OUR GEOBUSINESS FUTURE

BIG DATA, MACHINE LEARNING, AND AI

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Figure 1. Workshop participants broke up into discussion groups.

"Life can only be understood backwards; but it must be lived forwards." — Soren Kierkegaard, Danish philosopher and theologian

Have you ever stared out the window wondering how your company will operate in the future? What will your clients want? What will your team need? The Geoprofessional Business Association (GBA) convened its latest Crystal Ball Workshop (CBW) to try to answer these questions. Held in Louisville, KY, in October 2019, this widely acclaimed series brought together 24 distinguished geoprofessionals to brainstorm current and potential future trends most likely to disrupt our industry (Figure 1). These individuals included representatives from GBA member firms and collaborative partners for the event, ACEC's GeoCoalition, the Geo-Institute, and ADSC, all of whom provided broad and insightful inputs to the outcomes of the CBW.

With the help of technology specialists, the group explored the Fourth Industrial Revolution. Never heard of it? It's time to learn. The Fourth Industrial Revolution is the broad cultural change currently sweeping the globe. It includes concepts like big data, machine learning (ML), artificial intelligence (AI), and the increasing speed of technology adoption. We expect these technologies will forever change the nature of how our profession delivers professional services.

Facilitated by Kyle Davy from Engineering Change Labs USA, the CBW set the stage by inviting subject matter experts from construction, engineering consulting, and technology consulting. Chris Bellusci, associate business systems architect with Aspect Consulting, LLC, Gordian Ulrich, director of BAUER products, sales, and service, and Stephen Brockwell, product owner for AEC with esri provided insights on technological advances, expanding the attendees' understanding and preparing them for changes on the horizon. With the internet enabling new relationships between traditional engineering, computer science, and analytics, many participants were surprised to learn how technology is already changing our business.

Framing the Revolution

Engineers are no strangers to technological revolutions (Figure 2). When the First Industrial Revolution introduced industrial disruptions from steam-powered mechanization, engineers led the way. Coupled with the rise of electrically powered machines, the Second Industrial Revolution created the demand for mass production and assembly lines, and again engineers rose to the occasion. By the 1960s, our understanding of electrically driven technology had grown, and the Third Revolution brought changes in automobiles, computing, and electronics.

Today, the world is witnessing an unprecedented acceleration of networked digital technologies set against a backdrop of climate, infrastructure, and political, economic, and societal imperatives, giving additional depth to the already complex nature of technology. This is the core of the Fourth Industrial Revolution. Are we ready to resume our role as leaders in the revolution?

After listening to the experts and debating the information on hand, CBW participants were left with two important questions:

1. Will engineers embrace technology, support disruption of our current practices, and help bring about a better quality of life for all through the Fourth Industrial Revolution?
2. In the future, will we be working for *engineering* companies with advanced technology capabilities, or *technology* companies with advanced engineering capabilities?

