NEUROTECHNOLOGY: ENHANCING THE HUMAN BRAIN AND RESHAPING SOCIETY

SYMPOSIUM REPORT
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EXECUTIVE SUMMARY

The Potomac Institute for Policy Studies held a seminar on "Neurotechnology: Enhancing the Human Brain and Reshaping Society" on June 30th, 2014. Neuroenhancements can maximize our physical, cognitive, innovative, and technological potential as a society. The panelists in attendance included Dr. Amy Kruse (Vice President, Intific), Dr. Jonathan D. Moreno (Professor, University of Pennsylvania), Dr. Gerry Yonas (Mind Research Network, University of New Mexico), and Congressman Chaka Fattah (D-PA). The panelists drew from their experience in industry, government, and academia to discuss current neuroenhancements, the future of the field, and policy solutions. The speakers emphasized the further enhancement and development of neurotechnology with the support from both the private and public sector.

In his opening remarks, Mike Swetnam called for greater investment in neurotechnology, an endeavor that should match our past investments in nanotechnology and information technology. In the future, neuroenhancement will be as widespread as today's computing technologies. Our society and economy is heavily based on the computerization of information through powerful computer chips. A continued progression into the Digital Age requires further strengthening of the field of neurotechnology.

Congressman Chaka Fattah emphasized the great transformative potential of neuroscience on our lives and our society. Congressman Fattah outlined how neuroscience will solve diverse sets of problems, from curing dementia and other brain-based diseases to creating new industries and bolstering the economy. Congressman Fattah applauded worldwide efforts in neuroscience research and called for continued cooperation to solve these problems.

Dr. Amy Kruse highlighted the role of the private sector in developing new neurotechnology and bringing neuroenhancements to the everyday consumer. Dr. Kruse believes that the current market is ready for neurotechnology: the commercial world has poured a lot of money into neuroscience. However, we need a rigorous, tested set of technologies and a set of trusted providers. The government should encourage and provide the necessary research and funding to develop the applied neurotechnologies that fit into this framework.

Next, Dr. Jonathan Moreno pointed to the immense growth of excitement surrounding neuroscience over the past few years and its potential to affect society. Dr. Moreno detailed the rich history of enhancement in neuroscience, including the CIA interest in the "Mind Race," investigations into oxytocin, and the development of transcranial magnetic stimulation. Dr. Moreno's numerous examples helped to illustrate the many ways in which neuroscience has already and will continue to enhance our lives. As a professor of bioethics at the University of Pennsylvania, Dr. Moreno explained several of the ethical dilemmas that may arise from these new technologies including the issue of cognitive liberty and reversibility.

The final speaker, Dr. Gerold Yonas, addressed the ability of neuroenhancements to revolutionize treatment and improve lives. Dr. Yonas focused on how electrical and magnetic stimulation can enhance and restore brain function. He described how increasing slow wave sleep time or using

stimulation to induce specific brain activity would improve cerebral blood flow and the ability of the brain to respond to stress. He also discussed the applications of transcranial stimulation (in both direct current and alternating current forms) and how research and proper investment can improve the safety and function of these neurological tools. Lastly, Dr. Yonas discussed the potential for neuro-systems engineering to transform our interactions and roles in society.

The panelists convened to discuss neurotechnology and to take questions from the audience. The discussion covered health topics including the value of sleep and how to improve it, treatments for migraines, and curing Alzheimer's disease. The discussion hinged on the respective roles of business and government regulations. How do we ensure that neuroenhancements are rigorously tested and validated? The conversation also included discussion of how scientific progress can be hindered by government regulation and control. Neuroscience, like the Internet, is advancing quickly and a balanced approach to regulation is necessary.

Dr. Jennifer Buss highlighted how policy solutions for neuroenhancement can address the field of neuroscience as a whole. She called for expanding the BRAIN Initiative into a National Neurotechnology Initiative. The coordinating and oversight power of the initiative would be placed within the National Science Foundation. There is great potential for neurotechnology, and increased government funding, inclusion of industry, and developed research focuses will make this potential a reality. Neuroenhancements will provide new means of communication, learning, machine control, and medical treatment, all while spurring new industries and job creation.

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

THEME #1: THE ENHANCING POTENTIAL OF NEUROTECHNOLOGY

FINDINGS:

- **Neurotechnology is becoming a part of our society.**

  Neurotechnology is not just a futuristic proposition anymore. Our society is adopting a brain-focused outlook through research into transcranial direct current stimulation (tCDS) and transcranial magnetic stimulation (TMS), neuroenhancement drugs, and neurostimulation devices for hobbyists. People are attending neurotechnology conferences in greater numbers, and the private sector is taking notice. There are more and more neuroimaging and neurostimulation devices on the market every day. Neurotechnology is still in its relative infancy, but it is enhancing education, communication, intelligence, cognitive ability, disease treatments, and the military.

- **Collective findings from neuroscience big data are changing our understanding of the human race.**

  The more we know about the role of the brain across different levels of social interaction, the more we can design our systems around this knowledge. We are gaining information about normative brain states as well as individual differences. Collective human performance is being enhanced by neurotechnology. This technology is creating a powerful system that is able to simultaneously monitor function of many individuals, monitor function of many individuals, coordinate resources, quantitate cognitive load, and improve social order. On the individual level, we are more able to interface with our own biology.

CONCLUSIONS:

- **Enhanced social systems and empowered individuals will transform society.**

  Neurotechnology has great potential to improve the performance of our nation, economy, security, and military. Neuro-rehabilitation and neuroenhancement will be the best options for addressing needs in our lives, behavior, and cognition. At the same time, the social implications of enhancements and claims about their utility could lead to increases in addictions, competitive pressures, and conflict about unequal access as a result of socioeconomic inequality. For better or for worse, neurotechnology is going to enter society, so we should ensure that each of its impacts are positive.

- **Neurotechnology will converge with other scientific revolutions to enhance humanity.**

  Computing, artificial intelligence, nanotechnology, biologics, and now neurotechnology are fields that are reaching new heights and becoming intertwined. The government will need to play a more involved role in order to stay on top of these trends. The synergistic nature of these advances means that new paradigms and technologies for enhancing humans will develop at exponential rates. As a case example, neurological medicine will be transformed by big data analytics of large populations, nanoscale therapies, and improved neurotechnologies for imaging and treatment. An ever-growing knowledge base and the capacity to capitalize on that knowledge and enhance the human race will become the norm.

RECOMMENDATIONS:

- **The US should become the definitive leader in neurotechnology.**

  Demonstrating leadership in research, technology, and strategic direction will ensure that we can make great progress in neurotechnology. With leadership that understands the importance of managing and nurturing a strong neurotechnology industry, we can achieve this by dedicating time and resources to understanding the full scope of neurotechnology, from its potential for societal-level enhancement to its influence on the individual. Our leaders should recognize that it is for the good of our society to give people safe and well-researched options instead of leaving them with no choice but to choose unregulated and dangerous enhancements.

- **Utilize a framework for evolving and growing neurotechnology.**

  The government should engage as often as possible to coordinate with researchers, the market, and the public. Building up neurotechnology requires a multi-faceted approach that includes enabling business startups, funding solid research, and regulating product safety. Even without government input, the market will drive the creation of novel neurotechnologies. Therefore, it is imperative that the government becomes involved as quickly as possible so that it can actually have a voice in the conversation.

THEME #2: THE MARKET DRIVERS OF NEUROTECHNOLOGY

FINDINGS:

- **The industry for neurotechnology is growing independently from government funding.**

  Similar to computer science, the Internet, and other technology industries, neurotechnology is developing on its own without significant governmental funding and influence. The industry is receiving support from venture capital and research and development organizations that take the technical and scientific risk off of the table. As events like the Neurogaming Conference grow in size, neurotechnology gains attention from businesses and investors who are often more concerned with profit margins than the overall benefit to society. Because the government is not investing heavily in neuroscience research and development, its role in protecting our society's wellbeing is not represented in the market right now.

  There is a growing demand for neurotechnology and interfaces that can enhance the human body.

  The demand for neurotechnology and brain computer interfaces has already outpaced the supply of goods. Allowing physicians and other licensed professionals to prescribe these devices off-market would encourage demand in a *de facto* manner and legitimize the need for supply. Demand is only going to increase as more and more people recognize the emerging benefits of these neurotechnologies.

CONCLUSIONS:

- **Coordination between the government agencies and industry will benefit the neurotechnology market.**

  Government and industry have individual strengths and capabilities that can be bridged through a coordinated effort: the government is well equipped to establish regulations and provide large-scale investment while industry excels at innovation and technology development. It is vital to ensure that these processes are occurring in tandem rather than independently and at odds with each other.

- **Increased government funding and continued venture capital support will expand the neurotechnology industry.**

  Increased financial support behind neurotechnology will promote research and development in the field. The interest of venture capital groups can continue to be increased with frequent and large public events such as the Neurogaming Conference. The federal government is uniquely qualified to allocate funding and provide oversight that enables innovative companies and researchers to produce neurotechnologies.

RECOMMENDATIONS:

- **Government assistance to industry should be swift.**

  The federal government, specifically the NSF, NIH, FDA, DoD, DoE, and the White House should contribute funding and resources to neurotechnology. Doing so would ensure the direction is in the favor of public safety and innovation occurs at the quickest rate possible. An investment that matches the scope and commitment of previous government initiatives like the Manhattan Project and the Apollo Program will lead to success.

- **Government should coordinate its efforts with and within industry to lead a successful neurotechnology initiative.**

  The federal government should create a coordinating office for a national neurotechnology initiative. It needs to mediate the competing interests of industry, government, and society. It must oversee the combined investments in neurotechnology research and development across government agencies. This coordinating office will serve as a forum for communication and dialogue that keeps the private sector and public sector arms of neurotechnology in lockstep with each other.

THEME #3: IMPLEMENTING SUCCESSFUL NEUROTECHNOLOGY REGULATION

FINDINGS:

- **Guidelines for neurotechnology development do not exist.**

  The people who are using neurostimulation devices on their own do not have user manuals, standards, or guidelines. This trend will only become more apparent as more technologies are developed. Without this information, many people will be unable to differentiate between pseudoscientific offerings and reliable, safe products. Some companies and research institutions create their own guidelines for safety and regulation. These guidelines may be sufficient on an individual level, but do not contribute to a unified and coordinated system of regulation. The FDA's previous attempts to regulate devices, such as the Fisher Wallace Stimulator, focused solely on safety criteria and placed no emphasis on efficacy.

- **Misguided regulation can inhibit innovative research.**

  Federal regulations of research efforts such as Institutional Review Boards control the timeline of research development and the types of research conducted. Regulations always intend to protect the rights of the individual. Public sentiment plays a large role in determining federal action. Therefore, science policy decisions are often influenced by ethics and politics rather than the direction of scientific research. Leaders at research institutions and their ethics boards select projects that do not incur risk, ensure guaranteed funding, and avoid controversy in the public eye. This sometimes means that research institutions will avoid projects that are ethically sound, but economically and politically risky. In the early 2000s, embryonic stem cell research was restricted, causing researchers to either refocus their efforts on less restricted projects or pursue research outside of the United States. A large secondary impact of this political process is that the nation's young innovators, scientists, and students are discouraged from pursuing a career in such a restricted field.

CONCLUSIONS:

- **A balanced regulatory approach will be the most successful.**

  There are striking concerns with neurotechnologies, especially when they can cause direct and undue harm to individuals. There must be a regulatory body that protects individuals from dangerous technology. On the other hand, overzealous regulations, limits, and bans will harm the research institutions and private companies that are trying to devise innovative technologies. Regulations that play a role in shaping progress and innovation will be key to a healthy neurotechnology field.

RECOMMENDATIONS:

- **Promote technologies that provide the greatest social and scientific benefit.**

  The government should build up a middle space between commercial ventures, basic science research, and government oversight so that open discussion between interested parties can occur. It should provide support and resources to companies and research institutions that take the time to demonstrate and validate safety measures. Conversely, actors that create damaging devices should be constrained. Both activities are crucial, but it is important to show that they build an overarching narrative: neurotechnology can transform our society for the better if government, research, and business collaborate.

- **Base federal regulation and policies on scientific findings.**

  There should be a federal commitment to staking out a primary role in regulating novel neurotechnologies. The decision-making bodies for this activity should be comprised of agencies that can provide solid science-based advice, such as the FDA. Research institutions should be encouraged to take experimental risks, as long as they follow ethical guidelines. Safety parameters need to be established and modified by a dynamic research process. The research institutions can collaborate with federal agencies to complete this mission. The government should create regulations that do not slow down the process of building technologies, but it should provide opportunities for the

public to participate in informed decision-making and safeguards. Innovative products can be evaluated on the basis of safety and ethical quality without discouraging the development of truly revolutionary technologies.

