ENGINEERING CHANGE LAB USA

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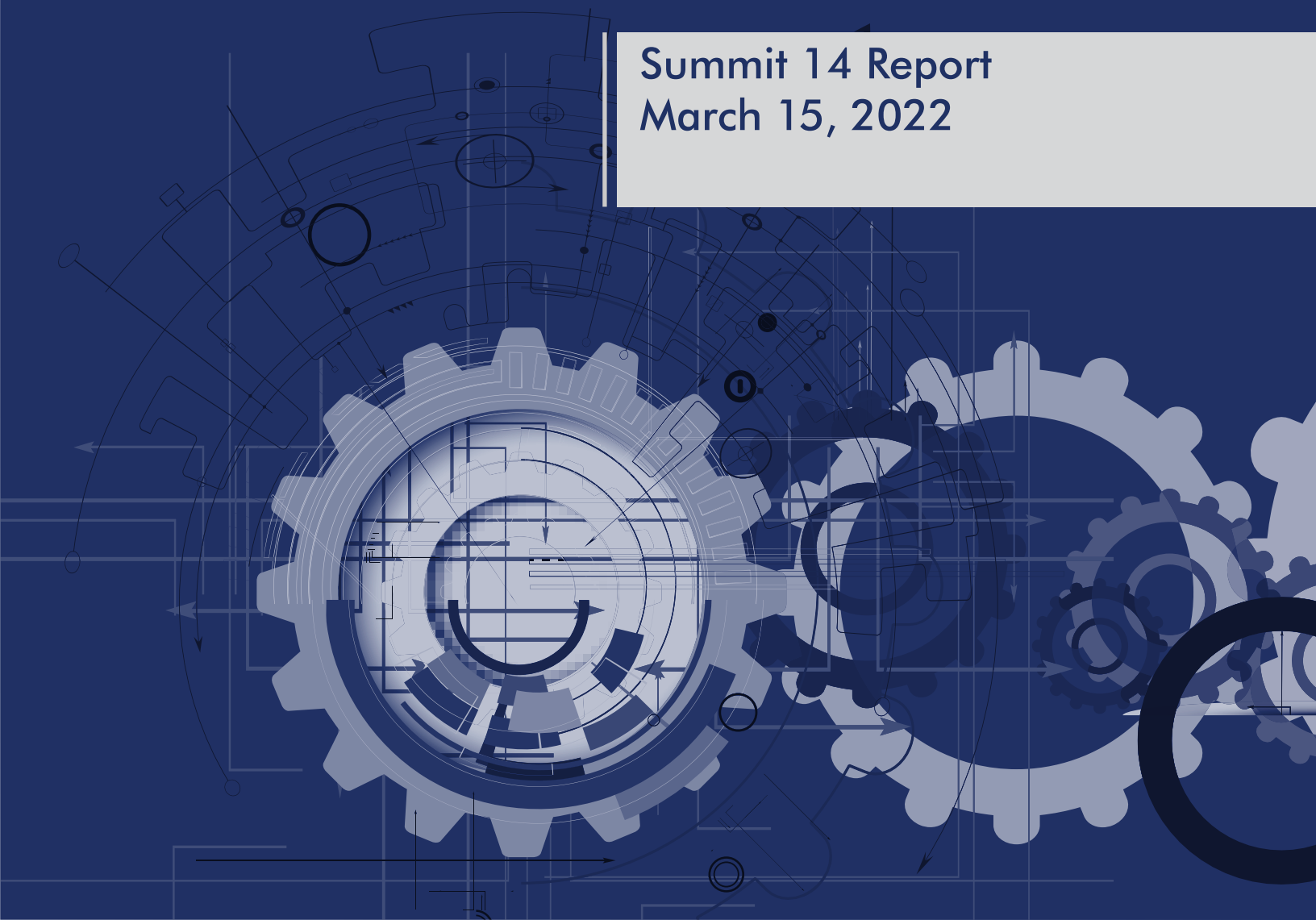
AUGMENTING THE ENGINEERING WORKFORCE THROUGH TECHNOLOGICAL INNOVATION

