenarios. Participants again created a prioritized list of these issues that is included below. The list of critical uncertainties included below is in order from highest to lowest priority with those shown in bold judged to be most important in exploring possible futures for the engineering community.

Political landscape and the future of democratic society in the U.S. and beyond. Will it get better or worse?

Extreme climate events. Was this the best year we can expect in the next 10 years? How do we come together to make progress? Can the engineering community play a major role?

Future workforce issues. Will diversity in engineering increase? What enrollment trends in engineering programs will emerge?

Will innovation solve current challenges with renewable energies; carbon capture; decarbonization of building materials, industry, agriculture, etc.?

AI – what will happen? How do we live with something that is smarter than humans?

Catastrophic events impacting the economy, e.g., pandemic, earthquake, domestic terrorism, etc.

Geo-political crises.

National unifying event.

Economy.

Immigration reform.

Emissions scenario.

Managing disruption in engineering.

Human psychology / behavior – risk perception, trust in experts, individual decisions, how we form relationships.

Generating Scenarios - Identifying Alternative Scenarios

As the group prepared to move to generating its future scenarios, ECL Creative Director and Lead Facilitator Kyle Davy offered guidance on best practices. One area of guidance is to understand the possibilities for the types of scenarios that can be generated.

ECL Creative Director Kyle Davy

Conventional Wisdom vs. Other

Winners and Losers (Zero Sum Game)

Challenge & Response

Revolution

Multiple Critical Uncertainties

Two x Two Matrix

Kyle also offered examples of sets of future scenarios.

- The Mont Fleur Scenarios (from Solving Tough Problems, Adam Kohane), which were used in South Africa.
  - » Ostrich (business as usual, head in the sand, things fall apart).
  - » Icarus (quick turnover to the Black community, flow of international funds, too much too soon – collapse).
  - » Lame Duck (Afrikaners stay in place).
  - » Flight of the Flamingos (all rise together).
- ASCE's Future World Vision Scenarios for Cities of the Future (from "What Lies Ahead," Laurie A. Shuster, Civil Engineering, June 2019).
  - » Resilient Cities.
  - » Progressive Megacities.
  - » Dispersed Settlements.
  - » Unequal Enclaves.

Finally, Kyle offered guidelines for good scenarios (from *Scenario Planning: The Link Between Future and Strategy*, Mats Lindgren and Hans Bandhold, Palgrave MacMillan, New York, NY, 2003).

- Decision-making power - provide useful insights for the question being considered.
- Plausibility - fall within the limits of what future events are realistically possible.
- Consistency - have an internal logic that is consistent.
- Differentiation - each scenario should be structurally or qualitatively different and it is not enough for them to be different only in terms of magnitude.
- Memorability – scenarios should be easy to remember and to differentiate.
- Challenge - the scenarios should really challenge the organization or community's perceived wisdom about the future.

In group discussion of the key elements of the scenarios, several important points emerged.

- Leadership from the engineering community is a key question regarding all scenarios.
- Climate change consistently shows up, particularly the potential for impacts getting worse faster, possibilities for a new energy future, insurance crises, water resources impacts, and migration impacts.
- Workforce uncertainty also consistently shows up - shifts in values and mindsets (purpose), work-life balance, and remote work issues.
- Political landscape is the third element that consistently shows up – polarization and threats to democracy.
- Technological innovation seems like it should be a predetermined element of all scenarios.
- Demographic changes should also be a predetermined element.

Scenario 1 - United Regions

During the first decades of the new millennium, increased political polarization across the United States led to many of the Federal government's functions all but crumbling. Misinformation and disinformation became impossible to avoid, causing more and more citizens to turn their trust away from doctors, scientists, engineers, and other traditionally trusted experts. Extreme weather events, coupled with the Federal government's inability to pass policy changes that would foster solvency of the program, led to the demise of the National Flood Insurance Program and left housing vulnerable in many coastal and riverine locations. States across the country saw large swings in human migration, with people moving to more stable climates and economies, and away from the states hit hardest by disparities in income, housing, and jobs. Increasing political polarization also contributed to this migration as some people sought out communities that aligned with their view.

With the people no longer able to count on national politicians and the traditional institutions to get things done, a new order began to emerge where states, regions, and metropolitan areas banded together to create a new coalition-style system that could focus on the specific needs of a region. Within certain locales, resources are pooled, and citizens vote on shared priorities, such as water rights, insurance protections, zoning and building codes to address issues affecting constituents. They also enter trade agreements with the other regional Coalitions that have common interests. Other places were left out of this new system and their residents faced increasing hardships. These new mechanisms and forums for civic engagement began to rebuild a shared sense of community and confidence in the ability of diverse groups to work constructively together.

The national election in 2028 saw a majority of new members of Congress coming from the ranks of the most successful members of the Coalition governments. And then, in 2032, despite malicious misinformation campaigns by both domestic and foreign parties, a candidate lovingly nicknamed "The Great Unifier" emerged as winner of the presidential election. Many within the Great Unifier's own party saw this as nothing short of a miracle. While the nation faced plentiful challenges large and small, the Great Unifier declared the only priority of their first 100 days to be putting an end to the ongoing war against facts and truth.

The Great Unifier assembled high ranking members of each regional Coalition, and engineers, scientists, doctors, and technologists across a range of professions. From this field, Cabinet secretaries and undersecretaries were selected. To build trust with citizens across the nation, nonpartisan civilian committees were also appointed to sit within each cabinet department. Working together with experts in A.I., blockchain, non-fungible tokens (NFT's), and other advanced technology, a system for verifying the accuracy and authenticity of all sources of information posted online and shared via other media was created. The Seal of Truth system provided a check on every post to an online forum, and a confirmation for those reporting the news via television, online newspapers or other forms of media that the information they had collected was verified by a trusted committee.