EVENT TRANSCRIPT

MICHAEL S. SWETNAM

Introduction

I am Mike Swetnam, the CEO of the Potomac Institute for Policy Studies. It is my honor and privilege to welcome you here today to the Potomac Institute to talk about neurotechnology. The Potomac Institute has been involved in the study of neurotechnology and neuroscience for almost 14 years. Almost a decade and a half ago, we were charged by Congress to study the future sciences and technologies that might revolutionize human affairs. That effort, called "Out of the Box and Into the Future", came up with a list of technologies that we thought were going to change the human race in ways akin to the printing press, advanced transportation like trains and airplanes, and the internet and digital technology. Even today, digital technology is still radically changing the way everything happens worldwide. The Internet changes the way we think, live, do business, and more.

So what is going to happen next? What are the next big technologies that are going to affect our society? In 2000, the Potomac Institute delivered a report to Congress that listed some of these technologies. Most importantly, it noted that neurotechnology - the study of the brain and the implementation of technology that involves the brain - was already impacting our society. We stated it would create impacts at least as profound as those that Internet technology was producing at the time. Fourteen years later, this is still the case. Internet technology is continuing to impact the human race, and neurotechnology is catching hold in more ways than many people even realize. Not everyone realizes that neurotechnology products are available today and they extend far beyond prostheses and devices to measure activity inside the brain. There are game interfaces on the market today and novel technologies that will radically change way we live and work. The impact of these technologies reaches far beyond medical and research applications.

Fourteen years after we completed the report for Congress that identified neurotechnology as one of the biggest influences on the human race in the next 100 years, we still do not have a major neurotechnology investment in the United States government to bring this about or help it happen yet. We have made major investments in the past: manufacturing technology that instigated the Industrial Revolution, investments in NACA and NASA that created the airline industry, and massive investments in microelectronics technology that brought about transistors and integrated circuits for our computers. What great technology would we create if we had a major investment in neuroscience and neurotechnology?

We here at the Potomac Institute are involved in a follow-on effort to the 2000 effort. In 2006 and 2007, the Institute was sponsored by DARPA to look at the necessary investments for

making neurotechnology advancements happen sooner. We created investment roadmap. This neurotechnology report is available to you (http://www.potomacinstitute.org/attachments/article/2970/Neurotech%20Futures%20Studyweb.pdf). Most of that work was finished 7 years ago and we have updated it recently. It lays out an investment portfolio that the government could choose to invest in. That report outlines an investment portfolio equivalent to our investment in space and the airlines industry, an investment equivalent to the investment that the United States government made in digital technology and microelectronics that gave us cell phones and computers.

Last year, the President announced the BRAIN Initiative, which seeks to map the networks and the connections inside the human brain. The President's Initiative is a great start. It is an investment in just a few of the areas that are necessary to make this revolution happen. Here at the Potomac Institute, we are trying very hard to emphasize science and technology that affects policy and policy that drives science and technology in ways that are good for the human race. We strongly advocate that the government, Congress, and the executive branch sponsor and fund activities on the order necessary to help the neurotechnology revolution actually happen.

In 1975, we talked about computers as great big things that filled a room and did mathematics. Computers helped calculate the trajectory of missiles. Computers helped scientists work on their formulas. Computers literally occupied an entire room and people looked at computers as advanced computing devices, a big calculator. During that time frame there was an enlightened engineer named Frank Garcia that published a magazine called Byte Magazine. He believed that everyone would eventually have their own computer in their home. The world thought that he was absolutely nuts to say that people would not only have their own computer, but that they would have a use for it. What would you do if you had your own computer? Would you be able to pay your bills a little faster and be able to calculate how much interest you owed on this or that? What else could you do with a computer? Back in 1975, he wrote about how computers could learn to do much more than just add, subtract, and multiply. When we learned how to program computers, we would probably learn how to change our entire society and operate with computers.

Today, as most of you know, we have far more than one computer for each one of us. Each one of you probably owns a dozen computers: your car, your cellphone, your actual desktop computer. Modern refrigerators today have computers in them. I wanted to emphasize this point with a little story from yesterday. We bought a brand new dishwasher and one of the best things about it is that you just put dishes in it, press Start, and it does all the rest by itself. Yesterday it stopped working. The dishwasher had a readout message that said: "Dishes overstacked". Just by moving a few dishes inside, the dishwasher was able to continue operating. That intrigued me enough to read the manual. It turns out that this is a computer-controlled dishwasher. It knows what I put in it. It has lasers that actually sense whether there are pots and pans and how much gunk is on the pots and pans. It changes its cycle based upon what I put in it. Who could have imagined in 1975 that first, I would be doing the dishes and second, that a computer would remind me that I was too stupid to stack the dishes in there properly?

The impacts of technology are very difficult to envision today, but back in 1975, there were people who understood that computing technology was going to change everything. These

enlightened people, some of whom are sitting here today, were in leadership in the government at the time and advocated for major investment in science and technology that made computing technologies possible. We cannot even envision today what neurotechnology is going to do to the human race. When we talk about an investment to try and make neurotechnology help us solve some neuro diseases and we invest via NIH, we need to understand that this is far bigger than that. This could be one of the biggest things the human race has ever invested in. This deserves more than our attention: it deserves our dollars and it deserves our support. Thirty years from now, our children will be looking back at this discussion and will laugh about how we did not understand how neurotechnology was going to change everything. I would like to think that this room is full of people who do understand the importance of this technology. It is an enhancing technology: enhancing the human race, enhancing the way we think, and enhancing the way we do things.

In 2000, we wrote about how technology had come along to give us new tools. When we invented the wheel, it was a tool for moving things. When we invented the printing press, it was a tool for communicating ideas. When we invented manufacturing at the turn of the century, it was a tool for proliferating devices and updating our economy. Neurotechnology could very well be the first invention that delves into how we use tools and how we interface with our brain to use tools. This is the most important thing the human race has talked about in a long time and I want to do my best to emphasize that this is something we all need to discuss, think about, and research further.

While my remarks have run a little long, I do want to make it clear that this is something that I care about very deeply and I think is a very important focus of the Institute. Today, neurotechnology is essentially in its 1975 moment. I want to look back at today 30 years from now and see that we had a little bit of the vision of what neurotechnology could be. Dr. Jennifer Buss is the director of the Center for Neurotechnology Studies and it is time that I turned the program over to her so she can say a few opening words and introduce one of our Congressional leaders who understands and shares this vision.

CONGRESSMAN CHAKA FATTAH

Opening Remarks

First of all, I would like to thank the Institute for hosting this seminar. Moreover, I thank the Institute for its work over the past decade and for showing us how important neurotechnology is to our future. Our current Information Age and the future effects of nanotechnology and biomedical technological advancements cannot remotely occupy the transformative space that neuroscience represents. In addition to the work that the Institute has done, Dr. Philip Rubin at the Office of Science & Technology Policy has done an extraordinary job leading and developing the BRAIN Initiative. To sit in the East Room of the White House and to hear the President say that neuroscience is a priority was a very encouraging experience. It is because of Philip Rubin's extraordinary leadership that we are engaged in mapping the brain and joining our efforts around that goal. I want to thank him for his commitment to public service and for the great work that he has already done on behalf of so many others.

I have been around the block a little bit on this topic. Some of you may have heard when I spoke in Tel Aviv at the Israel Brain Technologies conference or when I spoke in Australia (via technology) at the Society for Brain Mapping. I am convinced that we are on the right path, especially now that we have increased United States government focus on the issue. The Potomac Institute and others have a plan moving forward to do even more for neuroscience and I think that this is correct. You will see that this year's Appropriations Bill presses OSTP to do more, particularly in terms of neuroimaging. Recently, I visited Stanford and met with Dr. Newson. I thanked him for the great work he has done. It was clear through the discussion that we need to understand the basic elements of a brain map and understand how these neural circuits work. To make an impact, we must have at least a theory of how everything interplays. Once we have that theory, we are armed to perform scientific experiments.

The President correctly laid out the BRAIN Initiative to focus on technologies. We do not have the capacity to see, chemically or electrically, how the trillions of neural connections in the brain actually function. Even implementing big data and our most powerful computers leaves us unable to simulate what occurs between our ears. Whether it is Henry Markram and the Human Brain Project or others tackling the issue, mapping the brain will be a great a challenge. This challenge is one truly worthy of our great nation. When John F. Kennedy went to Rice University in the early 1960s, he said, "We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard". Taking this same view, understanding how our brains function is not only a scientific challenge, it is also an absolute necessity.

Dementia is a global epidemic. Looking at the global population dependency ratios and the effect of the disease on global economies, it makes sense when people like David Cameron see dementia as a G8 priority. Wall Street has figured that out, along with millions of unfortunate families. Over 5 million families in our country are suffering because of Alzheimer's disease. To tackle this problem, Chris Smith and I worked together to pass some language in the Appropriations Bill that takes a global front on Alzheimer's disease. The bill is modeled after the Global Aids Fund and works to turn that idea into law.

Alzheimer's is an important disease to address, but it is just one of some 600 plus brain diseases and disorders. All within the same paragraph, we have to admit that we do not know exactly how these diseases and disorders come about, that we do not have any effective treatments, and that we do not have any results in a third phase clinical trial that offer solutions. This is true whether you are discussing dementia, epilepsy, or the whole range of diseases and disorders. We need to make a lot of progress. The NIH says that 15 million Americans are suffering from brain-related diseases and disorders. The World Health Organization estimates that there are over a billion people worldwide with a neurological disease or disorder. So you have a gigantic task in front of you. It is a worthy effort for us as a country and for other nations throughout the world. It is not the sole responsibility of our scientific organizations. Governments have to dedicate themselves to this activity as well.

It is great to see the ongoing research and accomplishments of the Human Brain Project, our own BRAIN Initiative, and the work that is being done across the globe. We need to meld these efforts together in ways in which we can all cooperate and coordinate between different research directions. It is important to remain open to novel approaches that can address our issues from

different angles. I wish you well as you delve into this grand challenge to treat disease, enhance the human brain, and transform society. Thank you for having me.

PANEL

The panel brought together a set of distinguished speakers to discuss the future of neuroenhancement and the role policy will play in its development. Innovative neurotechnologies will come from both the private and public sector. Their advancement should be greatly encouraged and smartly regulated to ensure public safety and efficacy. Novel neurotechnologies will enhance our cognitive abilities through biological, chemical, and sensorimotor means. These technologies will enter the market and will become as pervasive as cellphones and computers. Neuroenhancements will go past solving our medical conditions; they will collectively transform and enhance society. Neurotechnologies like transcranial magnetic stimulation will address medical conditions such as sleep disorders, but these technologies will also improve cognitive function by maximizing the overall quality of sleep. Collaboration between neuroscientists and others in research, business, and safety regulation will result in highly effective neuroenhancements.

The panelists discussed their concerns with a neurotechnology industry that is growing faster than the regulatory power of the federal government, but they also considered the danger that regulation can inhibit innovative research and stymie scientists from entering the field. Dr. Jonathan Moreno added to the conversation by detailing the history of neurotechnology and bioethics, while Dr. Gerry Yonas prescribed predictions for future technology, leadership in the field, and regulatory processes. By discussing the past success and failures of large science initiatives and companies like Fisher Wallace, the speakers established the framework of actors contributing to neuroenhancement efforts. The field of neuroenhancement has a tremendous need for increased funding and federal support, which can be accomplished by expanding the BRAIN Initiative into a National Neurotechnology Initiative.

AMY KRUSE

The Great Potential of Enhancements

I would like to thank Mike and everyone at the Potomac Institute for their continued leadership in the field of neuroscience. As Mike mentioned, I came straight out of academia and worked in Washington, DC in the field of neurotechnology. At that time, neurotechnology was absolutely a new exploration, particularly for the Department of Defense. The DoD became very interested in employing neuroscientists and I was recruited from Illinois.

From 2005 to 2010, I was at DARPA and had the privilege to start seven programs in the field of neuroscience. Many of these programs were related to human performance, which is a piece of the enhancement theme. As a society, we can rally around this. Neurotechnology is not just about medical restoration and repair, but it is also about performance that is vital to the nation and to the military.

After DARPA, I went to work for a software company, which was a natural transition from my position as a program manager. Neurotechnology was lacking in one space, and that space was application. Through software, we were able to do something with what we had learned. We had piles of research, lots of great hardware, and all kinds of toys that really needed to be brought to together. At Intific, I have been working with that very task. We are also looking at how large industries are going to view neuroscience in the future.

