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U.S. House of Representatives

Statement by Dr. Regina E. Dugan

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Submitted to the

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It is said that "Vision without execution is daydreaming."[1]

There is a time and a place for daydreaming. But it is not at DARPA. DARPA is not the place of dreamlike musings or fantasies, not a place for self-indulging in wishes and hopes. DARPA is a place of doing. A place where vision is paired with execution. Where new things are imagined and then turned to reality. Where doing is as powerful a force as thinking. And where it is commonplace for something once deemed impossible to become improbable and then inevitable. It is a place where the Nation's best scientists and engineers go to serve a purpose greater than self. Together, they form the Nation's army of technogeeks with vision, and they "make it so." They stand on a 50-year history of people who changed the world.

DARPA's singular mission is to the technological superiority of the Nation's Defense; specifically, the creation and prevention of strategic surprise. Chairman Thornberry, Ranking Member Langevin, Members of the Subcommittee, my name is Regina Dugan. I am the Director of the Defense Advanced Research Projects Agency. I'd like to center our discussion today on the accomplishments of the Agency over the last 12 months and, as well, in support of our budget request, our intentions for the coming year.

Some mistakenly believe that strategic surprise necessarily conforms to a predetermined timeline. Strategic surprise can occur on any timescale. We get a vote. And so does the adversary. Sometimes it requires 5 to 10 years… sometimes only 90 days. This full dynamic range is illustrated in the breadth and scope of work that DARPA does, and it is punctuated by the intensity of our support to ongoing operations. The authenticity of such engagements inspires greater genius. And it cannot be created in the abstract.

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[1] This quotation is attributed to Bill Gates.

DARPA's support to ongoing operations.

In April 2010, shortly after last year's testimony, DARPA stood up Task Force JDOT[2]. It was motivated by a trip to Afghanistan, which revealed that many operators regarded DARPA as the organization to call when they believed they had a 5- to 10-year problem to solve. It seemed clear that many operators did not believe DARPA was in the fight with them. We were determined to change both the perception and the reality of that belief, because when the country is at war, and we can contribute, it is our duty to do so. Indeed, the Agency's participation in ongoing conflicts dates back to the Vietnam War.

At any point in time, DARPA has technologies in all stages of development, from nascent idea to system ready for fielding. Further, the Agency has a unique perspective on emerging technologies, megatrends, talent, and potential opportunities to synthesize advances in disciplines that might be brought to bear quickly to serve the warfighter. The Agency can respond rapidly to provide such support because of its leanness and adaptability.

Under Task Force JDOT, the Agency undertook eight specific efforts in direct support of Afghanistan covering the full spectrum of possibilities. Included were rapid fielding efforts for mature technologies; a 90-day Skunkworks activity that brought together some of the country's best computer and social scientists, counterinsurgency (COIN) experts, economists and analysts; advanced training tools; and organically-developed capabilities that harness crowd sourcing and social networking technologies. DARPA deployed teams to Afghanistan to support operations, sometimes within a month of being asked. These teams deployed not for a week, but for rotations of 3 to 6 months. The Agency stood up a forward operating cell, brought state-of-the-art advances in large-scale computational and visualization techniques to sparse database analysis, and created an in-theater data processing, exploitation, and dissemination cell complete with a full flight team. DARPA personnel work side by side with personnel from large

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[2] Joint DARPA Operational Trials

and small companies in 24/7 efforts to meet timelines needed to support forward operations. Some of the Nation's most talented young researchers took leave from their universities to deploy. These engineers and scientists enlisted in the DARPA army of technogeeks. I have watched young men and women, some as young as 27, go toe to toe with four-star generals. Because it mattered, and because it had become deeply personal to them. They decided they could make a difference, so they got in the fight. It is their way of serving country.

Other activities included the fielding of a wide-area high-definition, off-nadir light detection and ranging (LIDAR) collection system to provide much-needed 3D map data. LIDAR systems use light to image objects in the same way that RADAR systems use radio waves. Sensitivity at the photon-counting level matters to operations. The DARPA High Altitude LIDAR Operational Experiment (HALOE) system was five years in the making. It incorporates advances in short-wave infrared sensitive material properties that permitted photon-counting detector arrays so sensitive that it is now possible to make range measurements with fewer than 10 photons received, versus 10's of thousands of photons. As is true with your camera, increased sensitivity means that an image can be captured more quickly—the shutter has to be open for less time. And less light is required to capture an image. Less time and lower power translate to higher collection rates at larger standoff. HALOE can collect data at a rate that is more than 10 times faster than state-of-the-art systems or 100 times faster than conventional systems. At full operational capacity, this means that the HALOE system can map 50 percent of Afghanistan in 90 days. State-of-the-art deployed systems would have required 3 years to accomplish the same task, and more conventional systems would have required 30 years.

Communication nodes to allow coalition voice and data interoperability have also been deployed. Novel training aides based on current technological trends in smart phone application development, immersive simulation environments, and competitive improvised explosive device (IED) detection training are also part of the suite of capabilities.

We fielded systems to increase the risk and decrease the effectiveness of adversary attacks on U.S. helicopters and ground vehicles. Advanced acoustic detection and data processing exploit the supersonic shock wave produced by a bullet in flight to detect the presence and direction of incoming hostile small arms fire against helicopters, which accounts for 85 percent of hostile fire engagements. Last year, a prototype system for helicopter alert and threat termination (HALTT) was installed on an Army UH-60 L Blackhawk helicopter. This year, four HALTT systems were deployed to Afghanistan, with additional deployments scheduled for 2012.

Acoustic arrays and a radar system combine to detect, classify, and track small arms, rocket-propelled grenades (RPGs), and other advanced threats to ground vehicles. CROSSHAIRS geolocates and displays shooter position on an interactive map and then slews to cue an overhead weapon. Both CROSSHAIRS and HALTT began with the vision to detect and counter adversary action at the source. The fielding of both systems in Afghanistan last year was that vision realized.

