ENGINEERING CHALLENGES FOR THE 21ST CENTURY

Summit 7 Report
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Issue Description

Over the late 19th century and the entire 20th century, engineers played a critical role in transforming quality of life – from electrification to clean water to transportation to computers and the internet. Now organizations like the National Academy of Engineering (NAE) and the American Society of Civil Engineers (ASCE) are highlighting the engineering challenges of the 21st century. The technological disruptions of the 4th Industrial Revolution, combined with the societal and environmental challenges posed by climate change, population growth, and urbanization, have led to an imperative for the engineering community- to change and adapt in ways that will commit to a vital new role. We must add to our obligation to safeguard public health, safety, and welfare with increasing contributions in ENTREPRENEURSHIP, TECHNOLOGICAL STEWARDSHIP, ENVIRONMENTAL STEWARDSHIP, and LEADERSHIP to address the engineering challenges of the 21st century.
NAE frames the challenges of this century in their Grand Challenges for Engineering initiative. The 14 challenges selected by NAE’s global panel of experts center around the themes of sustainability, health, security, and the joy of living. Nearly ten years after its initial release, NAE continues to spread the message of the grand challenges. According to Randy Atkins, NAE’s Director of the Grand Challenges for Engineering project, the most important issue related to the grand challenges is engaging the public in embracing the grand challenges.

"THE MOST IMPORTANT ISSUE RELATED TO THE GRAND CHALLENGES IS ENGAGING THE PUBLIC IN EMBRACING THE GRAND CHALLENGES."

- Randy Atkins, Director
National Academy of Engineering

NAE also continues to emphasize the grand challenges in the education of future engineers, both at the K-12 level and in universities. At the university level, the Grand Challenges Scholars Program is being used as a supplement to engineering curriculum.

**Grand Challenges Scholars Program**
http://www.engineeringchallenges.org/GrandChallengeScholarsProgram.aspx

Copies of presentations for all of the Summit 7 provocateurs can be viewed on the Engineering Change Lab – USA website at the Information Hub tab (https://ecl-usa.org/information-hub/).
AMERICAN SOCIETY OF CIVIL ENGINEERS
FUTURE WORLD VISION

ASCE’s view of this century’s challenges to the civil engineering community are captured in the Future World Vision initiative (https://www.futureworldvision.org/). Summit 7 featured a presentation on the Future World Vision project by Jerry Buckwalter, ASCE’s Chief Operating and Strategy Officer. After analysis of the trends shaping the future, ASCE settled on six macro-trends as “key drivers of change for civil engineers and the built environment.”

SMART CITIES  
CLIMATE CHANGE  
ALTERNATIVE ENERGY  
AUTONOMOUS VEHICLES  
ADVANCED MATERIALS  
POLICY & FUNDING  
HIGH-TECH CONSTRUCTION

Using the potential transformations that these trends make possible, ASCE has created four scenarios of future cities.

Resilient Cities  
Progressive Megacities

Dispersed Settlements  
Unequal Enclaves

Click to check out the article on ASCE’s Future World Vision.  
Learn more about ASCE’s Future World Vision in this interview with Jerry Buckwalter.
ASCE’s message to civil engineers of the 21st century is to embrace urgent needs for transformation.

- Prepare for resilience and anticipate changes in demographics and urbanization.
- Incorporate advances in technology, materials, and engineering/construction processes.
- Embrace digital models and big data.
- Understand system dynamics and systems integration.
- Increase the pace of innovation and lead in change management, risk management and ethics.
- Create alignment and collaboration with other engineering disciplines and non-engineering partners for non-traditional projects.
- Attract new talent and commit to lifelong learning.

ECL-USA Summit 7 included an exploration of the implications of the future cities scenarios for engineers and engineering firms. From this exploration, several common themes emerged.

- Collaboration and integration with other fields of expertise will broaden our network of problem-solvers.
- More engagement is needed in developing effective public policy to address societal and environmental challenges.
- Challenges of the future highlight the importance of long-term, life-cycle thinking and systems thinking.
- Engineering practice in the future will benefit from an increase in entrepreneurial risk-taking ethos, while maintaining balance with engineering ethics.
- Engineering leaders of the future will need communication skills that combine listening with the ability to persuade in ways beyond the use of logic.

The exploration of the “Future World Vision” scenarios highlighted the importance of scenario planning as a tool to prepare engineers for a VUCA (Volatility – Uncertainty – Chaos – Ambiguity) world future. Engineering organizations of all types could take advantage of the “Future World Vision” scenarios as part of organization-level strategic planning work.
ROLE OF EMERGING TECHNOLOGIES IN SOLVING 21ST CENTURY ENGINEERING CHALLENGES

The 21st century has already seen the emergence of technologies that, at a minimum, will significantly change and could disrupt the practice of engineering. Part of the mission of ECL-USA is to help prepare the engineering community for this potential disruption. To explore the linkage of 21st century engineering challenges to the potential of emerging technologies, the participants in ECL-USA Summit 7 took part in a new exercise developed for ECL-USA, the “Innovation Matrix Game.” The objectives of the Innovation Matrix Game were to explore several important questions.

How can emerging technologies create new forms of value for engineering clients and society?

Is there a linkage between the technologies engineers use to do their work and their capacity to act as leaders in addressing 21st Century challenges?

Can engineers of the future do well by doing good?

The key learnings from the Innovation Matrix Game mirrored the key learnings related to the discussion of ASCE’s Future World Vision initiative.