I have been a neuroscientist for two decades. I am here now to report from the front lines of neurotechnology. As a citizen and neuroscientist, I was ecstatic when I heard about the President's BRAIN Initiative. Standing in the White House and hearing the President talk about neuroscience and the brain was beyond anything I could have imagined. On the other hand, as a businesswoman and neurotechnologist, I wanted more. I wanted to take it one more step, to where we are headed with neurotechnology. Those of us on the front lines of neurotechnology and business must think about this future. The great potential of neurotechnology is not an impact on individual lives, but its ability to impact the military, national security, and new industries. We want the results of these decades of work to make it into the hands of users, consumers, patients, students, parents and our military.

In 1975, it was inconceivable that each one of us would have a computer in our house, but now we have that ability everywhere we go. I have repeatedly mentioned that theme when I talk about neurotechnology. Soon we will know a lot of information about our individual brains, not just information in studies, published papers, and collective research. I coined the term applied neuroscience or operational neuroscience, while at DARPA, which takes research from the lab and into the field, home, and everywhere else. We are on the verge of losing our voice in this discussion. The market is much more impatient than we are, in terms of funding and policy. The market will not wait.

I recently spent three days at the Neurogaming Conference, hosted by the Neurotechnology Industry Association. Last year, I went to the conference and it was small with around 300 attendees and 10 booths. This year, it had easily tripled or quadrupled in size. There was also no shortage of business people in attendance, who will not be patient for government funding. I think we are at risk. The market is ready, and as a larger neurotechnology entity, we are not.

I am grateful for the support that the venture capital world has given to commercial neuroscience. We now have an abundance of commercial EEG headsets. Unfortunately, venture folks care more about selling headsets than they care about technologies or benefits for society. In a similar vein to my transition out of DARPA into the software space, we need to build up the middle space between entertainment, commercial applications, and basic science research. We in the neurotechnology field must set the standards of rigor and validation that we would like to see in these applications. My colleagues and I will discuss the variations in rigor for different applications. The potential and appetite for enhancement are both great, but the assistance for trusted providers is lacking.

Where do these providers come from? They come from small and big businesses, funded by organizations like NSF and DARPA. We create these businesses. They are very dissimilar to the medical device industry. Without DARPA funding, we would not have the next generation

of prosthetics or the Google Car. It is the role of these organizations, military research, and development organizations to take technical and scientific risk off of the table, so that new products and industries can be created.

Let's look specifically at enhancement. I call it an off-label activity. The current market space for enhancement is comprised of a lot of the DIY community, desperate parents, and gamers. I would like to argue that enhancements should be more like a product sold at CVS or Walgreens, rather than products that are sold at GNC. Neurotechnology is in danger of going into this off-label, invalid space. I would prefer that the technology is rigorously tested, but maybe not as much as a $5 billion pharmaceutical. Again, if we do not act proactively, this technology will become the domain of the GNC world.

In my time at DARPA, I worked on the Accelerated Learning program. This program asked whether the brains of experts exhibit evidence of their expertise and whether you can take what you know about these experts' brains to change the learning trajectory of a novice. We did this for a variety of different tasks, the most successful of which was expert marksmanship. An expert marksman enters a brain state before he or she takes a perfect shot. In this state, the power of alpha wave activity is over the temporal lobe. You can use electrodes and an EEG headset to measure it before the shot is taken. It is very repeatable. This is the focused, concentrated "zone" common in archery, putting, and many other fields.

These are observable, measurable, recordable, and algorithm-ready phenomena. Knowing this about experts, we looked to see if it was possible to encourage a novice to enter this brain state and improve their performance. The answer is yes. Before taking the novices out to the firing range, we did a simple neurofeedback training task to create this expert brain state. Their shot group performance increased by over 100%, simply through brain training. Although this is a simple example, I like to think of it as a multi-billion dollar DARPA investment that is ready to be turned into a product. This product is backed by rigor, data, and evidence. It is ready to enter the market place. To me, this is a very sharp example of neurotechnology.

I could ask the same question about many other everyday tasks. This is the essence of neuroscience. It can be done across the whole space. We do not necessarily need to know all of the connections in the brain. Knowing the end state is not necessary to build technologies and applications that we can collectively use as a society. No one will find this information without funding and this research is far too expensive for a small business to take on. This will lead the venture funding into gadgets and not into their utility. As we hear about the great promise of neurotechnology, and particularly enhancement, let us do it within the framework and context of creating the National Neurotechnology Initiative.

Let's not do this in a way that is cobbled together, scraping only the dregs of opportunity. Let us be direct and purposeful. Let us set the agenda shaped by our hopes, our fears, our concerns, and all the rest that keeps us up at night. If we take a leadership position in this space, we will be able to realize the promise of neurotechnology for ourselves and for future generations.

JONATHAN D. MORENO

Military Uses of Enhancements

Thank you very much for giving me the opportunity to speak today. The first time I was here was about six months after my book, *Mind Wars*, came out. There were aspects of *Mind Wars* that made people wonder why a philosopher and historian would write at length about people who were worried about their brains being tracked by the CIA. I am a philosopher and a historian, not a scientist, neuroscientist, or physician. I am interested in how society integrates new science and technology. Everybody in this room has a deep and sophisticated perspective on the topics that I am going to cover today, so my goal is to present the story in a different light.

We are in the era of big neuroscience. The Congressman mentioned the recent Human Brain Project and the BRAIN Initiative in his remarks. I am grateful to hear his enthusiasm about neuroscience and technology. So, we are in an era of big neuroscience, just as we had an era of big physics with the Manhattan Project and an era of big genetics with the Genome Project. We have entered a new era. The growth of neuroscience is something that I often have to explain to people because it took off so suddenly. The metrics can be shown through the number of papers published or the number of people who attend the Society for Neuroscience conference, but they are all growing. The Society for Neuroscience now contains 40,000 people. Those are just the registrants, and there are still people like me who attend the conference as non-members. At the University of Pennsylvania, we have a neuroscience boot camp, which my friend Martha Farah runs for judges, lawyers, and journalists. There is an International Society for Neuroethics, of which there are about two or three hundred members. There is also a lot of excitement in the academic world, especially for people who want to run labs. Functional MRI is responsible for helping many of my friends in neuroscience keep their jobs, keep their post-docs employed, obtain funding for their investigations, and get new PhD students. The BRAIN Initiative is supplying $100 million of funding to neuroscience and DARPA is contributing a lot of money as well. How much money is being spent on the overlap between neuroscience and national security?

In my book, I cover a series of topics, but I always like to start with the history. With lay audiences, it is hard to talk seriously about it because we get hung up on anxiety over brainwashing and mind control. During the Korean War, Dulles and others were worried about our people who were signing false confessions and saying treasonous things at a much higher rate than previous conflicts. They were concerned that an ego-suppressant, LSD, was to blame. Albert Hofmann accidentally developed LSD while at Sandoz Labs. During his long lifetime, Hofmann got close to Timothy Leary and used LSD hundreds of times. Again, I am not a physician, but it did seem to be an enhancement for him.

In a formerly top secret document (one of the few survivors of the CIA era of interest in LSD antagonists), there is a record that $39,500 was used for research on LSD and LSD antagonists in 1953. There was also the famous MK ULTRA project, which had a bioethics component. In a bioethics course you will learn that the most important person in the history of American human research ethics was Henry Beecher, a Harvard professor. Beecher wrote an expose in 1966 about 22 unethical human experiments in the published medical literature. This was a blockbuster article. In my view, it had a much bigger influence on American research ethics, American medicine,

and American science than the Nuremberg Code did. Beecher was also a CIA consultant from the late 1940s. He used LSD as a control drug in his lab at Massachusetts General and in his anesthesiology research. Beecher also had a very complicated relationship with Timothy Leary, who he helped to get thrown out of Harvard in 1963.

There is a video that has been available on YouTube for about 10 years and seen by many of my undergraduate students. It details the British military's interest in hallucinogenics' effects on soldiers. This video was released from the Imperial War Museum, as part of a series about combined U.S. and U.K. activity. This exercise, conducted in the early 1960s, involved combined British, U.S., U.K, and Canadian efforts to determine if a hallucinogen could get into the drinking water. The drug was very disruptive to the soldiers. Interest in these kinds of topics was reflective of America in the 1970s, which was the era where we began to consider consciousness expansion and human potential.

By the late 1980s, there was worry about the Mind Race, which was led by the Soviets, and not a nuclear weapons gap, but an effort for advanced neuroscience. During that time, a committee was created to try and access the meaning of the Mind Gap for America. A report by the National Research Council stated, "The claimed phenomena and application presented by several military officers range from the incredible to the outrageously incredible. The 'anti-missile time warp,' for example, is somehow supposed to deflect attack from nuclear warheads so that they will transcend time and explode among the ancient dinosaur." In the 1960s, I read the short stories by Philip K Dick and others, so I know that if you go back in time and step on a butterfly, it will somehow affect the future. Going back to the quote, "One suggested application is a conception of the 'First Earth Battalion,' made up of 'warrior monks' including the use of ESP, leaving their bodies at will, levitating, psychic healing and walking through walls."

Today, there is a lot of concern about Modafinil. I was recently in Mexico City, where I met with 1500 bioethicist from around the world. Many of these ethicists had traveled from abroad and thus were tired, so I recommended that they be prescribed Modafinil. Even for my colleagues speaking in Beijing and traveling from Philadelphia, I recommend Ambien while on the plane and Modafinil upon landing. It is difficult to keep our warfighters awake and functioning with only 3 or 4 hours of sleep a night. As you may know, in the late 19th century, the Prussians tried giving their soldiers cocaine. In the 19th century, everyone tried cocaine. In the 20th century, we turned to caffeine, nicotine, Adderall, and now Modafinil, which has been shown by the NIH to keep you awake for up to 60 to 80 hours. This has always fascinated my first year medical students. There is no question that off-patent Modafinil has created a gray market. In fact, the People's Liberation Army announced, when they opened their museum in Beijing, that they had created their own version of Modafinil.

We now move onto oxytocin, which is often termed the cuddle drug. After an intimate encounter, oxytocin production increases. Paul Zak, a Claremont Graduate School economist, was curious to see if he could use oxytocin to make subjects more cooperative for his empirical economics studies, especially during gaming situations. He had trouble getting the FDA to approve his nasal spray devices, so he went to Switzerland to get approval. He began giving people oxytocin through the nasal route and placing them in competitive situations. He and his colleagues in Switzerland found that people are more cooperative when given oxytocin before a gaming or

competitive situation. This quickly raised the question of whether this could be used during interrogation, making an officer who enters the room seem more pleasant. In my opinion, this is a violation of the Chemical Weapons Convention. The answer likely depends on what flag you are fighting under.

In another instance, physicians prescribed beta-blockers to patients with heart diseases and found that it lowered their level of affect. It led them to question if beta-blockers could be given proactively. For example, you might give someone beta-blockers proactively before putting them in a combat situation. Five years ago, I was on a panel at the NIH with a researcher from Harvard, who did this original work in the 1990s. He was skeptical that this would actually work, but did say that eventually something would come along that could achieve this effect. This raises an ethical question. Would you want to have a generation of guilt-free soldiers coming back from war? They would remember an incident, but not feel shame or guilt. It would prevent a lifetime of a terrible disease, but with great cost.

Later today, you will hear more about transcranial direct stimulation. I would like to point out that there is at least a new article every week relevant to this conversation. And in March, evidence was published that a facial image can be created from evoked brain activities. Jack Gallant, from the Allen Institute for Brain Sciences, reconstructed a fuzzy image using functional MRI from a movie scene. Although the images are pretty vague and obscure, they are decently recognizable. Jack himself says he is scared of what he can do with this system.

Next, I would like to demonstrate a reconstruction of sound from the stimulation of certain auditory pathways. The studies consist of individuals already undergoing open brain surgery, and they are implanted with additional electrodes. The patient hears a word, and then the researchers determine the word's sound based on the systems simulated. These research projects have led to two different means of reconstruction for two dimensions of our sensory apparatus.

Brain-based interfaces are not very high-tech systems, but they do get headlines. A few months ago in Seattle, a man hooked up to an EEG device was instructed to think about moving a finger to strike a target on a monitor directly in front of him. The brain signal was sent over the Internet to a receiver, on the other side of campus, and a separate individual was then stimulated through tCDS to move his finger. It is not the Vulcan Mind Meld and it is not all that sophisticated, but it is provocative and raises interesting questions.