Following the implementation of the Seal of Truth, the Great Unifier began the work of healing the vast political divide and building on the successes achieved through partnerships among regional coalitions. Residents of all regions, including those who had been left out for decades, began to benefit from actions taken by new leaders creating beneficial policies based on verified data. Success did not happen overnight, but slowly and surely, the public's trust and shared civic commitment began to return to the nation's institutions, and the people who made them function.

Scenario 2 - An Abundant, Inclusive , Innovative and Accessible Workforce

In 2033 "abundance" replaced "chronic shortage" as a descriptor of the engineering community's workforce relative to its needs. A new purpose-driven, diverse cohort of graduates from an expanding range of engineering educational experiences combined with new means of leveraging emerging technologies to augment workers within this community drove this surprising outcome over the last decade. As a result, the engineering community is trusted by society because...

- it is driven by purpose;
- guided by values of inclusion and access, integrity and ingenuity, humility and respect, responsibility and accountability; and
- represents a professional community for human flourishing led by leaders who represent the diversity of our society.

Earlier in the decade, professional engineering societies and organizations were faced with a dwindling engineering workforce. Individuals were not motivated to pursue engineering education due to the narrative of rigorous classroom requirements and irrelevant assignments, followed by a career of extreme workloads, inadequate compensation, and high responsibility combined with low authority to make meaningful change. Individuals did not feel that their organizations and industries reflected their desires for purpose and human flourishing nor the demographics of those they served. The engineering profession was divided, siloed, and at risk of becoming relegated to a technical role, putting the health and safety of the public at risk. Changes needed to be made.

Professional societies came together to change the image of the engineering profession and to unite the engineering community behind a common goal, "Protect and Better Humanity Through Scientific and Technological Innovations." Organizations like the National Academy of Engineering, ABET, NSPE, NCEES, and other discipline-based engineering societies highlighted the positive impact of the engineering community. Leaders across all sectors of the engineering community, including higher education, teamed up to rethink the diverse pathways one could navigate in contributing to human flourishing. This meant that technicians, technologists, engineers across all disciplines, and other related professionals came together to be part of this community of professionals. Clear and diverse pathways were created for people to contribute, with a commitment to better humanity responsibly being the common thread.

Now, due to a narrative shift and modern, digital technologies to augment the workforce, a sense of abundance has emerged. The agility of the profession to respond to the needs of society is embodied by the multiple, diverse pathways to be part of the engineering community. The depiction of entering the profession has shifted from "engineers must be good at math" to "engineers better humanity and improve the lives of people." As a result, a diverse, abundant, and purpose-driven workforce has emerged. Multiple entry points into the profession, such as high school programs, two-year degrees, four-year degrees, post-graduation career changes, certificate pathways, licensure pathways and more has led to its growth. Engineering and other related careers are introduced in early education as a career and life choice that allows contribution to bettering your community and increasing the quality of life for people everywhere. With time, the leadership of engineering community organizations has evolved and is now as diverse as the populations they serve.

Professionals across the engineering community are passionate about the work they do. Technologies such as AI and blockchain are utilized for typical mundane engineering tasks, allowing individuals to focus on the work that motivates them. Organizations encourage workers to perform purpose-driven work and technological advancements allow this flexibility. Industry exemptions no longer hold engineering professionals back from upholding their responsibilities to protecting and bettering humanity. The engineering community is as diverse as our society. Anyone and everyone feel empowered to enter this community, leading to an abundance of workers and a greater appreciation of the entire engineering community by society.

Scenario 3 - Miami Devastated by Hurricanes

The 2020-2030 decade was marked by nearly constant and overlapping natural disasters across the United States. The prolific run of devastating wildfires, flooding, and hurricanes elevated the Cybersecurity & Infrastructure Security Agency (CISA) to a household name, and resiliency to common dinner conversation. In 2025, after a major hurricane hit Miami and shut down the Port of Miami for the better part of a year and devastated the economy, CISA and cooperating agencies funded the multi-billion-dollar Florida Coastal Barrier System Project. Polls indicated that public support for coastal barriers and other resiliency-related infrastructure projects was high. Unprecedented regional bond programs were approved to support joint state and federal projects to erect barriers.

In 2030, a catastrophic ice shelf collapse raised sea level six inches in one year. In 2031, when the Florida Coastal Barrier System Project was well into construction, with significant portions completed, another devastating hurricane hit, destroying much of the barrier system and rendering large portions of South Florida uninhabitable. 15 million people were impacted. Most housing was rendered uninhabitable and over three million people were permanently displaced. The loss of life was estimated to exceed 50,000 people. After the second hurricane, the State of Florida voted to shift funding away from re-building all areas and, instead, relocate close to three million refugees from the hardest hit areas.

On the national level, the resulting society-wide awakening to the escalating impacts of climate change and extreme weather events sparked a new, shared transformation from apathy and short-term thinking to a commitment to long-term planning and funding for resilience and reduction of carbon emissions.

An example of this transformation was the institution of “Blackout Fridays.” Beginning in 2033, cell phone notifications appeared every Thursday afternoon throughout the United States as the weekly reminder that activities involving all discretionary energy use are to be suspended one day a week. This nationwide blackout was just one of a set of dramatic changes agreed to by society in the wake of the two Miami hurricanes.

A flurry of activity takes place in communities across the country each Thursday evening as people rush to finish work and school, run errands, and communicate with their friends and families before the power and internet are shut off at midnight. In many communities, Blackout Friday’s have centered around volunteer events to support the relocation of the three million South Florida refugees. Other communities focus on constructing micro renewable energy systems, proliferating community gardens, retrofitting homes to house multiple families, and volunteer-led masterclasses. These community projects are all undertaken with the ambition to reduce energy consumption behaviors and adapt to the new extreme climate norm.

