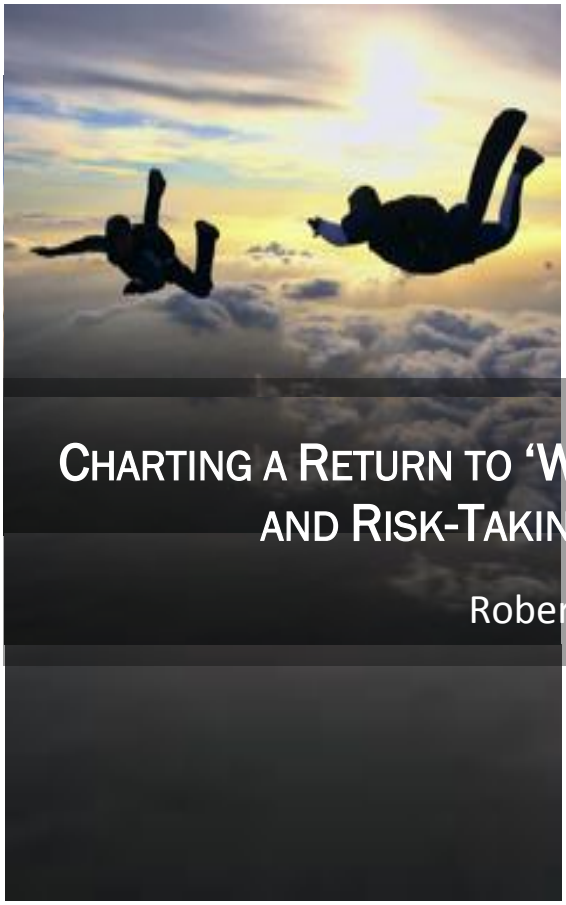
MEETING SUMMARY



CHARTING A RETURN TO 'WAY OUT THERE' RESEARCH AND RISK-TAKING AT THE EDGES

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Government-University-Industry Research Roundtable Meeting
June 14-15, 2011

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The U.S. has a long and impressive history of fostering "way-out-there" research followed by "neck snapping" practical results. There are many examples, ranging from the high- impact inventions of individuals like Edison, to computers, the space program, and the Internet. In recent years however, there has been an increasing sense that the U.S. is in danger of losing (or has perhaps already lost) its "mojo" in high-risk, transformative research with resulting high payoff results. The GUIRR meeting presented some recent success stories of transformative R&D in government, academia, and industry. In addition, speakers considered lessons learned from the successes and failures of U.S. R&D over the years, with the purpose of identifying both the kinds of innovative partnerships and mind-set needed to rekindle our mojo in a new technological renaissance.

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An opening presentation was provided at the dinner on June 14 by **Regina Dugan**, director of the Defense Advanced Research Projects Agency (DARPA). Her talk, "The Department of Mad Scientists," considered some of the factors behind DARPA's previous and current successes. One key factor is the wholehearted institutional acceptance of risk by DARPA at a project level as an inherent fact of life in transformative research with breakthrough military applications. A short video "trailer" was presented that impressively illustrated the DARPA philosophy on risk, contrasting the early rocky beginning of the U.S. space program and its dramatic "failures", with the Apollo 11 lunar landing a decade later.

Dr. Dugan emphasized that DARPA research is not research for the sake of fundamental knowledge. The focus is rather on needs-driven blue-sky research at the intersection of Pasteur's Quadrant (the intersection between basic research – both "pure" and use-inspired – and applications-oriented applied research). At DARPA, the lines are thus blurred between basic and applied science. DARPA research is not done in-house, but rather by contractors in outside institutions and companies. The research is conducted with a strong sense of urgency and with highly compressed time frames. Most of the programs have cascading implications in society.

The currency of DARPA is national security on a broad range of fronts. Examples given were rapid production of vaccines, mach 20 hypersonics, and fully homomorphic encryption, where operations are performed on fully encrypted data, without first decrypting it. DARPA is prepared to consider some very "outside-the-envelope" ideas, like the possibility that biological sensors like those in bird navigation are governed at least in part by quantum physics, rather than wholly by classical physics.
The institutional management of DARPA buttresses the above research philosophy. There are no entitled programs. Program managers come from outside institutions with limited tenures in DARPA (3 to 5 years). These managers must be at the top of their game, good communicators, and good executors. Moreover, they must have "fire in their bellies" and be determined to make others see what they see. Other essential ingredients are continuity of defense funding, eliminating automatic go-no go decision points for projects, and granting considerable latitude of program managers to exercise their best technical judgment.

Dugan noted that DARPA's relations with academia have been mixed. Some key ingredients in successful interactions are the building of trust, a sense of shared service to the nation, and protection for basic research in all contracts.