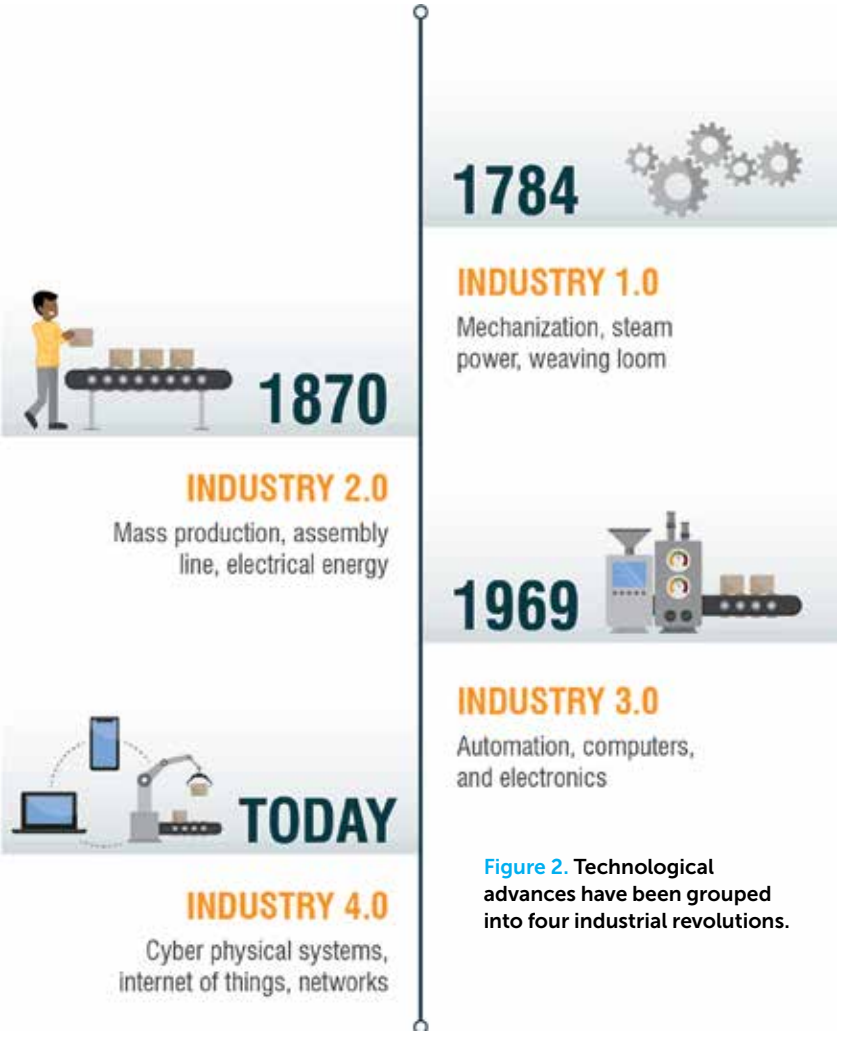

Figure 2. **Technological advances have been grouped into four industrial revolutions.**

Engines of Disruption (Threats)

Over the course of two days, CBW participants identified dozens of potential agents of disruption. We evaluated their potential for disrupting our current business models to identify related threats and opportunities. Ultimately, we concluded that these agents of disruption are positioned to change our companies, our clients, and our deliverables.

Outside Financial Influences. Silicon Valley investors have taken notice of the potential for technology advancement in the marketplace. In 2018, U.S.-based construction technology startups surged by 324 percent, up to nearly $3.1 billion from $731 million in 2017, according to Crunchbase data. Our industry has yet to attract the interest of construction technology investors, but those conditions may be changing. Early innovators who develop technologies aligned with investor interests will reap the rewards. Areas of entrepreneurial investment that leverage new technologies and deserve our attention include:

- Autonomous devices (e.g., self-driving vehicles)
- Digital twins (i.e., adaptable virtual representations of objects, products, and processes)
- Data analytics (i.e., automated mechanical processes and algorithms to analyze big data sets)
- Parametric design (i.e., algorithmic thinking that defines, encodes, and clarifies the relationship between design intent and design response)
- Blockchain (e.g., records "blocks" that are resistant to data manipulation, such as cryptocurrency)

Big Data. Big data is the common term used to describe data sets too large or complex to be dealt with by data-processing software traditionally used to analyze and extract trends. We

anticipate struggles over big data access, data sharing, data ownership, visualization, data quality, and privacy. These issues must be resolved so widespread data sharing and new partner collaborations can advance the geoprofessions.

AI and ML. Artificial Intelligence (AI) is intelligence demonstrated by machines, and machine learning (ML) is a subset of AI. ML takes AI a step further by allowing computers to analyze and learn from the data, independent from human interaction. Computer systems use ML to perform specific tasks without using explicit instructions by relying on patterns and inference. Within our profession, AI and ML will focus on the interrelationships between complex earth systems like climate, soil, and water sourcing/quality. They will be tasked with recognizing predictive trends and improving modeling. Geoprofessionals will increasingly be asked to define traditional earth-science and engineering problems for ML applications to solve.

