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Subcommittee on Terrorism, Unconventional Threats and Capabilities,
House Armed Services Committee, U.S. House of Representatives

Statement by Dr. Tony Tether

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Submitted to the

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Mr. Chairman, Subcommittee Members and staff: I am pleased to appear before you today to discuss the Defense Advanced Research Projects Agency's (DARPA) Fiscal Year (FY) 2004 activities and our FY 2005 plans to continue to transform our military through technological innovation.

Let me begin by saying a few words about the DARPA.

Since the time of Sputnik, DARPA has had a special mission within the Department of Defense (DoD): maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security. DARPA does this by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use long before our adversaries can do so.

Two simple questions help illustrate much of our mission:

- "What technologies would allow an adversary to surprise the U.S.?" and
- "What technologies are needed to ensure that US forces will always have new capabilities to surprise our adversaries?"

A historical example of this DARPA's development of stealth – a dramatic technological capability that is one of our military's greatest asymmetrical advantages.

As a Defense Agency, DARPA is part of the Office of the Secretary of Defense and is the DoD's only research agency not tied to a specific operational mission. DARPA is designed to be the "technological engine" for transformation, supplying technological options for the entire Department.

This is a unique role within DoD. The Department's operational components focus on nearer-term needs because they must meet urgent needs and requirements. Consequently, a large organization like the DoD needs an organization like DARPA whose *only* charter is radical innovation. We try to imagine what a military commander might want in the future and accelerate that future into reality by changing people's minds about what is technologically possible.

DARPA's Eight Strategic Thrusts

Through the years, DARPA has continuously refocused its work in direct response to evolving national security threats and technological opportunities. The eight strategic research thrusts that DARPA is emphasizing in response to emerging trends are:

- Detection, Precision ID, Tracking, and Destruction of Elusive Surface Targets
- Force Multipliers for Urban Area Operations
- Location and Characterization of Underground Structures
- Networked Manned and Unmanned Systems
- Robust, Secure Self-Forming Tactical Networks
- Cognitive Computing
- Assured Use of Space
- Bio-Revolution

Force Multipliers for Urban Area Operations is a new area that we have begun this year, partly in response to what we have all seen in Iraq and Afghanistan, and the increasing likelihood that conflict in the future will be fought in cities.

Let me tell you about these eight thrusts, the forces driving them, and illustrate them with some examples.

Detection, Precision ID, Tracking, and Destruction of Elusive Surface Targets

For many years, the Department of Defense has steadily improved its ability to conduct precision strike. Timely, accurate, and precise delivery of bombs and missiles helped the United States overthrow hostile regimes in Afghanistan and Iraq in short order with few American or unintended casualties. However, our experience shows that major challenges remain in target detection, identification, and tracking. It is still difficult to strike targets that are hiding, moving, or that require U.S. forces to react rapidly to destroy them.

Providing a focused response to these challenges, DARPA is assembling the necessary sensors, exploitation tools, command systems, and information technologies to rapidly find and destroy ground targets in any terrain, in any weather, moving or not, at any time, with minimum accidental damage or casualties. To do this, we are working to seamlessly meld sensor tasking with strike operations, leveraging platforms that carry both capable sensors and effective weapons.

Of course, this blurs or even erases barriers between the Intelligence and the Operations functions at all levels of command. This is a difficult technical challenge that requires a joint approach and has potentially large implications for U.S. military doctrine and organizations.

DARPA is supporting research in four general areas: sensors to find targets; sensor exploitation systems to identify and track targets; command and control systems to plan and manage the use of sensors, platforms, and weapons throughout the battlespace; and information technology to tie it all together and ensure the effective dissemination of information.

DARPA's sensor work is exemplified by the Standoff Precision Identification in Three Dimensions (SPI-3D) program to develop an airborne LIDAR sensor to provide positive target identification from standoff ranges via high resolution three-dimensional representations. SPI-3D will be cued by wide area surveillance sensors, such as synthetic aperture radar, which can determine the presence of possible targets but may be unable to confirm target type or identity. SPI-3D technology will close this gap, allowing commanders to positively identify targets as needed by our rules of engagement.