Summit 14 Report
March 15, 2022



The Impending Crisis in the Engineering Workforce

The Engineering Community is facing an unprecedented talent crisis. Unemployment rates for the industry are less than three percent. The retirement of baby boomers continues. The number of new graduates is increasing at low rates. Meanwhile, the demand for new talent continues to increase dramatically, driven by a growing economy and increasing investments in infrastructure. These stresses on our workforce come at a time when the Engineering Community is challenged by the need to contribute at higher levels in addressing the challenges of the 21st Century. Engineering Change Lab – USA (ECL-USA) Summit 14, ***Augmenting the Engineering Workforce Through Technological Innovation***, held on March 15, 2022, and sponsored by Autodesk, explored how technology may be viewed as a significant strategy for closing this unfolding supply and demand gap- augmenting the engineering workforce using emerging technologies to increase productivity, enhance creativity, and work more efficiently and safely.

THE CHALLENGE: BRIDGING THE DEMAND & SUPPLY GAP IN THE ENGINEERING WORKFORCE

The shortage of engineering talent, although not a new problem, has been exaggerated in recent years by the pandemic and the Great Resignation. The shortage is set to be further compounded by developments such as the recent passage of the Federal Infrastructure bill. Some of the brutal facts of this challenge are highlighted below.

Unemployment rates for STEM occupations are low (Sept 2021)

Architecture & Engineering	**2.6%**
Software, Hardware & Mathematics	**1.7%**
Sciences (Life, Physical, & Social)	**2.0%**

0.14 People available to fill every open position in engineering and the sciences.

6x open positions to people availailable

25% of current mechanical engineers are in the "retirement risk zone."*1

Demand for engineering and design services snapped back in the second half of 2021 to the 2019 (record) level and has continued to rise.

Labor cost and availability are the key concerns of companies in this sector. Three quarters of firms surveyed expect further increases in hiring demand.

$550 BILLION

82,000 JOBS

The Federal Infrastructure Bill will generate an additional $550 billion in net new design and construction spending over the next five to eight years, increasing A/E output 5.6% over previous baseline forecasts and supporting an additional 82,000 jobs annually in the engineering and design sector. *2

5,500 per year

In 2018-2019, the number of engineering degrees granted by US colleges and universities was 127,000 across all disciplines. That number has grown by about 5,500 graduates per year over the previous decade. (National Center for Education Statistics}

*1 Acatalent Whitepaper: First Come Droughts, Then Come Fires, Part One: State of the Labor Market, Sept. 2021

*2 ACEC Research Institute: 2021 Economic Assessment of the Engineering & Design Services Industry

Provocation

AUGMENTING THE ENGINEERING WORKFORCE THROUGH TECHNOLOGICAL INNOVATION

PAUL SURIN
GLOBAL LEAD FOR ENGINEERING, CONSTRUCTION, OPERATIONS AND BIM, IBM

BIO: Paul Surin is a chartered member of both the Institute of Engineering and Technology and the Chartered Institute of Building in Europe. He has degrees in Energy and Sustainable Development, Mechanical Engineering, Robotics, IT and Architecture, along with a postgraduate diploma in Eco-Building Design. He is a member of Built Environment Executives at the Institution of Engineering and Technology, vice-chair of BIM4HOUSING, and co-opted UK expert at the European Standardization Working Group for BIM – CEN TC 442 and ISO. He is Chairman of the Construction Product Europe Digitalization Task Group.

Paul Surin, Global Lead for Engineering, Construction, Operations and BIM at IBM Consulting outlined his work in Europe in digital transformation strategies that are redefining possibilities in construction, manufacturing, and operations through standardization that enables creation of digital twins from BIM, AI that enables learning from past projects, and IOT that enables predictive maintenance and energy conservation. Surin began his provocation by summarizing the current industry landscape as a combination of lingering industry problems, recent exacerbating factors, and emerging market demands (see exhibit below).

