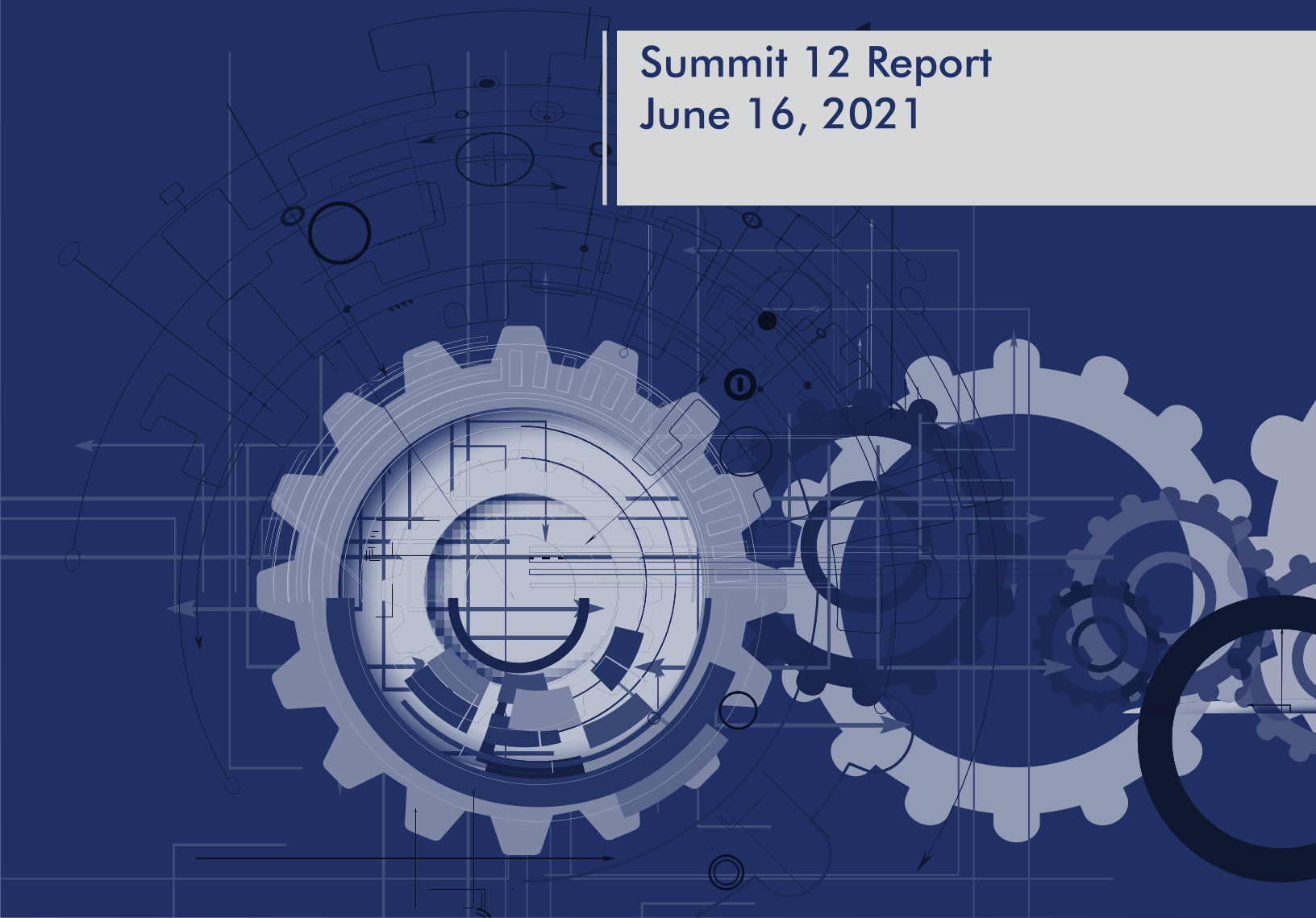
ENGINEERING CHANGE LAB USA

For more information on Engineering Change Lab-USA, contact Executive Director Mike McMeekin at mike.mcmeekin@lamprynearson.com and visit our website www.ecl-usa.org

THE ENGINEERING FIRM OF THE FUTURE

Summit 12 Report
June 16, 2021



INTRODUCTION

Over the coming decade, engineering firms will face significant challenges from both the external environment and from internal forces. Impacts from the external environment will be shaped by global risks (economic, environmental, geopolitical, societal, and technological), including how the clients of engineering firms respond to these risks. Internal challenges will include adapting to the aspirations, values, and needs of new generations of engineers and other young professionals that manifest as they join and build careers within firms. Engineering Change Lab – USA (ECL-USA) Summit 12 explored the potential impacts of these challenges.

PROVOCATEURS

Stephen Brockwell
SENIOR PRODUCT OWNER FOR AEC, ESRI

Stephen Brockwell is the Senior Product Owner at ESRI for AEC, working with the largest AEC firms and their customers to define the future of integration between GIS and BIM. Stephen previously worked at Autodesk where he was Director of Product Management for GIS products. He subsequently established Brockwell IT Consulting to work independently to improve integration between ESRI and Autodesk products. His work with Autodesk on connecting Autodesk Civil3D with ArcGIS and his work with early GeoBIM prototypes led to the acquisition of Brockwell IT by ESRI in 2019.

Martha Rogers
NATURAL CAPITAL ECONOMIST, THE NATURE CONSERVANCY

Martha Rogers joined The Nature Conservancy in 2017 as the Natural Capital Economist in the Center for Sustainability Science. She is the technical lead for the TNC-Dow Collaboration, working closely with Dow staff to help test and implement the company's ten-year Valuing Nature Goal, which aims to generate $1 billion in business value from projects that are good for business and better for ecosystems. Beyond the TNC-Dow Collaboration, she is working to build a broader business case for natural infrastructure investments as a key climate adaptation strategy.

Chris Murphy
CHIEF TECHNOLOGY OFFICER, BLACK & VEATCH

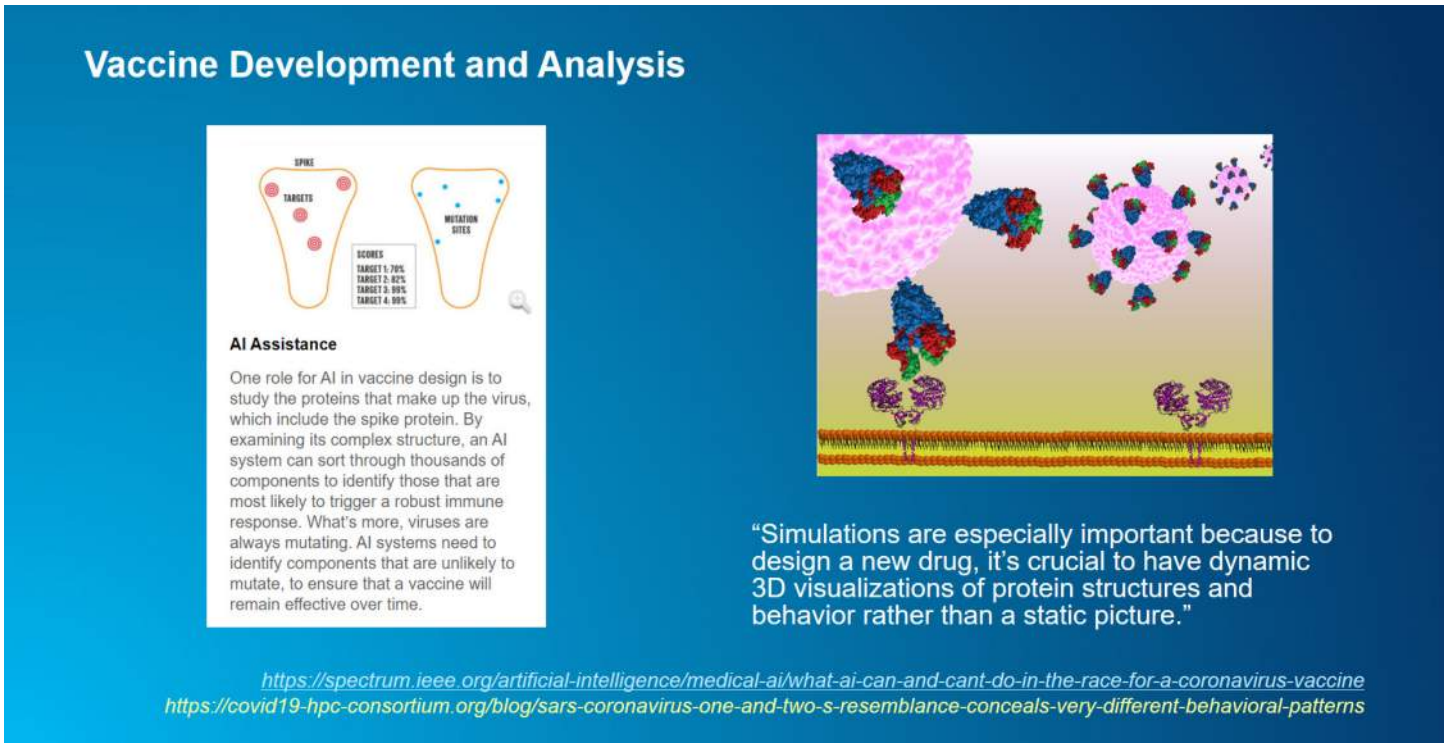
Christopher Murphy has worked across myriad industries including software and hardware industries with roles in software engineering, customer support, sales engineering, software partner engineering, including the telecom industry with roles focused on security and risk management as software and systems architect, including healthcare and CPG industries with roles that included consulting, software and systems architecture, and solutions architecture. Now, he works in critical human infrastructure as the Global Chief Technology Officer at Black & Veatch.