But we didn’t stop there. Net armor surrounding a vehicle is used to crush the casing of an incoming RPG, thereby disrupting the formation of the shape charge and degrading lethal effectiveness. Technically elegant in execution and simply engineered, the ultra-lightweight, low-cost and easily adaptable system met with some initial skepticism.

Until the reports started rolling in… While conducting a patrol along a highly traveled road in eastern Ghazni, insurgents ambushed the Soldiers of 2nd Platoon, B Company, 187th Infantry, 101st Airborne Division. U.S. Army First Lieutenant R.J. Peek reported that on September 19, 2010, from less than 100 meters away, insurgents fired a volley of RPG rounds, followed by a series of machine gun fire and another RPG. In the course of the engagement, U.S. trucks took three direct hits by insurgent RPGs. None had penetrated. The nets performed exactly as advertised, and all of the Soldiers of B Company are alive today.

The breadth, urgency, and technical demand of these activities focus DARPA's work. They offer lasting lessons regarding the challenges of shipping product to customer. This transformative force underpins all the activities the Agency undertakes to transition novel technologies whether an exquisitely tuned laser mapping system or a simple net of armor. Experience and credibility are important to building confidence and trust with users. This is best done through active engagement and a track record of successful response under stressing conditions.

It is critical to balance our focus on today with a bold vision of tomorrow.

To catalyze the development of advanced capabilities for next-generation conflicts, we had to redouble our efforts to reach. To risk. At DARPA we say that we must not lose the nerve for the big failure. The nerve you need for the big failure is the same as the nerve for the big success, until the moment you know which it will be. It's the exact same nerve.

Just a few weeks ago, IBM's Watson supercomputer, which is designed to deal with unstructured data and to interpret natural language, beat two *Jeopardy* champions. The final tally: Watson: $77,147. Jennings: $24,000. Rutters: $12,600.

Many felt the contest was a vindication of the academic field of artificial intelligence, which as stated in *The New York Times*, "…began in the 1960s with the vision of creating a thinking machine and which became the laughing stock of Silicon Valley in the 1980s when a series of heavily financed start-up companies went bankrupt."

For decades, computer scientists have had nerve in the face of failure and even ridicule. It turned out that failing was a part of succeeding. Tenacity in the field, in execution, led to victory. Their vision, paired with execution, was realized in Watson's win.

One of the *Jeopardy* participants, Mr. Jennings, said that "I had a great time and I would do it again in a heartbeat… this is about being part of the future."

We have endeavored to revitalize this sensibility at DARPA… the Agency's willingness to take on the big risk.

We have embraced programs such as PROCEED, which is focused on accelerating recent advances in computer science that only recently produced a theoretical construction for fully homomorphic encryption. After thirty years of research and a period of time when homomorphic encryption was treated as a foundation for impossibility proofs, in 2009, Craig Gentry produced a construction that proved the opposite, indeed, that it is possible to compute on encrypted data without decrypting it.

Why does this matter? Because encryption is one of our most basic methods for protecting information. But if we want to operate on encrypted data—process it, actually do something with it—we have to decrypt it first. And it is necessarily at greater risk in the decrypted state. We operate on it while it's in a decrypted state, then take the result, encrypt it again, and send it on.

The fundamental mystery is whether it is possible to perform operations on encrypted data without decrypting it first. And even if it is theoretically possible, is it practical?

Gentry's work about a year and a half ago opened the door. He proved that it could be done. That's the good news. The bad news is, it's very inefficient right now—14 orders of magnitude less efficient than it needs to be. The first demonstration involved a simple "and" function. It took 30 minutes. A comparable computation using existing systems today would take a fraction of a nanosecond.

PROCEED is working to improve that efficiency. The program tackles a number of research areas that will be needed to successfully turn theory into practice. It seeks to develop improved mathematical foundations for fully homomorphic encryption as well as secure multiparty computation protocols. It will develop highly optimized implementations of the necessary cryptography. The PROCEED program attempts to crack this computational challenge to develop a practical means to compute on encrypted data, even on possibly compromised computational infrastructure.

If we are successful with PROCEED, it fundamentally changes the calculus for computations in untrusted environments… on computer systems of unknown provenance. The potential implications for the cybersecurity of cloud computing architectures are profound.

Practical implementation of fully homomorphic encryption is the goal of PROCEED. Unlocking the fundamental measurement of nature is the aim of QuASAR. Quantum-Assisted Sensing and Readout seeks to develop clocks and sensors that operate at the standard quantum limit. Once these individual devices are made as 'quiet' as possible, however, the story is not over. Quantum mechanics allows one last trick: by entangling multiple sensors, we can wring out additional quantum noise to surpass the standard quantum limit.

The complexity of this goal exploits a simple idea: the best measurement devices, atomic clocks, when subjected to external stimuli might also make the best sensors.

Such advances may enable high-resolution magnetic imaging capable of resolving individual nuclear spins at the nanometer scale. Such resolving power would enable the detailed, 3D structures of biological molecules with elemental specificity in their native environment and could streamline assessment of inhibitor drugs against a virus (whether naturally occurring or engineered as a biological weapon). It could alter the landscape of small-molecule development as did x-ray crystallography, electron and atomic force microscopy.

From our support to ongoing operations to the challenge of homomorphic encryption, at DARPA, the problem is not coming up with enough good ideas… but rather choosing among them.

As we looked forward to 2012 and beyond, to the future strategic areas for DARPA, and how best to choose from among the multitude of ideas, we developed three key questions that reflect the core attributes of DARPA programs.

- Will it be game changing and have lasting impact for the Department and National Security?
- Does it require DARPA technical expertise and daring?
- How does it contribute to the balance of existing investments?

Further, each decision to apply resources comes with an opportunity cost. Today, DARPA is tackling some of the most pressing and vexing challenges facing DoD. We sought to develop a means for identifying opportunities and gaps and to balance the Department's responsibility to the present, while maintaining a commitment to the future. The Agency has begun to address these executive-level Department decisions through the technology and innovation lens enabled by its unique science and technology (S&T) perch.