Industry Landscape for Built Environment & Manufacturing

Lingering Industry Problems	Recent Exacerbating Factors	Emerging Market Demands
Low margins & high cost of failure	Talent shortage & skills gap	Standardization & productization Digitalization of products and processes
Low productivity for decades, low collaboration and visibility	Major disruptions to supply chains & building materials	Industrialization. Offsite construction & modularization
Complex ecosystems Data silos Fragmented solutions	Remote/hybrid work model is new & challenging	Major government infrastructure funding Recovery Fund
Low digitization Poor construction quality leading to disasters	High market volatility & increased pressure on cost reduction	Global push towards sustainability & carbon footprint reduction, circularity
39% Construction & facilities' contribution to global carbon emissions [1]	Major venture capital inflow did not solve for industry problems	Expand beyond traditional & create new revenue streams

Industry's 2022+ Outlook

1. New operating models powered by end-to-end platforms
   - Open hybrid computing models
   - Support digital twin, standardization & globalization
2. Connect ecosystems leveraging interoperable data & AI
   - Uniform data structures
   - Advanced IoT deployments
3. Build capabilities to help reduce and report on operational & embodied carbon
4. Increase revenue by offering technology to the industry
   - Be the front mover
   - Profitable & reliable

He emphasized that BIM is relevant for every stakeholder in the built environment eco-system,

from design and construction into operations, from individual buildings to cities and their systems…

He emphasized that standardization enables the transformation from BIM to digital twin.

He described how new digital technologies are redefining possibilities in construction, manufacturing, and operations (see exhibit below).

He then cited several case studies from his work.

- Fluor's Cognitive Engineering & Construction Management Initiative that is driving innovation and improving quality through learning from past projects.
- IBM's Cognitive Procurement Advisor that improves purchasers' expertise and efficiency by aggregating data from a host of sources.
- Australian Metro Tunnel Project Quality Assistant that utilized AI for review of document quality.
- IBM's Health, Safety and Wellbeing app for monitoring of employee health indicators.
- Ferrovial Centre for Asset Management project that produced massive savings through automation of asset data management processes.
- IBM's AR Maintenance Solution that gives field engineers the ability to look at a physical object and have assembly guides or maintenance notes superimposed in augmented reality.

Provocation

FUTURE TECHNOLOGY TRENDS

MICHAEL GUSTAFSON
SENIOR INDUSTRY MANAGER, AUTODESK

BIO: Michael Gustafson is responsible for establishing long-term industry strategy for structural analysis, design, detailing and fabrication within Autodesk. He has published industry papers about topics like structural optimization, DfMA (design for manufacturing and assembly), digital twin and embodied carbon design. Michael is registered as a PE in California, holds an MS in Civil Engineering from the University of Minnesota, and an MBA from the Michael J. Coles College of Business. He recently received a certification from MIT in Artificial Intelligence for Business Managers.

Michael Gustafson provided insight on how access to cloud services and the use of assisted AI are accelerating, allowing the automation of routine tasks and increased focus on high value tasks. Gustafson began his provocation by outlining the new norms in the AEC landscape.

- **TALENT SHORTAGES**
- **INCREASED OWNER DEMAND FOR NEW TECHNOLOGIES**
- **INCREASED BUILDING DEMAND**
- **SMARTER CONSTRUCTION**
- **RENEWABLE ENERGY**
- **SUSTAINABILITY**

Gustafson and Autodesk believe that BIM is the foundation for technological innovation and workforce augmentation (see exhibit). Usage of BIM is accelerating worldwide with usage in mechanical/electrical and structural engineering rapidly increasing.

BIM applications that are impacting the workforce include mixed reality applications that allow visiting the jobsite while at the office, cloud applications that create efficiencies through sharing of data as opposed to sharing of files, and assisted AI applications that automate routing tasks allowing an increased focus on high value tasks.

