This paper was published in June 2015. The ideas and recommendations within it are among dozens of suggestions that arose from the Stanford Engineering Future process. Share your thoughts with us at SoEFutureFeedback@stanford.edu.
In January 2015, the SoE Future Committee, composed of faculty, staff and students, was formed and asked to answer two strategic questions:

1. In what areas can the School of Engineering make significant world-changing impact?
2. How should SoE be configured to address the major opportunities and challenges of the future?

After a rigorous and inclusive process that captured input from a wide range of stakeholders, the committee developed 20 whitepapers with more than 130 specific recommendations, providing a strategic vision for the future of the Stanford School of Engineering.

In a 1902 speech, Jane Stanford shared her vision for Stanford University:

“The moving spirit of the founders ... was love of humanity and a desire to render the greatest possible service to mankind. The university was accordingly designed for the betterment of mankind morally, spiritually, intellectually, physically and materially. The public at large, and not alone the comparatively few students who can attend the university, are the chief and ultimate beneficiaries of the foundation. While the instruction offered must ... qualify the students for personal success and direct usefulness in life, they should understand that it is offered in the hope and trust that they will become thereby of greater service to the public.”

Mrs. Stanford’s timeless remarks embody the spirit of Stanford today and evoke the role engineers can play in making the world a better place.

Engineering has always attracted people who want to harness science and nature to improve life and enhance our planet — whether by building aqueducts and sanitation systems in ancient civilizations or by designing airplanes, electricity grids and integrated circuits today. Engineering has brought us enormous prosperity and dramatically improved our quality of life. As we look ahead to the many complex challenges our planet faces, engineering advances and breakthroughs will be essential to maintaining and improving the quality of life for all.

History has taught us, however, that engineers cannot make an impact by working in isolation. While engineers must partner with the sciences to push the frontiers of technology, they also need to embrace the humanities, social sciences, business and liberal arts to ensure that engineering solutions address real needs and can be sustainably implemented. Stanford’s excellence across all disciplines, encompassing both research and education, provides an incredible and unique opportunity to tackle complex problems.

SoE has been very effective, and we should not break things that are working well. At the same time, SoE must avoid complacency if it wants to continue to lead. We must be strategic, identifying and understanding the unmistakable global trends facing our world so we can see the opportunities and challenges ahead. We also must create flexible plans that allow for the inevitable surprises the future will bring.
Earth’s growing population and dwindling resources present urgent challenges, while the power of computation, new materials and biotechnology offer opportunities previously unimagined. Engineers can play a crucial role in creating solutions to the world’s problems while ensuring that advances in technology are used for the benefit of all.

**Population dynamics, urbanization and globalization**

The world population will grow from about 7 billion people today to about 9.5 billion people by 2050. Most of this growth will be in Asia and Africa. The world’s rural population will probably remain unchanged. The additional 2.5 billion people will live in urban areas, with some cities growing as quickly as 2 percent to 10 percent a year.

While population is growing in developing economies, the population in developed economies is aging. Today we see this issue in Europe, Japan and North America; in the future, it will be magnified in China. By 2050, about 90 million people in China will be 80 or older, compared with about 30 million in the United States. The differences we see today in the population demographics of developed and developing countries will increase.

Today, global trade is about 33 percent of the global GDP of $80 trillion. Driven by better communication and telepresence enabling specialization, global trade is likely to grow to 40 percent of GDP by 2020 and continue to grow. Large businesses currently are leveraging the benefits of global value chains. At the same time, new software and Internet technologies can quickly disrupt existing markets.

These trends will have huge effects on education. By 2020, the demand for post-secondary education (ages 18-22) is likely to be highest in India, the United States, Brazil and China. The highest growth rates will occur in India, Brazil, Indonesia and Turkey. With increased mobility, the supply and demand of the global talent pool will adapt accordingly.
Energy, water and the environment

Economic growth can raise people from poverty and improve society, but the ecological impact can be unsustainable. Our goal should be to increase the human development index while simultaneously decreasing the corresponding ecological footprint. Data show that this is possible, but not in line with today’s trends. We need to make significant changes to how we manage energy, water and our impact on the environment.