Provocation

MACHINE LEARNING, ARTIFICIAL INTELLIGENCE, GENERATIVE DESIGN AND THE IMPACT ON ENGINEERING PRACTICE

STEPHEN BROCKWELL
SENIOR PRODUCT OWNER FOR AEC, ESRI

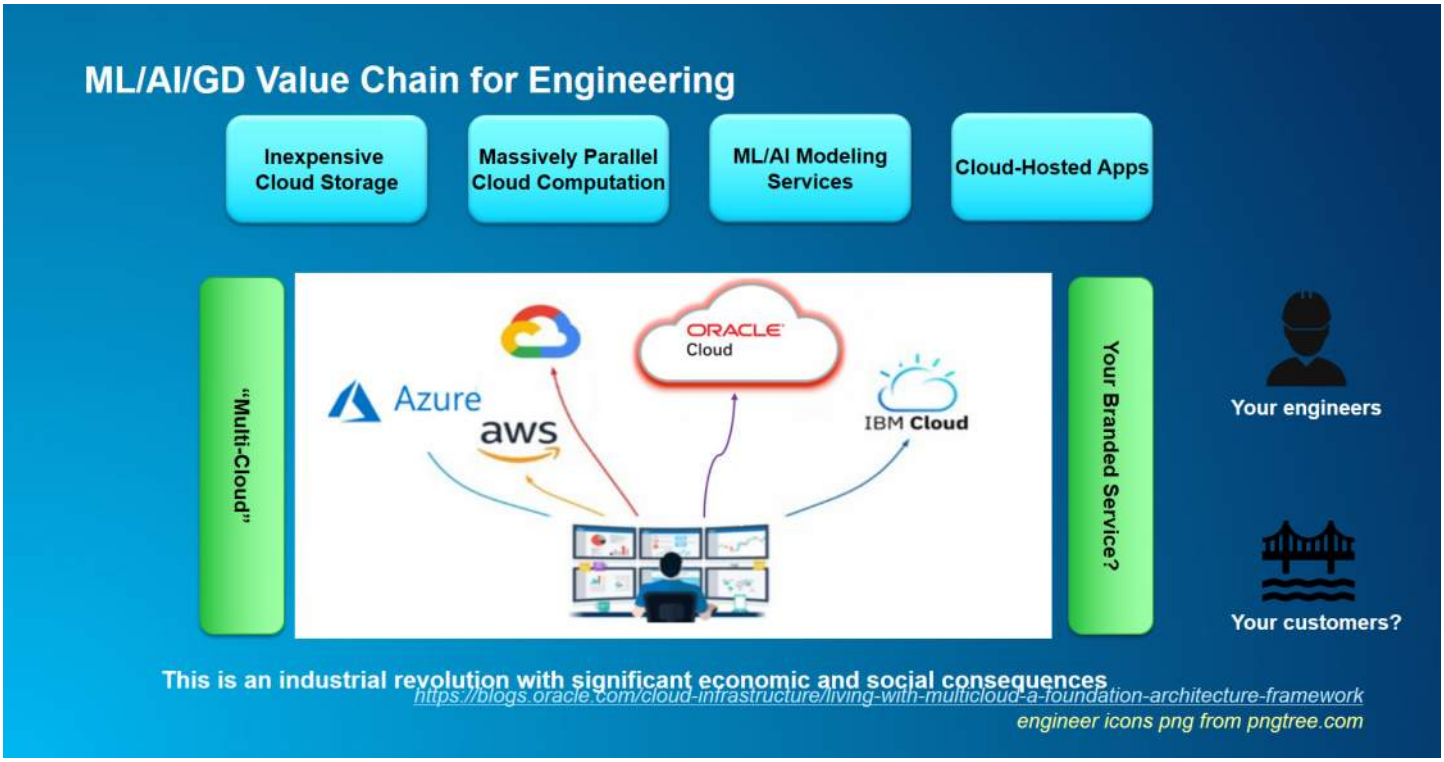
Stephen Brockwell outlined accelerating changes in digital practice for engineering firms. He described the current uses for machine learning and artificial intelligence in engineering today. These applications/tools are rapidly becoming commoditized and available to all, including the clients of engineering firms. He cited the contributions of 3D visualizations and simulations driven by machine learning in vaccine development for COVID-19.



According to Brockwell, the combination of machine learning, artificial intelligence, and generative design provide the ability to create things that solve problems. Possibilities with these new tools include the exploration of a wider range of design options, making seemingly impossible designs possible, optimizing for materials and manufacturing methods with the result that components are lighter and are produced with less greenhouse gas emissions, and the ability to monitor performance. In addition, price parity with conventional methods is being achieved.

MACHINE LEARNING, ARTIFICIAL INTELLIGENCE, GENERATIVE DESIGN AND THE IMPACT ON ENGINEERING PRACTICE continued

The emergence of these new tools creates new and different value chains for engineering firms made up of inexpensive cloud storage; massively parallel cloud computations, ML/AI modeling services, and cloud-hosted apps. As clients adopt similar technologies, new opportunities for collaboration within value chains will emerge.



Brockwell described the transformation that is underway from the present – design with the help of computers – to a future of collaborative teams of engineers, cloud computing service providers, intelligent machines, clients, and contractors working together to innovate design and construction projects and processes. Engineers of the future will need to learn new techniques for design, and younger engineers trained in digital technologies will expect to have opportunities to apply these skills. The role of the engineer will shift to include defining the parameters for digital design and understanding the impacts to construction and testing of results. Questions will emerge for engineering firms and their clients related to licensure, billing for new digital areas of practice, ethical application of new technologies, liability, and how to manage continued cybersecurity threats. New types of competition will arise from offshore machine learning / artificial intelligence labs. Some public policies will also need to be re-visited. Engineering firms will need to determine their unique approach to the digital world. Importantly, these developments in digital practice will allow engineering firms to contribute in new ways to more sustainable designs.

Provocation

ENGINEERING FOR NATURE

MARTHA ROGERS
NATURAL CAPITAL ECONOMIST, THE NATURE CONSERVANCY

Martha Rogers, Natural Capital Economist at The Nature Conservancy, reminded participants of the growing environmental challenges that society and the clients of engineering firms will face in the future. Of these challenges, reducing biodiversity loss and reducing carbon emissions are the primary drivers of the work of The Nature Conservancy (TNC). She described TNC's concerns with the increasing pressure on the environment due to projected future growth in population (41% increase to 9.7 billion by 2050) and future economic growth (317% growth in global GDP by 2050). This growth will drive projected increases of 53% in cropland caloric demand, 56% in energy demand, and 234% in domestic water demand by 2050. Rogers challenged participants to consider two paths to 2050 – business as usual or sustainability. TNC strongly believes that a sustainable approach allows equivalent growth potential with lower environmental impacts.