Automation accelerates to fill workforce gaps

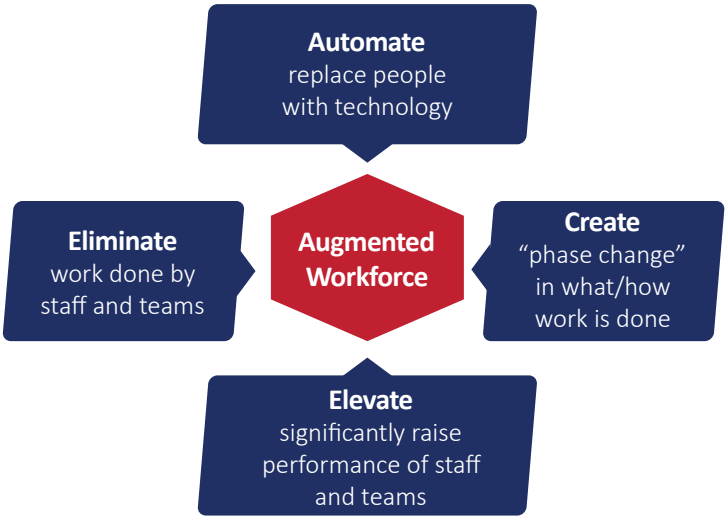
Gustafson described the new technology paradigms that he believes will drive future applications of emerging technologies – outcome-based experiences, insights developed through AI, and interactive design assistance. He cited several examples including Systra, an application that streamlines quantity takeoffs for reinforcing bars, and a generative design application that was developed for the Museum of the Future in Dubai and significantly reduced the number of connections and weight, while producing an idealized geometric design.

In the Q&A session, Surin and Gustafson addressed the need for strategic investments in technology that are based on intentionally defining business goals and desired outcomes prior to jumping in. They believe that Owner needs for data in operations is an important trend driving investments in technology. Finally, they agreed that the fear of job loss to technology is becoming irrelevant due to the overriding workforce augmentation needs.

EXERCISE I – IMAGINING THE POSSIBILITIES

In group exercises, the summit participants engaged in discussions intended to produce meaningful strategies applicable to engineering organizations. The first exercise, "Imagining the Possibilities" utilized a four-part, "Blue Ocean Strategy" framework for brain-storming potential strategies (see exhibit).

BLUE OCEAN STRATEGY: FOUR ACTIONS FRAMEWORK



1. Eliminate: Technological innovations and new tools that can be used to eliminate work that is currently done by staff and teams.

2. Automate: Technological innovations and new tools that can replace (substitute for) work that is currently being done by staff and teams.

3. Elevate: Technological innovations and new tools that can be used to significantly increase (raise) the performance and productivity of staff and teams.

4. Create: Technological innovations and tools that catalyze a "phase change" in how engineering staff and teams work and/or how they create value?

Highlights in each of the four sectors of the framework are summarized below.

1. ELIMINATE: What technological innovation(s) could be used to eliminate work that is currently done by staff and teams within your type of engineering organization?

- Cloud-based databases, including from previous projects, to eliminate some of the survey/exploration work.
- Use of job-site cameras, scanners, drones, and low elevation satellites to eliminate site visits and ground surveys.
- Utilization of AI to eliminate or reduce the need for coaching and mentoring by the "gray hairs."
- Team collaboration platforms that streamline information sharing, communication, conflict resolution, plan reviews, and decision-making, while also allowing greater flexibility in where staff needs to be located.
- Advances in project management software.
- Collaboration platforms that allow regulators to improve the efficiency of their work thereby minimizing time spent on regulatory reviews (see sidebar).

Tech Focus: New Initiatives Push State DOTs to Adopt Digital Workflows

The Utah Dept. of Transportation is moving projects through design and construction entirely in 3D, saving time and reducing the time contractors need to spend redoing models after winning bids.
Photo courtesy UDOT

Click to read article

2. AUTOMATE: What technological innovation(s) could replace (substitute for) work that is currently done by staff and teams within your type of engineering organization?