Economic growth requires energy. Beginning with the industrial revolution in the mid-1750s, the source of energy has been predominantly fossil fuels. Its use is now leading to unprecedented acceleration in atmospheric CO2 concentrations and global warming, with potentially catastrophic environmental and climate effects. For the global economy to continue to grow and be healthy, we must have new, affordable and sustainable ways to generate, store and manage energy, as well as approaches to capture and convert CO2 to something of value.

Clean water for people, industry and agriculture is also a tremendous challenge. An increasing population will demand more fresh water. Currently, inefficient water management and the changing climate are putting enormous stress on our freshwater supply. This stress will only grow with time. As populations become more concentrated in urban areas, local variations in water resources will have more pronounced effects. The recent California drought is one example we at Stanford experience personally.
These global trends pose enormous and daunting challenges. But we are simultaneously experiencing tremendous technological growth and evolution. We are beginning the third industrial revolution, in which information technology transforms industries, society, day-to-day life and our relationship with the world around us. Stanford sits at the epicenter of this transformation: Silicon Valley. This boom in technology and innovation may have started with silicon and software, but it now spans energy, transportation, construction, computing broadly construed, and humans. With decreasing silicon costs and ever-increasing access to sensing, computing, communication and automation, the future will involve even greater generation, processing, storage, analysis and use of massive amounts of digital data.

Data
The ability to generate and process vast amounts of data is already transforming disciplines, from automatic document analysis in legal offices to economic analysis, law enforcement and geological surveying. The future will see this effect grow, with computation and data analysis becoming integral components of almost every job and industry, including education.

Biology and human health
This growth of computational capabilities is also transforming how we understand a much older technology base: biology. With rapidly decreasing costs of genomic analysis and new tools for genomic and proteomic manipulation and synthesis, it is fair to say that we are entering a golden age of biology. The first steps in biology-focused medicine and agriculture are small compared with what we are likely to achieve in the future. In parallel, new technologies such as optogenetics provide incredible new opportunities for engineers to improve human health at all scales. Personalized medicine, drug creation and delivery, medical devices, synthetic biology, health care services — the future of each depends on engineers.

Security
As information technology (biological, digital and the not yet imagined) becomes foundational to our society and lives, security could quickly become the Achilles heel that limits its impact and benefit. The past 30 years of security research have shown that simply attaching security solutions to existing systems is expensive to deploy and leaves them vulnerable to new threats. As we research and invent all types of new technologies, we must do so with security as a constant and vigilant concern.

Energy and sustainability
The past decade has brought several unpredicted revolutions in the energy industry, including huge reductions in the cost of extracting natural gas, tremendous cost reductions through technology innovations in carbon-free electricity from wind and solar, and a rapid reduction in the cost of electricity storage in batteries. These changes will probably make carbon-free energy competitive with traditional sources and electric transportation economically viable in 2020 and beyond.
Online Education

Finally, massive open online courses have grown from a few classes at Stanford to the early stages of a global industry. They have kindled new creativity and exploration in education, with open research in what tools can be engineered, and data leveraged to improve education at scale and distance.

Together, these technological advances open the door to a future very different from what we might have imagined 10 years ago. How we harness these advances to conduct groundbreaking research and educate the engineer of the future is the challenge that must be addressed.
In response to these myriad trends and challenges, the SOE Future Committee drafted whitepapers recommending ways to expand the way we educate engineers and develop new ways to organize and incentivize collaborative research. The committee identified research themes that build upon and leverage Stanford’s unique strengths, and suggested ways we can adapt our culture to maximize impact in the next decade and beyond.

**Education**

The confluence of the digital world in the form of computing and communication, the physical world in the form of making things, and design as a fundamental component of engineering, has already changed our educational system, and is likely to do so even more through their meaningful integration. This integrated approach appeals to our students. When juxtaposed with the core scientific foundations of engineering, it requires us to think holistically about how to balance our educational program to offer depth, breadth and integrated project experiences. Also, to truly appreciate how engineering relates to the world, our students need to gain first-hand experience with a spectrum of global cultures and values and more deeply connect to the humanities and social sciences.