Two Paths to 2050

Sustainability or Business as Usual

Note. Green bars indicate sustainable path to 2050, while grey bars indicate business as usual path.
Global Temperature – Temperature Rise
Air Quality - % of People Breathing Healthier Air
Fishery Health - % of Fisheries Sustainably Managed
Land Protection - % of Lands Protected

ENGINEERING FOR NATURE continued

These challenges have defined TNC's priorities, and they also present multiple future opportunities for engineering firms and their clients.

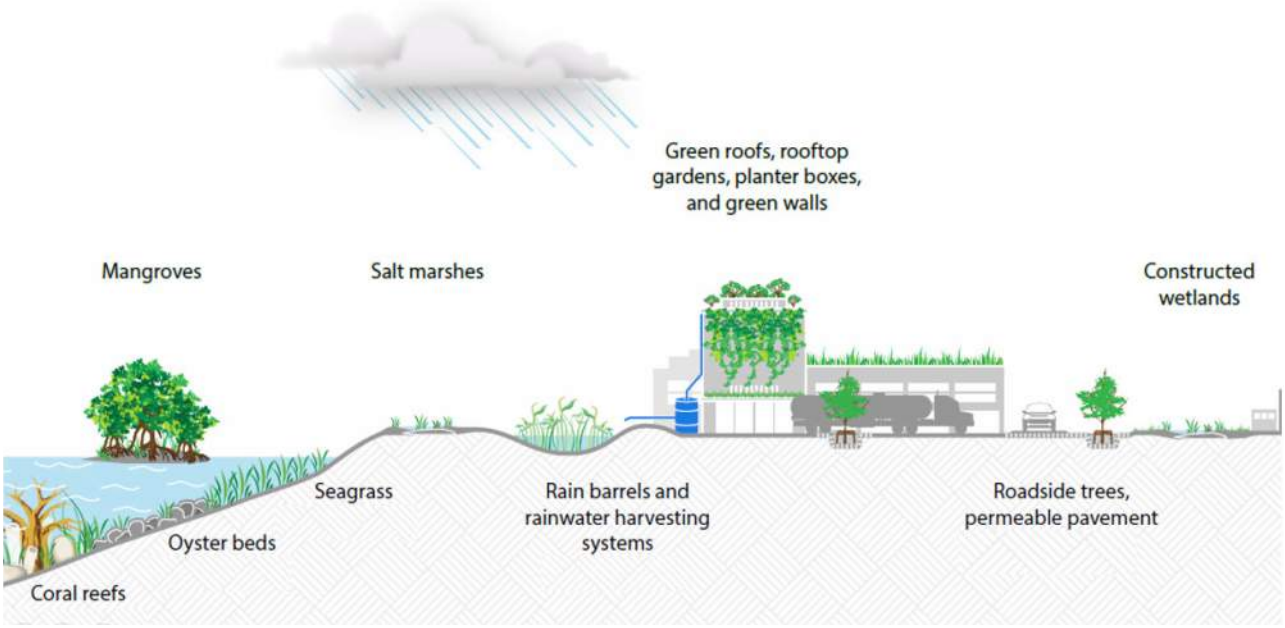
1 **Provide Food and Water Sustainably**

2 **Tackle Climate Change**

3 **Protect Land and Water**

Nature-Based Solutions

Driving adoption of NBS as strategy for addressing conservation challenges



TNC's work is founded on the principle that nature is an asset we can leverage in engineering design. Nature-based solutions (NBS) provide the opportunity to address engineering challenges while also addressing the conservation challenges of the future. TNC's work with Dow Chemical is an example of the use of NBS. Rogers presented two examples from the TNC/Dow partnership.

- Reforestation as a strategy for abatement and compliance with ground-level ozone requirements near Houston. Modeled scenarios demonstrated that reforestation provided equivalent control at lower or comparable costs compared to conventional air-scrubber controls and provided multiple environmental benefits. Despite the multiple benefits, regulators have not approved this approach demonstrating an ongoing challenge with NBS.

- Ash pond closure in Michigan. The traditional approach to ash pond closure is capping with soil, groundwater treatment and long-term monitoring. The alternative approach, proposed by TNC, was conversion of the area to a riverside wetland. This alternative approach resulted in cost savings of about $2 million to Dow over a ten-year period, along with ecosystem and stormwater benefits.

ENGINEERING FOR NATURE continued

The ten-year collaboration between Dow and TNC has demonstrated the "business case for nature." In 2015 Dow committed to their 2025 Valuing Nature Goal, a long-term commitment to integrating nature into their business. Dow has conducted Valuing Nature Goal workshops at 32 of their sites in 12 countries to embed the concept of incorporating nature into decision-making and to transform their culture.

TNC's work with Dow has led to the development of a tool box/ road map for adopting NBS in working with large companies that is based on business drivers. The stacked benefits of NBS can offer cost effective solutions to environmental challenges faced by the private sector. As an example of innovative approaches that are possible using NBS, Rogers highlighted the development of insurance products for coral reef restoration in Mexico. In scaling-up the use of NBS, TNC anticipates a set of barriers that will have to be navigated, including satisfying the need for more:

- Enhanced understanding of the benefits of NBS- both in engineering firms and in the regulatory sector;
- More research to identify revenue streams and financing mechanisms;
- Engagement across industries and sectors- partnering with experts in NBS like TNC; and
- Shared learning.

TNC sees collaboration with engineering firms as having increasing importance in implementation of NBS.

Provocation

TRANSITIONING TO DIGITAL BUSINESS MODELS

CHRIS MURPHY
CHIEF TECHNOLOGY OFFICER, BLACK & VEATCH

Chris Murphy, Chief Technology Officer at Black & Veatch, described the opportunities and challenges for engineering firms transitioning to digital business models. He characterized a digital business as one that blurs the physical and digital worlds, while aligning with customer needs. Murphy outlined key questions and issues related to the adoption of digital business strategies. He also stressed the importance of agility, flexibility, and an ability to "learn from failure" for firms moving toward adoption of digital business models.

He also provided examples of digital business models.

- Subscription (Netflix).
- Razor and Blades (Amazon, HP), which offers added convenience and lower initial costs with additional revenue from operation and maintenance.
- Ecosystem (Apple), creating a network of dedicated users and supporters.
- Free (Facebook), offering free usage with access to data.
- Freemium (LinkedIn), added costs for expanded use of service.

Murphy cautioned that only 20% of non-technology companies succeed in the world of software development, and he described important considerations related to these models. These include the need for rapid adaptation as technology changes and awareness of the potential pitfalls that come with innovation using digital models- strategy match, levels of investment, connection of strategy to execution, process gaps, metrics that track effectiveness, and cultural match. Cultural factors to consider include risk aversion, unwillingness to listen and change, and lack of diversity. Finally, Murphy reminded attendees that engineering firms need to overcome forces of inertia inside firms, including the "we still have to do our regular work" factor.

GROUP EXERCISE – IMAGINING NEW VALUE PROPOSITIONS & MODELS OF PRACTICE

In group exercises, participants explored the future risk landscape for different types of engineering firm clients (government, institutional, private sector). Risks evaluated included economic, environmental, and technological that were drawn from the World Economic Forum "The Global Risk Report 2021."

THE GLOBAL RISK REPORT 2021, WORLD ECONOMIC FORUM

ECONOMIC

- Prolonged Economic Stagnation. Near-zero or slow global growth lasting for many years.
- Failure to Stabilize Price Trajectories. Inability to control an unmanageable increase (inflation) or decrease (deflation) in the general price level of goods and services.
- Severe Commodity Shocks. Abrupt shocks to the supply and demand of systemically important commodities at a global scale that strain corporate, public and/or household budgets (chemicals, emissions, energy, foods, metals, minerals etc.).
- Asset Bubble Burst in Large Economies. Prices for housing, investment funds, shares and other assets in a large economy increasingly disconnected from the real economy.

ENVIRONMENTAL

- Human-made Environmental Damage. Loss of human life, financial loss and/or damage to ecosystems resulting from human activity and/or failure to co-exist with animal ecosystems, deregulation of protected areas, industrial accidents, oil spills, radioactive contamination, wildlife trade etc.
- Biodiversity Loss and Ecosystem Collapse. Irreversible consequences for the environment, humankind, and economic activity, and a permanent destruction of natural capital, resulting from species extinction and/ or reduction.
- Major Geophysical Disasters. Loss of human life, financial loss and/or damage to ecosystems resulting from geophysical disasters (earthquakes, landslides, geomagnetic storms, tsunamis, volcanic activity etc.).
- Natural Resource Crises. Chemical, food, mineral, water or other natural resource crises at a global scale resulting from human overexploitation and/or mismanagement of critical natural resources.