DARPA conducted a project, known as the Roborat, ten years ago at SUNY Medical Center in Brooklyn. A graduate student in a lab remotely controls a rat's movements. The electrodes in the rat's brain allow the user to control its movement in any direction. It can be made to walk in any direction, climb up a ladder, and clamber along a narrow edge. The question is, ethically, how far up the evolutionary chain can you go? The researchers are not yet sure about the mechanisms occurring. Is it a muscle jerk or something more? There are ethics problems, especially if you want to do it with humans. I am not sure if you could get it past the Institutional Review Board.

When a cartoon was published in the *New Yorker* decades ago stating: "We've found by applying just the tiniest bit of an electric shock, test scores have soared.", it was a joke, now it is a reality. Using TDCS, the DIY community is reporting through blogs and other sources that they are able to improve at Sudoku and other similar tasks, all with a simple zap. Researchers are unsure what

the long-term implications are. I wanted to show you an ad by a company, Fisher Wallace, which is selling these machines. They are used for conditions like insomnia. The commercials are video ads from a woman that claims sleep improvement with the zap of their machine. She is seeing great improvements after using the Fisher Wallace device several times a week.

Optogenetics is one of the most exciting laboratory methodologies, and it has been around for at least a dozen years. It uses a light-sensitive protein, rhodopsin, and encourages it to find its way into the brain. Investigators are able to push this protein around and follow its path, which is tremendously exciting. Here is a video in which a mouse that is not hungry is made ravenous. In the light on condition, specific cells are activated and the rat is ravenous, but when the light is off, he is no longer interested in food.

In another study, conducted at MIT, they managed the behavior of a male mouse that is copulating with a female mouse. When the light was switched on, the male mouse became pathological, attacked, and bit the female. When the light was turned off, the violent behavior ceased. It does not mean this is normal behavior, this is pathological behavior created by the system. It reminds me of the debate in 1950s, where S.L.A. Marshall's work brought up the question of how to get soldiers to fire their weapons in combat. Could you switch them on and off? The problem is that you do not want to create an enraged pathological warfighter, rather than a warfighter that knows what he or she is doing. And, of course, you do not want them to walk around with a light sensitive fiber optic cable in their heads. While checking my email this morning, I discovered that MIT has announced a light sensitive molecule, instead of a light sensitive cable. If it is done with a molecule, organisms under manipulation can be larger, can be in motion, and can be distant.

Using transcranial magnetic stimulation, you can change some components of people's ethical beliefs. As an ethicist, I find this fascinating. We frequently have discussions in ethics between the different fields: duty-oriented philosophers, deontologists, and utilitarians. If you take a group of white, right-handed males from MIT, you can turn them from deontologists into utilitarians. In a study, they told a group of men a story in which their girlfriend was about to walk across a dangerous bridge. The researchers asked the men what they would do. They replied that they would tell their girlfriend not to cross the bridge. The researchers then questioned the men's motives and they claimed it was their duty to save their girlfriend. After a brief transcranial shock, they were unable to reason their duties to their girlfriend. They had changed their perspective and reasoned in the utilitarian mode. They said they would let her cross the bridge, and if nothing happened, then everything would be fine.

These modifications and enhancements raise the question of what kinds of burdens we want to put on warfighters. Many warfighters already struggle to give up their weapons when they leave the armed forces. As we ask more of warfighters, how many burdens, exposures to risk, medications, and behavioral changes can we expect soldiers to bear? I understand that soldiers sign up to protect us and to take risks. In the 21st century, we need to slice that request a bit finer than in the past, as we are asking for more things from them.

The National Research Council has also been taking these issues seriously. In 2009, just after I had published *Mind Wars*, the Defense Intelligence Agency was cited on EEG and helmets in vehicles. None of this has come to fruition, due to the depleted material coming back from 10

years of warfare in the desert. At this time, it was considered on-the-shelf technology; eventually it will come off the shelf and see usage in the military.

On the other hand, the handheld lie detector is an example of a dubious piece of technology that is seeing implementation. One of my favorite devices to talk about is the Brain Fingerprinter. The company that makes it has supposedly sold these devices to the FBI. They operate by giving off a signal before we think we recognize something, which is a problem as we only think we recognize it. I am unsure if neuroscience lie detection has advanced very far. I find it interesting that this handheld lie detector is only as accurate as the traditional lie detector, which is only accurate 70% of the time, even though the technology has changed so much. While I was on a workshop committee in Baghdad, I met a man responsible for training others to use the handheld lie detector to screen locals for work in the Green Zone. I find this distressing.

I urge you to read a recent report from DARPA on the ethics, laws, and social impacts of new weapons technologies, including neurotechnologies. There is a library of reports from the Swiss, Italians, and even Americans. There are so many reports available that when I teach bioethics at the University of Pennsylvania, the students are unable to even scan all of the material published in the last 10 years on neuroethics and national security. It has grown that quickly.

The relationship between cyber security, the Internet, and neuroscience is one that we need to pay attention to. There is talk in some quarters about lethal autonomous weapons. A key issue is facial recognition. There is a study that says there is now a computer algorithm that recognizes peoples' faces better than you and I do. When it is easy to obtain images of our faces and other identifying information through the Internet, there are concerns for autonomous and artificial intelligence.

I have not presented a lecture in ethics today, but people do expect that I ask ethical questions. There is an aspect of international law that will govern some of these questions. Should there be new ethical principles? William James told us in 1890 that we have problems implementing and developing new ethical principles. A common concern is cognitive liberty: who has access to your thoughts? What steps should we take to ensure that a neuroscience experiment is reversible? We know pretty well that anything done to our brain is not fully reversible. Learning from the history of neuroenhancement and speculating about the future of the technology will require careful consideration of these questions.

GEROLD YONAS

Zapping your Way to Enhancement

My philosophy has always been to try to understand how some things work. As such, I am more of an engineer than a physicist. For over 45 years, I have been conducting fusion research. On your behalf and through much iteration, my teams at Sandia National labs have spent many millions of dollars and countless hours to build a machine that produces 26 million amps. And when it finally produced that 26 million amp pulse, I realized I was never going to make fusion with it. In 1978, I published a *Scientific American* article that said laboratory fusion was only 20 years away, but in 1998 I repeated a new version of that article and said we were still 20 years away. On

the 40th anniversary of my prognostications, which is 4 years away, I will have to write another *Scientific American* article, and we will still be 20 years away. By that time, however, I think my latest venture of zapping the brain to enhancement will have succeeded and become a product.

Let's begin with a history lesson. How did electromagnetic brain stimulation really happen? Many people use this technology frequently, due to an increasing scientific and technology base over the past decade. It all began because Emperor Claudius, who suffered from terrible headaches, turned to his assistant and asked if he had any ideas for a solution. The assistant's solution was to place a cold fish on Claudius' head, which happened to be an electric torpedo fish. The torpedo fish did provide relief, but not because of the low temperature, but because of the electric shock. Of course, it was not very practical. The FDA has now approved the modern-day technology that replicates the electric torpedo fish, and I will soon tell you about that. For many years, electric eels were similarly used to treat epilepsy. This was also not practical. Similarly, when Galvani invented the battery about 200 years ago, people picked up on the use of a Galvanic brain stimulation to treat depression but this not become accepted. In the last 20 years, electrical brain stimulation treatments for headaches, epilepsy, and depression have come a long way.

Electroconvulsive therapy (ECT) became well-known thanks to the 1975 movie *One Flew Over the Cuckoo's Nest*. The movie, unfortunately, gave a very bad impression of electroconvulsive therapy. However, ECT is now an accepted and effective approach for depression. ECT is very poorly understood, but has saved many lives and offered relief to many. This 1000 volts/meter electric field therapy is now supplemented with anesthesia and muscle relaxers, but it does correlate with memory loss.

An impressive new treatment for depression is transcranial magnetic stimulation (TMS), which uses a pulsed magnetic field to create an electric field a short distance inside the brain. A psychiatrist in Albuquerque, uses this in his practice, and he tells me has seen good results, including prevention of suicidal behavior. Although he admits he does not know how it works, he and others claim it is safer than ECT at 1000 volts/meter and TMS is only 10 volts/meter. TMS does excite neurons and can be tested by detecting muscle twitching by stimulation of the motor cortex. In my opinion, even more interesting are TDCS, transcranial direct current stimulation, and TACS, transcranial alternating current stimulation, that work at 1 volt/meter. Transcranial alternating current stimulation uses alternating polarity of current to effect changes in the brain. It can manipulate frequency, amplitude, and waveform. This variability in stimulation allows for flexibility and control, and the key to tACS' success is the use of closed loop feedback. This low cost technology has become the craze of the DIY community, where they purchase 9V batteries and electrodes to stimulate themselves with TDCS. Being a fan of Nicola Tesla who invented AC power, I believe electrical stimulation should be done with AC stimulation in order to modulate brain waves, whereas DC simulation is useful for excitation of brain regions.

TMS is FDA approved and is widely used as a localized treatment that stimulates the left frontal cortex. It uses 10 pulses/second for about 20 minutes. For the next few weeks, the patient returns and receives the treatment. More recently a TMS research publication states that good results are found with treatment 3 times a day for 3 days, which is a much shorter time frame than performing TMS every day for a few weeks. The stimulator still costs many tens of thousands of dollars, and although the treatment works, it surely would be more successful if it were lower cost and this might be possible using TACS.

In the last 10 years, DC stimulation has become more accepted. One application of DC stimulation is to enhance the rate of learning. DARPA's AugCog Program and the Air Force research lab are two places where DC stimulation is of research interest. DARPA tested training analysts to find a target hidden in a complex background, but the results were modest. The Air Force recently reported cutting the needed learning time by a factor of two with DC stimulation.

Another advance in understanding has resulted from calculation of current propagation from scalp electrodes into the brain. MIT has carried out these calculations by modeling various electrode geometries and calculating the details of excitation distribution and intensity. There are many variables and parameters in this simulation, which undoubtedly will also depend on the brain geometry of each individual, and the theory is not solid and most of the work is still empirical.

One of the most important developments is the number of companies making and marketing brain stimulators, where users can control waveform and voltage. Neurocon supplies one such widely used device. Previously, I showed you the work of a company, Soterix, that emphasizes localization of excitation. Another company, Neuroelectrics, is seeing advances by combining an EEG cap with electrical stimulation. The EEG cap measures the brain waves and the stimulator excites the brain. Waveform, rise time, pulse duration, and current density can all be modulated by this system, but a consideration yet to be resolved is the interference of the stimulator with the EEG recordings.

With so many variables, and individual characteristics, coupled with a lack of theory, I asked myself how we could ever make progress. I came to the conclusion that the key to making a successful AC stimulator is the same as controlling the room temperature properly without knowing too much about the details of the room. Heating and cooling the room usefully without using a thermostat is impossible. Why don't we combine the EEG with the AC stimulator and build a closed loop control? I went to work on a patent disclosure. Unfortunately, I could not get anybody interested and it went away for a while. I shared it with my friends at Lockheed Martin, and after they added the needed engineering details, they filed a patent on closed loop control of brain wave modulation. It could be the route to empirically achieving many of the desired benefits. Of course, advances in theory could speed up the process.

Fisher Wallace is one of the many companies using AC technology. They are providing a complex frequency spectrum to perform brain stimulation. There has been controversy over whether the device is safe, but this year FDA said that it could be safe and they proposed it as a Class II device. The FDA is not saying it is effective, but they are saying it is a safe device. The device uses a complex electromagnetic spectrum up to 500 Hz, but it is modulated with 15 Hz wave. This means that it is very close in range to the alpha wave frequency. Possibly the brain is receiving the reported calming effect from the stimulation. This should be even more effective if matched to the alpha frequency of the individual with the subject's eyes closed.

My concept is to determine the subject's brain wave frequency during a specified behavior, and then bring the brain into an enhancement of that brain state using closed-loop control. The AC stimulator in effect becomes a brain wave trainer, but as you know from the local fitness center, the subject has to cooperate.

Another product, AlphaStim, places the stimulator electrodes on the earlobes and it employs about 0.5 to 1 Hz which is the characteristic frequency of slow wave sleep, when body temperature goes down and you are essentially motionless. This device is available with a prescription from a specialist and it is claimed to be useful for treating anxiety, depression, and insomnia.

The Cerena single TMS pulse device is an FDA approved product that is the modern-day version of Emperor Claudius' torpedo fish. It works by holding the device on the back of the head and applying a magnetically generated high voltage pulse at about 10 volts/meter to the occipital cortex at the start of a migraine aura. If it is not applied at the start, it is unable to disrupt the regular brain waves that instigate the migraine. This product has substantial scientific validity based on the research on TMS.