The meeting continued the next day with a presentation by **Dean Kamen**, inventor of the Segway® and numerous medical devices, and President, DEKA Research and Development Corporation. In his talk, "Grasping the Future," Kamen emphasized that a progressive increase in risk aversion in the United States has developed over the past several decades, with a highly adverse effect on the current pace of transformative research and resulting applications. He contrasted the 'anything but safety' philosophy of DARPA with the safety-oriented low-risk approach of the FDA and other agencies. He stressed that the problem is not the agencies that inevitably respond to prevailing public attitudes in a democracy. Rather he attributed the risk-averse nature of many agencies to public expectations that new innovations be effectively risk free, where a very small level of perceived risk can outweigh even very large benefits of the invention.

In the case of the FDA, Kamen asserted that half of the innovations (under FDA oversight) we have today would not exist if the FDA of 30 years ago were what it is today.

Kamen said that an insistence on zero risks for new innovations ultimately means that nothing can be invented and introduced into use. He used the recent development by DEKA of prosthetic arms for DARPA to contrast DARPA and FDA approaches. DARPA set what he initially believed was an impossible two-year goal of a fully functional prosthetic arm weighing only 9 pounds and able to function like a natural arm. He met the hardware goal for the arm (with 14 active degrees of freedom) in one year and, about a year later, the achievement was usable by bilateral amputees with only 10 hours of training. Although existing hook type arms have a class 1 FDA classification, the DEKA prosthetic was given a class 2 level of risk by FDA (e.g., like dialysis devices). In Kamen's estimation, the robotic arm is less dangerous than a hook type prosthetic, yet it has been stymied by the classification and thus kept out of use.

Kamen then discussed the FIRST program (For Inspiration and Recognition of Science and Technology) to encourage science and technology in youth ranging from secondary to high school. He noted the inventiveness of even the youngest participants, citing a team invention that involved the use of a beanbag to enable a young girl born without a hand to grasp an object like a crayon.

The next talk, "Catalyzing Energy Breakthroughs for a Secure American Future" by **Arun Majumdar**, discussed the new ARPA-E in the Department of Energy, which is broadly modeled after DARPA. Dr. Majumdar is the director of the ARPA-E (Advanced Research Projects Agency-Energy) program.

He emphasized that the ARPA-E program does not aim at incremental improvements, but rather the investigation of blue-sky approaches, ones with potentially transformative impacts on U.S. energy security and energy economics. There is an upfront acceptance of inherent risk with the funded efforts: there is no guarantee that any given technology will ultimately prove economically and/or technologically practicable. He gave several examples of technology development programs that are being funded under ARPA-E:

- Use of non-photosynthetic microbes that are 10 times as efficient as photosynthetic microbes in energy conversion. (He noted that natural photosynthesis is only one percent efficient.)
- Grid level power conversion in 100 pound suitcase-sized units, instead of 10,000 pound units. (He noted that a high proportion of transformers are currently being imported from China.)
- Rechargable, high- efficiency lithium-air batteries with very high- power densities (approaching that of gasoline).

Next to speak was **Thomas Cellucci**, chief commercialization officer in the Science and Technology Directorate, U.S. Department of Homeland Security, who discussed commercialization approaches at DHS. His talk "It Ain't Business as Usual at DHS S&T", focused on ways that the government can expedite the development of new technologies and products. Dr. Cellucci said that while the U.S. is still the leader in innovation and invention, it is no longer the leader in commercialization. The commercialization problem is not one that can be fixed by spending more money, but rather requires a change in approach. A key initial step is for agency program managers to clearly state the problem that needs to be solved. He contrasted the familiar government acquisition model with a requirements based approach. In the former case, the government specifies the detailed characteristics of the product or system, thereby highly constraining the development effort and final product. In the second requirements based approach, the government specifies the performance characteristics of the product in a very broad way, at the level of what it must do (e.g. the problems it must solve). It is the job of industry to come up with a solution that meets the requirements. There is no guaranteed commercial market in the second case. It is ultimately up to industry to find commercial markets. But products developed in response to broad requirements are more likely to have subsequent commercial uses. An example is the potential use by police of security related monitors initially developed for government use.

Christopher Monroe, professor of Physics at the University of Maryland, College Park, spoke next on the subject of "Pushing the Envelope with Quantum Technologies." Professor Monroe emphasized that quantum devices for cryptographic and computing applications are currently speculative, and there is no guarantee that they will ultimately pay off. One major incentive for the research is the virtual certainty that Moore's Law will not continue to hold 20-30 years from now, when the size of computational elements inevitably approaches atomic dimensions.

