

Key messages from the Engineering and Innovation sessions

Eric Mazur — STS Forum 2015, Kyoto, Japan

It is great a pleasure to summarize the key messages from the four sessions in Theme C: Engineering and Innovation.

The first of the four sessions, entitled “Industrial Innovation,” discussed the interactions of the three entities driving industrial innovation: government, academia, and industry. Government to seed the innovation through funding and supporting policies, academia to carry out fundamental research and lay the foundation for disruptive innovation, and industry to bring innovation to fruition through commercialization.

Several examples of successful collaboration between government, academia, and industry were provided. One is the development of the blue LED, which led (no pun intended) to a revolution in the lighting industry and in energy savings (as well as to a Nobel prize). The search for a blue LED was originally carried out in industry, but when it failed to produce results, it was moved from industry to academia, where over a decade later, fundamental research led to a major breakthrough. Government then promoted the tie-back from academia to industry, which then commercialized the basic findings from academia. Another example is graphene, a novel material that is essentially a single layer of carbon atoms. This research started about decade ago in an academic lab, where Andre Geim pulled off layers of carbon atoms from a piece of graphite with scotch tape — nanotechnology on a nano-budget. Government funding in the billions then pushed the research further at a pace no one could have imagined. Just a decade later, products involving graphene are hitting the market.

Such success stories require stable government funding. Given the long-term nature of fundamental research, stability of funding and stability of policy, even across changing governments, is crucial as changes in policy can be very disruptive. Also, successful partnerships between academia and industry should involve multiple partners on both sides so as to ensure a bigger impact and broader range of benefits. Finally, in order to mitigate the risk of start-up technologies, it was suggested to begin the incubation of technologies in academia, where existing university facilities can be leveraged, avoiding costly and often risky investments.

The second session dealt with future nanomaterials — materials whose dimensions are measured in nanometers — a billionth of a meter. They range

in size from one-hundredth the diameter of a hair down to one hundred thousandth the diameter of a hair. They can be made either “top-down” by taking something large and making it smaller, or assembled “bottom-up” from single atoms or molecules.

While we mostly think of “engineered nanomaterials” when the term “nanomaterials” is used, biological systems have involved natural, functional nanomaterials for millions of years. Viruses, cell membranes, and the nanostructures on lotus leaves that give rise to the water repellant lotus effect are just some of the examples of natural nanomaterials. The replication of DNA is nanotechnology at work.

The last decade and a half has seen tremendous advances in engineered nanomaterials. In just fifteen years, the field has gone from academic breakthroughs to applications in a variety of products and new materials.

Bottom-up technologies have yielded interesting nanostructures that allow us to design novel materials. One example are layered compounds made from “nanosheets”. Peel off single sheets of atoms, such as graphene, and then reassemble layers of alternating elements. Using this technique it is possible to design materials for very compact storage of electrical energy.

As the field advances, it is clear there are several challenges: First, the field is inherently crossdisciplinary, involving physics, materials science, chemistry, biology. Research, on the other hand, tends to be organized along disciplinary boundaries and therefore it is important to bring researchers from different disciplines together and integrate research, education, and innovation across disciplines.

Second, bottom-up technologies are hard to bring up to manufacturing scale. Assembling materials atom by atom simply doesn’t go that fast. Therefore, for nanotechnology to be useful we will need new approaches. It was suggested that self-assembly of materials will likely play an important role.

Finally, several speakers pointed out the role of informatics. Increases in computational power and advances in modeling techniques now make it possible to design materials. This ability will guide the design of novel nanomaterials by predicting their properties, their biosafety, and their environmental impact.

The third session addressed what kind of new manufacturing technologies we need to realize a sustainable society. Ever since the last industrial revolution, manufacturing, supported by consumption, has fueled economies around the world. Over the past decades, however, several interesting changes have occurred.

First, even though the physical lifetime of products has generally increased, the useful life of products has decreased. For example, the lifetime of cars has steadily increased, yet people, desiring to have the latest technology, are changing cars faster. The mobile phone industry takes this point to the extreme. Even though electronic components have a lifespan of about 40 years, people tend to replace their phones every two years. So we are moving into an era where people replace products not because they have exceeded their physical life, but because they have exceeded their desirability.

Second, the current interplay between mass production and consumption produces a shortage of resources, mass waste, and environmental problems. There is a growing list of endangered elements: helium, zinc, and rare earths, just to name a few. Some of these elements are geographically restricted and often in politically unstable areas. At the other end of the product life, we are producing rapidly increasing amounts of complex product waste, most of it exported to developing countries, where it cannot be efficiently recycled. This trend cannot continue.

One emerging technology, 3D-printing, is beginning to revolutionize the way items are manufactured. 3DP makes it possible to design for functionality, without the constraints imposed by conventional manufacturing technologies. In addition, 3DP enables distributed, localized, and personalized manufacturing. You produce where the product is needed, eliminating shipping and storage.

This paradigm shift in manufacturing from centralized mass manufacturing to distributed and personalized manufacturing will require rethinking both our approach to education and training, and our business models.

Many of these same themes were revisited in a different context in the last session, which dealt with the subject of robotics. Now robotics, in the minds of most of us, involves a human-looking machine mimicking the capabilities of a human. But it became clear from this session that the future of robotics is much richer than that. At the opening of this Forum we heard Prime Minister Abe mention autonomous driving cars. In some sense the network of sensors and actuators permitting cars to be autonomous is a robotic entity.

An important issue to address in the realization of robotic systems is reliability and trustworthiness. Cars that incorporate technologies that assist drivers are already available. What separates those cars from fully autonomous ones is reliability and trustworthiness. The same holds true for

robots that are used in surgery: at this point their public acceptance is still severely limited by a perceived lack of trustworthiness.

An exciting frontier is the intersection of robotics and cognitive computing. Because of a confluence of factors, cognitive computing is rapidly making it possible for computers to achieve near-human level performance in a variety of tasks. These factors are the: digitization of the world and the availability of massive data about the world we live in; the development of machine learning algorithms that obviate the need to program; and increases in computing power that make it possible to process data in situ. An example is medical diagnosis. While the average medical researcher/practitioner reads about 100 out of 100s of thousands of articles that are published in a year, a computer system, for example, can ingest the entire medical literature, make connections across them, and help medical practitioners make diagnoses that no single human being could make.

Let's step back one moment to put this in perspective: The creation of technology to do what our muscles can do freed us from the drudgery of manual labor and revolutionized manufacturing. If embedded cognitive systems extend what our brains can do, the impact can be even more transformative.

It is clear that it is a very exciting time for engineering and innovation, and I am greatly looking forward to the next breakthroughs. I just hope that, at least for now, I am still better at summarizing sessions than one of these robots with cognitive computing abilities.