The Jigsaw program is developing a three-dimensional imaging laser radar capable of reliably identifying hidden targets through gaps in foliage and camouflage. The Jigsaw sensor will collect high-resolution, three-dimensional images from multiple viewpoints and combine them to form a composite three-dimensional image to enable the warfighter to see underneath the canopy and recognize targets, day or night. In field tests, we have successfully integrated, tested, and flown prototypes against targets hidden by various densities of foliage and types of camouflage. We are proceeding to ruggedize and miniaturize the Jigsaw sensor for the Army's Future Combat Systems.

The National/Tactical Exploitation (NTEX) program uses imagery and data from both national reconnaissance systems and tactical assets to locate and identify enemy air defense units. During Operation Iraqi Freedom, NTEX supported our forces in Iraq by screening synthetic aperture radar imagery to look for enemy air defense emplacements.

Other DARPA programs have performed significant demonstrations. These programs have: located short-duration emitters with high accuracy; detected dismounted soldiers moving through trees; identified ground vehicles from acoustic/seismic sensor networks; maintained track on designated vehicles through obscured terrain; and delivered precision munitions to destroy moving tanks and trucks from 30 kilometers away.

Force Multipliers for Urban Area Operations

Urban area operations can be the most dangerous, costly, and chaotic forms of combat. The number of military operations in urban areas is increasing, and this trend will likely continue for the foreseeable future. By 2025, nearly 60 percent of the world's population will live in urban areas. Adversaries will seek to fight U.S. forces in cities as a way to mitigate the U.S's superior ability to quickly destroy fixed and mobile targets in open and semi-concealed terrain. Accordingly, DARPA has created a new strategic thrust, Force Multipliers for Urban Area Operations.

The basic idea is to do for the extremely complex urban environment what has been done for open terrain combat: find and use technology that significantly increases U.S. forces' power and flexibility so that fewer forces are required to accomplish the mission.

If successful, new urban warfare concepts and technologies would enable U.S forces fighting in or stabilizing a city to achieve the same or greater overall effect as a larger force using current technology.

Some initial concepts suggest making strong use of the vertical dimension for entry and attack. Other ideas focus on bringing situational awareness quickly into the complex urban battlespace. Information should flow smoothly from prehostilities intelligence into a tactical network that quickly disseminates information. The goal is to ensure U.S. forces can find and neutralize the enemy wherever he is located – on the streets, inside buildings, or hidden in underground bunkers.

To achieve this vision, reconnaissance, surveillance and target acquisition (RSTA), firepower, and communications must be robust, persistent, integrated, and immediately available. Firepower might include highly responsive precision air and ground fires, or even loitering and soldier-launched weapons, all networked directly to RSTA sensors.

Command and control systems to improve the collaboration at all echelons and on-demand, precise air delivery of forces and supplies to the ground are also key elements. Situational awareness of combatants and noncombatants will be critical to avoiding fratricide and targeting noncombatants.

DARPA has some programs underway already. We are exploring ways to navigate accurately inside buildings and underground in tunnels. Other programs seek to allow forces to accurately determine a building's layout before they enter, along with capabilities to determine whether hostile personnel are hiding in the building.

Location and Characterization of Underground Structures

Many potential U.S. adversaries are well aware of the U.S. military's sophisticated intelligence, surveillance, and reconnaissance capabilities and global reach, so they have been building deeply buried facilities to hide what they are doing and to harden themselves against attack. These facilities can vary from the clever use of caves to complex, carefully engineered bunkers. Possible uses of such installations include ballistic missile basing, leadership protection, command-and-control, and the production of weapons of mass destruction.