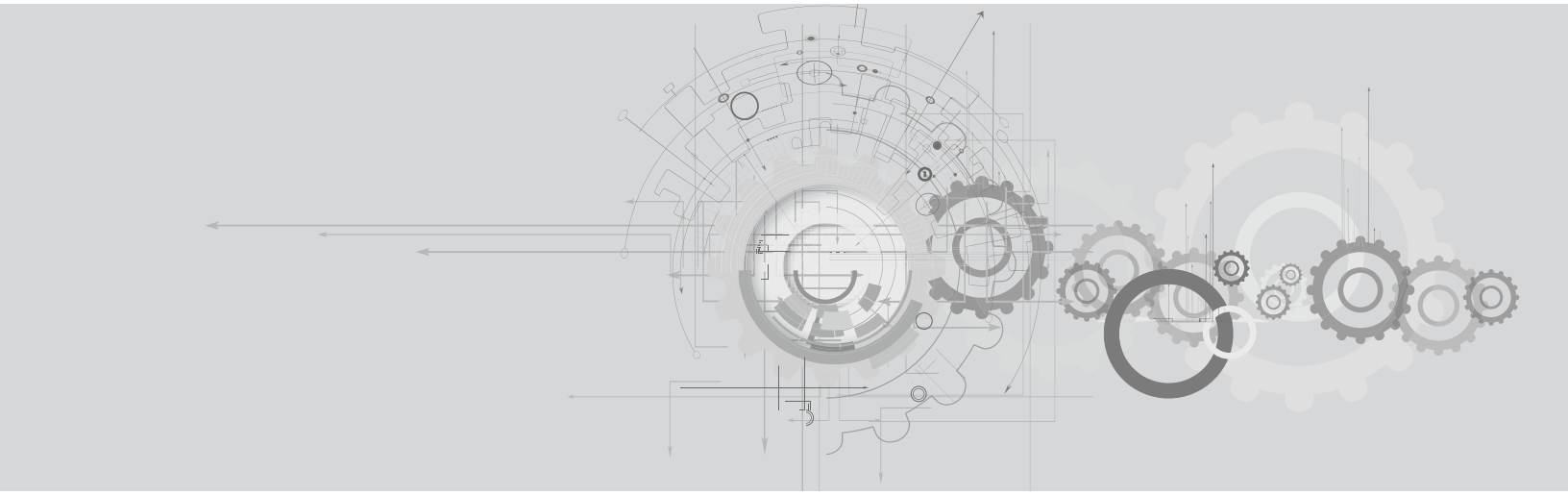
TECHNOLOGICAL

- Failure of public infrastructure. Inequitable and/or insufficient public infrastructure and services resulting from mismanaged urban sprawl, poor planning and/or under-investment, negatively impacting economic advancement, education, housing, public health, social inclusion and the environment.
- Breakdown of Critical Information Infrastructure. Deterioration, saturation or shutdown of critical physical and digital infrastructure or services resulting from systemic dependency on cyber networks and/or technology (AI-intensive systems, internet, hand-held devices, public utilities, satellites, etc.)
- Digital Inequality. Fractured and/or unequal access to critical digital networks and technology, between and within countries, resulting from unequal investment capabilities, lack of necessary skills in the workforce, insufficient purchase power, government restrictions and/or cultural differences.
- Failure of Cybersecurity Measures. Business, government and household cybersecurity infrastructure and/or measures are outstripped or rendered obsolete by increasingly sophisticated and frequent cybercrimes, resulting in economic disruption, financial loss, geopolitical tensions and/ or social instability.

The focused discussions addressed how clients might be impacted by these risks; how these clients could respond to risks; the types of assistance needed in coping with risks; how engineering firms could provide this needed assistance; new value propositions and business models that could emerge for engineering firms; and the new types of collaborations and talent that firms may need to acquire to provide this assistance.

KEY INSIGHTS

- Public sector clients will need assistance in thinking "bigger" and more creatively with respect to funding and the revenue generation potential of their assets (e.g., new uses for public right-of-way) and in broadening their perspectives with respect to addressing environmental challenges.
- Public sector and institutional clients will need assistance in recognizing the importance of investments in long-term planning and resilience, in everything from design and construction to O&M programs.
- Engineering firms can create value by assisting public sector clients in thinking beyond outdated processes and standards- updating the standards and practices that are ill-fit to the risks and challenges they will be facing in the future.
- Private sector clients will need guidance in why and how to incorporate a long-term perspective (a 200-year view) into their thinking and planning. They also will need assistance in listening and responding to a wider and more diverse groups of project stakeholders.
- Opportunities for engineering firms include embracing increased diversity in both demographics, values, skill sets, and thought.
- Firms will recognize that the complexity of many of today's challenges (e.g., urban redevelopment) can only be addressed by groups working together and moving beyond adversarial positions. New types of partnerships/ collaborations can become the equivalent of "collective master builders" to take on those types of challenges.
- The financial metrics of engineering firms will need to move beyond quarterly or annual profits as well as traditional billable hour business models to incorporate long-term "holistic" value creation strategies.
- An overriding insight that emerged was that to contribute at higher levels in the future and to escape current commoditized financial models, engineering firms will need to adapt their cultures to accept more of an entrepreneurial mindset.



ADAPTING TO THE ASPIRATIONS, VALUES, AND NEEDS OF NEW GENERATIONS IN THE WORKFORCE

In the second half of the summit, participants explored the challenges and opportunities that will come along with the workforce of the future, with emphasis on the values and aspirations of those future generations, and emerging mindsets that may be particularly significant for firms in the coming decade.

PROVOCATEURS

Doug Melton
PROGRAM DIRECTOR, KERN FAMILY FOUNDATION

Dr. Doug Melton is a program director, electrical engineer, educator, researcher, inventor, network and team-builder, spokesperson, intrapreneur and entrepreneur, and a musician with more aspiration than rhythm. But most importantly, he's an advocate for the development of an entrepreneurial mindset and character in engineering graduates — the combination is critical to the future of the U.S. At the Kern Family Foundation since 2012, he and a team have helped grow a network of 50 university partners, known as KEEN, who share the mission of developing entrepreneurially minded engineers.

Mark Abbott
EXECUTIVE DIRECTOR, ENGINEERING CHANGE LAB CANADA

Mark Abbott currently serves as the Managing Director of the Engineering Change Lab Canada, which is a catalyst for evolving the engineering community to reach its full potential as stewards of technology for the benefit of all. Previously, Mark served as a member of the Executive Team at Engineers Without Borders for several years. And before that, Mark spent fourteen years working for a heavy industrial consulting engineering firm based in Vancouver.

Darshan Karwat
ARIZONA STATE UNIVERSITY

Darshan Karwat is an assistant professor with a joint appointment in the School for the Future of Innovation in Society and The Polytechnic School at ASU, where he runs re-Engineered, an interdisciplinary group that embeds environmental projection, social justice, and peace in engineering. Darshan also works as co-founder of the Constellation Prize.

Provocation

WHAT IF EVERY ENGINEER WERE ENTREPRENEURIALLY MINDED?

DOUG MELTON
PROGRAM DIRECTOR AT THE KERN FAMILY FOUNDATION

Doug Melton, Program Director at The Kern Family Foundation, described their work to develop an entrepreneurial mindset in engineering students. He challenged participants to consider two questions. "What if every engineer were entrepreneurially minded?" "Would that be welcome or frightening?" Melton reviewed the history of The Kern Family Foundation and the "Animating Ideas" that form the foundation of their work.

GOOD CHARACTER

QUALITY EDUCATION

PURPOSE AND MEANINGFUL WORK

ENTREPRENEURIAL MINDSET

Melton highlighted the difference between the traditional engineering mindset and an entrepreneurial mindset through this video Entrepreneurial vs. Traditional Engineering - YouTube. Engineers with an entrepreneurial mindset look to exceed conventional expectations by providing value. He also highlighted data from McKinsey's work in looking at how companies are reskilling to address talent gaps. These reskilling programs often include entrepreneurship and initiative taking.