While there are many commercial devices, neurotechnology researchers, mostly in Europe, are publishing rapidly. There have been hundreds of papers in the last few years, and many stating that AC stimulation can entrain brain waves, if the brain is cooperative. With eyes closed, subjects enter an alpha state, around 10 Hz. At this point, a wave can be superimposed to enhance alpha waves. This is similar to meditation and I am sure it would be a great benefit for people suffering from many problems, such as stress disorder or anxiety.

The key is that brainwave entrainment depends on the natural brain wave state. The state the brain is in will determine whether the brain will be responsive to enhancement. This means that if researchers want to drive subjects into deep sleep, the brain ought to be operating at close to one Hz. On other hand, if they want them to learn new information, the brain should be at around 5 Hz. The brain waves are so complex and I am applying my concepts in an admittedly simplistic approach to important, applications such as slow wave sleep, enhanced learning, and meditation. But at this point you are probably wondering is there any physics in this?

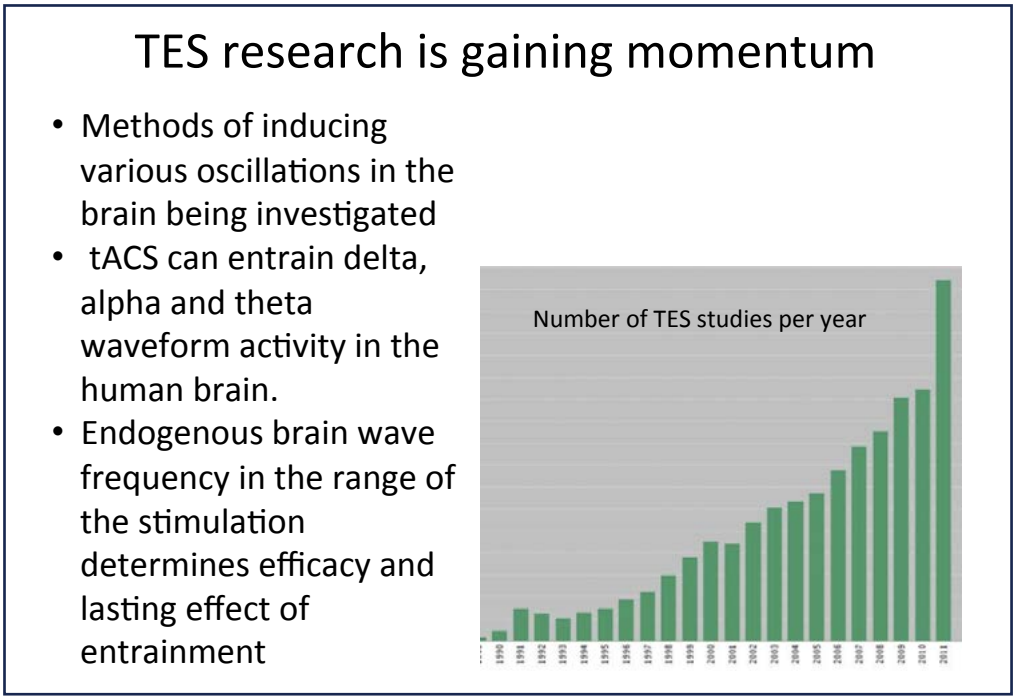

Image courtesy of Gerold Yonas.

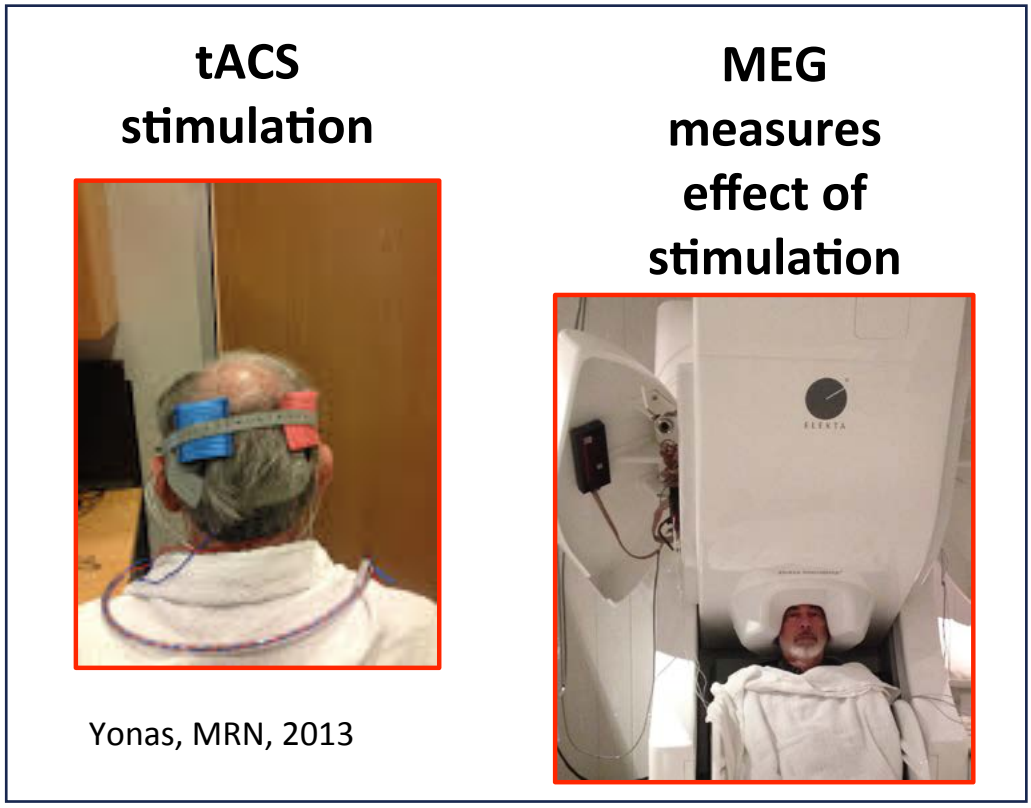

Image courtesy of Gerold Yonas.

When an electric field is applied to drive ions into the head or soma of a neuron, it creates an increased electric field across the neuronal membrane. The generated voltage caused by changing the ion distribution may only be about 10 mV, which is small compared to the resting potential of a neuron, which is about 70 mV. This small field is useful, as it primes the neuron and makes the neuron excitable and it fires rapidly when triggered. In contrast, if you apply a field with opposite polarity to the neuron, you extract the ions from the neuron and the neuron is less likely to fire. You can get enhanced firing from the positive anode potential near the soma. With the opposite polarity, you get attenuated firing. The physics shows that neurons can be excited or attenuated with an electric field.

How do you begin to make sense of this without considering the coupling of hundreds of billions of neurons, accounting for the highly connected circuitry, and making circuits work in a controlled fashion? From an electrical engineers point of view, if the circuits are highly coupled, they can oscillate in a synchronized manner. If you can get one part of the brain to function at a specific frequency, then you can get the other parts of the brain to couple. Then we can make certain circuits work at certain frequencies and amplify those frequencies. But how can we study this coupling, if it is real?

I am beginning to look at AC stimulation, with eyes open and eyes closed, and with changes in frequency and intensity of excitation. This kind of brain stimulation research is occurring all over the world. In 2006, Lisa Marshall conducted a fascinating study focused on slow wave sleep. Her work was on entraining slow waves, which is particularly interesting because the voltage level of EEG signals was 100 microvolts. That is 10 times the normal voltage that for EEG signals under awake conditions. Why are these slow wave signals at such powerful and dominant high voltage frequencies?

Researchers are investigating coupling of brain waves using neural feedback and closed-loop wave feedback to amplify those waves. Researchers at the California Institute of Technology showed that slow waves coupled electromagnetically. Many in the field of neuroscience believe that neurotransmitters are the key to neural function, but it has been shown that coupling works quickly and enhances the brain waves throughout the brain. I believe EM coupling can trigger slow wave sleep that I think is the key to solving an important neurological problem. Many of us are bad sleepers and could benefit by electrically enhanced slow wave sleep.

One of the most impressive neuroscience research results was on slow wave sleep. It showed that increasing slow wave sleep reduced both neurological and physiological problems. It is well accepted that on a lousy night's sleep, particularly with disruptions in slow wave sleep, you feel unwell the next today. I believe that electrical stimulation that elicits and amplifies slow wave sleep can be the most important discovery to enhancing human behavior. This year, Rochester University, researchers showed that slow wave sleep enables cerebral fluid to travel faster through the brain. This recycling and metabolic regulation of chemicals, neurotransmitters, and cellular detritus through slow wave sleep can enhance performance significantly. The road to enhancement is through slow wave sleep, where increased cerebral flow removes harmful metabolic byproducts and irreparable damage is avoided. Slow wave sleep can be further enhanced by tACS.

We have yet to show conclusively that that brainwave entrainment is enhanced by closed-loop control and can then be used to enhance behavior. There are various components of the frequency spectrum that are very important to behavior. The key is slow wave sleep that can reduce problems over time. As you age, you tend to sleep poorer; in my opinion, this causes the accumulation of toxins that lead to dementia. If this slow wave sleep has the potential to reduce dementia, then there are great implications for the rest of neurological disorders and enhancement. Researchers as well as the DIY neurotechnology community are beginning to talk about orchestrating neural networks and effecting control over neural communication in the brain and the consequences could be profound.

I have come at this topic from an empirical point of view and my knowledge is based on studying publications from all over the world. I have also produced an iTunes U course on an "Introduction to Neurosystems Engineering" and the recent publications by Eliza Strickland (The Latest DIY Craze: Brain Hacking, http://spectrum.ieee.org/geek-life/reviews/the-latest-diy-craze-brain-hacking) and Toralf Neuling (Orchestrating neuronal networks, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3639376/) demonstrate that the field is gaining recognition. There are many applications of neurotechnology and neurosystems engineering that will have enormous impacts on humanity. Neurosystems engineering can provide mental disease detection, intervention, and prevention. It can heal brain injuries, reduce disabilities, maintain health, and enhance cognition. We have learned a great deal about the science and technology associated with neurological problems and soon we will see neurotechnological solutions to stroke, dementia, brain injury, health maintenance, and cognitive enhancement. In the next few years, before the publication of my next *Scientific American* article, we will see real payoff in this field.

PANEL Q&A SUMMARY

The panelist discussion explored issues in ethics, history, and potential of neuroenhancements. An underlying ethical and policy concern for neurotechnology was the lack of regulation and the effect this has on users. If regulation is left to the free market, neurotechnology's public image could be degraded and devices could easily be abused and misused. Deficiencies in regulations can be overcome by private or federal entities alike. These safety regulations do not have to initially construct determinations of device efficacy.

As a lack of sleep can lead to huge detriments in performance, the panel focused their attention on this topic. Emerging means of improving sleep include pharmaceutics, such as Ambien, and neurostimulation devices like tCDS and TMS. Improved quality of sleep can result in an improvement in cognitive function. Soldiers and other Department of Defense personal are often expected to work with little sleep. Their best performance is necessary for public safety, so we should ensure that our soldiers are not cognitively overloaded.

The neurotechnology of the future will shift from computer-like devices to smartphones and will be affordable, compact, and integrated into social networks. Neuroenhancement devices will provide real-time user data that can be used for immediate feedback and direction for behavioral changes to an optimal brain state. The government will not necessarily be the first player to adopt this new technology, and it is possible that it will be quickly left behind by commercial advancements in neuroenhancement.

PANEL DISCUSSION

MODERATED BY AMY KRUSE

Amy Kruse
I have a couple questions for my colleagues here. In terms of the do-it-yourself items that you have seen, I assume that most devices come without instructions. I was wondering your thoughts on whether there should be an instruction manual for brain stimulation? What would you like to see out there?

Gerry Yonas
I am really worried. The potential for using these technologies at the wrong current density or at the wrong frequencies and waveforms is terrifying. I can easily imagine situations where a user has an uncomfortable experience with brain stimulation and propagates negative perceptions of the technology. I mentioned electroconvulsive therapy in my talk, which has a very successful track record. Yet, the public fears the technology. It elicits a fearful reaction because it is difficult to understand the relative therapeutic differences between one volt per meter and something like a thousand volts per meter. If people do not understand these differences, then it would be very easy to mistakenly administer or self-administer an incorrect dosage.