To meet the challenge posed by the spread of these facilities, DARPA's Counter-Underground Facility program is developing and using a variety of sensor technologies – seismic, acoustic, electro-optical, radio frequency, and chemical – to locate and characterize underground facilities. The program is working on tools to answer the questions, "What is this facility for? How busy is it now? What are its structures and vulnerabilities? How might it be attacked? Did our attack destroy the facility?"

To provide answers, DARPA has improved ground-sensor sensitivity by two-orders-of-magnitude, and also developed advanced signal processing for clutter rejection in complex environments like cities. Underground facility characterization and battle damage assessment will be demonstrated using these advanced systems later this year. New initiatives in this arena include wide-area search for the detection of unknown urban underground facilities on rapid (i.e., tactical) timescales, and work to determine the interconnectivity of urban facilities and caves.

Networked Manned and Unmanned Systems

DARPA is working with the Army, Navy, and Air Force toward a vision of filling the strategic and tactical battlespace with unmanned systems that are networked with manned systems. The idea is not simply to replace people with machines, but to team people with autonomous platforms to create a more capable, agile, and cost-effective force, and one that also lowers the risk of U.S. casualties. The use of unmanned aerial vehicles (UAVs) in Afghanistan and Iraq clearly demonstrates the value of this idea.

Much of the activity in this area is expected to transition to the Services over the next few years.

Two broad trends have combined to make this thrust feasible. First, there is an increasing appreciation within the Services that combining unmanned with manned systems can enable new combat capabilities or new ways to perform hazardous missions. Second, improved processors and software permit the major increases in on-board processing needed for unmanned systems to handle ever more complex missions in ever more complicated environments. Moreover – and this is key – networking these vehicles in combat can improve our knowledge of the battlespace, targeting responsiveness and accuracy, the survivability of the *network* of vehicles, and mission flexibility. A network of collaborative systems is far more capable than the sum of its individual components. If I may borrow from a commercial slogan, "The network is the force."

A prominent program in this area has been Future Combat Systems (FCS). FCS is aimed at developing collaborative manned and unmanned Army units as lethal and survivable as an M1 Abrams-based heavy force, but as agile as a light force. The Army assumed leadership of the FCS program from DARPA in FY 2003. Since the Army is using a spiral development approach in FCS, DARPA will continue to develop technology for the program, particularly communications networks and tactical UAVs.

More recently, the Office of the Secretary of Defense established the Joint Unmanned Combat Air Systems (J-UCAS) program at DARPA to accelerate the Department's progress in making networked unmanned combat air vehicles a reality for suppressing enemy air defenses, precision strike, and persistent surveillance. The program is a joint DARPA, Air Force, and Navy program, building on DARPA's earlier work on unmanned combat air vehicles for the Air Force and Navy. DARPA will lead the program until it reaches the point of operational assessments, at which time a transition to the Services will begin. The program will develop new air vehicles, but it is crucial to understand that the heart of the J-UCAS system will be the network that combines those vehicles with each other and with other systems to create an entirely new type of fighting force.

Complementing J-UCAS is DARPA's Unmanned Combat Armed Rotorcraft (UCAR) program with the Army, which aims to transform how the Army conducts armed reconnaissance and attack.

I'd like to give you an update on DARPA's first Grand Challenge event, held almost two weeks ago in the southwestern desert. It was designed to accelerate the Department towards meeting the Congressional goal that one-third of our operational ground combat vehicles be unmanned by 2015.

A few years ago, Congress gave DARPA the authority to award prizes for technical accomplishments. This is similar to the prize awarded to Charles Lindbergh for his solo flight to Paris. We used our prize authority to hold our first Grand Challenge on March 13th.

The challenge was for an autonomous, unmanned ground vehicle to go 142 miles, across the desert back-roads between Barstow, California, and Primm, Nevada, in under 10 hours. The team that built the first vehicle to do it would be awarded one million dollars. And that was the only money they would get from the government.