- Cloud-based databases linked to design models.
- Use of job-site cameras, scanners, drones, and low elevation satellites to eliminate site visits and ground surveys.
- Geotechnical predictive analysis based on existing data.
- Use of AI to select the proper structural system faster.
- Automation of quantity take-offs and cost estimates based on AI.
- Use of sensors to measure ground water levels, slope creep, and soil properties.
- Automated report writing through form-based data collection tools and reporting platforms.
- Automated checklists.
- Embedded intelligence in files/documents/models to streamline data sharing and ease hand-offs.
- Inventory management.
- AI applications for business operations, e.g., contract reviews for acceptable/non-acceptable terms.

3. ELEVATE: What technological innovation(s) could be used to significantly increase (raise) the performance and productivity of staff and teams within your type of engineering organization?

- Higher quality data acquisition from drones and scanners that enhance public outreach and engagement. Improvements in understanding disruptions from project construction.
- Geotechnical predictive analysis based on existing data.
- AI-assisted tools to design faster (BIM as a full-usage tool, not just drawing), e.g., structural analysis software.
- AI applications that utilize drone or static scanners for overall site management, e.g., energy leak detection.
- 3D modeling showing underground facilities.
- Virtual reality applications to detect mistakes in the field; replace cardboard models.
- Application of AI to give the engineer more insight that improves the evaluation of options and decision-making.
- Automated risk analysis.
- Data mining of prior projects to develop a starting point for designers.
- Creation of “app stores” from previous projects/solutions.
- Creating new ways for teams to work together.
- Voice to design applications, e.g., voice commands from designer to bring concept to reality.
- Digital twins to optimize facility operations for owners.
- Digital applications than enhance the public feedback process resulting in improved trust from the public.

4. CREATE: What technological innovation(s) could be used to catalyze a "phase change" in how engineering staff and teams work and / or how they create value?

- Creation of digital twins of building systems enabling predictive maintenance, energy monitoring, etc.
- Transformation of business model to value creation rather than selling hours; catalyze change in the market for expectations and appropriate cost for the work.
- Acceleration of construction through off-site or modular construction.
- Open-source library of standards, design details, building components, etc.
- Enhanced supply chain monitoring to identify bottlenecks and find workarounds (design changes or construction schedule changes autonomously).
- Enhanced communication with people impacted by projects; ability to present multiple design alternatives.

KEY TAKEAWAYS

Overall key takeaways from the large group discussion of the **Automate/Eliminate/Elevate/Create** framework are captured below.

- Data collection technologies and 3D visualizations combining data on existing conditions and design data enhances decision-making in design, in construction, and in communication with the public. *Data collection technologies enable everything else.*
- Generative design algorithms allow much more extensive analysis of design alternatives and, by freeing up time and through automated analysis, provide an enhanced ability to look at the environmental and social impacts of engineering work.
- Digital twins, combined with smart sensors, can provide value in operations such as predictive maintenance and reduced energy consumption.
- Data mining of historical data from previous projects, characterized as an app store for digital design, can increase efficiency and improve quality.
- Potential transformation of regulatory and approval processes.

Provocation

DIGITAL DELIVERY, AUGMENTING THE ENGINEERING WORKFORCE

CHRIS HARMAN
DIRECTOR OF DIGITAL DELIVERY AND INNOVATION, WSP

BIO: Based in Atlanta, Mr. Harman leads the implementation of the firm's digital delivery offering by elevating existing services and developing innovative new approaches, including connected data environments and digital twins. Mr. Harman participates in the full life cycle of project delivery through all phases of planning, design, construction and asset management. He works with experts in modelling, simulation, data management, systems, and artificial intelligence to provide enterprise-level strategy for clients, assisting them to realize the true benefits of their data and information.

Chris Harman described how digital augmentation through both automation (parametric design, algorithmic design, and content libraries) and innovation (generative design, AI and machine learning, and multi-criteria-based design analysis) frees engineers from mundane tasks and enables more complex, meaningful, and thoughtful designs.

Like Paul Surin and Michael Gustafson, Harman framed his provocation around the newest challenges facing the Engineering Community.