Some community members have better access to getting their needs met during Blackout Friday than others and are exposed to extreme heat and cold events. National protests rise against the disparate impact on socio-economically disadvantaged populations. Battles ensue between neighbors reporting each other for unauthorized Friday power usage. Some communities are brought together by Blackout Fridays, but others are divided.


Provocation

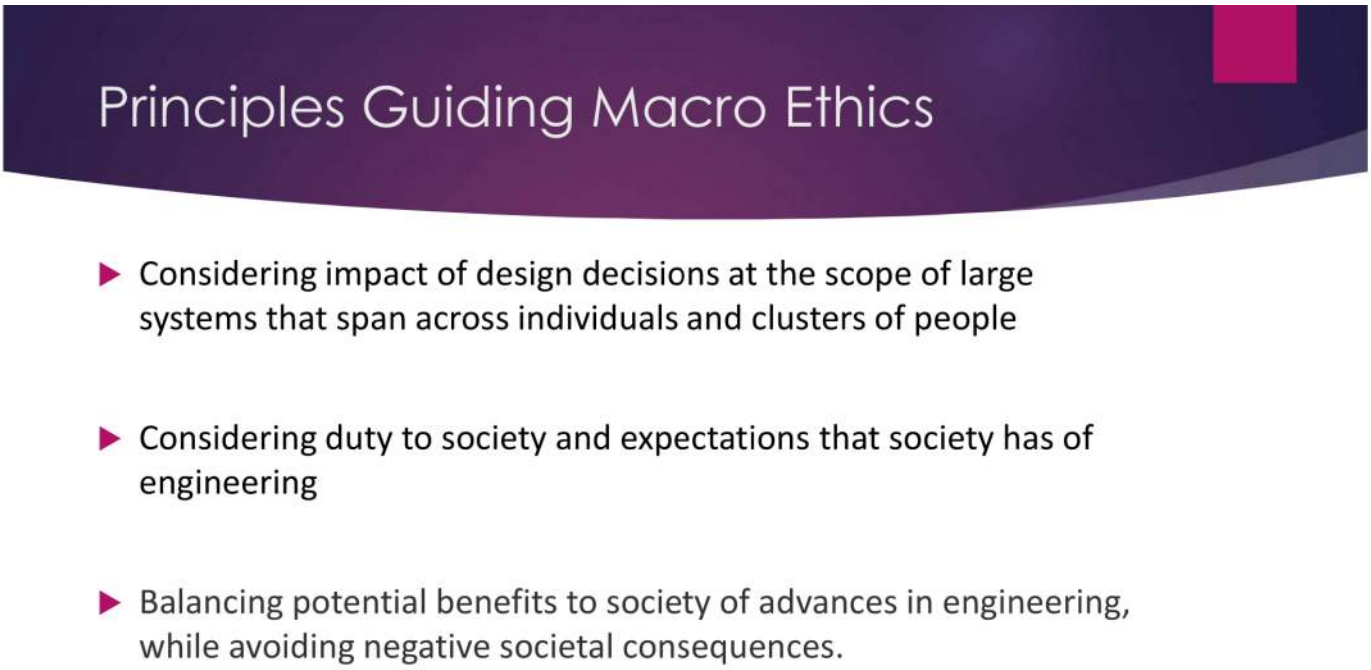
Provocation - Intention and the Future of Engineering: Macro-Ethical Considerations

ROSALYN BERNE

Olsson Professor of Ethics & Chair of the Department of Engineering and Society, University of Virginia

Rosalyn W. Berne, Ph.D., is the Olsson Professor of Applied Ethics in the School of Engineering and Applied Sciences at the University of Virginia, Chair of the Department of Engineering and Society, and directs the Online Ethics Center for Engineering and Science. Her books include Creating Life from Life: Biotechnology and Science Fiction; Nanotalk: Conversations with Scientists and Engineers about Ethics, Meaning, and Belief in the Development of Nanotechnology; Waiting in the Silence; When the Horses Whisper; and Waking to Beauty. Animals, Ethics & Engineering is forthcoming (2024).

Rosalyn Berne's provocation challenged Institute participants to consider the intentional application of macro-ethics in our scenarios of the future. Berne characterized the relationships between individual engineers and their clients, colleagues, and employers as micro-ethics, while macro-ethics represents the collective social responsibility of the engineering community. Issues that fall in the realm of micro-ethics include integrity, bribes, competency, and safety. Issues that fall in the realm of macro-ethics include environmental impacts, sustainability, and emerging technologies such as AI. Berne outlined the principles at the heart of macro-ethics (see exhibit).



Provocation - Macro-Ethics and the Engineering Community

According to Berne, the consequences of failing to consider the principles of macro-ethics are that the work of the engineering community, despite good intentions, sometimes causes unintentional societal and environmental harm.

Berne emphasized the importance of intentionality in action. She described the components of intentionality (see exhibit).

Four components of Intentionality

- **Desire:** for an outcome or, the outcome as a goal, purpose, or aim
- **Belief:** or thought about consequences, or act itself, before acting
- **Intention:** to perform act; meaning, deciding, choosing, planning to act
- **Awareness:** of the act while the performing it
- **Skill:** or the ability to execute action in a controlled, replicable manner

She cited the development of plastics as an example of failing to act in accordance with the principles of macro-ethics and intentionality. The unintended consequences of the development of plastics include vast amounts of plastic waste that are fouling the environment and the growing presence of plastics in the human body.

Berne then described the five principal causes of unanticipated consequences.