One powerful whitepaper discusses the engineering core curriculum; the possibility of a new major emphasizing breadth and human aspects of engineering; integrated maker spaces; and topics in online learning. A second whitepaper explores the importance of the many lecturers, consulting professors and other nontenure-line educators who bring skills and experience to the classroom and lab.

- How do we educate in the future?
- Nontenure-line educators

**Research**

Cutting-edge research is integral to SoE. To address the challenges of the 21st century, we must look at how we conduct research today, what issues Stanford can uniquely address, and how we can ensure engineering’s continued global impact.

**Interdisciplinary 2.0**

At the heart of SoE’s vision for the future of interdisciplinary research is the committee’s recommendation to create a new, dynamic mechanism that accelerates collaborative research focused on problem-solving. One whitepaper outlines a vision for taking interdisciplinary collaborations to the next level:

- Accelerator for Collaborative Engineering

The challenges in federal research funding and the complexity of the world’s most pressing problems require a new approach if engineers are to continue having the scale of impact they have enjoyed in the past. For modern challenges, engineering faculty must be better integrated with domain experts in the sciences, humanities, social sciences, arts and business, as well as with experts from industry and global organizations who understand the barriers and opportunities.
We will create a new organization called the Accelerator for Collaborative Engineering to recruit, nurture and bring together problem-solving talent at Stanford. Each year the Accelerator will recruit Stanford faculty, postdoctoral fellows, graduate students and a cohort of visiting faculty and practitioners to form an integrated, solution-oriented team. Students and post-docs will act as the “glue,” conducting research with faculty and practitioners to offer engineering solutions for large societal challenges. Research areas identified in the SOE Future process will provide rich themes for initial Accelerator teams. Incentives, activities and a culture that encourages collisions and collaborations among people from different fields, will leverage and enhance Stanford’s bottom-up culture of innovation and experimentation.

The Accelerator will be fundamentally different from current institutes, centers and laboratories at Stanford. It will not focus on building new research facilities or creating permanent research programs. Instead, it will focus on a nimble structure for bringing together people, culture and resources to support dynamic new collaborations.

Research themes
When we consider SoE’s current and potential strengths for addressing global trends and technological challenges, several powerful themes emerge. Posed as 10 questions, these themes are not meant to be comprehensive, but rather to provide examples of areas where SoE can have considerable impact.

- Engineering information

  With the digitization of matter, we will enter a period when business-as-usual scaling according to Moore's Law is unlikely to continue. Will other computing paradigms enable continued exponential growth in our power of data processing, communication and storage? Furthermore, computing and big data are quickly permeating every field of discovery. It is our obligation and challenge to help drive new discoveries across campus and to offer new capabilities and services. Finally, security is a significant and growing threat in our digital world and beyond. Three whitepapers address these themes:

  - How do we sustain the exponential increase in information technology performance?
  - How can we use our strength in computation and data analysis to drive innovation throughout the university?
  - How do we secure everything?

- Engineering materials

  Recent developments in designing, synthesizing, probing and controlling matter at the level of electrons, photons, atoms and molecules offer new and unprecedented opportunities to address major challenges involving computing, tissue engineering, energy conversion and storage, and many others. One whitepaper addresses these challenges:

  - How can we engineer matter from atomic to system scales?
• Engineering sustainability

As our global economy and population grow and the world urbanizes at an unprecedented massive scale, it is apparent that 20th century approaches to human development are unsustainable. There are significant challenges across energy and climate, as well as infrastructure for electricity, transportation, water, sewage, information and other services. Could automation of large systems play a role in addressing some of these challenges? Three whitepapers frame the significant advances in engineering that will be required:

- How do we provide humanity with the affordable energy it needs and stabilize the climate?
- How can we ensure that humanity flourishes in the cities of the future?
- How can we use autonomy to enable future engineering systems?