Jonathan Moreno
There is a really interesting analogue between what could be happening here and LSD, which was of tremendous interest to clinical psychologists and psychiatrists a couple of decades ago. When LSD was incorporated into popular culture, its reputation for clinical utility was damaged. It has taken many years for hallucinogens to be taken seriously in the research literature again. From this historical example, it is interesting to see how much damage can be done if this stimulation technology gets out without the right user manual. What is the capacity of the FDA to regulate enhancements?

Bill Casebeer
In terms of trans-cranial direct stimulation, Lucas Parra at CCNY has helped form a consortium that aims to self-regulate the kind of safety guidelines and manuals that you have suggested. They work from the perspective of a profession and an internal source rather than an external regulatory source. They have been taking great steps towards articulating these safety concerns.

Amy Kruse
I believe that the market is ahead of the policy in terms of considering these details. Is it the case that everything needs to be regulated by the FDA just as they do for pharmaceuticals? Is there a middle space for enhancements that do not involve the kind of double-blind placebo studies seen for treatments of illnesses?

Gerry Yonas
This could just focus on safety criteria, not effectiveness. I was encouraged to see that the FDA is looking at some of Fisher Wallace's technology and is designating them as Class II devices, which means that they are considered safe but does not evaluate their effectiveness. The operating manuals for these devices give you guidelines for safe boundaries and ranges of use.

Amy Kruse
It would be ideal to see evaluations of safety like that for DIY and gaming applications. Gamers could not care less if their devices are in correct operating variables for clinical applications.

Gerry Yonas
There are so many variables: the current density, the geography of the stimulation, the rise time of the waveform, etc. However, there is no real theory or complete models on these complex networks and this is definitely a needed area for further research.

Jonathan Moreno
I want to raise a point. We often seem to go after high-tech solutions for our problems. Once you have moved past the regulation of a device's safety, there is still a question of whether you are reaching too far and applying a therapy or device where a simpler approach should be used. For example, a lot of people who are experiencing insomnia will go to Ambien or even try this tCDS therapy, but maybe they should be tested for sleep apnea.

Gerry Yonas
There is certainly a problem with sleep apnea. The interruption of breathing that causes a sleep disruption and prevents any sort of sustained, restorative sleep. You need a doctor and

the appropriate lab equipment to determine whether someone has obstructive sleep apnea. A person with obstructive sleep apnea snores and the airflow intake becomes turbulent just after the peak of inhalation. I read some recent work with transcranial magnetic stimulation, where pulses are applied at the peak of inhalation and shut down this phenomenon. I suspect that there will be an electrical brain stimulation device for obstructive sleep apnea.

Amy Kruse
Jonathan, are you as concerned for our privacy and safety from intelligence as you were when you wrote *Mind Wars*?

Jonathan Moreno
The conversation has gotten a lot more voluminous. We are still poor at predicting the future directions of these technologies. I have started to think about how technology affects our warfighters. We are overloading them with responsibilities in counterintelligence and cyber capabilities. The anthrax scare in the 1990's brought up the concern of how much medication can we mandate that soldier take. One of the reports I mentioned earlier, Army Opportunities in Neuroscience, talks about tDCS for warfighters. The technology could monitor operator's behavior and provide stimulation or therapy when he or she becomes fatigued or overloaded. This presents interesting problems. How do you field-test these interventions? How much can we ask from the men and women that pledge to protect us and how will it affect them in the long term?

Amy Kruse
I see some short-term benefits for neurotechnology through training in the military environment. People are becoming more comfortable with data about themselves, certainly more so than 10 years ago. We are able to purchase a Fitbit and many other similar devices, all of which track our daily behavior. Maybe we could mentally calculate this information, but it is much easier with automatically collected, real-time data. I believe neurotechnology could play a role in providing informative technology about optimal brain state for a given task, whether that entails pharmaceuticals, brain stimulation, or enhancement. I think there is even a utility to observational data itself, before moving onto a more prescriptive functionality. However, this raises issues of privacy and data ownership. I think that as we develop metrics and mechanisms that are more effective, this application will develop value and appeal.

Jonathan Moreno
As Americans, we have a tendency to jump to gadgets and medication first to solve our problems. That is why pharmacists rank so well in public opinion. I have cognitive neuroscience friends who tell me that cognitive behavioral therapy will be the easiest thing to achieve, not enhancement. That is why I appreciate the concept of sleep. It is a straightforward answer to poor health. Markets do respond to these things, but may take us further in ways we do not need to go.

Gerry Yonas
I became really depressed when talking to soldiers as I worked on a National Academy study and a Defense Science Board study. One study involved predicting violent behavior and the other had to do with Marines leadership. I spoke with young men, platoon leaders, and many more and became convinced that none of them sleep. They have destroyed an important body

function by service to our country. By reducing their sleep, they inhibit their self-regulation. The soldiers were not aware of the value of sleep. It seemed to be an important mark among them to not sleep very much. During a meeting with a man from the Special Forces, I said to him, "You would not send your troops into the battlefield without bullets. They will be even more unprepared if you send them out without sleep." His response was one of incredulity. I think we need to address the issues of morality and physiology here. If brain stimulation works, we can help soldiers take short naps to restore functionality. The military might go for a capability like this.

Amy Kruse
I agree. In my time at DARPA I funded a project like that. It was essentially a nap cap with advanced brain monitoring.

General Alfred Gray
Unfortunately, I believe you experts are being misled by some of these military people. If you want the military to adopt these practices, which I think we should, you all should really focus your effort on one or two items at first. That would help to focus and push those ideas forward. It would help if the studies showed that there were no reasonable medical problems, but you are already well beyond that point. I was well-known on the base as a poor sleeper and I never slept than 3 hours at a time during my stay in Vietnam. I agree that most people do not understand the value of sleep.

Soldiers are kept busy with some non-useful things. Their daily schedule is to wake up, go on patrol, return to the tent camps, and then work out. I think when things return to normal, you will be able to pick a unit to test these things. You will be successful and they will run your trials.

Michael Swetnam
I would like to make a follow up comment to the idea that we can discuss sleep. Jonathan, you made the point a moment ago that it may be easier to get to a normal level of sleep than an enhanced one. I would like to argue that the important thing about being able to develop a sleep aid would not be for assisting with disorders. Instead, the true opportunity here is to increase the ability to function at very high levels with very little sleep over extended periods of time. The military would be greatly interested in what can be accomplished after an hours worth of slow-wave sleep. The enhancement potential of this technology is so much greater than its curative potential.

Gerry Yonas
Can you imagine what a super-soldier General Gray would have been had he slept more?

General Alfred Gray
I would have missed all the fun. There is a lot going on in the military. In the Navy, Air Force, and other services, there are watch officers, intelligence officers, and enlisted analysts. These are people working 14 to 16 hour days, and doing it every day. You can go out to the National Security Agency right now and find young men and women working this many hours today. The concept of improved sleep is just as applicable for these individuals. They would probably appreciate anything that makes them less tired.

General Stephen Xenakis
Just to introduce myself, I am Steve Xenakis, I am an Army psychiatrist and was Senior Adviser to the Chairmen of the Joint Chiefs under Mike Mullen on topics like psychological health and traumatic brain injury. I am interested in your policy question and where you go forward with that because of the challenges I found during my time. To save time, I will go into just 3 data points that show examples of when achievable progress was slowed down. The first was under the tenure of Chief of Staff General Wickham at Fort Hood in the 80s. We developed sleep discipline and sleep hygiene programs and some of the warrior monk research. When I tried to bring that research back to Army leadership and 4 star generals who were running the war, they were frankly uninterested. No matter whether they acknowledged the importance of sleep or the science behind the research, they flatly refused to do anything. Secondly, the concept of neurofeedback has been around for a long time. We are now able to use EEG to show when someone is not paying attention. We now have data on attention deficits and exercises to enhance that performance. Again, we found that the communities that should have been responsible – DARPA and Fort Detrick Medical Command - were not interested in doing a focused project, despite the clear opportunity to assist our high performance people. Thirdly, I served on the review board for the Fisher Wallace device. The FDA's issue with the device in 2012 was the efficacy of the device. The FDA was concerned that a small company like Fisher Wallace would not reach the same numbers of large trials that pharmaceutical companies can achieve. Whose responsibility is it to look at the efficacy of a device for soldiers who already having difficulty sleeping, who have problem recovering from IED blasts, and headache problems? That responsibility belongs to the military. We need to use our resources to figure out what specifically will be the utility for our warfighters. I think that is the policy implication. The science will continue moving along. The issues are the institutions. Inertia will prevent straightforward and cost effective projects from getting off the ground.

Amy Kruse
That is the point I was trying to make. The market is moving that direction, but the venture funding folks will not invest there. They see it as the military's problem. That is why I am so excited to pursue it from a neurotechnology perspective and to use it for applications and not just basic science.

Gerry Yonas
There is an elephant in the room, which is the pharmaceutical industry. What is the problem with a nation hooked on pharmaceuticals, to such an extent that we exclude other options?

Audience Member
You speak of target applications for neurotechnology. It is not just the device; it is also the protocol for using it. The devil is in the protocol and in the details. If it is just a matter of marketing and patenting devices, you wind up with problems that Jonathan referred to. Dr. Yonas, you wind up with misuse and damage because there are no established protocols. From the standpoint of policy and incentivizing market involvement, an idea is to consider intellectual property issues with applications and protocols themselves. Just as with drugs, there is the concept of off-patent use and off-license use, along with generics. In a certain sense, neurotechnology gives you all of those options but it is all about how it is used and how it is applied for those purposes. Right now I understand you have safety, regulations, and efficacy and the regulations are shaped by

the efficacy and how you can say it was done. The future of neurotechnology is not talking about specific devices, but maybe about the specific protocol for certain devices.

Gerry Yonas
I agree. The literature is now showing that neurological change depends on brain state. Brain state depends on the protocol that provides preparation for the subject. The research is saying that the protocol is very important. That is another area for which the science and applications could be profound. The protocol is highly important to this technology.

Audience Member
Take direct brain stimulation for example. It is already approved for use in many applications. Just because it has been approved in that regard does not mean that the protocol has been as well. Currently, they are doing it on case-by-case bases. How do you regulate that, specifically when protocol changes for different targets result in enhancement?

Gerry Yonas
There is so much variability in terms of how the brain is wired and how it functions. Maybe a plan would be to establish a baseline for each subject. Once that baseline is established, you modify it with a feedback system in the direction you are interested. In the end, the cost will not be associated with the use of the object. It will be associated with establishing a protocol and going through a brain-training program. I see these gadgets like the weights in a fitness center. Anyone can use the weights, but having a trainer makes a great difference. The same thing will likely occur with neuroenhancements. There will be brain trainers that apply low cost gadgets in an effective way.

Gladys White
How will the standard of medical care practice be established in an environment where treatment ranges from 1000 volts per meter to 1 volt per meter? Will the standard of care involving treatment of depression evolve? Will it migrate to lesser voltage in terms of treatments of intervention? Will all of these possibilities remain extant at any point in time? What will be the impact on policy for changing amounts of electrical stimulation? Additionally, we face an epidemic of heroin abuse at this point in time. What is the potential of neurotechnology to be mobilized to treat heroin addiction and abuse?

Gerry Yonas
Standards of care are going to require a lot more science research. The baseline for this is safety. Using the baseline science behind neurological damage can be understood as a function of voltage across the neuronal membrane. Washerman established the number of neural pulses in 10 volts per meter. In very serious cases, such as suicides and psychotic tendencies, achieving a baseline is very difficult. Brainwaves are a function of stimulus and stress. There is acute and chronic stress; sleep deprivation is a chronic stress. This is a guess, but most of addiction is a negative way to manage stress. I would do research on stress management and the role of addiction. The research would involve trying to understand, for a particular person, how to manage stress without drugs. The research would have to be rather substantial, going from understanding the fundamentals to managing stress and addiction.

Audience Member
This is related to stress, but we have yet to touch on it. Would the panel comment on the possibility of manipulating neurogenesis towards augmented cognition, in terms of taking new real neural networks and embedding them into existing neural networks? What about the process of going from brain-machine based interfaces to brain-to-brain ones?