He described how entrepreneurship requires both "mindset and skillset." Behaviors that exemplify entrepreneurial mindset include curiosity about our changing world, connections to integrate information from many sources, creating value, and contributing to doing good. The complementary skillset of entrepreneurs includes identifying and evaluating OPPORTUNITY, developing and executing product or service DESIGN, and validating and communicating IMPACT. The Kern Entrepreneurial Engineering Network (KEEN) within engineering schools is focused on the development of these skills.

Adoption of an engineering mindset that reframes the work of engineering for students requires moving beyond just technical problem solving to "creating value for people." He challenged summit participants to consider if we are ready for new generations of engineers trained as entrepreneurial thinkers and actors.

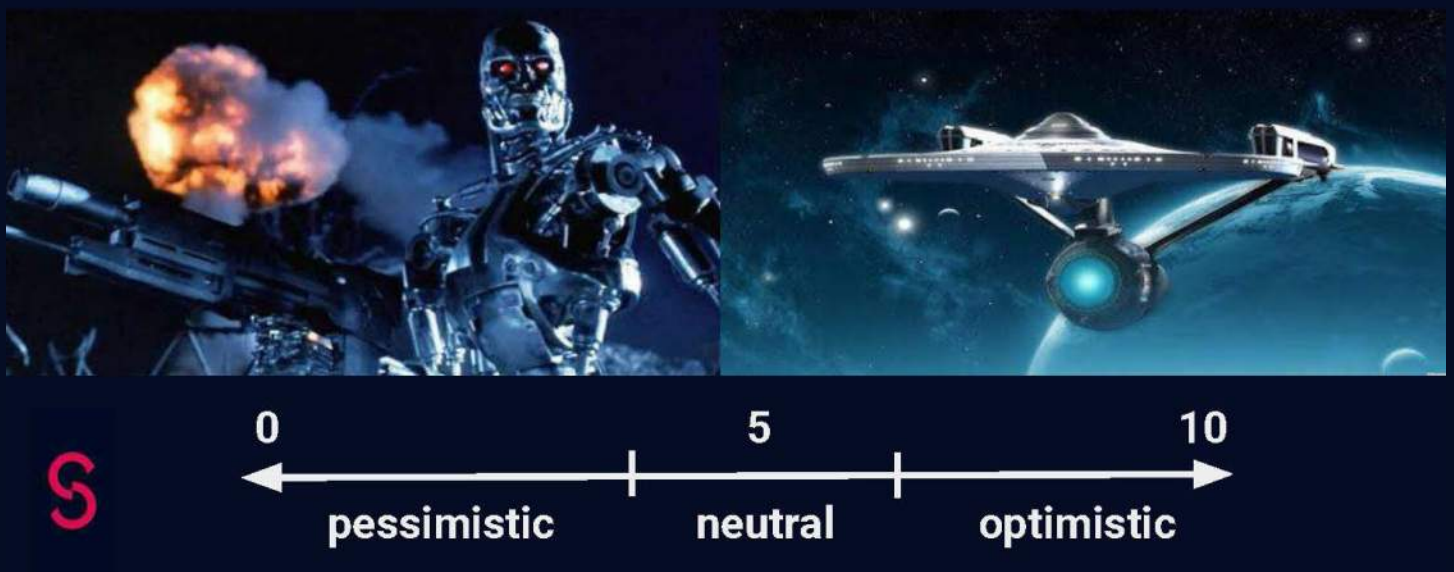
Provocation

TECHNOLOGICAL STEWARDSHIP

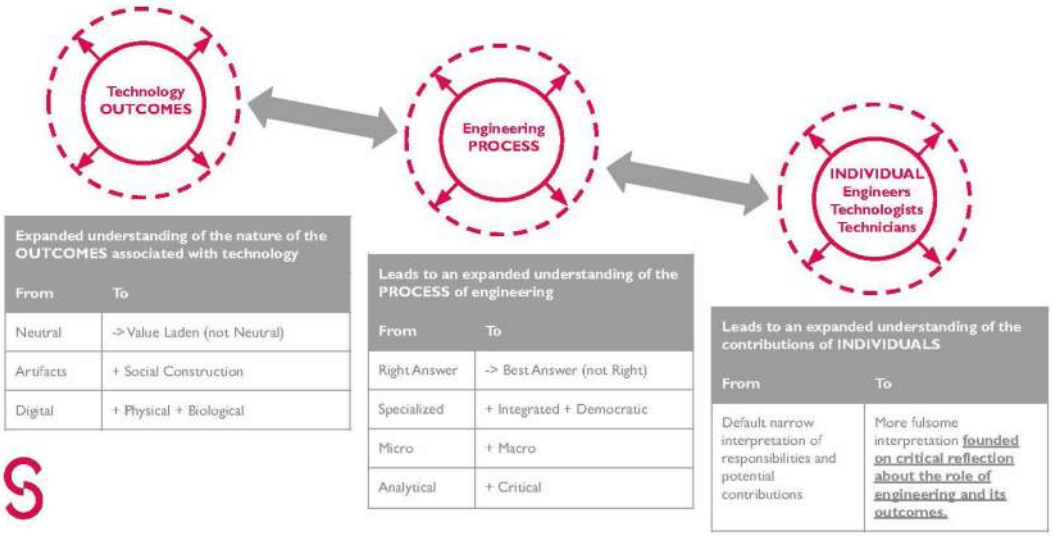
MARK ABBOTT
EXECUTIVE DIRECTOR, ENGINEERING CHANGE LAB CANADA

Mark Abbott, Executive Director of Engineering Change Lab – Canada, outlined ECL-Canada's strategies to foster the practice of technological stewardship in the Canadian engineering community. ECL-Canada defines technological stewardship as behavior that ensures technology is used to make the world a better place for all. Their goal is to create a tipping point in the adoption of technological stewardship as a fundamental mindset and set of values and behaviors for the engineering community, with 25% of the Canadian engineering community practicing technological stewardship within the next ten years.

According to Abbott and ECL-Canada, technology will not necessarily take us to the world we want. A contributing factor is that creators of technology rarely talk with those working on the impacts of technology. ECL-Canada seeks to expand knowledge of technology outcomes, which leads to expanded understanding of the process of engineering, which leads to expanded understanding of the contributions of individuals.



TECHNOLOGICAL STEWARDSHIP continued



Abbott highlighted the behaviors that characterize technological stewardship.

Seek Purpose. Direct technological development to maximize positive outcomes for all.

Take Responsibility. Consider, anticipate, and manage the complex impacts of technology across the entire life cycle.

Expand Involvement. Integrate a broad range of non-technical experts and ideas into technological development.

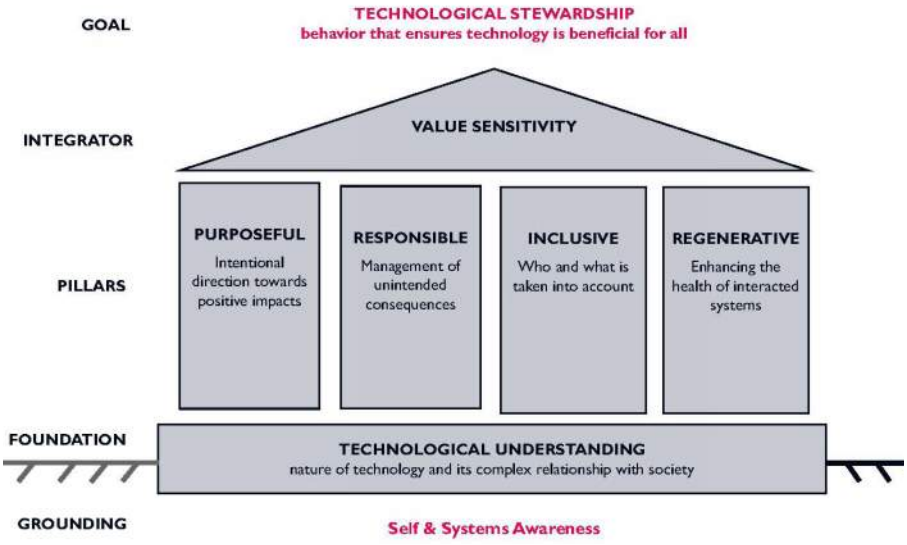
Widen Approaches. Explore alternative ways to solve problems.

Advance Understanding. Foster dialogue about technology and technological stewardship.

Realize Diversity. Ensure technological development contributes to creating equity.

Deliberate Values. Consider underlying values and make intentional decisions.

Seek Regeneration. Proceed in a manner that helps enhance the health of the systems with which you engage.