• Engineering human health

With a rapidly developing toolkit and declining costs of manipulating biology at the molecular level, we are poised to consider how well we can engineer living matter. In parallel, a new understanding of biology and advances in technology provide incredible opportunities for extending and improving human health — but at what cost? Two whitepapers explore these challenges and opportunities:

- How good can we get at engineering living matter?
- How can we engineer effective yet affordable healthcare everywhere?

• Engineering and humans

Engineering for its own sake is not sufficient — it must focus on solving problems we face as individuals, as communities and as a society. From the beginning, engineers must also think of how to design systems that humans can and will use most efficiently and effectively. One whitepaper focuses on this important interface:

- How do we create a synergistic interface between engineering and humanity?

An environment to ensure success

SoE’s impact on education and research depends on three interwoven elements: culture, people and resources. They serve as the underlying fabric of any organization and must be addressed in any strategic plan. The SOE Future committee provided a series of recommendations on ways to adjust how we view ourselves, how we organize ourselves and how we go about our work. Some are simple. Some will require big cultural shifts. All will be instrumental in the school’s success.
Culture
The culture and values of an organization are critically important for its success. The bottom-up culture of SoE drives our decision-making; our commitment to diversity ensures a rich variety of perspectives; and our celebration of interdisciplinary research positions us to solve the big challenges. Culture is what makes us strong. Shifting cultural norms to adjust to the future can be really tough. Asking the right questions is critical.

Despite significant efforts toward increasing the representation of women and underrepresented minorities, we clearly need to do better.

For engineering to make true societal impact, we need to partner internally with the physical and social sciences, humanities, law, medicine and business, and externally with industry and worldwide organizations that are directly addressing people’s needs. To foster such collaborative work, we need to value and incentivize it internally. Two whitepapers examine critical cultural topics that SoE must address:

- Diversity: a grand challenge in engineering
- Interactions across the university

Infrastructure
Talent, facilities, research funding and quality of life will be key to SoE’s success going forward. Stanford has the ability to attract top talent — faculty, staff, students, post-doctoral fellows and non-tenure-line educators — and has done exceptionally well in the past. How we continue to attract the best talent, and how we value, empower and manage our talent, are issues of enormous importance. Challenges related to cost of living in the Bay Area are universal and are well known. Although Stanford has devoted significant effort and resources to address this challenge, it has been difficult to keep pace with local growth, highlighting the sense of urgency and the need for pre-emptive measures and new approaches to address them.

Academic and administrative staff play a critical role in the success of our educational and research missions. We need to ensure that our staff is motivated and trained, feels ownership of the school’s mission and shares in its success.

We are living in times of flat federal research funding and industry’s increasing focus on short-term engineering research. Yet we know that sustained long-term research with bold and audacious goals is critical for breakthroughs, especially to address the profound questions and challenges highlighted in our research themes. The Accelerator for Collaborative Engineering is a start, but given that many of the challenges are global, we must engage globally to support our research enterprise.

World-class research requires world-class facilities. Given our constraints in space, we need to think creatively about how best to use our laboratory resources to maximize our support for research. Our students need a learning and creating environment that will prepare them to make a positive impact on the world.

The SOE Future committee separately called out a variety of ways to improve the school’s environment and business practices. The school has already implemented many of these ideas and has initiated efforts to evaluate others over the coming years. The School is committed to providing a robust infrastructure and the resources to ensure success.
In preparing this strategic plan, we enthusiastically embraced the meaningful and timeless remarks of Jane Stanford about the purpose of Stanford University. We hope our analysis and our recommendations will advance our educational and research mission to serve humanity and our planet, and to meet the high standards she set for us.

Although we took a long-term view of our future, it took us only five months to put this plan together. Therefore, this plan remains a snapshot in time. Times change, and so should plans. We recommend that this plan become a living document — always with a view toward the long term but constantly under assessment and course correction. It is only through this nimbleness and agility that Stanford Engineering can continuously innovate and improve.