Jonathan Moreno
I am glad you brought this topic up, as I was about to speak about neural stem cells. I mentioned the Nuffield Bioethics council report, in which they choose to measure neurogenesis as a cognitive enhancing device. They measured neurological stem cells, and this takes us back to the human embryonic stem cells problem. The results for adult stem cells have not panned out; our future is with human embryonic stem cells. The result is that people are attempting to develop large organs for animals, particularly the pig because it has organs similar in size to a human. In the next year we will start hearing more about putting human neural stem cells into the blastocysts of a pig in order to make a pancreas. This pancreas could then be translated into a human being. Xenografts could be a response to the problem that there are not enough cadaver organs to go around. I was on a National Academy of Sciences committee that said, "You have to make sure you know where the stem cells are going in the animal blastocyst. If they start going into the brain, this raises an alarm and concerns about strange mutations." We are going to learn indirectly about where these cells are going, and if they contribute to the formation of the brain and central nervous system of another animal. The question of neurogenetics and the stem cell biology debate, this is where they start to merge. We might learn something about neurogenesis from the embryonic stem cell biology world. This information may in the long run give us the power to modify adult animal brains.

Amy Kruse
I was thinking about the potential for exercise or other stimuli to induce changes. When we think about enhancement, we would do well to remember that there are multiple paths into that space.

Mike Swetnam
I started the discussion off with a discussion of computers when they occupied a whole room. The protocol for communicating with computers was slow and cumbersome. A lot of people focused on how to improve this protocol with keyboards and interfaces, but the really interesting people were thinking about how computers would someday fit into our pockets, like this smartphone. I am challenging you today to think about where you see neuroenhancement 30 years from now.

Gerry Yonas
I think the next big thing is collective human performance. You can look at enhancement on the individual level, and I think stress plays a big role here. Stress management will lead to high levels of performance, in a predictable manner. It could also affect other problems, like providing a solution to addiction. People will not turn to drugs to manage stress. They will learn to self-regulate with food, sleep, and exercise. If you learn to self-regulate in these ways, you will be a good stress manger. Next, how do you have a collective population of people working at this high level of performance? There will probably be a central computer that is talking to each one of the individuals in the collective. The central computer will help monitor everyone and manage

the group. The group will then have a higher performance than the individual. This group can even be called the Borg. There is only one question you should consider: is resistance futile?

Amy Kruse
I want to discuss the future of an enhancement interface: how we collect and access signals about ourselves, how we communicate with one another in a collective fashion, and how we move past the relatively simple technologies we have today. The way we are going to interface with our own biology and with each other is going to change radically. Just as the computer in the room became a computer in your pocket, I can see implants, consumable enhancements, and outpatient procedures becoming highly prevalent. That radically changes where neural interfaces are headed. I think that there is a future where the lines between the individual and a computer become blurred, and there are many important protections that need to arise from this phenomenon.

Audience Member
Will these enhanced group dynamics apply to government? Right now we see that cell phone and Internet technologies have the potential to affect governance.

Mike Swetnam
We have looked into digital governance here at the Potomac Institute. The way I see it, government is often the last area to adopt a new paradigm or technology. Alternatively, neuroenhancements might shake things up so dramatically that we get rid of our old government to address the new paradigm.

Audience Member
I want to discuss the ethics for all of this. I was in the former Soviet Union when they were starting to perform genetics research. I saw a lot of advanced work in the field that was surpassing the United States' work because we were concerned about the ethical issues with the research. To what degree have you felt impeded by our concerns on ethics? To what degree do you feel impeded in terms of technological advancement compared to other nations?

Amy Kruse
For even basic, straightforward research, there are often hurdles and roadblocks to achieving progress. It certainly has not been my experience that things have gotten better. We have been over-evaluating everything, to the detriment of our ability to be concerned about invasive, disruptive, and damaging technologies. Things that are very simple are over-studied.

Gerry Yonas
In my experience, it has been difficult to get IRB approval. The reviewers rarely understand the experiment. When you write an IRB proposal, you are supposed to protect the individual, but there is a lot of protection of the institution instead. It is problematic that we are more concerned with protecting the legal status of the institution.

Amy Kruse
In contrast, there are nations that have fewer constraints on experimentation or approvals. Do researchers come to these countries to do their work?

Jonathan Moreno
In the stem cell era, as a public advocate for it, I talked a lot about the brain drain. The brain drain did not actually happen then. Researchers did not move away from the US. They will try to circle around restrictions and do something else. The big impact is that graduate students see a tainted field and they decide not to go into it. Simply, many Institutional Review Boards are bad. They are poorly run and poorly managed. Often, the scientist and physicians sitting on the IRB get more excited about regulation than the ethicists, even though the ethicist are the ones with more experience in regulation. Let me say one more thing about these problems and general democracy in an open society. The problem is often not the short term. I was very involved with the Human Genome Project in the 1990s. It is very often that people can look back at history and say that the people in authority did the wrong thing. They are supposed to be making these decisions because we are incompetent and for various other reasons. I think the long-term consequences of ethical lapses can be very severe. I grant you, it does create a potential for someone to achieve neurotechnological advancements before us. There is a long-term impact to unethical research, particularly when they are done to American citizens or to the American people.

Mike Swetnam
We have just completed seven years of neural, ethical, legal, and social issues research here at the Potomac Institute. Jonathan has contributed to many of those discussions. I have personally come to the conclusion that the neurotechnology crowd will figure out how to enhance themselves and a few others. They will leave the rest of the population to worry about ethics. We will not be able to stop this action by arguing about it. Dr. Kruse was saying at the beginning that you might buy it at GNC or you might buy it at Best Buy. It may have a Google or an Apple logo, but he who gets there first is going to start the next huge corporation. The government will not be able to get in the way and regulate it.

Audience Member
We have a friend that bought a pacemaker in Europe, far ahead of medical evolution of equipment. Look at the evolution of nuclear weapons; we now have a prohibition on research on nuclear weapons. During that time other people have fielded whole new research on nuclear weapons.

Mike Swetnam
Nuclear weapons, pacemakers, and other similar things are things that 1% of the populations really want. Neurotechnology is something that all of society wants and can use. Neurotechnology will be like a smart phone: it will cost $400, it will be accessible to everyone, and it will be manufactured in China.

Nancy Shinowara
We deal with a lot of grants and contracts involving devices and therapeutic treatments, usually not so much with pharmaceuticals. I think that for clinical studies and clinical research, it is very hard to support a study for long-term assessment. This is why there is not long-term study on many devices and treatments unless it is in an area with many labs working together. In neural technology, the market is driving development and the public is very aware. People are very willing to try noninvasive devices. Do the panelists have any thoughts as how to approach this

issue and how to develop a framework where this kind of data can be collected for devices and treatments over the long term? For better or for worse, the possible impact of neurotechnology spans a very plastic environment, and this information would inspire confidence in a particular approach.

Jonathan Moreno
This is a data aggregation problem that is not only found in neuroscience. I'm not familiar with this greatly. Ruth Haymen and her colleagues at Johns Hopkins are thinking about the clinic as a research site in a systematic way, you may want to talk to her.

Gerry Yonas
One of the aspects of brain stimulation is the emergence of the literature. The Brain Stimulation journal is published every other month with many papers as well as reviews of articles and reviews of meetings. Researchers are building this community. The field is beginning to come together, similar to the way physics and weapons communities did. Weapons researchers created a classified journal to share information. Researchers will come together and share information in order to build up the body of knowledge. If there were international regulations, the whole field could move more productively. I would encourage those who are working together.

Amy Kruse
Going back to the quantified software, there is also data to be found given the open DIY experimentation nature of the technology. Individuals could also contribute to this body of knowledge.

Gerry Yonas
CUNY hosted a community meeting on brain stimulation. More of these meetings and publications will build up this body of knowledge and accelerate its trajectory. The great problem is hackers getting into this. How do you build the cyber security of the collective?

Jonathan Moreno
There is already a story about hacking the collective, the effects of regulation, and its entwinement with society's demands. Has anybody been following this Facebook experiment? Facebook changed the comments of some of the friends on Facebook to be more negative. They noticed that the responses of hundreds of users whose pages they manipulated became more negative. As we know there are isolates that spend all day on Facebook. Some of those people could have well been damaged by sad and inaccurate information from their Facebook friends. This brings together several of the problems. This should have been IRB. It was a social psychological experiment.

Amy Kruse
My understanding was that they did not fabricate or change the content shown on your feed. They simply used the algorithm they are already are using to determine which of your friends' posts are seen. They filtered those comments so that they only showed you the comments with the emotional leaning they wanted. In simple terms, they showed you 300 things out of a pool of 2,000. And they chose the most negative things to show.

Jonathan Moreno
Clearly it is a social psychology deception study. It proves that we are herd animals. There is an epidemiology to negative and positive affect.

CLOSING REMARKS

JENNIFER BUSS

Thank you to all our speakers for taking the time to share your thoughts on the transformative power of neurotechnology on society. Neurotechnology has the potential to revolutionize how we interact with one another. Today we have heard how neuroenhancements can impact our lives.

Neuroenhancements are already changing our lives. We are seeing college students abusing pills to get ahead, companies marketing brain-training, and individuals using brain-zapping devices. Everyone wants a leg up and better efficiency. Achieving this is possible in many ways. The dial can be turned up 1, 2, or just 5% on the first iteration to get better efficiency. We will slowly progress to get better sleep, think faster, and make more neural connections, and to think in new ways. Although each individual enhancement is only a 1 or 2% increase by combining things in this way there is a total 8 to 16% increase in efficiency. Furthermore, changing it one more percentage point we're quickly at 50 or 60%.

We want our students to be the best in the world, our economy to be the best in the world, and our military to be the best in the world. In order for that to happen, it starts at home and it starts now. How many times have you said "if only I had a few more hours in the day?" Neuroenhancements are providing us with the tools to gain the extra hours we've always dreamed about. What will you do with your extra time?

How will we get there? Neuroenhancements are the best investment we can make in the 21st century, as they allow us to do everything better, faster, and stronger. They will allow us to invest in everything we desire more efficiently. Enhancement will help us learn faster, investing in education. Enhancement will help us be more alert, think harder, and become stronger soldiers, investing in our military. Enhancement will help us become smarter researcher, investing in disease research.

Over a year ago, the President announced the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative. Through funding from three agencies and a variety of industry organizations over $100 million was invested in neuroscience research. In June, the NIH released its BRAIN 2025 Report documenting their call for an annual investment of $400 million for the next ten years, totaling $4.5 billion.Compared to research funding for other successful national science programs this is an insufficient amount. The Race to the Moon, the Manhattan Project, and the Nanotechnology Initiative all commanded more than $21 billion, in 2014 dollars, of funding to reach their goals. The Space Race did not just build a rocket; it combined knowledge from many fields to put a man on the moon. The National Nanotechnology Initiative is not focused on individual achievements like 3D printing, electronics, or materials; it is a collaborative effort

that will takes our ability to manipulate matter at the nanoscale to revolutionize our technology, industry, and society. The Human Genome Project sequenced the genome, yet society is still waiting for personalized medicine This is the result of meek funding, $3 billion. We propose expanding the BRAIN Initiative to a National Neurotechnology Initiative (NNTI) to increase the funding, but also to expand the breadth of topics addressed by the initiative.

The President's BRAIN Initiative will not deliver on its promises, unless it is driven by greater, more robust goals. The current effort is reminiscent of the Human Genome Project, which promised personalized medicine from the sequence of human DNA. Ten years after the project was declared a success, we are still waiting for cures to diseases and individualized medicine. The Human Genome Project did not live up to its expectations and neither will the BRAIN Initiative. We needed more than the sequence of the genome to cure disease. We will need more than a map of the brain to understand how we think.

Both of these initiatives were sold as national science programs like the Space Race. Currently, these initiatives are akin to building rockets and promising the moon. We needed much more than rockets to put a man on the moon. Now, we need much more than a gene sequence to cure disease; we need more than the map of the brain to understand it. These initiatives have contained empty promises. It is now time to make the real promise with the right goals.

We need a National Neurotechnology Initiative with $2 billion in yearly funding. In order, for the BRAIN Initiative to achieve its the goals of curing diseases and understanding brain function this is the only way. Mapping the brain is only one step in the process. We need to supplement the NIH's investment with funding from a variety of government agencies. Interdisciplinary research is an integral part to success. Additionally, we need to create a National Coordinating Office that will oversee the investments from other agencies to synchronize research efforts. Each agency has their specific focus and occasionally these focus areas will overlap, creating ideal partnerships and collaborative research efforts. The Coordinating Office should remain in conversation with industry to stay abreast of the newest developments in research and products. Without continued coordination, we will lose sight of what we cherish most – our health, our minds, and our future.