National Security is a high-tech endeavor. Many of the Department's most intense challenges have deep technical roots and invoke, in addition, concepts of operations, policy, economics, and the adversary's advances. The choreography of the technical, operational, policy, and fiduciary constraints has become more important than ever. DARPA has arguably one of the highest densities of technical subject matter experts in the U.S. Government. Over the last 2 years, DARPA has used this capacity to frame these complicated issues quantitatively so as to inform complex decisions. This perspective, in turn, guides investment decisions, structures our engagement with the Services, and informs the broader decisions of the Department's senior leadership.

We call these assessments analytical frameworks.

Analytical Frameworks

Over the last 18 months, the Agency has developed several analytical frameworks. They are designed to be deeply quantitative, to reveal the essential parameters governing a decision space, and to question existing assumptions. Accessible to technical and non technical executives, the analytical frameworks are structured to ensure the Agency, and the Department, are better able to focus investments. Ultimately, these frameworks have the power to reveal areas where we are divergent with threats and technological trends and, thus, need new options. The frameworks help to create the stimulus for fundamental shifts in thinking. For preventing or creating strategic surprise.

Three of these analytical frameworks are described below: global intelligence, surveillance, and reconnaissance (global ISR); manufacturing; and cybersecurity. The perspectives and understandings revealed by these frameworks have resulted in changes in our approaches.

Global ISR

There is a near-constant complaint that we are drowning in data. So, we decided to assess exactly what this means…in quantitative terms. Essentially, if we are drowning in data, we asked ourselves, how much water? We calculated data volume as a function of sensor resolution and area coverage, and we compared the data volume required to accomplish certain operational objectives. For example, to detect strategic bombers, one needs resolution of approximately 10 m^2. Over an area the size of Reagan National Airport, this resolution results in a data volume equivalent to about 1 second of Milstar SATCOM. To detect dismounts, however, one needs resolution of approximately 10 cm^2. Over an area the size of Baghdad, this is about equivalent to a data volume equal to 1 second of US Internet traffic in 2009. Nearly five orders of magnitude—100,000 times—more data. Not surprisingly given the current conflicts, when we plotted existing and new or planned ISR systems, there was a general trend toward higher resolution and larger fields of view.

One of two things must happen: either we must give up the target set, or we must deal with the data volume. They are linked. Obviously, we do not want to give up the target set. The only choice before us, therefore, is to develop capabilities that dramatically improve our ability to manage and use the data.

The trend set by the detection of increasingly difficult targets is driving data volume exponentially. We cannot solve this exponential problem with a linear growth in analysts. Our need is divergent from our capability. Specifically, if we examine the implications of U.S. Central Command (CENTCOM) requirements alone and a modest deployment of the new high-definition DARPA system named ARGUS-IS[3], the number of analysts required to managed the data volume created by this demand increases roughly 15 fold.

What's the solution? Counter intuitive but DARPA-like, the problem has in it the seeds of the solution. That higher resolution, wider area coverage, namely better sensors do not always worsen the problem. Indeed, as the data improves, the performance of automated systems improves. The fundamental knee in the curve cannot yet be determined *a priori*, from first principles, but empirical results suggest that better sensors give us better data. More and better data leads to better automation. Better automation enables better analysis.

As a representative example of what this means, ARGUS-IS provides video data at five times the frame rate of conventional systems. Five times the frame rate means five times more data, but it also means that an automated system tracking a dismount or vehicle gets five times as many "looks" at the target as it moves. Increasing the frame rate makes the automated tracking both more accurate and less likely to lose the track. More data leads to better automation and, ultimately, to *less* of a load on an analyst.

[3] Autonomous Real-time Ground Ubiquitous Surveillance – Imaging System

Such tracking algorithms, in concert with more accurate image analysis enabled by higher resolution, can be trained to identify and flag actions captured on video such as “digging,” “unloading,” and “walking.” Such an advance would allow more of the existing and new ISR data feeds to be interpreted by untiring 24/7 automated analysis systems. Not by people.

These automated systems promise to free humans to do what humans do best and leave computers to do what computers do best. If successful, the combined efforts at DARPA devoted to improving this matching would imply a linear growth in analysts, by less than a factor of two, rather than the 15-fold increase envisioned using conventional approaches. Such an advance would make the user’s ability to analyze the data convergent with data generation capacity. And we didn’t give up the demanding target set.

Manufacturing

On February 12, 2011, *The New York Times* published an article entitled “When Factories Vanish, So Can Innovators.” It challenged previously held assumptions about the ability to decouple innovation and manufacturing. Indeed, it suggested the emergence of real questions regarding the Nation’s ability to be competitive in R&D when we are not making what we innovate.

At DARPA we have a shorthand for this… we say “to innovate, we must make.” And further, that the connection to the Nation’s defense is profound, because it is also true that “to protect, we must produce.”

Norm Augustine, former CEO of Lockheed Martin and author of *Augustine’s Laws*, observed that if projected to the future, current trends in the manufacturing of defense aircraft show that, by 2054, the entire Department of Defense budget would be required to purchase one fighter airplane. Quite obviously, this trend is not sustainable. It impacts the affordability, relevance, and adaptability of the Nation’s defense.

We argue that just as the cost of such systems in not sustainable, we can no longer afford the time that it takes to design, develop, and field such systems. Extended design, test, evaluation, and production times for complex defense systems, oftentimes of order decade, and the resultant lack of adaptability, has become a vulnerability in and of itself. Naturally, time and cost are linked and, importantly, in an almost self-fulfilling cycle. If upon beginning a new system development effort, we anticipate a decade-long development, then it becomes necessary to encompass all the uncertainty in the threat environment projected 10 years into the future. This drives a dramatic expansion in the design envelope, the incorporation of technologies likely not yet invented, and requires robust margins for error. All these factors contribute, in turn, to increased risk, cost, and schedule difficulties.