In the area of cryptography, one potential quantum application is to send, via quantum entanglement, a decoding key consisting of a string of random numbers which are nevertheless correlated at two distant locations. Although the number string is random and no information is accordingly sent, the resulting random number string at the distant location is correlated with the string at the sending location. This mathematically allows the sending of a decoding key.

Another possible application is in computing where a quantum calculation of "all possible solutions" to a given computing problem can in principle be "filtered" to result in a unique remaining answer containing the desired computational result. Quantum computers are relevant to cryptography, since they have the potential to factor very large numbers, a property which would enable the breaking of coded information.

MODERATED PANEL DISCUSSIONS WITH GUEST SPEAKERS. The speakers spent most of their time discussing why a more innovative mind-set is not prevalent in the U.S. at-large and how such a mind-set might be fostered. Michael Belfiore (a speaker scheduled for after lunch) emphasized the need to make better use of existing communications and entertainment networks (e.g. Internet, TV, magazines) to better connect with the real lives of people. Thomas Cellucci emphasized the need to never give up (e.g., in spite of obstacles at the national level) giving a personal example of success with his autistic son. Dean Kamen stressed the need to market innovation to youth and society at large through a wide variety of venues (e.g., FIRST). He said that the greatest enemy of our future success as a nation is our previous success, and our

tendency as a nation to live off our previous investments as technology consumers, rather than being innovators. He noted that winners of Intel competitions are celebrities in immigrant newspapers.

Vivek Wadhwa gave a presentation during the Roundtable lunch on "Myths in the Debates about Innovation and Competitiveness." Mr. Wadhwa is a tech entrepreneur, academic, researcher, and writer.

In his talk, Wadhwa took issue with a number of widely held views regarding innovation and competitiveness, some examples of which include:

- *Questionable nature of a lot of information on foreign trained engineers.* In the case of China for example, the numbers of engineers being graduated is highly inflated and misleading due to the excessively broad definitions used for engineers, said Wadhwa.
- *Nature of China's innovative efforts.* Wadhwa suggested that China is effectively pirating Western-developed technologies on a massive scale, disregarding intellectual property laws.
- *Lower labor costs, not relative engineering or production competence is currently the primary source of the competitive advantage for engineering and manufacturing in developing nations*, he asserted.
- *Clusters do not work, contrary to hype.* Wadhwa asserted that technology clusters have never really worked in practice, in contrast to their hype and funding over the years.
- *More funding for basic research does not lead to more innovation.* A number of factors are required for successful innovation, said Wadhwa. For example, university technology commercialization arms commonly try to squeeze every cent they can out of an invention, out of the fear that they would be criticized for extracting too little value from a new technology resulting in say the next Google. This stifles extraction of commercial value from university research, he posited.

Another problem is that professors with commercially viable patents are often denied tenure as a result (e.g., out of professional jealousy). The challenge is to make the university system work better.

In summary, Wadhwa said that government cannot foster innovation, but can help by removing bureaucratic obstacles. It would be better for universities to give away their technology for free. "R&D does not by itself lead to innovation." He also said that more immigration would help (there are about a million individuals currently waiting for permanent-resident visas in the United States, and the backlog could result in a sizable future brain drain to other countries).

The final presentation on "Innovative Government-Private-Academic Partnerships for Technology Breakthroughs" was given by **Michael Belfiore.**

Mr. Belfiore is the author of *The Department of Mad Scientists* and a contributing writer to *The New York Times, Scientific American* and other publications. He is an optimist on America's prospects, and believes that the United States is "on the verge of a technological renaissance" comparable to the one following the initial Russian Sputnik. According to Belfiore, the United States has never really lost its mojo.

In the old days, one had a massive one-shot Apollo program, he noted. In contrast, the newer approach is for small teams consisting of innovative partnerships of public and private participants (G-U-I) which leverage the strengths of different types of organizations. The goal is sustainable R&D which results in new business and business revenues.

People are turning towards the DARPA approach which includes permission to fail, term limits for managers, small innovative teams created around a challenge, contractor-driven R&D, and focus on attaining new capabilities.

Belfiore cited the leveraging effect of competitions driven by prize money, such Google's Lunar X-Prize purse of $30M for the first team to successfully accomplish an autonomous lunar landing, including bonus money for accomplishing various additional objectives (e.g. high resolution photos of the original Apollo landing site). The goal is to give space travel a solid commercial (as opposed to government) footing, thereby leveraging NASA and creating new sources of revenue (e.g., space tourism). NASA is interested in buying technical data resulting from the various team efforts, thereby leveraging its own programs. Another example, said Belfiore, is DARPA's urban challenges for autonomously driven vehicles, with competing teams with corporate sponsors. The competitions are resulting in new technological capabilities.

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