To reach their 25 percent tipping point goal, ECL-Canada's organizational focus has shifted to a multi-level approach to educating the Canadian engineering community about technological stewardship. This approach includes an online platform intended to build connections between individual practitioners of technological stewardship as well as organizational consulting. Underpinning this approach is the belief that technological stewardship empowers the best talent within organizations and creates cultures that enable innovation in a win-win-win manner.

VALUES & ASPIRATIONS OF TALENT COHORTS

INSIGHTS FROM ECL-USA FOCUS GROUP RESEARCH

Kyle Davy & Mike McMeekin

Summit 12 also featured the presentation of results from two ECL-USA sponsored research efforts exploring workforce values.

Kyle Davy and Mike McMeekin presented the findings from ECL-USA's series of focus groups of different age cohorts within engineering firms. The objectives for the focus group research are summarized below.

- Develop a picture of over-arching core values and aspirations of engineers within engineering firms.
- Examine both personal and organizational values.
- Compare and contrast findings across age cohorts.
- Assess the degree of alignment between individual and organizational values and aspirations.

55 PARTICIPANTS

12 ENGINEERING FIRMS

8 FOCUS GROUPS

Companies represented included GMB, Degenkolb Engineers, Jose I. Guerra, C&S Companies, Ulteig, Lamp Rynearson, Mead & Hunt, Power Engineers, Raba Kistner, Pennoni, Stolfus & Associates, and Black & Veatch. These firms have all been engaged with the work of ECL-USA. Participants were segmented into three age cohorts, three focus groups from the 1-3-year age cohort, three groups with participants from the 5-10-year age cohort, and two groups including participants from the 20-25-year age cohort.

You can see complete results from the focus groups at the ECL-USA website. Summit-12-Provoc-Davy-McMeekin.pdf (ecl-usa.org) Key findings are summarized below.

Making the World a Better Place and positively impacting communities is the predominant theme – demonstrating the importance of purpose.

Organizational Values.
- Putting People First given high importance.

Alignment.
- High degree of felt alignment between individual and firms.

Personal Values.
- Integrity / Honesty as fundamental core values.
- Work/Life Balance significant for older cohorts.

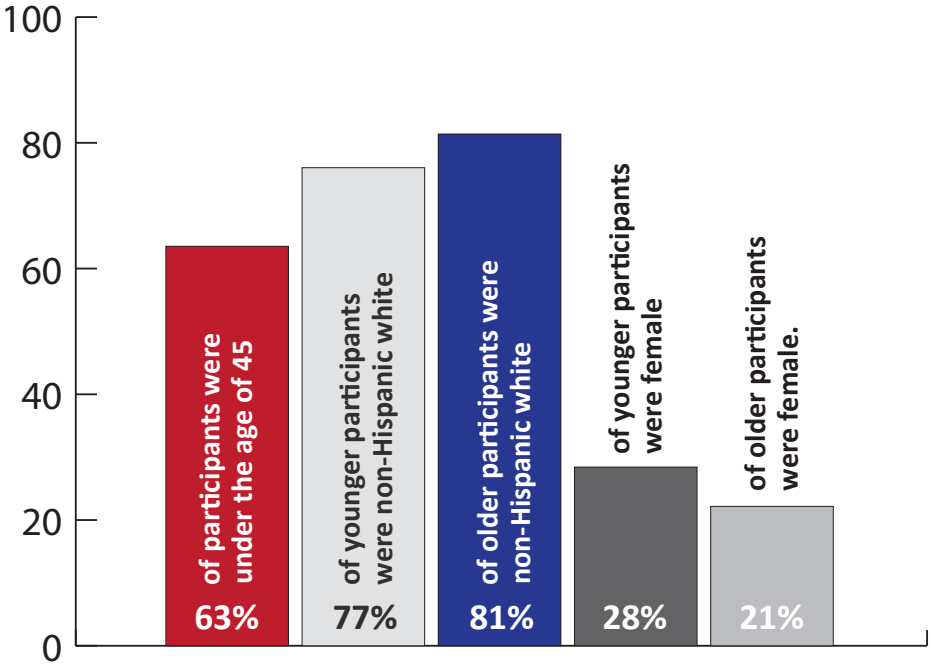
Aspirations & Wishes.
- Improvements in Diversity / Equity / Inclusivity as a significant wish for the future.
- Innovation significant for younger cohorts.
- Environmental Stewardship is on the radar.

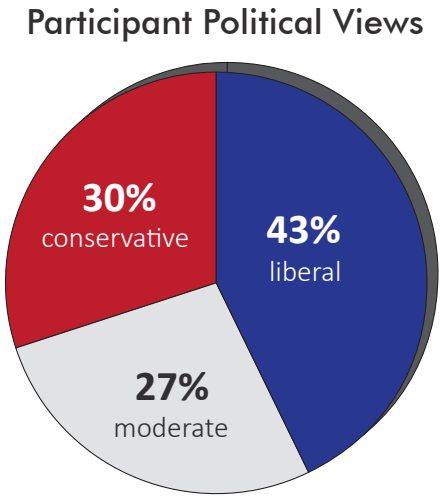
WILL THE VALUES OF THE FIRMS OF THE FUTURE LINE UP WITH THE ENGINEER OF THE FUTURE?

DARSHAN KARWAT
RE-ENGINEERED RESEARCH TEAM, ARIZONA STATE UNIVERSITY

Darshan Karwat, Arizona State University, assisted by team members Eric Stribling and Madison Macias, presented the results of ASU's online values survey of employees in consulting engineering firms. The survey, a pilot project funded by ECL-USA, included 365 participants and focused specifically on the environmental and social values of practicing engineering firm professionals.

Demographics of the 365 participants broke down as follows.





Younger engineers identify as more politically liberal, and older engineers identify as more conservative.

Complete results of the ASU survey are available on the ECL-USA website Summit-12-Provoc-Karwat.pdf (ecl-usa.org) and a summary is attached to this report. The survey results indicated that environmental protection, social justice, and workplace diversity are viewed as personally important across all demographics with environmental protection showing the strongest support. The survey revealed an important finding that younger professionals and females were most likely to agree that their employer should be more concerned about the impacts of engineering on the environment. The survey also revealed a wide disparity in beliefs regarding the importance of diversity in engineering firms and the impacts of engineering on social justice depending on political views.

ENGINEERING CHANGE LAB USA

GROUP EXERCISE: VALUES, MINDSETS & THE FUTURE OF FIRMS

In the second exercise of the summit, participants reflected on how evolving personal values and mindsets will impact firms over the next decade. Values / mindsets that were discussed included the list below.

ENTREPRENEURIAL MINDSET

TECHNOLOGICAL STEWARDSHIP

ENVIRONMENTAL PROTECTION SUSTAINABILITY WARDSHIP

SOCIAL JUSTICE

DIVERSITY, EQUITY & INCLUSION

Participants reflected on how they personally relate to these values and the current alignment between these values and the values and mindsets of talent cohorts and leadership teams within firms. Participants then examined the implications of the full expression of these values/mindsets in firms over the next decade. Questions examined included:

- Will firms be changed? What will firms need to do to retain a younger talent cohort possessing these values/mindsets?
- What tensions may arise and how can firms manage those tensions?
- Will client organizations and communities share these values?

Key insights from the group discussion are summarized below.

- The firm of the future will need to find a balance between traditional practice and new demands for attention to environmental protection and social justice in its project work and diversity, inclusion and equity within its organization.
- As new generations of young professionals express concern over the environmental and social impacts of their work, there could be tension with traditional project delivery and performance metrics – schedule, budget, etc.
- There are factors in the current environment that limit firms' ability to adapt to new values and mindsets, such as risk management, inertia created by resistance to fast changes, and public-sector procurement practices and standards.
- Conflict could also manifest when client goals and objectives clash with the values of young professionals in firms.
- There is evidence now of the emergence, in some firms, of tensions around environmental values, of efforts to provide young staff with more of a voice in decision-making, and of shifts in types of projects being pursued (or not pursued) based on employee interests (e.g., turning down a coal-fired power plant project).
- To constructively confront these types of conflicts, firms need to create a safe space/culture that supports dialogue and reflective practices.
- There is a clear need for investments in training and development related to entrepreneurship, with some firms already moving in this direction.
- Firms are seeing the need for shifts in policies to support women employees and maintain diversity.
- Firm leaders will need to adapt their thinking and their practices to accommodate emerging values and aspirations.