DARPA is not a policy organization. Our charge is not the laws or regulations that may change the landscape of DoD acquisition. Rather, we argue that fundamental shifts in the technical means by which we make things could dramatically alter this landscape. By reducing the cost and time to design, test, and produce such systems, even within existing constraints, we may be able to drive increased innovation and competition by lowering the barrier to entry. This would potentially enable the Department to move from a “buy then make” to a “make then buy” strategy.

At DARPA we have focused our investment in defense manufacturing innovation, totaling approximately $200 million per year, or $1 billion over the next 5 years, on reducing the time needed to design, develop, and field. We are synthesizing and integrating these efforts so as to contribute alternative design and production methods for next-generation systems spanning ground combat vehicles to vaccine production. Of note, while the implications of the DARPA programs may also benefit the overall US manufacturing base, our activities are focused on the needs of defense.

One such effort is the Manufacturable Gradient Index Optics (M-GRIN) program. Lens and optics technology is old. Lenses augment human sight, but present optical systems and lenses can be heavy and cumbersome; indeed, the miniaturization of many systems is limited by the optical lenses. DARPA's M-GRIN program seeks to change traditional lens and optical systems construction by collapsing multiple lenses and their assembly into a single lens using stacked polymeric layers that better manipulate light. This means that a warfighter's flip-down helmet optics might be seven times lighter. And weight savings matter to warfighters. It could also mean that the optics currently carried on a Predator could be fielded on a miniature unmanned air system – the required wingspan for equivalent optical power could potentially go from 48.7 feet to 4.25 feet. And because the M-GRIN technology is an entirely revolutionary method for lens manufacture, it means that customized, programmable, large-scale manufacturing of unique lenses is possible for the first time. Need a custom lens? Send us your bits.

Historically a major user and driver of advanced microelectronics, today the Department of Defense is a relatively low-volume customer and at increasing risk of losing access to off-shore, state-of-the-art process and facilities. The Maskless Nanowriter program at DARPA promises to contribute to the restoration of cost-effective, integrated circuit manufacturing in small wafer lots in the United States.

The program will develop a unique nanolithography tool that writes directly on the wafer without the use of present-day multimillion dollar lithography machines and mask sets. This new tool permits tight control over wafer writing (nanolithography) to ensure greater security and low-cost integrated circuit customization, which are critical to most major U.S. Defense systems. High-resolution lithography manufacturing is dominated by foreign states at present (Netherlands and Japan). The development of this unique tool at DARPA could restore the U.S. position in the supply-chain manufacturing of critical systems components for National Defense and commercial applications.

The new tool not only yields greater control over security and cost, it also increases the speed of fabrication by 100 fold over existing electron beam lithography tools. The Maskless Nanowriter is a massively parallel electron-beam lithography tool using 1 million independently controlled electron beamlets formed by a unique reflection electron beam process. The high-resolution, high-throughput Maskless Nanowriter enables affordable fabrication of application-specific integrated circuits. And because these systems are important to the performance and security of Defense systems, our ability to produce such components is connected to our ability to protect.

Tackling one of the most vexing challenges for the Department, the Adaptive Make effort seeks to compress the design, development, and production of complex electromechanical systems by a factor of 5: from 10 years to 2 years. With implications across Defense systems, the initial target for the program is ground vehicles. Adaptive Vehicle Make (AVM) represents a portfolio of programs intended to change the fundamental approach to the design and manufacture of major Defense systems. Simply put, it will control for time first. All elements of design, test, evaluation, production, and quality control are targeted at meeting an objective line in the sand… time.

To generate systems that are technologically advanced, adaptable, and precisely suited to mission, manufacturing for Defense applications requires the production of potentially highly differentiated systems in low volumes. This is unlike commercial systems, which do not require much variety (automobile customization is dominated by small, mostly cosmetic changes) and are produced in high volumes. Reflective of this difference, the DARPA portfolio is directed at three primary and Defense-driven challenges: the development of design and verification tools that support rapid trade space exploration and the ability to probabilistically verify correctness by construction; the creation of programmable manufacturing facilities that can produce vehicles based on the verified designs; and the enabling of crowd-derived designs that seek to expand the pool of designers and innovators by 100-fold. Through a series of design competitions, the program will culminate in the production of a “first-of” infantry fighting vehicle using these advanced manufacturing methods.

Our goal, simply put, is to create breakthroughs in manufacturing that enable massive innovation, much like the breakthrough of the Internet enabled massive innovations in the communication and IT industries. The implications for controlling the cost, adaptability, and suitability for intended purpose of our major defense system purchases are far reaching.

Cybersecurity

In a globalized world, borders and boundaries, or “edges,” no longer conform to geographic lines on a map. The ability to define these new edges, from a technological perspective, has not yet evolved. Nowhere is this felt more acutely as an opportunity than in the global mindshare of democratized, crowd-sourced innovation. Nowhere is this felt more acutely as a threat than in the cyber world.

Threats in cyberspace are multi dimensional. They range from network penetration, to the provenance of the supply chain, to the role of users. The DARPA cyber analytical framework sought to quantify elements of the threat and create a context for understanding the nature of the asymmetry. This understanding is a means for reassessing our strategy.

A key attribute of the analytical frameworks is the identification of areas where we are inherently divergent with the threat. Such areas have the seeds of strategic surprise. Such divergence is an almost inherent characteristic of asymmetric threats like cyber.

One illustration of the cyber asymmetry is illustrated by the following example: In response to the diversity and evolution of malware, cyber defense has moved from simple firewalls and application proxies to more complex firewall systems. The first appearance of “security appliances” shifted toward so-called unified threat management systems, which now approach the complexity and size of entire computer operating systems.

Over the last 20 years, using lines of code as a proxy and relative measure, the effort and cost of information security software has grown exponentially—from software packages with thousands of lines of code to packages with nearly 10 million lines of code. By contrast, over that same period, and across roughly 9,000 examples of viruses, worms, exploits and bots, our analysis revealed a nearly constant, average 125 lines of code for malware. This is a striking illustration of why it is easier to play offense than defense in cyber, but importantly, it also causes us to rethink our approach. To seek new approaches that might lead to convergence.