Provocation - Macro-Ethics and the Engineering Community

Five principle causes of unanticipated consequences
Robert K. Merton (1936)

I. Ignorance (We didn't know)

II. Error (Oops)

III. Interest which neglects longer term, potentially negative consequences

IV. Values leading to non action, despite potential negative consequences

V. Self-defeating prophecy: non action due to fear of negative unanticipated consequences.

Berne concluded by challenging participants to consider the role of macro-ethics and intentionality in our work.

What do we **desire** as outcomes?

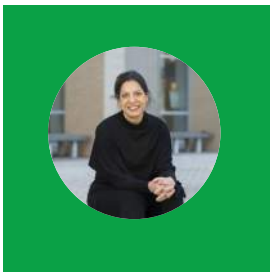
What is our **belief** in considering consequences before acting?

What is our **intention** in decision-making?

Do we have **awareness** of the consequences of our actions?

Do we have the **skill** to execute in a controlled, replicable manner?

Provocation - Sustainable Energy Transition for Our Future



DEBBIE CHACHRA
President of Engineering, Olin College of Engineering

Deb Chachra is a professor at Olin College of Engineering and the author of HOW INFRASTRUCTURE WORKS: INSIDE THE SYSTEMS THAT SHAPE OUR WORLD (Riverhead, October 2023, supported by the Sloan Foundation). Her research interests include the engineering student experience (for which she received an NSF CAREER award), equity and inclusion, and the intersection of technology and culture. She speaks, writes, and consults widely in these fields. Prior to Olin, she held a postdoctoral fellowship at MIT, and she earned her PhD in materials science and bioengineering from the University of Toronto.

In her second provocation, Debbie Chachra continued her discussion of the challenges of the energy transition that is a key future driving force. She gave several examples from the past of the relationship between energy and our use of materials.

One example she cited was aluminum, which was originally an expensive material used for baby rattles for the children of royalty and for buildings such as the Washington Monument. As electricity became more available, the energy intensive process for producing aluminum became more affordable, and usage began to increase. Usage skyrocketed during World War II as aluminum became a primary material in airplanes. Now the abundance of cheap energy has resulted in aluminum becoming a widely used, disposable material.

This is an example of how abundant, cheap energy accelerates the cycle of extraction, use, and disposal. Other materials that have experienced this cycle include steel, glass, and plastic. For all these materials, the cost of reprocessing materials for re-use equals or exceeds the cost of producing new materials.

Renewable energy is changing these equations. According to Chachra, it is critical that we not take the same approach with renewable energy that we did with fossil fuels, so that we do not maintain or worsen our current wasteful practices with respect to materials.

Chachra also pointed out that our current renewable energy technologies require materials, such as lithium, whose extraction has significant negative social and environmental consequences. It is critical that we develop alternatives to these materials.

Chachra emphasized that a significant challenge of the future is learning to deal with the abundance of new forms of energy in a sustainable manner. The engineering community will play a critical role in guiding society through this transition, not just creating new technologies and infrastructure, but helping people and communities rethink their fundamental relationships with both infinite sources of energy and finite material resources.

Exploring the Three Scenarios

Imagine yourselves in these future scenarios ten years from today. Now that you are in the future, reflect on the following questions…

How might the conditions described in the future scenario impact the engineering community?

What opportunities can you detect for significantly increasing the contribution that the engineering community makes to society?

- How could the engineering community use its unique strengths to help others in this future?

What are the biggest surprises the engineering community will face as society moves into this future?

What actions should members of the engineering community take today (or in the near future) in response to the prospective conditions outlined in this scenario?

What actions would be obvious mistakes?

These were the questions explored by the Institute participants for the three scenarios. Discussion highlights are included below.

SCENARIO ONE: UNITED REGIONS

Opportunities for Increased Contributions from the Engineering Community.

- Assistance to new metropolitan and regional entities in identifying and prioritizing problems.
- Helping communities address the impacts of migration across regions.
- Development of best practice regional standards.
- Combatting misinformation.
- Increased focus on service to the public well-being.

Surprises.

- Continued polarization.
- Surprised that we are not looked to.

Actions Now.

- Increased involvement in public policy. How do we support this?
- Support for new approaches to education, e.g., macro-ethics, purpose, avoiding unintended consequences.

SCENARIO TWO: AN ABUNDANT, INCLUSIVE, INNOVATIVE AND ACCESIBLE WORKFORCE

2

Impacts.

- More diverse workforce.
- Multiple paths.
- Interdisciplinary training.
- New business models.
- Highly motivated workforce.
- Focus on ethics and humanity.

Surprises.

- Salaries – increase or decrease?
- Potential dilution of trust or increase in trust.
- Loss of status of the PE.

Actions Now.

- Changes in hiring practices to focus on social impact.
- Changes in continuing education requirements.
- Building relationships with younger generations.
- Changes in engineering education.

Mistakes.

- Getting rid of licensure without a replacement system.
- Failure to change the culture that you have to pay your dues and do the grunt work.

SCENARIO THREE: MIAMI DEVASTATED BY HURRICANES

3 **Impacts.**

- Engineers as heroes. The public knew they should have listened to the engineers' warnings. Created trust.
- More social license.
- Proactive identification of where growth should / should not happen.
- Code changes.
- Opportunity to be more vocal in policy engagement.

Opportunities for Increased Contributions from the Engineering Community.

- Development of better modeling practices (e.g., flooding models).
- Better public engagement and communication.
- Client education.
- Ethics.
- Resilience planning, emphasizing ROI.
- Contributions to addressing trauma caused by inequities.

Surprises.

- For profit engineering model beginning to shift.
- New industries not related to engineering may draw people away from engineering (e.g., organizations that help people relocate).

Actions Now.

- Increased emphasis on the purpose of engineering.

Mistakes.

- Continued investments in fossil fuels.