We had two reasons for picking this Grand Challenge. First, we wanted to promote technology important to our national defense, technology that will eventually take more Americans off the battlefield and save lives as we let robots do the driving in things like supply convoys. Second, we wanted the challenge to be something that anybody could participate in. Our goal was to reach out and involve people who would never ordinarily be found working on a problem for the DoD.

Over 100 entrants filed applications to compete. Of the 25 teams invited to the qualifying tests, 21 vehicles showed up.

And what an amazing variety of vehicles! They varied from completely homebuilt vehicles to modified SUVs. One had tracks, some had four wheels, others six and one was a motorcycle.

Some weighed a few hundred pounds, one weighed 16 tons. They were built by high school student, college undergraduates, moonlighting engineers, technicians, software enthusiasts and backyard mechanics. Many had multiple private sponsors, and one was partly financed by winnings from the television game show "Jeopardy."

The qualification tests showed that 15 of the vehicles were safe enough to go out on the route. The teams got their first look at the route approximately two hours before the early morning start of the event on March 13th. Nearly all vehicles made it out of the starting gate. Four of the vehicles made it from five to seven miles, and another four made it roughly one mile from the start point before the challenge of autonomous, robotic driving – or the perils of the dirt roads – caught up with them. We had asked them to do something incredibly difficult, but their enthusiasm never waned.

You should also know that throughout all this we put a huge effort into protecting the environment, particularly the desert tortoise. We worked with the U.S. Bureau of Land Management, the Fish and Wildlife Service, and the California Bureau of Land Management to make sure we had a good plan and the right procedures. On the day of the event, a team of about 20 biologists was out in the field to protect the tortoise. I am pleased to report we had no problems.

The output of the Grand Challenge was far more important than just the technology in the vehicles, even if it is harder to measure. All across the nation, from garages to high schools, from universities to corporate laboratories, thousands of people worked on solving a problem important to the DoD.

Anyone who was in the stands that day or talked to any of the teams cannot have helped but notice the incredible energy and enthusiasm in the air, a can-do spirit of innovation. This event planted seeds that will lead to many more talented people working on this problem and ones like it.

Lindbergh's feat did not create a tremendous new technology. What he did was show what was possible, what the future would look like, and excite people about aviation. And that excitement brought talent, and that talent created huge progress in the years that followed.

We would have liked to have paid out that million dollars this year, but what we really got was absolutely priceless.

So we will run the Grand Challenge again in 12 to 18 months. But this time the prize will be two million dollars. And the Palos Verdes High School team said that next time everybody else better watch out for them, because next time they will have *seniors* on their team!

Robust, Secure Self-Forming Tactical Networks

The Department of Defense is in the middle of a transformation to what is often termed "Network Centric Operations." In simplest terms, the promise of network centric operations is to transform information superiority into combat power. The U.S. and coalition allies will have better information to collaborate, share knowledge, and synchronize joint operations far more quickly and effectively than our adversaries. In essence, this next level of networking will use "better brains" to create a more agile and effective brawn.

At the heart of this concept are survivable, assured, spectrum-agile communications, encompassing both the strategic and tactical levels. The goal of this work is a high capacity network that degrades gracefully under attack, while always providing a critical level of service.

DARPA is conducting research in areas including self-forming, *ad hoc* networks; high capacity, multiband, multimode communications systems; ultra-wideband communications; spectrum sharing; information assurance; and low probability of detection/intercept/exploitation communications.

The Optical and Radio-Frequency Combined Link Experiment program will combine large-bandwidth, free-space optical communications with radio frequency communications to demonstrate compact, robust, high bandwidth mobile communications for our military forces. This hybrid of optical and radio frequency technologies will yield higher performance than either could achieve on its own.

An example of how DARPA's work in component technology are enabling these robust networks is the wristwatch-sized Chip-Scale Atomic Clock. Microelectromechanical systems (MEMS) technology will put an entire atomic clock onto a single chip, reducing its size and power consumption by factors of 200 and 300, respectively.

At the heart of a communication network is a common time reference.