This is not to suggest that we stop doing what we are doing defensively. On the contrary, our existing efforts are necessary. But if we continue only down the current path, we will not converge. The analogy is similar to being in the ocean and treading water. If you stop treading water, you will drown. Treading water is necessary for survival, but if all you do is tread water, eventually you will drown anyway. It is best to build some additional options.

Informed by the above and other insights from the analysis, we assessed that DARPA had a significant role to play; so, we recruited an expert cyber team made up of individuals from diverse experiences including the “white hat” hacker community and major commercial companies, in addition to the Defense and intelligence communities. DARPA launched several new initiatives focused on novel topics such as clean slate design of resilient, adaptive, and secure hosts inspired, in part, by biological mechanisms for resilience. In addition, efforts are underway to seek assured computations on untrusted hardware and safer Internet communications in untrusted environments.

The Cyber Insider Threat (CINDER) program seeks to develop techniques for countering one of the most significant and malicious threats to military networks and systems: the cyber insider threat. Current defenses are based on network and host intrusion detection, and look for "break ins" and abnormal behavior, but do not attempt to characterize a user's mission. Single events oftentimes evade detection or are lost in a sea of false reports. However, the conduct of a mission and the resultant insider behavior is deliberate and involves a coordinated set of actions. Strategies for detecting the mission enable templating on more complex actions and “tells” that provide a cue subject to additional screening, forensics, or heightened alerting. Together, we argue, this promises a more robust detection capability. If successful, the CINDER program will build tools and techniques that characterize user mission in a multi level security environment.

Using the defensive mechanisms of biological systems as inspiration, the Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) program seeks to develop cyber security technologies that radically rethink basic hardware and system designs. Higher level organisms have two distinct immune systems: the innate system, which is fast and deadly, but is effective only against a fixed set of pathogens; and the adaptive system, which is slower, but can learn to recognize novel pathogens. Similarly, CRASH will develop mechanisms, at the hardware and operating system level, which may eliminate known vulnerabilities exploited by attackers. However, because novel attacks will continue to be developed, CRASH will also develop software techniques that allow it to defend itself, to maintain its capabilities, and even “heal” itself. Finally, biological systems show that diversity is an effective population defense; CRASH aims to develop techniques that make each computer system evolve over time, thus appearing unique to the attacker.

The Military Networking Protocol (MNP) program is creating architectures, protocols and network controllers to provide attribution of traffic on our military networks to improve network integrity. Currently, our network traffic is identified only by Internet Protocol address an easily falsified form of attribution that cannot be relied upon to tell us who the individual or organization actually sending the information may be. To remedy this problem, the MNP program has developed technology that has successfully attributed traffic to individual actors in a test environment of 200 devices networked at 100Mbps. In future tests, the MNP program will achieve attribution in environments of 10,000 devices networked at 100 times faster speeds.

By enforcing military user authentication, military network protocols will provide full attribution of every military device and track each device's network flows to provide full attribution down to the individual source of bad/erroneous data or malicious activity. Prioritization schemes can be controlled by military commanders at various echelons so as to address changing mission requirements. MNP technologies will transition to Defense Information Systems Agency and the Military Services.

The Cyber Reserve Corps program is designed to develop the necessary technologies and tools to permit massive numbers of non cyber experts to participate in the defense of cyberspace. Individuals already collaborate on cyber defense through numerous blogs and message boards dedicated to issues such as diagnosing problems on computers/networks and remediating the effects of malware on popular commercial systems. These activities are facilitated through a variety of software tools; however, additional tools for detecting and diagnosing known exploits, as well as variants of known exploits, will be developed. Cyber Reserve Corps will also create technologies for generating shareable host and network log files that both preserve the privacy of user data and inform participants about new exploits. Ordinarily, this information would remain widely segmented and dispersed; the toolset and community for Cyber Reserve Corps seek to make it possible to bring together relevant information that may reveal subtle patterns of hostile activity that would otherwise go unnoticed.

Whether you believe in a war metaphor or a law enforcement model for cyber, the goals of the response are common. The Agency is investing over $250 million in cyber initiatives in 2012, a 100 percent increase over the FY 2011 cyber request. Additionally, beginning in 2012, the President's budget request includes another $500 million for cyber research over the Future Year Defense Program. An expanded level of effort at DARPA rests on an existing foundation and continuing contributions to cyber. Indeed, DARPA-developed technologies are widely prevalent in both commercial and military use, including the technology that protects all Department network connections to the Internet against denial-of-service attacks. These additional resources are focused on the development of options beyond treading water by accelerating and expanding programs in clean-slate initiatives, the defense of cyber physical systems, and the security of supply chains. They are motivated by the Agency's history of innovation and its willingness to challenge conventional wisdom.

Getting our business practices right is part of the job.

No one remembers changes in business practices that enable success because they are, quite simply, enablers… amplifying forces that allow us to achieve great things. But getting them wrong can be a significant impediment. Execution is what turns ideas into reality – the Agency must operate effectively with agility, speed, and with technical and administrative integrity.

DARPA executes a budget of nearly $3 billion as appropriated by Congress. It does so with approximately 120 program managers—a number that has been at or below this level since 1992—and a roughly equal number of Government support staff. Financial resources and lean business practices allow the Agency to pursue ideas that most dare not touch. And to do so quickly. There are no entitlements to programs or people, no captive laboratories, no immutable tenets. The Agency has what might be characterized as a “thoughtful ruthlessness” in its dogged pursuit of the best people, ideas, and output.

The breadth, urgency, and technical demands of DARPA programs are real—the capabilities being developed may literally protect the lives of our warfighters. The innovative ideas that the Agency pursues are fragile and fleeting. To protect them, you must say “yes” before “no,” and the organization’s business practices must be aligned with the speed and flexibility required to do so. The “no kidding, it must work” authenticity of Defense applications demands an organization dedicated to excellence in execution through all levels of management, policies, and personnel. Indeed, in the face of such pressures, creativity requires heroic intellectual leaps not just from the technical side of the organization, but equally from the support side of the organization. And such heroic leaps mean that DARPA must find the best people, the best jumpers, for all positions at DARPA.