Provocation

Provocation - How Do We Learn and Work in a Disruptive and Changing Future?

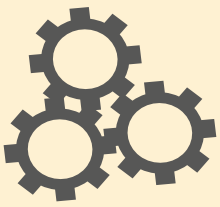
ALAN CHEVILLE
Professor, Bucknell University

Alan Cheville studied optoelectronics and ultrafast optics at Rice University before joining Oklahoma State University working on terahertz frequencies and engineering education. While at Oklahoma State he developed courses in photonics and engineering design. After serving for two and a half years as a program director in engineering education at the National Science Foundation, he served as chair of the ECE Department at Bucknell University. He is currently interested in engineering design education, engineering education policy, and the philosophy of engineering education.

Alan Cheville titled his provocation "How do we learn and work in a disruptive and changing future?" Cheville maintained that we are not educating students in a way that will help them to address emerging challenges. He offered several sobering observations to support this position (see exhibit), including that "students recognize that while engineering remains the path to a comfortable life, it is not necessarily the path to a good life."

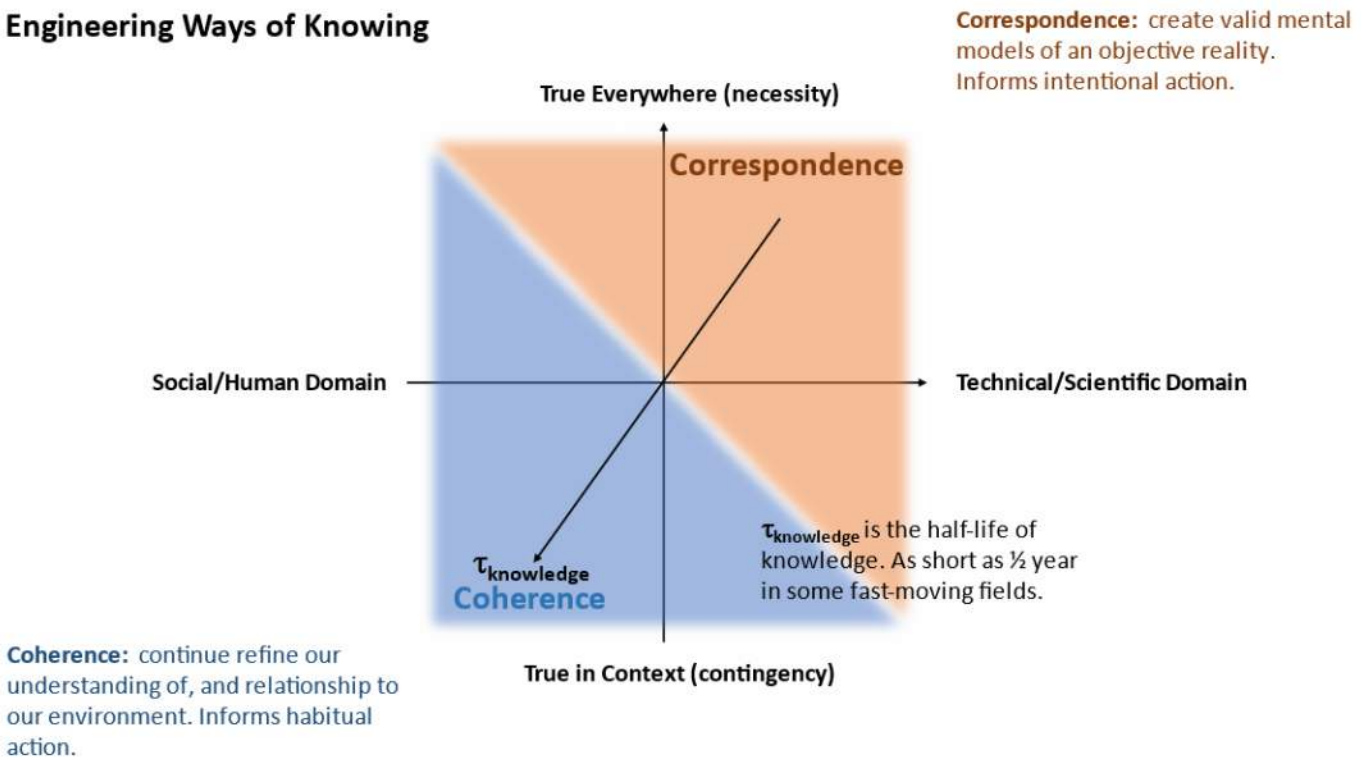
WE ARE NOT EDUCATING STUDENTS IN A WAY THAT WILL HELP THEM TO ADDRESS EMERGING CHALLENGES

- The economic benefits of engineering are becoming increasingly disconnected from its personal meaning. As a result students recognize that while engineering remains the path to a comfortable life, it is not necessarily the path to a good life.
- Engineering's success has led negative systemic side effects—on environment, climate, and societal equity—that can no longer be conveniently ignored. We often fail to teach that engineers cause problems as well as solve them.
- If engineering cannot reflect the diversity of our society it will not have the moral authority it needs to address systemic challenges.
- If lack of representation is a societal injustice, then by seeking to improve engineering education without first addressing equal representation we are perpetuating injustices.
- Injustice and catastrophe are tightly coupled.
- Higher education as a system is being squeezed by economic and cultural pressures that is causing it to become increasingly authoritarian. Those within this system fight back.



Provocation - How Do We Learn and Work in a Disruptive and Changing Future? (Continued)

He described "Engineering Ways of Knowing" utilizing a four-quadrant approach comparing the technical/ scientific domains of engineering with the social / human domains. He challenged the participants to consider how engineers divide up their mental tasks among these quadrants and what types of work fall into these quadrants. Cheville maintained that current models of learning do not work to support thinking in the coherence quadrant.