Environmental & Social Governance

Stakeholder & Public Involvement

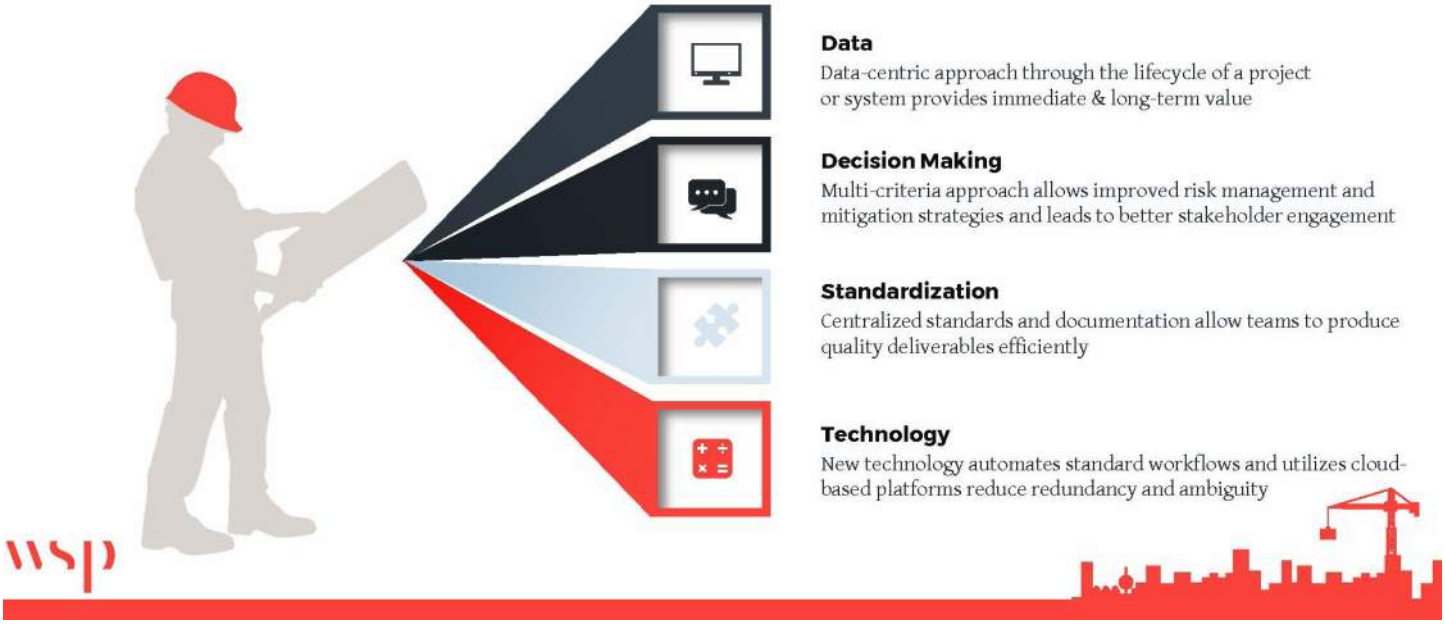
Funding & Rising Construction Costs

Labor & Workforce Shortages

Material Scarcity

He then outlined the newest tools that are available to address these challenges.

The Newest Tools



Harman framed the two sides of the digital delivery issues facing the Engineering Community – the need to deliver more with less during planning, design, and construction versus the need to operate and maintain assets longer for less. Digital tools available to assist in meeting these demands fall into two categories.

AUGMENTATION THROUGH AUTOMATION	AUGMENTATION THROUGH INNOVATION
› Parametric Design	› Generative Design
› Algorithmic Design Learning	› Artificial Intelligence & Machine Learning
› Content Libraries Analysis	› Multi-Criteria Based Design Analysis

He then outlined important changes that need to occur in how we address capital projects. He summed up these changes through the phrase, "Approximate global optimum is more important than a precise local optimum." He cited a case study from a WSP heavy rail project in Minnesota that utilized "rapid optioneering." The development of this digital tool was driven by a recognition of the importance of moving beyond looking at only two or three alternates during the planning phase of the project. The tool was based on algorithms and criteria-based planning and created multiple benefits for the project.