Notably, the absence of bureaucracy is an oft-cited characteristic of DARPA. The Agency has only one layer of management between the Director and the program managers. There are currently six offices in the Agency that comprise a dynamic and fluid construct that changes in accordance with technological and personnel opportunities. In the last year, DARPA stood up two new offices and combined two offices to the benefit of our efforts. We have support offices dedicated to essential functions that enable the mission through innovative practices that mirror the technical innovations of the Agency.

DARPA attracts some of the country's best technical minds who serve for a tour of 3 to 5 years. Program managers with technical acumen and nerve are empowered to run programs, adapting in accordance with advances and challenges. They have authorities matched to their responsibilities. Accountable to the Agency, to the Department, to the Nation, and to our warfighters, DARPA's program managers are drawn from academia, industry, nonprofits, the Services, and laboratories. Program managers, office directors, the Director, and the Deputy Director change on a regular cadence. This practice ensures the Agency is current with existing and emerging technological trends, encourages a continual challenging of bureaucracy, and imparts an ethic of urgency and delivery for all personnel.

In recent years, Congressional oversight committees have expressed concern that DARPA's financial execution was inadequate; specifically, that DARPA was not obligating a significant fraction of the money it had requested. These concerns resulted in budget cuts and rescissions, but, as well, obligation delays meant fewer resources at work for the Department. In 2010, we placed a significant emphasis on financial execution. At the end of September 2010, the Agency's obligation rate was 23 points higher (86 percent) than the 5-year average (63 percent) despite the delayed January 2010 Appropriations signing. At the end of fiscal year 2010, the improved execution translated into more than $600 million in the performer community, working for the Department and Nation.

Speed is part of the vibrancy of innovation. Consistent with these improvements in execution, the average contracting time is down by 18 percent. From proposal approval to contract signing, the Agency took 56 days in 2010, compared to 68 days in 2009—nearly a full 2 weeks across both internal and external contracting actions, large companies and small businesses. Contracting vehicles are also being used in the best interests of cost savings. For example, the Agency saved $60 million in the renegotiation of a multi performer, high-performance computing effort through the use of a contracting method better matched to the effort and mix of performers. We streamlined decision making and simplified contracting. The process is now clear, fair and fast. Better business practices are just better Government. It affects not only the performers, but the Agency too.

The programs and ideas developed at DARPA are not ours alone. Rather, they are the result of vibrant exchange among many. One of the Agency's strengths is its ability to build bridges between disparate communities and to uncover ideas in unexpected places.

This ability to build new communities is predicated on the Agency's commitment to work at the intersection of basic science and application, so-called Pasteur's quadrant. DARPA is not a pure science organization, but neither is it a pure application organization. To be successful, we need the minds of the basic scientists and the application engineers, those in universities, and those in industry. And we need them working together, often on a single project, in the cauldron created by the urgency and technical demands of Defense. This is almost a unique characteristic of DARPA projects, which are often multidiscipline, multicommunity, and multistage. Our talent pool spans our interactions with universities, industry, the Services, among others.

Universities.

Over the last few years, the university community articulated concerns about a breach in DARPA's commitment to basic research. There was much said on both sides about the veracity of these concerns. Regardless of one's opinion about how a breach may have occurred, it was clear that one had.

Last year, we related to this committee that, upon arrival at DARPA, we were determined to understand and repair the breach. The first step was to get ground truth. We did a deep dive and discovered that indeed, between 2001 and 2008, DARPA funding to US research university performers did decrease in real terms, by about half. Many attributed the breach to that alone. But we found that it wasn't only about the money. As importantly, a noble and recent focus in the Agency on solving nearer term problems for the Department had resulted in some additional, perhaps unintended, consequences.

The nature of the work changed, from multiyear commitments to those with annual "go, no-go" decisions governing continued funding. The later stage focus also resulted in more work done by universities as subs to prime contractors responsible for integration efforts since, it was argued, the larger contractors would be more suitable for translating research to fielding. The result, however, was that the larger companies imposed restrictions on the use of foreign nationals, export control, prepublication review, among others, onto the fundamental research conducted on campus at universities. All these restrictions combined to threaten the very nature of fundamental research and, worse, at some universities, made it impossible within their acceptable contractual constraints, commitment to students, mission and culture, to contribute to the Defense mission.

The result meant the intellectual power of the academic community was not nearly at capacity in its contribution to Defense and National Security. Truth be told, though, it wasn't damaging only us. Many researchers who had historical interactions with the Agency said that DARPA performer meetings would be the ones you never missed. That the nature of funding, the community, the challenge involved in a DARPA program led by a spirited, technically uncompromising, and slightly "unreasonable" visionary program manager… well, it was just different. And it inspired them to do their greatest work. Oftentimes they spoke with a nostalgic longing for those glory days.

We need the minds of the basic scientist and the application engineer, those in universities and those in industry. And we need them working together, often on a single project, in the cauldron created by the urgency and technical demands of Defense. Because it is almost a wholly unique characteristic of DARPA projects–the blending of basic science and authentic application. And in a way, perhaps unexpectedly, these communities need DARPA too.

That's where we stood more than a year ago. And then, we got to work.

We established protections for basic research. Under existing guidance dating back to 1965 with a National Security Decision from the White House, Directive 189, and reiterated in a DoD memo dated June 26, 2008, the products of fundamental research are to remain unrestricted to the maximum extent possible. And while there may be compelling reasons for DoD to place controls on some applied research that is performed on a university campus, such occasions should be rare and each must be carefully scrutinized.

Only a few months after our visits to universities, in January 2010, DARPA spearheaded an effort to switch the default… namely, to ensure that fundamental research protections are used in all contracts unless a waiver is secured at the Deputy Director or Director level. In 2010, the DARPA Deputy Director approved waivers for only 5 of 275 total contracts in fiscal year 2010. In all five cases, the university participants engaged in the deliberations and concurred with the restrictions imposed.