All provocateur presentations from the summit are available on the ECL-USA website (Summit Information | Engineering Change Lab – USA (ecl-usa.org). *You can also see the recording of the summit on YouTube* (https://youtu.be/MG3QmC3QkY4.)

UNDERSTANDING THE ENVIRONMENTAL PROTECTION, SOCIAL JUSTICE, AND DIVERSITY, EQUITY, AND INCLUSION PERSPECTIVES OF PRACTICING ENGINEERS: RESULTS OF A PILOT SURVEY PRESENTED TO ECL-USA

BY ERIC STRIBLING[*‖], JEAN L. BOUCHER[†], MADISON M. MACIAS[*], AND DARSHAN M.A. KARWAT[*]

ADVISORS: ADAM CARBERRY[*], DAVID DOUGLAS[◊], MIKE MCMEEKIN[‡], AND KYLE DAVY[§]

[*]Arizona State University; [‖]l'Université des Montagnes; [†]Dublin City University; [◊]Independent; [‡]ECL-USA; [§]Kyle Davy Consulting

For correspondence: Email estribli@asu.edu and darshan.karwat@asu.edu

July 9, 2021

Abstract: There is evidence that younger engineers are coming into the workforce with stronger environmental and social justice values than previous generations driving both societal and institutional change. This study seeks to understand better how today's firms line up with the values of these engineers of the future, employing an attitude survey of practicing engineers (*n* = 365), followed by three focus groups. The results of this study suggest that environmental issues are slightly prioritized over concerns about social justice or workplace diversity. Environmental values are also where more engineers state that their employers align less congruently with their own values. Cultural attitudes toward environmental and social values are having an increasing impact on engineers' daily work, with some variation by discipline. This study also finds that young and liberal-leaning engineers seem motivated to push for changes in the workplace to reflect their values, and some employers see this as important for retaining talent.

Introduction: The last couple decades have seen a tremendous change in the way American society values environmental and social justice issues. Both environmental issues—such as pollution, sustainability of natural resources, and climate change—and social justice issues—such as racism, gender discrimination, societal polarization, and poverty—have grown in societal importance, and younger generations are often believed to be driving societal change on environmental and social justice issues (Rouse & Ross, 2018; Taylor & Center, 2016).

As designers and builders of the human world, the work of engineering firms and associated industries are implicated—both in cause and response—in these issues. Heavy manufacturing and mining has led to many disruptive environmental changes. Engineering designs have been increasingly blamed for increasing discrimination, societal inequality, or polarization (Boutyline & Willer, 2017; Winner, 1980). Moreover, there are times that engineering is seen as the solution to these same environmental and social problems. While engineering has oftentimes been understood as value-less, an "applied science" concerning itself only with the *impartial* creation of goods, tools, and buildings (Pitt, 2000; Miller, 2021), research in science and technology

studies, sociology, and philosophy argues otherwise, namely that values are embedded in and expressed by the design and building of engineering artefacts and technologies (Mitcham, 1994).

Further, research has highlighted that engineering students are taught "that things like public welfare considerations get defined out of engineering problems" (Cech, 2014, p. 48), a finding that stands in stark contrast to ways in which, for example, engineering codes of ethics put primacy on public welfare (National Society of Professional Engineers, 2019). More recent critiques of the role of technology in society argue that engineering fundamentally involves making trade-offs between value-laden solutions (Franssen et al., 2018).

While it may be either unfair and/or unproductive to cast engineers as villains or saviors, there are numerous motivations and attitudes guiding individual engineers in the workplace and these may come into conflict, possibly along generational lines. And there are increasing calls for engineering firms to meet both the environmental and social justice challenges facing society but also to address in meaningful ways the values of a changing workforce (Boucher et al., 2020; Engineers Declare, n.d.).

How will firms need to change as younger engineers come into more senior positions of leadership in engineering firms? There is a dearth of literature in this area. Surveys of the public's environmental and/or social justice values are commonplace (Akerlof et al., 2010; Saad, 2021); however, most studies of engineering attitudes are conducted on students or professors, rather than practicing, workaday engineers (Azapagic et al., 2005; Canney & Bielefeldt, 2015).

Given this lack of understanding, we designed an exploratory study of practicing engineers to understand their

1. personal values and professional goals as they relate to environmental protection (EP), social justice (SJ), and diversity, equity, and inclusion (DEI);
2. perceptions on available opportunities to discuss conflicts and challenges in their work as they relate to EP, SJ, and DEI; and
3. perceptions on the professional opportunities to advance EP, SJ, and DEI through their work
4. what they want to learn regarding EP, SJ, and DEI

To focus specifically on the ECL-USA Summit 12 theme, *The Engineering Firm of the Future*, we paid specific attention to the degree younger engineers' environmental and social justice values align with those of their firms. We focused on two particular research questions:

1. What are the environmental and social justice values of engineers? and
2. How do the environmental and social justice values of younger engineers compare with those of their companies and older engineers?

Theoretical frameworks: In order to develop a relevant research tool (like a survey instrument) for professional engineers, we sought to develop definitions for environmental values and social justice values rooted in the engineering literature. Based on Catalano (2006), environmental

protection was defined as the process working towards a greater societal appreciation for the natural world, a maintenance of the Earth's biodiversity, and a commitment towards a sustainable ecological balance. Based on Riley (2008), social justice was understood as the process of working towards a greater equality of human rights, opportunities, and dignity. Through discussion, a third value category became apparent – Diversity, Equity, and Inclusion. While DEI has numerous, often murky definitions, the engineering profession has been highly White and male, and numerous professional organizations have spent millions of dollars to encourage minorities and females to join engineering. Based on work from the National Science Foundation (NSF), DEI was defined as the equal representation of women, persons with disabilities, and underrepresented minority groups in engineering roles (National Science Foundation, 2015).

Development of the survey also relied on a multiple identity framework for engineers (based on Gee and Tate), which posits that people have multiple identities that they use to identify with different social, personal, and professional groups (Godwin, 2016; Patrick & Borrego, 2016). An individual engineer was thus assumed to have a personal identity, a social identity (engineering firm), and an engineering identity (the engineering profession and disciplinary knowledge) that combined to inform their environmental and social justice values.

Methods and demographic data: The research team gathered data using an online questionnaire (see appendix) and focus groups, and both of which were informed by the theoretical frameworks described above. The online questionnaire, deployed using Qualtrics, was designed through consultation with project advisors. The questions were categorized into sections on environmental protection, social justice and diversity, equity, and inclusion. There were also questions on the demographic characteristics of our respondents. The questionnaire took about 13 minutes to complete. The survey was distributed by the leaders of engineering firms affiliated with ECL-USA to their staff by email between April and May of 2021.

After removing all the incomplete questionnaire responses, we were left with a sample of 365 adults who self-identified as professional engineers. The questionnaire contained 27 value questions (Table 2) and 16 demographic questions (Table 3). All value questions were measured on a 7-point Likert scale from "strongly disagree" = 1 to "strongly agree" = 7, with a neutral option. Demographic question responses were categorical. The results were analyzed using a multivariate linear regression.

The overall sample consisted of 67% males, 26% females, and 7% other. The sample was 78% non-Hispanic White, 11% self-identify, and all other racial/ethnic groups were 5% or less. When asked about political orientation, 12% identified as "very liberal", 31% as "somewhat liberal", 30% as "moderate, middle of the road", 20% as "somewhat conservative", and 7% as "very conservative." The age distribution is represented in Table 1; however, the multivariate linear regression used two larger categories for the analysis, under 45 and over 45. Most engineers (62.75%) were under 45 years of age, and 37.25% were over 45.

Table 1: Age distribution of survey respondents

Age Range	Count	%	Cohort for Multivariate Regression
Ages 18 to 24	19	5.21%	Under 45 (Younger)
Ages 25 to 34	110	30.14%	
Ages 35 to 44	100	27.40%	
Ages 45 to 54	71	19.45%	Over 45 (Older)
Ages 55 to 64	56	15.34%	
Ages 65 to 74	8	2.19%	
Ages 75 to 84	0	0.00%	
Ages 85+	1	0.27%	

Source: Authors own data.

After a preliminary analysis of the survey results, we conducted three focus groups (with eight total self-selecting participants) between June 8 – 9, where we asked participants to discuss a series of open-ended, in-depth, semi-structured interview questions, with the goal of clarifying and enriching our results.