- Create stakeholder buy-in and social acceptance.
- Reduce negative effects on people, the economy, and the environment.
- Lowest total cost to construct and operate.
- Provide strategic market access for key customers.
- Meet regulatory approval process.

Moving to "What's Next for Operations," Harman emphasized the importance of digital twins, which he defined as "a realistic digital representation of something physical." He described the information value chain created by the physical-digital connection and how data management inputs lead to sense-making and improved decision-making.

Harman concluded his provocation by emphasizing the application of the "Gemini Principles" to digital twins and other new technologies (see exhibit), stressing that the application of new technologies should be based on creating positive public outcomes.

EXERCISE II – EXPLORING TRANSFORMATIONAL IMPACTS

The second group exercise, "*Exploring Transformational Impacts*," explored the business impacts of technological innovation, including organizational shifts (financial, operational, etc.), risk management and contractual issues, impacts on people inside engineering organizations, and macro-ethical issues related to augmenting the engineering workforce through technological innovation. Some of the common themes and key takeaways and questions from the small group discussions are summarized below.

- Potential impacts on engineering education – how do we add technology requirements to current curriculum?
- Young workers proficient in technology will look for organizations that value those skills.
- How do we attract technology workers into engineering organizations?
- What will be the impacts on salary structures associated with hiring of new types of technologists?
- Partnering or out-sourcing may be an alternative to hiring.
- Engineering organizations and engineering project teams will look different, and this will have impacts on organizational and team structure and on collaboration and project management.
- There will be resistance to change from those who want to do things the way we have always done them.
- Significant contractual issues may arise around data ownership.
- Private sector firms will need to invest – in new types of people, in technology assets, in training and in the change management necessitated by technological shifts.
- How will private sector engineering firms ensure that they are compensated for investments in technology that create efficiencies? How do we address the age-old issue of selling hours vs. value-based compensation?
- How do we get clients and regulators to keep up with technological shifts, such as providing access to digital models?
- Cyber-security risks and risks associated with data ownership and data integrity will increase with increased reliance on technology.
- Larger firms may have an advantage over smaller firms with respect to access to resources and funding.
- There is a need to address licensure issues. Where does responsibility lie with the integration of new technologies developed outside of traditional engineering organizations into traditional engineering work?
- Will increased digitalization create disparities in under-served communities?
- Better designs developed through the positive utilization of technology will increase our contributions to addressing environmental and social challenges.

OVERALL IMPORTANT THEMES CAPTURED IN THE LARGE GROUP DISCUSSION ARE SUMMARIZED BELOW.

- Shift to value-based compensation is still a major challenge.
- High demand for technology workers along with engineering workers. Need to utilize partnerships and technology consultants.
- Young workers proficient in technology will look for firms that value those skills.
- Need to take a long view of technology's ability to augment the workforce.
- Need to craft five-year strategies that fit your organization. These strategies require significant new investment. Accept the change management that is needed.
- Infrastructure bill creates growth potential which translates into funds available to invest.
- Autodesk and Bentley are major influencers in the industry. Industry relies on their work. Are we open to stepping outside the known players?

CONCLUSION

The most important takeaway from the summit discussions regarding technology's ability to augment the workforce in engineering organizations was the need to take a long view. Organizations will need to commit to crafting long-term strategies that best fit their culture and environment. Then, they will need to commit to the significant new investments and to accepting the change management that will accompany these shifts.

Provocateur presentations from the summit are available at the link below.

SUMMIT 14 PROVOCATEUR PRESENTATIONS

A full recording of the summit is available at this link.

SUMMIT 14 RECORDING

For a graphical overview of the summit, we have also developed a "Workforce Augmentation Map of the Future" that is available at the link below. Thanks to Kyle Davy for his work in creating this map.

WORKFORCE AUGMENTATION MAP OF THE FUTURE