Provocation - How Do We Learn and Work in a Disruptive and Changing Future? (Continued)

Cheville then described new learning models for our dynamic world. With these models the instructor needs to focus students' attention on the results of an action. He highlighted the different ways to reflect on our actions, emphasizing that we need to teach students all these options.

- Generalization – a pragmatic mode of reflection where we seek to learn how to perform an action more effectively or efficiently the next time.
- Particularization – focusing on our emotional evaluation of an action (how we feel).
- Personal – focusing on how the action impacts building better relationships with others, which is the basis for moral action.
- Systemic – reflecting with recognition that we are a part of the world, and our fate is tied to others. Having care and empathy for larger systems.

Specific / Individual

Inwards Facing

Outwards Facing

particularization: artistic/contemplative

- Supports the individual's emotional development and ability to find significance in their actions emotions can be developed through action in the same way intellect is developed.
- More difficult to develop than the pragmatic mode.
- Does not extend the agent's capacity for action, but rather helps to better understand one's own values and identity.
- I cannot speak for what you should value or, if we value the same things, what aspects are of value to you need for autonomy in education.
- The crowded nature of most engineering curricula do not leave time or offer necessary support to develop individual values.

personal: moral/communal

- Enables the agent to act in a heterocentric manner, for others, and build community.
- Addresses morality – the proper form of our relations with others.
- By emphasizing professional ethics rather than moral good, engineering neatly sidesteps many concerns.
- The type of friendship network we have and what groups we associate with matter.
- The quality and meaningfulness, or heterocentricity, of relationships matters more than number of relationships.

generalization: scientific/pragmatic

- Attention is focused inwardly on developing the means to improve subsequent action.
- The agent's world or environment come to serve as a means to future action.
- This mode is predominant in engineering (education).
- The pragmatic mode leads to an over-emphasis on education as a means and corresponding neglect of the ends it serves.
- Too much focus on efficiency undermines regard for persons organizations and societies that undervalue being human have profound negative impact.

systemic: holistic/ecological

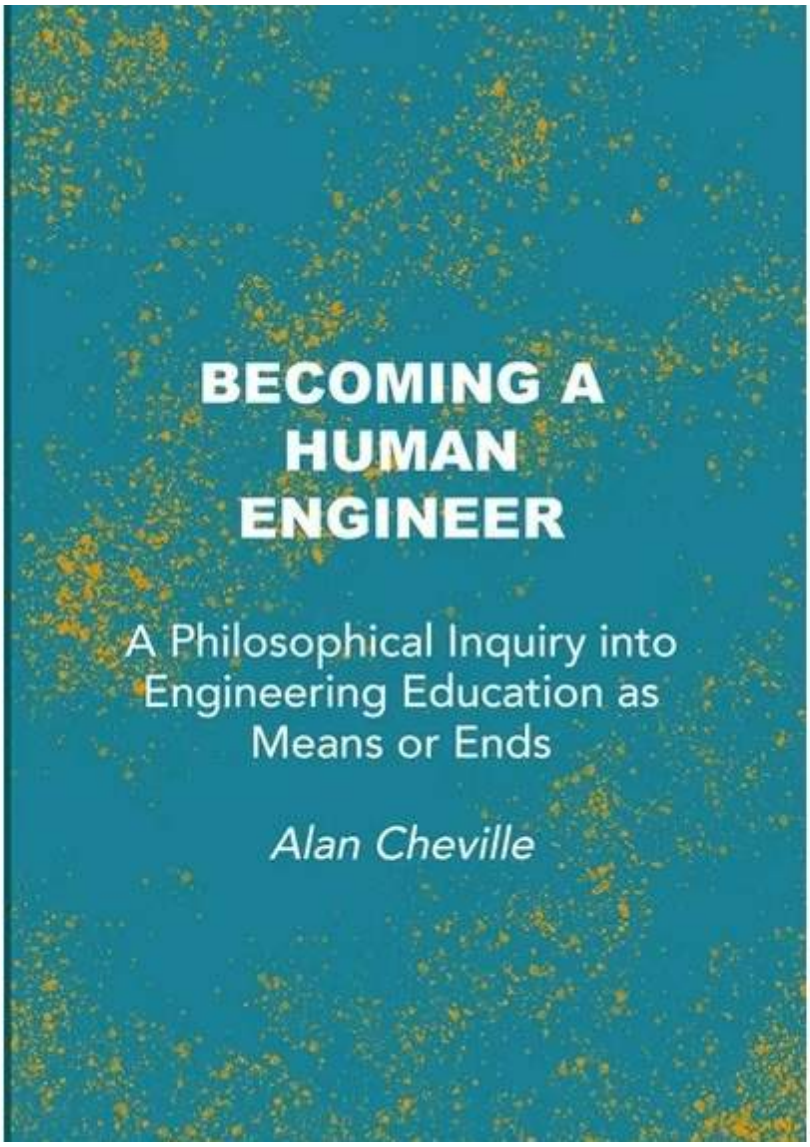
- Being a part of the world and a belief our fate is tied to that of others and the larger world.
- Care and empathy for the larger system in which we exist.
- Supported by:
  - » Activism
  - » Contextualizing engineering work with larger systems
  - » Constructing stories about alternative realities as an ongoing recursive process
  - » Rejecting deficit mindsets in favor of understanding structural inequalities
  - » Rejecting scarcity mindsets in favor of sufficiency and equity.

General / Societal

Provocation - Engineering Ways of Knowing continued

Cheville commented that all modes of reflection are required to develop holistically as a person. He emphasized that students are always learning but not always what we are teaching. Finally, he reminded participants that it is more important to develop as a person than as an engineer.

To learn more about Alan Cheville's thoughts regarding the future, check out his book, Becoming a Human Engineer.