The human brain is the most powerful tool we know and we do not understand how it works. We should do everything we can to understand its capacity, to utilize its worth, and to enhance its value to ourselves and our species. This can be accomplished by expanding the scope of the BRAIN Initiative beyond medicine and health to include all of society: intelligence, commerce, industry, communication, and education. The BRAIN Initiative as it stands is narrowly focused on medicine and health, specifically as "a bold new research effort to revolutionize our understanding of the human mind and uncover new ways to treat, prevent, and cure brain disorders." Understanding the complexity of the human brain and how to augment it should excite and motivate us to explore unknown arenas. An investment in enhancement is critical to the goals of the initiative. The science and technology that results from multibillion dollar investments is a contribution to society, but the true impact is in how a better understanding of our cognition and intelligence drives further innovation. The NNTI is the United States' next shot at the moon, the next research investment in revolutionary technologies, and the true last frontier.

CONGRESSMAN CHAKA FATTAH

U.S. Representative for Pennsylvania's 2nd District

Congressman Chaka Fattah is a senior member of the House Appropriations Committee. This committee is responsible for setting spending priorities for over $1 trillion in annual discretionary funds. Congressman Fattah is Ranking Member on the Subcommittee on Commerce, Justice, Science and related agencies (CJS). The Subcommittee on CJS oversees close to $51 billion in discretionary spending including the Commerce and Justice Departments, NASA. NOAA and the National Science Foundation. Congressman Fattah is the lead Democrat responsible for funding some of the largest science agencies in the federal system, including NASA, NSF, and the Office of Science and Technology Policy. Through his position in the Appropriations Committee Fattah directed the OSTP to establish an Interagency Working Group on Neuroscience, which convenes representatives across the Federal government to make recommendations about the future of neuroscience research. The Fattah Neuroscience Initiative is a policy initiative designed to make major progress understanding the human brain by intensifying, in a collaborative fashion, federal research efforts across brain disease, disorder, injury, cognition and development. The initiative aims to coordinate Federal research across agencies and draw upon public-private partnerships and the world of academia. Fattah is also Chair of the Congressional Urban Caucus, a bipartisan group of Members representing America's metropolitan centers.

Chaka Fattah is serving in his 10th term in the U.S. House of Representatives. Before his election to United States Congress in 1994, Fattah served six years as a Representative in the State House followed by six years as a State Senator. In May of 1986, Congressman Fattah earned a Master's degree in Governmental Administration from the University of Pennsylvania, Fels Institute of Government. Fattah is the recipient of numerous honors and awards including 10 honorary doctorates and the University of Pennsylvania's Fels Institute of Government Distinguished Alumni Achievement Award. Time Magazine named Fattah one of the 50 most promising leaders in the country. In 1984 Fattah attended Harvard University's John F. Kennedy School of Government where he received a certificate in the Program for Senior Executives in State and Local Government.

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MICHAEL SWETNAM

CEO and Chairman of Potomac Institute for Policy Studies

Michael Swetnam assisted in founding the Potomac Institute for Policy Studies in 1994. The Potomac Institute for Policy Studies focuses on Science and Technology Policy. Since its inception, he has served as Chairman of the Board and currently serves as the Institute's Chief Executive Officer. He has authored and edited several books and articles including: *#CyberDoc, No Borders, No Boundries; Al-Qa'ida: Ten Years After 9/11 and Beyond; Cyber Terrorism and Information Warfare*, a four volume set he co-edited; *Usama bin Laden's al-Qaida: Profile of a Terrorist Network; ETA: Profile of a Terrorist Group;* and *Best Available Science: Its Evolution, Taxonomy, and Application*. Mr. Swetnam is currently a member of the Technical Advisory Group to the United States Senate Select Committee on Intelligence. In this capacity, he provides expert advice to the US Senate on the R&D investment strategy of the US Intelligence Community. He also served on the Defense Science Board (DSB) Task Force on Counterterrorism and the Task Force on Intelligence Support to the War on Terrorism. From 1990 to 1992, Mr. Swetnam served as a Special Consultant to President Bush's Foreign Intelligence Advisory Board (PFIAB) where he provided expert advice on Intelligence Community issues including budget, community architecture, and major programs. He also assisted in authoring the Board's assessment of Intelligence Community support to Desert Storm/ Shield. He has served in several public and community positions including Northern United Kingdom Scout Master (1984-85); Chairman, Term limits Referendum Committee (1992-93); President (1993) of the Montgomery County Corporate Volunteer Council, Montgomery County Corporate Partnership for Managerial Excellence (1993); and the Maryland Business Roundtable (1993).

GEROLD YONAS, PH.D.

Mind Research Network, Director of Neurosystems Engineering

Dr. Yonas joined the Mind Research Network in 2009, as the director of neurosystems engineering. In his current work, he is dedicated to creating the new fields of neurosystems engineering that links advances in neuroscience with systems engineering through interdisciplinary teams that focus on the development of solutions to complex system problems involving behavior, cognition and neurotechnology. Previously, Dr. Yonas worked at the Sandia National Laboratories, where he served as vice president of Systems, Science and Technology, and later became Sandia's principal scientist and initiated Sandia's Advanced Concepts Group. He is a Fellow of the American Physical Society and a Fellow of the American Institute of Aeronautics and Astronautics. He has received numerous honors including the US Air Force Medal for Meritorious Civilian Service, the BEAMS prize, the Peter Haas Award by the Institute of Electrical & Electronics Engineers, the Fusion Power Associates Leadership Award, and the Secretary of Defense Medal for Outstanding Public Service. He serves on the U.S. Special Operations Command Science Panel, the U.S. Army Science Assessment Group, the U.S. Senate Select Committee on Intelligence Technical Advisory Group, and the Center for Strategic & International Studies Commission on Global Aging. Dr. Yonas received a B.S. in Engineering Physics from Cornell University, a Guggenheim fellowship for graduate study at California Institute of Technology, and a Ph.D. in Engineering Science and Physics.

JONATHAN D. MORENO, PH.D.

University of Pennsylvania

David and Lyn Silfen University Professor of Ethics

Jonathan D. Moreno is an American philosopher and historian who specializes in the intersection of bioethics, culture, science, and national security, and has published seminal works on the history, sociology and politics of biology and medicine. Dr. Moreno is the David and Lyn Silfen University Professor of Ethics at the University of Pennsylvania. As the David and Lyn Silfen University Professor, Dr. Moreno is one of fourteen Penn Integrates Knowledge professors. He is a Senior Fellow at the Center for American Progress and served on the Obama-Biden Transition Project in 2008 as the Director of the Department of Health and Human Services Agency Review for Bioethics. Dr. Moreno is a senior advisor for the Presidential Commission for the Study of Bioethical Issues, and served on the senior staff of the Clinton Administration's National Bioethics Advisory Commission and the Advisory Committee on Human Radiation Experiments. He is an elected member of the Institute of Medicine of the National Academy of Sciences and is the U.S. member of the UNESCO International Bioethics Committee. Dr. Moreno has served as an adviser to the Howard Hughes Medical Institute and the Bill and Melinda Gates Foundation. He is a member of the Governing Board of the International Neuroethics Society, a Faculty Affiliate of the Kennedy Institute of Ethics at Georgetown University, a Fellow of the Hastings Center and the New York Academy of Medicine, and a past president of the American Society for Bioethics and Humanities.

AMY KRUSE, PH.D.

Executive Director, Intific

Dr. Kruse joined Intific in January 2010 as an Executive Director, forming their new Neuroscience Division. She has recently led Intific in the release of their first commercial product, the RealWorld with NeuroBridge software platform. She also directs active Intific programs with the Office of Naval Research (Team Neurogaming), DARPA (ENGAGE, NowTu, Narrative Networks, DCAPS, SMISC), and the intelligence community. Dr. Kruse has more than 10 years of experience developing novel neuroscience-based programs and technologies for the Department of Defense. From January 2005 to January 2010, she served as a government civilian Program Manager in the Defense Sciences Office at DARPA in Arlington, VA. During her tenure at DARPA, Dr. Kruse managed more than nine programs including efforts in Augmented Cognition, Neurotechnology for Intelligence Analysts, Accelerated Learning, and Cognitive Technology Threat Warning Systems among others. Prior to DARPA, Dr. Kruse served as a technology and program management consultant at Strategic Analysis Inc. in Arlington, VA. During her time with SAINC, she provided hands-on technical assistance to nascent neuroscience programs at DARPA, the Office of Naval Research, and the Naval Research labs. She has been actively involved in neuroscience research for over 15 years. Dr. Kruse earned her B.S. in Cell and Structural Biology (1995) and her Ph.D. in Neuroscience (2001) from the University of Illinois at Champaign-Urbana where she was awarded a National Science Foundation Graduate Fellowship in Neuroscience.

JENNIFER BUSS, PH.D.

Research Fellow and Director, Center for Neurotechnology Studies

Potomac Institute for Policy Studies

Jennifer Buss, Ph.D. is a Research Fellow at Potomac Institute for Policy Studies. She is a member of the CEO's office and provides the scientific background for the think tank within the Potomac Institute, where she has been for two years. She is the Director of the Center for Neurotechnology Studies (CNS) at the Potomac Institute, having special interests in topics such as music and the brain as well as creativity and cognition. As Director of the CNS, she leads a team studying issues in neuroscience technology and policy and has been instrumental in organizing the Neuroscience Symposia Series 2014. Dr. Buss is a Fellow in the Center for Revolutionary Scientific Thought, a group at Potomac Institute that brings together individuals from a variety of backgrounds to foster discussion on science and technology futures from both an academic and policy perspective. In addition to these efforts, she has supported contracts for DMEA, OSD, and the Office of Corrosion Policy and Oversight. She is the Program Manager for the Rapid Reaction Technology Office contract for OSD in searching for innovative technologies to enhance government systems.

Dr. Jennifer Buss was awarded a doctorate in biochemistry from the University of Maryland Department of Chemistry and Biochemistry in 2012. Her dissertation was on iodide salvage in the thyroid and the evolution of halogen conservation in lower organisms. She performed graduate research in the areas of enzymology, bioinformatics, molecular and structural biology. Dr. Buss received her B.S. in biochemistry with a minor in mathematics from the University of Delaware. She is a member of the American Chemical Society, the American Association for the Advancement of Science and the American Society for Biochemistry and Molecular Biology.

BRIAN BARNETT

Policy intern, Potomac Institute for Policy Studies

Brian Barnett is a policy intern at the Potomac Institute for Policy Studies. He performs research and coordinates initiatives within the Center for Neurotechnology Studies. Brian obtained his B.S. in Neurobiology & Physiology at the University of Maryland, College Park, where he participated in the Gemstone research program and the Global Semester program. At the university, he worked in Dr. Matthew Roesch's behavioral neuroscience laboratory. Brian completed a thesis that investigated the behavioral and neural components of an animal model of ADHD. He also contributed to publications on the valuation and representation of reward within the rat fronto-striatal circuit.

NEUROTECHNOLOGY: ENHANCING THE HUMAN BRAIN AND RESHAPING SOCIETY

The Potomac Institute for Policy Studies held a seminar on "Neurotechnology: Enhancing the Human Brain and Reshaping Society" on June 30th, 2014. The speakers and panelists shared their insights into novel neurotechnologies that can improve our cognitive abilities through biological, chemical, and sensorimotor enhancements. Just as computing technologies brought us into the Digital Age, neuroenhancements will become widespread and transform our society. A collaborative effort between policy-makers, scientists, and the private sector will ensure that neuroenhancement of the individual will result in enrichment of our society as a whole. The human brain is the most powerful tool we know. Therefore, we should do everything we can to understand its capacity, to utilize its worth, and to enhance its value to our species and ourselves.

SYMPOSIUM SPONSORS

The Potomac Institute for Policy Studies is an independent, 501(c)(3), not-for-profit public policy research institute. The Institute identifies and aggressively shepherds discussion on key science, technology, and national security issues facing our society. The Institute hosts academic centers to study related policy issues through research, discussions, and forums. From these discussions and forums, we develop meaningful policy options and ensure their implementation at the intersection of business and government. The Institute remains fiercely objective, owning no special allegiance to any single political party or private concern. With over nearly two decades of work on science and technology policy issues, the Potomac Institute has remained a leader in providing meaningful policy options for science and technology, national security, defense initiatives, and S&T forecasting.

Center for Neurotechnology Studies (CNS) provides neutral, in-depth analysis of matters at the intersection of neuroscience and technology—neurotechnology—and public policy. The Center anticipates ethical, legal, and social issues (ELSI) associated with emerging neurotechnology, and shepherds constructive discourse on these issues. The Center partners with the research community for discourse and consultation on ethically sound neurotechnology research and applications. CNS serves as authoritative counsel to government agencies pursuing neurotechnology by providing expertise in the sciences, law and social policy through discussion on the implications of neurotechnology in academic, administrative, entrepreneurial, regulatory, legislative and judicial enterprises.