These chip-scale atomic clocks will greatly improve the mobility and robustness of military communication and navigation devices by giving everyone a near perfect time reference that cannot be disrupted. These clocks will improve communications channel selectivity and density and enable ultra-fast frequency hopping for improved security, jam-resistance, and data encryption.

In GPS receivers, they will greatly improve the jamming margin and help continuously track positions and quickly reacquire a GPS signal. And in surveillance systems, they will improve the resolution of Doppler radars and help locate radio emitters.

Borne out of the need for rapid and efficient utilization of the shrinking military bandwidth, the neXt Generation (XG) Communications program will make 10 to 20 times more radio frequency communication spectrum available to the U.S. military by dynamically sharing unused spectrum across frequency, time, and space.

It turns out that, on average, only a small portion of the spectrum is actively used at any given moment, even though most of the spectrum is licensed exclusively for its users 100 percent of the time. The key question becomes whether an XG system can exploit underutilized spectrum without interfering with the original licensee.

The threat to military networks from computer worms that have never been seen before, and that exploit previously unknown network vulnerabilities ("zero-day worms"), has exceeded commercial industry's ability to mount an adequate defense. The Dynamic Quarantine of Worms (DQW) program will develop a system of integrated detection and response that will dynamically quarantine computer worms. The DQW program is focused on zero-day worms and stealthy worms that try to slip into military networks undetected.

It may be nearly impossible to stop the initial infection from a zero-day worm. DQW's strategy is to quarantine the worm in a section of the network. "Vaccines" can then be automatically synthesized and distributed to protect other networks from a large-scale infection.

Cognitive Computing

Many elements of the information technology revolution that have vastly increased the effectiveness of the U.S. military and transformed American society, including time-sharing, personal computers, and the Internet, were given their impetus by a visionary scientist at DARPA some 40 years ago, J. C. R. Licklider. Licklider's vision was of people and computers working together symbiotically. He envisioned computers seamlessly adapting to people as partners that would handle routine information processing tasks. This would free people to focus on what they do best – think analytically and creatively – and, thereby, greatly extend their cognitive powers.

Despite enormous and continuing progress in information technology over the years, computer capabilities are still well short of Licklider's vision. Current computing systems are critical to U.S. national defense, yet they remain exceedingly complex, expensive to create and debug, insecure, unable to easily work well together, and prone to failure. And, they still require the user to adapt to them, rather than the other way around. Computers have grown ever faster, but they remain fundamentally unintelligent and difficult to use. Something dramatically different is needed.

In response, DARPA is again tackling Licklider's vision in a strategic thrust called "Cognitive Computing." Cognitive computers can be thought of as systems that know what they're doing.

Cognitive computing systems will be able to reason about their environments (including other systems), their goals, and their own capabilities. They will be able to learn both from experience and by being taught. They will be capable of natural interactions with users, and will be able to explain their reasoning in natural terms. They will be robust in the face of surprises and avoid the brittleness and fragility of today's supposed expert systems.

The fundamental importance of Cognitive Computing was underscored in a statement by Microsoft Chairman, Bill Gates: "If you invent a breakthrough in artificial intelligence, so machines can learn … that is worth 10 Microsofts." Mr. Gates' statement goes beyond just economics: this research, if successful, will bring profound changes to the way DoD uses computers to conduct operations.

Assured Use of Space

The national security community, including the U.S. military, use space systems to provide weather data, warning, intelligence, communications, and navigation. These satellite systems provide our national security community with great advantages over potential adversaries. American society as a whole also uses space systems for many similar purposes, making them an integral part of the U.S. economy and way of life.

These advantages – and the dependencies that come with them – have not gone unnoticed, and there is no reason to believe they will remain unchallenged or untested forever. As the Rumsfeld Commission explained, "An attack on elements of U.S. space systems during a crisis or conflict should not be considered an improbable act. If the U.S. is to avoid a 'Space Pearl Harbor,' it needs to take seriously the possibility of an attack on U.S. space systems."