Provocation - Industry Needs and Shifting Ideals

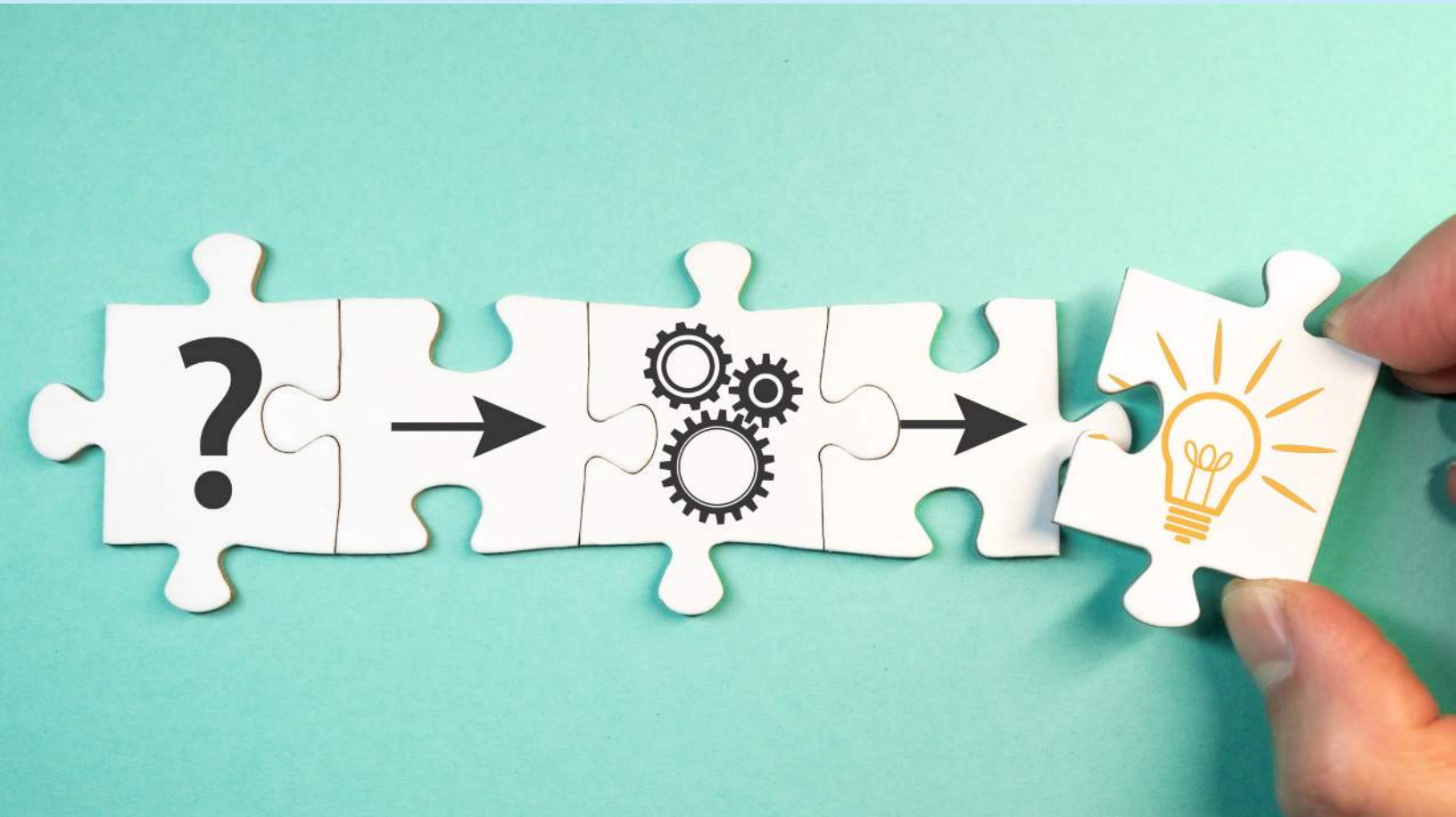
ATHMIKA SENTHILKUMAR
Masters Student, University of Chicago

I am a public policy masters candidate at the University of Chicago. Before this, I was working as a software engineer at Salesforce after graduating from Olin College of Engineering. My professional and academic experiences have led me to frame and rethink the role of engineering education in shaping individuals who hold key positions of power in tech and society. I believe in the importance of analyzing the political foundations of engineering education and pushing for fundamental transformations towards pedagogy that's better suited for the well-being of students and society.

Athmika Senthilkumar offered the perspective of a recent graduate of Olin College of Engineering on the history and current state of engineering education. She cited a common theme in the promotion of engineering education – "you will solve real world problems." But which world? What design? What does real mean?

She cited evidence from research that private corporate giving to universities creates pressures to conform and accept curriculum and faculty changes requested by industry. Olin was established to do things differently in engineering education.

According to Senthilkumar, the consequences of this over-emphasis on industry needs in education include a culture of disengagement among students, depoliticization of the work of engineering, technical / social dualism, and a meritocratic ideology.



Analysis Across Scenarios

As the next to last step in the scenario planning process, participants looked across the three scenarios to evaluate what the scenarios tell us about the engineering community's mission of stewardship of technology and nature on behalf of society. This discussion was framed around the following questions.

1 **What are "no brainer" actions that will be important for the engineering community to consider and take?**

2 **What are "no regrets" actions that the engineering community could take, that may be valuable in some futures, less valuable in others, but not damaging in any way?**

3 **What are the "no way" actions that would be unacceptable given how the future unfolds across the set of alternative scenarios?**

4 **What are the greatest risks for society present across the scenarios? How might the engineering community help mitigate those risks?**

5 **What could / should you do as a leader of your organization and as a member of the engineering community?**

Analysis Across Scenarios continued

Results of the group discussion are summarized below.