Results: We highlight below some high-level findings from our research but direct the reader to the associated slide deck that provides significant detail and analysis of the results we obtained from the survey and focus groups.

Personal Values: Three questions (Q11, Q16, Q24; see appendix for all questions) sought to measure personal values concerning environmental protection, social justice, and DEI. While there was wide agreement that environmental (Likert mean = 6.28), social justice (5.57), and DEI (5.98) values were personally important, environmental values were ranked as slightly stronger than other personal values (Env. Likert mean = 6.28, compared with social justice = 5.57, and DEI = 5.98). This trend of environmental values being relatively more important than other values is evidenced in other questions in the questionnaire, discussed below. Discussions with focus groups suggested that the term "social justice" (lowest ranked value) has slight political overtones. A conservative, male focus group member commented:

> "[Social Justice] is starting to have a bit of a bristly effect on the employees in the workspace because, while the intentions may be good, the execution of it is proving to be very tricky and I think that it is causing a lot more friction than existed before."

Feelings of Firm Alignment: Three questions (Q3, Q7, Q19) addressed questions of alignment between personal values and employer values. Regarding DEI, respondents claimed that their firms were well aligned with their views on DEI (Likert mean = 5.70); however, there appeared to be a weaker agreement that firms were aligned with individuals' social justice (Likert mean =

5.12) or environmental (Likert mean = 5.08) values. A lack of alignment for environmental values — the strongest held belief of the personal values in the set – was strongest among young and female engineers.

Two other questions (Q4, Q21) queried from the viewpoint of the environmental and social services firms provided, rather than firm attitudes. While there was general agreement (Likert mean = 5.73) that environmental impact had become a necessary part of engineering work, a significant percentage of respondents (about 20%) were neutral or agreed with the statement "The services my firm provides perpetuate social injustices." Agreement was significantly higher for engineers who identified as slightly or very liberal.

Some focus group respondents felt that there was a change in the way younger engineers think about work, seemingly highlighting that a sense of purpose may be an increasingly important aspect for younger engineers' feelings of job satisfaction. One middle-aged focus group member commented:

> "When I was coming out of school two decades ago, it was all about electronics, doing what I want to do, because it's a career, and I can think and solve problems, and make good money. It really wasn't about the environmental aspects… [Younger engineers] every single one of them, says… they want a job to make the world a better place, so a huge shift in the last 20 years from my perspective."

Values and Job Skills: Two questions (Q9, Q17) addressed whether respondents felt that environmental and social values were becoming integral aspects of their day-to-day work. General agreement on both statements, in agreement with comments from the focus groups, suggests that engineers largely agree that the ability to incorporate environmental and social considerations into their work is a valuable job skill. One middle aged, politically moderate focus group member commented:

> "Forty years ago, when I started out in the environmental business, we came on a project and people were like, 'Oh God, the environmental people are here they're just going to throw up roadblocks, and… make everything difficult.' And it changed quickly to … 'Oh, thank God, the environmental people here!'"

Despite these findings, there was more disagreement from respondents on the specific applications of those values. The statement "Environmental regulations create unnecessary costs to engineering projects" (Q8) had an average Likert value of 3.29 (4 being neutral). Notably civil engineers were more likely to see regulations as unnecessary. Across other statements of practical application, demographic effects corresponding to different engineering disciplines had significant effects on agreement. Focus group conversations illuminated several examples of ways that different engineering disciplines had different experiences with environmental or social values affecting their work. For example, one female, civil engineer explained that while she had to make buildings more energy efficient by adding insulation and sealing air leaks, her work caused new difficulties for mechanical engineers, who now had to induce air circulation due to mold problems.

In summary, while environmental and social justice values are changing the way engineers work, the effects may be significantly different depending on discipline. The experiences that engineers encounter in their work have a strong effect on how environmental and social values are applied.

Will Values Lead to Behavior Change: The question of whether personal values can lead to behavior change is a difficult question to address in the field of sociology. The concept of willingness-to-pay can be used as a proxy for taking significant action (Xiao & Dunlap, 2007). In the questionnaire, changing jobs was used to evoke willingness-to-pay (Q13, Q20, Q26, Q18). While most engineers would not be willing to change jobs for their values, a significant proportion (approximately 30%) did indicate a willingness to accept lower-paid employment if it were better in line with personal values. Liberals were significantly more likely to indicate a willingness-to-pay. Focus groups further described the feeling that engineering companies were being pushed by their employees to make environmental, social, and quality-of-life changes. At least one respondent stated that these changes were made to retain employees. A politically moderate focus group member commented:

> "What we're finding is that we're having to cave on a lot of that stuff, if we want to keep the retention of [younger] individuals here, which we've never had to do before… They want 12 weeks of paid [maternity] leave full out. The whole ability to work from home."

A liberal focus group participant stated:

> "Our company is stepping up a lot with the diversity and inclusion and starting to move towards more environmental issues as a company, and I think I've been intrigued to see who's spearheads the efforts. It seems to be a good mix from the CEO, who's probably 10 years from retirement, all the way down to people that don't have a license."

Focus group discussions also highlighted quality-of-life or work-life values that may require future research.

Conclusions: While the data obtained from the survey and focus groups was incredibly rich, several important takeaways were evident, especially in understanding professional engineers' perceptions, values, and behaviors in regards to environmental protection, social justice, and diversity, equity, and inclusion:

- While all three values were generally considered personally important, environmental values were strongest. This is also the value, where engineers felt employers least met expectations.
- Diversity in the workplace was strongly valued but provoked strong disagreement along political lines. The rigor of engineering work featured prominently in this discussion.
- Overall cultural attitudes toward environmental and social values were seen to be increasingly factoring into engineers' day to day work-life, though practical applications varied strongly across different engineering disciplines.

- Young and liberal engineers appeared most motivated to push for changes in the workplace to reflect their values, and some employers saw this as important for retaining talent.

Acknowledgments: We sincerely thank ECL-USA for financially supporting this project, and Mike McMeekin and Kyle Davy for their intellectual support; we look forward to future collaborations. We thank Dr. Adam Carberry and David Douglas for their intellectual insights and guidance, too. Thanks also goes to all of the research participants.

Appendix:

Table 2: The questionnaire

Questions
1. (Request for consent.)
2. As an engineer, I would like to play a more important role in improving human wellbeing.
3. My employer should be more concerned about the impacts of engineering work on the environment.
4. The services my firm provides contribute to environmental problems.
5. Helping people is fundamentally important in the practice of engineering.
6. The purpose of business is to increase profitability on behalf of shareholders.
7. My employer should be more concerned about the impacts of engineering work on society.
8. Environmental regulations create unnecessary costs to engineering projects.
9. The ability to assess the environmental implications of engineering designs is a useful skill that will help me be successful at my job.
10. Most scientists think global warming is happening.
11. Environmental protection is important to me personally.
12. Engineering work has no impact on environmental issues.
13. I would be willing to accept a lower paying job for the opportunity to work more on issues of environmental protection.
14. The so-called "ecological crisis" facing humankind has been greatly exaggerated.
15. Social justice is outside the scope of engineering work.
16. Social justice issues are important to me personally.
17. The ability to assess the social implications of engineering designs is a useful skill that will help me be successful at my job.
18. As soon as I find a job with more social impact, I will leave engineering.
19. My firm's management team is committed to social justice.
20. I would be willing to accept a lower paying job for the opportunity to work more on issues of social justice.
21. The services my firm provides perpetuate social injustices.
22. Problems of race in the United States are exaggerated.
23. My firm's management team is committed to diversity, equity, and inclusion.
24. Workplace diversity matters.
25. Women and men have the same opportunities to enter the field of engineering.
26. I would be willing to accept a lower paying job for the opportunity to work in a more diverse workplace.
27. I would consider it unfair if my firm created an internship for only minority students.
28. Diversity in the workplace leads to better engineering designs.

Table 3: List of demographic categories

Demographic categories
1. Gender
2. Ethnicity
3. Race
4. Highest level of education of mother or female parent/guardian
5. Highest level of education of father or male parent/guardian
6. Highest level of education
7. Age
8. Marital status
9. Years worked in an engineering occupation
10. Number of people supervised on a day-to-day basis
11. Political orientation
12. Total yearly household income
13. Engineering discipline
14. Industry of work
15. Employment status
16. Firm size

Citations:

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