IoT (the Internet of Things). We live in the age of a trillion sensors, where the Internet of Things is the most sought-after commodity. The IoT includes "things," such as computers, cars, and animals, and "sensors," such as heart monitors and fire detectors. In this new reality, everything has a unique identifier. We can collect data without interaction from humans or computers. Collecting this data and drawing insights into correlation and causation supports the integration of AI and ML in our business. Geoprofessionals will be challenged to find ways to employ sensors in their practice and capture data once thought unimaginable.

The workshop identified two ways that the use of AI and ML may trend. One scenario suggests that these technologies will serve as an augmentation to human thought. Thus, they may augment geoprofessional judgment in their more advanced forms. The more likely scenario is that AI and ML will perform the thinking/deciding through their own processes and won't try to think like a human. Computers are free from bias, emotional context, and risk aversion. They will consider scenarios that humans might negate, then build upon those options in ways we would not conceive. This "independent" thought scenario will likely be constrained, at least initially, by problems/questions that humans pose for computer systems. Since computers can initially only solve the problems we give them, and must interpret problems within the framework of the scenarios we envision, our unconscious biases will impede true progress from ML.

Innovation. We expect a surge of new innovations supporting design and construction activities. Predictive analytics will take advantage of big data sets. When combined with automated technologies, this may reduce the need to collect additional geotechnical and environmental information on project sites. Modeling and ML with historical data sets will supplement lengthy field investigations.

Workforce Changes. Automation, widespread deployment of sensors, and the greater availability of subsurface big data sets will reduce demand for lessor trained staff, redefine our current roles, and necessitate the integration of technology professionals into our business. It will redistribute our existing workforce into different roles and may reduce our overall workforce size.

Advanced network data mining and desktop analytics may drive the rise of unlicensed professionals, executing projects without the overhead burden of traditional firms. Clients could solicit engineering designs and solutions to their problems over the internet. The absence of insurance regulations permitting widespread use of unlicensed professionals may stave off this trend in the short term, but we expect the insurance industry to catch up if the market demands they do so.

New Competition. Big-tech companies are aggregating and using data that geoprofessionals generate. They are hiring geoprofessionals to interpret and use the data. These companies innovate on faster timelines than are typically available to the geotechnical industry, resulting in new service offerings and rapid response to changes in the marketplaces they choose to target.

Technology firms have also mastered value pricing, measuring performance by client satisfaction and results, and using subscription-service pricing. Generating greater revenue than our industry does allows them to pay more for talent. Meanwhile, the constraints of the billable-hours model continue to drive us toward commoditization pricing and lower revenues.

On-Demand Delivery. In the past, instant gratification and real-time delivery implied lack of character. They are now the "new norm." Our clients expect instant access to their consultants and designs. They seek access to data through mobile devices and prefer a more "self-service" approach. We expect to see a rise in demand for results and recommendations presented through graphics that are quickly digestible to nonprofessionals.

Opportunities

Change is constant. Fear of change is understandable. Wholesale global and cultural change can be terrifying. Each industrial revolution featured industries that found themselves threatened by radical changes in their businesses. Those that thrived focused on the opportunities presented by the change. Ultimately, a company's ability to adapt to technological change is central to its survival. Some opportunities are listed on Figure 3 and are discussed below.

Speed of Adoption. We are not keeping pace with technology. The U.S. is 10-15 years behind the EU in the adoption of current drilling technologies and automation advances. Firms that

Figure 3. (LEFT) The CBW participants identified five key areas every civil engineering firm should consider when evaluating their operations strategies and future growth potential.

Figure 4. (ABOVE) Actions every company can pursue to improve their chances of finding success in the future.

strategically welcome, adopt, and invest in technology will gain a competitive advantage.

The first autonomous drill rigs produced in Germany are excellent examples of the development of such technology. These rigs turn labor into a supervisory role rather than an operational role because the computer runs the operation. Operational safety, improved data quality, and increased production are the goals.

Business Models. Geoprofessionals don't monetize the value of technology in their work. Existing hours-based business models may no longer apply. GBA sees opportunity for firms that are willing to adapt their business models by embracing the subscription service and performance-based value pricing used in the technology industry. Geoprofessionals must explore how technology can be leveraged to increase staff efficiency.