- Creativity begins with individual ideas that grow with team input and outside stakeholder input.
- Engineering input is critical to linking emerging technologies to future challenges.
- Future engineering practice requires going beyond our typical practice of doing a little bit better on the same problems.
- Engineers are great at identifying unintended consequences. How do we balance this skill with increased entrepreneurship?
- Investments in research and development are critical to moving beyond commoditization.

If you are interested in learning how you can apply the “Innovation Matrix Game” in your organization, contact Mike McMeekin, ECL-USA Executive Director (mike.mcmeekin@lamprynearson.com).
The challenge for 21st century engineers and engineering organizations is captured in the Strategic Choices graphic. Our contributions to 21st century challenges require a shift from the lower left quadrant, the old way of practicing, to the upper right quadrant of the matrix, embracing emerging technologies to address new challenges. This shift requires higher levels of risk, but brings much greater potential of rewards, both financially and in our contributions to the world’s needs.

**Strategic Choices for Engineers**

- **Emergent Technologies**
  - **New Ways of Working**
  - Tactical Differentiator
    - Moderate Risk
    - Low / Moderate Rewards
  - Value Creator Leading in Blue Oceans
    - High Risk
    - Potentially High Rewards

- **Current Technologies**
  - **Current Ways of Working**
  - Combatant in Red Oceans
    - Low Short Term Risk
    - High Long Term Risk
    - Low Rewards
  - Role Player/Bit Player in Other’s Productions
    - Moderate Risk
    - Low / Moderate Rewards

20th Century Social / Environmental Challenges

21st Century Social / Environmental Challenges

**Cyber Security**

As the 4th Industrial Revolution matures, we are becoming aware that our digital lives come with necessary overhead costs. The use of new digital technologies does not come “free.” One of the critical overhead costs is dealing responsibly with potential cyberthreats that come with our digital world and increasingly digital engineering practice. The grand challenge of cybersecurity is another “complex, wicked problem” of the 21st century, with no “silver bullets.”

At ECL-USA Summit 7, Chris Walcutt, Director of Security Solutions, at Direct Defense outlined the risks and opportunities presented by cyber-security.

Discussions by participants in Summit 7 highlighted the cybersecurity risks that engineers face and the opportunities that can be capitalized on.

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<th>RISKS</th>
<th>OPPORTUNITIES</th>
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<tr>
<td>› Any type of digital data creates concerns.</td>
<td>› Engineers can lead the way in creating standards.</td>
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<tr>
<td>› Internet of Things and its reliance on 3rd party-developed products bring unknowns.</td>
<td>› We can create new kinds of value that can be monetized.</td>
</tr>
<tr>
<td>› Alterations to our plans, specifications, and digital models by outside parties is possible.</td>
<td>› Engineers can lead the way in collaboration with clients and public officials.</td>
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<td></td>
<td>› Incorporation of cyber-resilience (i.e., manual override) is critical to future practice.</td>
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Addressing cybersecurity is part of the stewardship of technology imperative for engineers. We must learn to bake cyber-security into engineering practice – in what we engineer (our work products), in how we do it (our tools and processes), and in how we manage engineering businesses. These practices must become part of our ethos as engineers.

**Implications for 21st Century Engineering Businesses.**

One of the themes of ECL-USA Summit 7 was the future of consulting engineering businesses. Two major learnings emerged from discussion at the summit – the role of engineering businesses as thought leaders and the importance of investments in research and development to moving beyond commoditization.

The concept of thought leadership is a central element in the new strategic plan for the American Council of Engineering Companies (ACEC). Summit 7 participants heard of ACEC’s view the future from Laura O’Neill Kaumo, ACEC’s **Chief Operating Officer**. ACEC’s strategic plan also recognizes the emergence of noble purpose beyond profit as a major element of the long-term vision of ACEC.

ECL-USA Summit 7 participants also heard from Thornton Tomasetti, a leader in investing in research and development. Robert Otani, Thornton Tomasetti’s Chief Technology Officer, presented the elements of their approach.

**Looking for innovation / efficiencies and the creation of IP.**

**Openness to employee ideas through a democratic decision-making process that is intended to prevent catering to executives.**

**Thornton Tomasetti R&D Focus Areas**

1. Preparing for the transition to 3-D deliverables with data.
2. Machine learning / AI to automate traditional design functions.
3. Field data collection for evaluation of existing structures.
4. Knowledge capture.
Another example of research and development related to the future practice of engineering was observed through a tour of the Autodesk BUILD Space in Boston. Robert Mansperger, Manager, Experience Design with Autodesk advocated that engineers and designers are at a crossroads that will require new creative and innovative ways to solve large complex problems. The visit to Autodesk was a vivid illustration of the potential of the 4th Industrial Revolution for design professionals through the convergence of robotics, 3D printing, and machine-driven fabrication capabilities. Engineering firms of the 21st century will need to take advantage of opportunities for collaborative approaches to research and development, teaming with partners like Autodesk and sharing knowledge and know-how with experts like the Autodesk mentors/technology coaches that staff their facility in Boston. Maker spaces like the BUILD space present multiple creative possibilities for the future practice of engineering.

**INFLUENCING CHANGE & TAKING ACTION**

ECL-USA Summit 7 was another vivid reminder of the change and adaptation needed for the engineering community to increase its contributions in addressing 21st Century challenges. The future of engineering depends on our ability to contribute at a higher level through ENTREPRENEURSHIP, TECHNOLOGICAL STEWARDSHIP, ENVIRONMENTAL STEWARDSHIP, and LEADERSHIP.

If you are interested in learning more about Engineering Change Lab – USA, contact Mike McMeekin, Executive Director (mike.mcmeekin@lampynearson.com).