Universities are also contributing to the leadership talent pool. In the 5 years prior to 2009, the per year average number of university faculty and researchers hired to work as program managers at DARPA was two. Last year it was 10. A five-fold increase. We challenged the universities to send their best and brightest, and they did. We have professional associations, individual professors, department heads, deans, presidents and provosts to thank.

Industry.

Equally important, of course, is the role of industry, from electronics to pharmaceuticals, software to space, small businesses to large. In January and September of last year, DARPA held Industry Summits to engage the leadership of U.S. industry: chief executive officers, chief technology officers, chief operating officers, and senior vice president-level executives. More than 70 percent of the participants were from small businesses, including some who had never before done business with DoD. The outcome of the Summits was much broader than anticipated. Nearly half the participants went on to build new business-to-business connections, for which DARPA served as a bridge.

More than 200 companies so far—Defense and non-Defense, representing 16 business sectors—participated in roundtable discussions regarding how competitiveness is affected by globalization and the implications for National Security. The discussions concerned the barriers to innovation, access to science and technology talent, and Government/industry relationships. The days were long, and the discussions were animated. Perspectives were refined, discarded, shifted. We gained insight, as did the participants.

Some of those insights we have turned into action. For example, we created a Small Business Innovation Research "EZ" contracting mechanism based on commercial best practices. Contracts have gone from 50 pages to 10. Using our Other Transaction authority, the contracts permit generally accepted accounting principles accounting and streamlined reporting, as well as data rights and intellectual property language that facilitates commercialization and addresses the concerns of investors.

The result: to date the time for contract award has been reduced from a typical 5 to 6 months to less than 30 days. This change is motivated in part by the Deputy Director's and my experience in the private sector. We know that time is money and that each opportunity pursued is another one not.

By ensuring our engagements and business practices better match the pace and expectations of the commercial sector, we will also open the aperture to those who can contribute. Many potential performers who may have innovative solutions are unfamiliar or misinformed about the challenges and constraints of working with the Federal Government. Business practices that facilitate the introduction of fresh perspectives from new performers increase the likelihood that the Agency and the Department are getting the best solutions, efficiently.

In certain emerging technical areas, most notably cyber security, some of the most innovative and ground-breaking work is conducted by small nontraditional teams. We find that they are willing, even eager, to contribute to Defense and National Security, but disincentives created by traditional Federal Acquisition Regulation based contracting mechanisms and the associated reporting burdens dissuade them. Over the next year, we aim to fix it.

The Services.

DARPA's partnership with the Services might best be described as a collaborative competition. We get crosswise when either party thinks it is only a collaboration or only a competition. An appropriate analogy might be much like that experienced by athletes, where competition serves as a means of identifying winning strategies, and collaboration through agreed-upon rules and scoring is a means of honoring higher goals. We agree to this collaborative competition because it works, but it is not without its struggles.

DARPA's responsibility is to our warfighters and to the technological superiority of the Nation's Defense. We exist in part to challenge existing perspectives. We break glass. We make people excited and, admittedly, sometimes, we make them uncomfortable. This includes the very people we honor most… the men and women of the United States military. Given the nature of the Agency's activities, it is understood that some of DARPA's most important contributions to the Nation's Defense have been in pitched opposition with established views. It would be impossible to prevent and create strategic surprise without a spirited willingness to take on the battles that ensue.

Throughout the process of transition, missteps occur on both sides. It is intensely difficult to penetrate existing systems and change prevailing views. When a new idea is outside one's worldview, it is virtually impossible to see. It is almost a hallmark brand for truly innovative work. The efforts to field stealth and unmanned aerial vehicles (UAVs) come to mind. An aircraft designed with angular shapes to control their radar cross section? An airplane without a pilot on board? Initially, both concepts met with great resistance. Persistence, demonstrations at convincing scale, visionary champions in the Services, the participation of many including other elements within the Department, and support in other branches of Government, yields success. A specific strategy for continued, substantive engagement across this spectrum helps.

Beginning in 2009, the Agency reinvigorated interactions with its primary customers, the Services. These interactions are designed specifically to highlight recent advances, clear obstacles, lay the foundation for analysis using our analytical frameworks, and better align for potential success of early research. DARPA has begun semi-annual exchanges with the Joint Requirements Oversight Council (JROC), and quarterly engagements with the Service Vice Chiefs and their senior staffs, as well as the Service Secretaries, through the Undersecretaries and chief acquisition officials. These interactions are in addition to regular engagements with the Service Chiefs, the Combatant Commands (COCOMs), the Service materiel development and science and technology organizations, among others. In addition, we support and interact with members of the Army Science Board, Air Force Science Advisory Board, Defense Science Board, and Naval Research Advisory Committee.

Importantly, we have found that the analytical frameworks, described earlier, have become central to these discussions in that they create a common ground and build a shared understanding. We have redoubled our efforts to instill credibility and frankness about the maturity and transition readiness of DARPA programs by clearly distinguishing technologies that are in the concept, prototyping, and fielded stages. The frameworks, a spirit of openness, clarity of transition readiness, and efforts that deliver capabilities to ongoing operations, have built better and lasting bridges between the technical experts within the Agency and those in the operational community. We better understand the problems, and senior leaders are better equipped to make decisions based on gaps and opportunities. We are both able to appropriately leverage our strengths and resources.

Educate. Inspire.

The quality of the country's talent in science, technology, engineering, and math matters for the innovative health of the country. It matters not only for our economic competitiveness, but also for the Nation's Defense. Education is a necessary condition, but it is not sufficient. It opens the door, but it does not close the deal. Curiosity. Wonder. Inspiration. They matter too.

Einstein said, "The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead; his eyes are closed."

DARPA has been creating mystery and purposeful wonder since its inception. Programs such as Big Dog, which created a decidedly life-like four-legged robot, tantalized imaginations. At last count, videos of Big Dog in action have been viewed more than 2.7 million times on YouTube. The DARPA Network Challenge, also known as the Red Balloon Challenge, made participating in a social media science experiment accessible for millions. Young and old. Scientists and poets.