Holistic Thinking. Taking advantage of big data, AI, and ML will require "systems thinking" — a holistic approach to analysis that focuses on the way a system's fundamental parts are interrelated with larger systems. AI and ML will produce a greater pool of potential solutions to problems. Evaluating those solutions and selecting the preferred alternative must remain the decision of the client and their geoprofessional.

Communication, Facts, and Quality. In the world of instant gratification, it's easy to forgo quality for speed. Texting, instant messaging, and social media platforms are challenging the communication supremacy of email. The emergence of these highly efficient means of communication is set against the backdrop of the skepticism of well-established facts. It's worrisome that digital communications are less likely to be reviewed for quality and appropriateness before being sent to external

parties. Information transferred to clients must be accurate, factual, or, at the very least, stated clearly as an opinion or inference. Firms that adapt their quality procedures and policies to deal suitably with instantaneous communications will see success in client satisfaction. Those that fail to adapt leave themselves at risk for miscommunications, professional claims, or at least decreased client satisfaction reports.

Ethics. A major difference between the professional service industry and the technology industry is our formal ethical standards. Professional service providers are held to well-established ethical standards, such as "do no harm." Tech firms have not yet accepted ethical standards as an essential requirement for their role as stewards of society. Further, there are no licensure requirements to enforce their implementation if there were any ethical standards. There's a growing realization that this lack of ethical standards in the development of technology represents a significant and disturbing gap that must be addressed for the good of society.

Recommendations

"Patience is necessary, and one cannot reap immediately where one has sown."
— Soren Kierkegaard

To realize the value of technology, CBW recommended that companies include technology strategies in their strategic plans. Start now and invest in staff, technology frameworks, and organizational capacity. Prepare your company for success in the revolution.

The workshop identified five strategic actions (Figure 4) that firms should consider in their planning:

1. *Monetize Data.* Recognize the vast amounts of data that you possess as an asset and explore ways to monetize it. Investigate and challenge your business model to seize technological opportunities.
2. *Control Earth Data.* Take the lead in controlling earth-science and related engineering data. Geoprofessionals are in the best position to be keepers of earth-systems data, leveraging its analysis and assuring quality while delivering on its potential to create value through visualization.
3. *Diversify Sources of Perspective.* Expand the diversity of thought in your organization by hiring outside of the traditional geotechnical workforce. Consider hiring staff with computer science degrees to help manage data and improve efficiency. Think about retaining teachers as project managers and evaluate emotional intelligence in lieu of GPA at all levels. In the upcoming decade, diversity will be key to a workforce capable of harnessing technological potential.
4. *Pursue Creative Data Management.* Pursue creative data management to create value. Using big data analytics, improve your operations internally, and deliver advice, new geotechnical designs, new materials, and new approaches to the marketplace. Engineers and scientists must increase data-management capabilities to have a voice at the table. Otherwise we yield our spot to technology-savvy enterprises that can leverage big data to generate value on projects.
5. *Inspire Young Professionals.* Inspire young professionals to help your organization think differently. Let them drive the change that's required to embrace technology. Don't stand in their way, but provide proper guidance. Invite them to contribute to the new business models.

Engineering Change: GBA and Its Partners

Engineers have played a leadership role in each industrial revolution. There are encouraging signs that the civil engineering profession recognizes the need to catch up with the pace of professional service and economic, political, and societal change in the current technology revolution. The Engineering Change Lab USA was developed to offer a platform for productive dialogue and idea generation through a deep dive into the future of engineering.

The 2019 Crystal Ball Workshop underscored the need for more collaborative efforts so geoprofessionals can rise to the challenge before us. GBA will answer the call as a catalyst for the advancement of geoprofessionals in technology. The organization will apply its decades of risk management experience with member firms and partners to help demystify and assist with developing solutions for dealing with potential liabilities associated with data sharing and the application of new technology.

This century will define whether the relationship we now have with the Earth is sustainable. Wise use of earth science/engineering, earth resources, and technology expertise will help ensure that a symbiotic relationship can continue. There's a technological fire burning to empower and spread knowledge. Let's put a geoprofessional log on the fire and not let it go out.

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