1 No Brainers

- Communicating more effectively with the public and developing skills for collaborating outside engineering.
- Early involvement and engagement in public policy and planning.
- Enhanced focus on the purpose of our work.
- Increasing the impact of "general education" in engineering education (humanities, liberal arts, etc.).
- Reimagining the workforce – creating new pathways for members of the engineering community.
- Raising the profile of the profession.
- Working on combating misinformation and disinformation.
- More focus on macro-ethics in the work and more training on macro-ethics.
- Increasing investment in STEM early – elementary.
- Solving the DEI puzzle for engineering - attracting a workforce and elevating leaders that reflect the population.

2 No Regrets

- Working with regulatory bodies to create more comprehensive codes/standards, with appropriate regional focus.
- Reimagining licensure, including state regulations that currently require PE's as head of consulting engineering organizations and creating alternative pathways to licensure (interdisciplinary, teams, etc.).
- Proactive action to change the business model of consulting engineers.
- Align the significant flood of work to be created and built with the needs of the future, as society cannot afford to build the wrong things.
- Achieve real leadership improvements – emotional, purpose-driven, feminine. Build more leadership development into education.

Analysis Across Scenarios continued

Results of the group discussion are summarized below.

3 No Way

- Continuing with "business as usual," as the engineering community cannot afford to play ostrich as the world and society changes.
- Underestimating the threats that will be encountered as the future unfolds.
- Abdicating our responsibility.
- Not claiming our agency.
- Under-valuing what we bring to the table.

4 Greatest Risks

- Lacking the will to change the negative trajectory we are on or to sustain it.
- Not focusing on macro-ethics - with respect to employees and to larger human and environmental systems.
- Becoming stymied / isolated / ignored due to misinformation and disinformation.
- Failing to effectively communicate risks to the public and policymakers.
- Speed of change. Regulators and policymakers not keeping up or going in the wrong direction. Engineers need to be more involved to build urgency and increase speed.
- Failure to recognize that, if the engineering community is not reflective of society, it will not reach its highest potential in the future.

Dialogue

The final step in the scenario planning process is the application of learning. Throughout the Engineering Ideas Institute, participants reflected on what life in the future might be like personally, what they might think, feel, and do. And, how they could lead change in their own organizations and communities. In the final dialogue of the Institute, participants reflected and discussed their futures and this question.

WHAT HAVE WE LEARNED ABOUT CATALYZING CHANGE WITHIN THE ENGINEERING COMMUNITY BY IMAGINING AND EXPLORING FUTURE SCENARIOS?

On Being Human

- The importance of purpose for engineers.
- Be human first, engineers second.
- Schools will play a major role in fostering this quality.
- Engineers need to be part of communities, that is part of being human.

On Hope

- Purpose is important, but we also need "hope."
- This type of work can foster hope and build confidence.
  - Scenario planning left me more hopeful and feeling more urgency.
- Importance of small wins to foster hope and avoid being trapped in negativity.
- Schools need to help students with mental health and "hopelessness" by changing the narrative.

On Learning and Change

- As engineers, we need to exercise our change muscles more.
  - Do we even have change muscles? How do we develop them?
- Engineers are "learners with humility to know that there is something to learn."
- You don't start being a marathoner by running a marathon. You must build up to it.
- We need to be OK with failing fast … and learning. Build that into our culture.
- You must be willing to raise awareness of the need for change.
- We need to recognize and use our power to "convene" people.
- We can't think of each other as competitors. We are all needed for challenges of the magnitude we are facing.
- The engineering community needs to include more than engineers, but this runs up against the problem of "identity" for engineers.

Dialogue continued

On Scenario Thinking

- This is fun! How do we make it safe for engineers to engage in this type of fun?
- There is a sense of agency that comes with scenario planning – it can easily be applied with students in academic settings.
- Scenarios can be "silo breakers."
- We can learn from planners (who do much more of this type of work) and other adjacent professions with skills and mindsets we need.
- What would it be like if engineers became known as "future thinkers" as well as problem solvers?
- Use scenario planning for the 30-year life cycle of road projects – not just having paving that lasts, but scenarios for the next 30 years for that community.
- Scenario planning can be used to surface "unknown unknowns."
- Creating personal space for "imagining" with set times each week.
- Shifting from micro (where we spend most of our time in firms) to thinking macro – from what's best for the firm to what's best for the larger system.
  - » There is an ethical responsibility for making this shift. It requires self-awareness.

Conclusion and Next Steps

It is our hope that the scenarios developed at the Engineering Ideas Institute can be utilized across the engineering community to generate thinking and action centered on elevating the contributions of the engineering community in any future that may unfold. If you or your organization would like assistance in these discussions, reach out to us.

As technologist Kevin Kelly notes in his book, **What Technology Wants**, "the future is unfolding, not as a 'distinct whole' that can be immediately perceived, understood, and acted upon. But rather like a complex messy, living, adaptive system with its own unconscious needs and tendencies."

To contribute at a higher level to society, the engineering community must develop its capacity for sensing, making sense, and acting appropriately within the context of Kelly's unfolding, messy world. The 2023 Engineering Ideas Institute helped participants understand how personal and group imagination and scenario planning processes can be used as vehicles for developing that capacity. The experience left many participants feeling more hopeful about both the present and the future and believing that they have more agency to help shape the unfolding future in desirable ways.

Provocateur recordings and presentations from the 2023 Engineering Ideas Institute are available at the **Knowledge Hub** of the ECL website. The Knowledge Hub also includes documentation of all past ECL summits. If you are interested in learning more about ECL, reach out to ECL Executive Director Mike McMeekin at **mikemc@ecl-usa.org.**