But it's not just the programs. People at DARPA carry a mystique about them too. Technically astute, inspiringly articulate, full of "fire in the belly," with the skills of a doer in addition to the vision of a dreamer, the quintessential DARPA program manager sees something that others do not yet see. And they see it so clearly, they cannot unsee it. They are hell-bent and unrelenting in their efforts to show the world what's possible.

The Gedanken exercise isn't enough for them. They aren't just curious daydreamers. They are technical visionaries that turn their visions into reality. They want to demonstrate at convincing scale… to turn impossible to improbable to inevitable. They are expert task masters, communicators, negotiators. The best are tenacious—they just don't give up. They step up to their responsibilities for S&T leadership and they do not stop at demonstrating a capability, but drive to clear the path for turning that new capability into use.

The paths are diverse and varied from the effort to field unmanned aerial vehicles in an environment that better understood pilots in the cockpit than on the ground; to creating a DARPA forward cell in Afghanistan in support of the war effort; to negotiating for a new fast track capability–the Medical Device Innovation Initiative–with the U.S. Food and Drug Administration so that wounded warriors can receive the most advanced, state-of-the-art prosthetics. Developing the technology isn't enough.

Perhaps one of the most publicly recognized programs at DARPA is the advanced prosthetics program. The goals of the Revolutionizing Prosthetics program are two-fold: to provide an arm with a range of motion and dexterity comparable to a natural arm and, eventually, to provide an arm that permits the same sensory experiences as a native limb. Motion and dexterity are enabled by a microchip on the surface of the brain that decodes neural activity into the signals to actuate and control the prosthetic, restoring near-natural arm, hand and finger function to patients suffering from spinal cord injury, stroke, or amputation. Currently, a neurally-controlled arm is undergoing qualification for its ability to restore tactile feedback to the user such that he or she can feel temperature and joint motion. We believe that, together, these features will restore functionality to the user that approximates that of their original, native limb.

Last year, I told you the story of Fred Downs, who I met first when he visited DARPA to demonstrate use of one of the new DARPA arms. Fred lost an arm in the Vietnam War and had been using a conventional prosthetic ever since. His command of the new arm was impressive. But what struck me most was the story he told of his own reaction to wearing it. He said that after a very short time, he was surprised by his sudden emotional response. Because, he realized that he was thinking like a bilateral again. For the first time in 40 years.

It was remarkable.

The program manager who made this happen is United States Army Colonel Geoff Ling. Doctorate in pharmacology from Cornell University's Graduate School of Medical Sciences. Medical degree from Georgetown University. Neurology residency at Walter Reed Army Medical Center. Research tour at Sloan-Kettering Cancer Center. Neurointensive care fellowship at Johns Hopkins Hospital. Serves on the critical care staff at Walter Reed Army Medical Center and Johns Hopkins Hospital. Credited with an innovative procedure that likely saved former Chairman of the Joint Chiefs of Staff, General Hugh Shelton, from a wheelchair after a catastrophic fall. Colonel Ling has the singular distinction within DARPA of having briefed a program from the war in Afghanistan.

Colonel Ling is widely known for his leadership, ethical standards, vision and commitment to excellence. He has had a profound impact on DARPA, our Nation's warfighters, and the medical community at large. He is a leader: on the battlefield, in an intensive care unit, or along the halls of DARPA. He takes charge of situations, asks provocative questions, and is uncompromising in his search for better. Good enough simply isn't in Colonel Ling's world.

Anyone who interacts with Colonel Ling knows… he does what he does because his internal compass points in the direction of service before self. It is what drives him. And his far-reaching programs—from Fracture Putty to Predicting Health and Disease—

are the evidence. He is credited with saving the lives of countless warfighters through his efforts at DARPA and as a doctor. He sets a standard that many of us strive to meet.

44th Medical Brigade (Airborne), MD, PhD, spirited. He's the archetypal DARPA program manager and the person to talk to if you want a little inspiration.

DARPA is committed to this archetypal program manager. Oftentimes viewed as "difficult to manage" in other organizations, DARPA is a place where their spiritedness and willingness to challenge existing opinions is valued, not "just tolerated." Truth be told, they are the inspirational force of the Agency. In a return to their classic role, program managers are once again running programs in their best judgment. They have both the responsibility and the authority to do so. Why does this matter? Because the best people come when they have the unique power to change things. And because they aren't afraid to be accountable.

Conclusion.

This last year was one of investments, risks and payoffs. From computer science to biology… from quantum sensing to infantry fighting vehicles… manufacturing to cyber… sniper fire to prompt global strike. From strategic surprises measured in 90-day Skunkworks efforts in support of ongoing operations to those likely realizable in a decade… we reinvigorated our work, challenged ourselves, and embraced mystery in big, bold DARPA strokes.

We took seriously the responsibility to use DARPA's resources effectively. We treated it as an opportunity to improve rather than a reluctant obligation. We set aggressive goals and quantitative measures of efficiency for the Agency. We used a deeply analytical approach to making our investment choices, saving or shifting focus to the most pressing Department needs. This was not change at the margins; it is a targeted investment in excess of $1billion over the coming years. As of September, improved financial execution put $600 million more of the Agency's resources to work in the economy and against Department problems as compared to our historical 5-year average. And our time to contract award is faster by almost 20 percent. We revitalized our engagement with Universities, Industry, and the Services.

It is progress to be proud of… progress in shared service to the Nation. Progress, we hope, that is worthy of the honorable men and women in our Armed Forces. This is our way of honoring the sacrifices of the men and women of our military who, through their service, have written a blank check made payable to the United States of America for an amount "up to and including their lives."

Vision without execution is daydreaming. There is a time and a place for daydreaming… but it is not at DARPA.

Sir Francis Drake said, "There must be a beginning to every great matter. But the continuing unto the end, until it be thoroughly finished, yields the true glory."

We're not finished.

Thank you.