DARPA began as a space agency, when the shock of Sputnik caused Americans to believe that the U.S.'s Cold War adversary had seized "the ultimate high ground." Over time, U.S. space systems have become one key to our military advantage. DARPA, once again, is taking a major role in this important technological area.

In FY 2001, the Secretary of Defense directed DARPA to begin an aggressive effort to ensure that the U.S. military retains its pre-eminence in space by maintaining unhindered U.S. access to space and protecting U.S. space assets from attack.

There are five elements in DARPA's space strategic thrust:

- *Access and Infrastructure:* technology to provide rapid, affordable access to space and efficient on-orbit operations;
- *Situational Awareness:* the means for knowing what else is in space and what that "something else" is doing;
- *Space Mission Protection:* methods for protecting U.S. space assets from harm;
- *Space Mission Denial:* technologies that will prevent our adversaries from using space to harm the U.S. or its allies; and
- *Space-Based Engagement:* reconnaissance, surveillance, communications, and navigation to support military operations down on earth – extending what the U.S. does so well today.

DARPA is focusing most of its efforts on the first four of these thrusts, while the efforts in Space Based Engagement are emphasizing technology complementary to research being done by the National Reconnaissance Office.

Three examples of DARPA's space programs are Responsive Access, Small Cargo, Affordable Launch (RASCAL); Innovative Space-Based Antenna Technology; and Force Application and Launch from the Continental U.S. (FALCON).

RASCAL is designed to place small payloads in orbit on a moment's notice by launching them from a high-speed, high-altitude, reusable aircraft that eliminates a large and expensive first stage booster. RASCAL is aimed toward a system to place 50- to 130-kilogram satellites and commodity payloads into low earth orbit at any time, at any inclination, and with a launch cost that is less than a third of current capabilities for the dedicated micropayload size. The first RASCAL launch is planned for 2007.

The Innovative Space-based Antenna Technology (ISAT) program is developing revolutionary large antenna technologies that could one day enable large, yet affordable, space-based radar (SBR) systems capable of operating at medium earth orbit (MEO). These antennas would be extremely lightweight (approximately five kilograms per square meter), compact (approximately 400 cubic meters, fully stowed), and affordable. They are designed to meet the stressing requirements of continuous, tactical-grade tracking of ground moving targets for intelligence, surveillance, and reconnaissance. MEO-based SBR would enable persistent, continuous coverage of ground mobile targets with far fewer satellites than that required with constellations based in low earth orbit. The first ISAT space-based demonstration launch is planned for 2009.

FALCON is designed to vastly improve the U.S. capability to reach orbit or almost anywhere on the globe promptly from bases in the continental U.S. This will improve the military's ability to strike fleeting targets far overseas or quickly position intelligence, surveillance, and reconnaissance payloads and reduce its reliance on forward and foreign basing. FALCON will proceed in stages, including a small, low-cost launch vehicle, a common payload vehicle, and eventually a hypersonic vehicle. The ultimate goal is to be able to deliver 12,000 pounds of payload 9,000 miles away in less than two hours. The technology required for FALCON will drive major progress in achieving low-cost, responsive access to space.

Bio-Revolution

DARPA's strategic thrust in the life sciences, dubbed "Bio-Revolution," is a broad effort to harness the insights and power of biology to make U.S. warfighters and their equipment safer, stronger, and more effective.

Over the last decade and more, the U.S. has made an enormous investment in the life sciences. DARPA is mining these new discoveries for concepts and uses that could enhance U.S. national security in revolutionary ways.

There is a growing recognition of synergies among biology, information technology, and micro/nano technology. Advances in any one area often benefit the others, and DARPA has been active in information technology and microelectronics for many years. DARPA is able to bring many disciplines together with biology to use new biological knowledge in novel ways.

DARPA's Bio-Revolution thrust has four broad elements:

- *Protecting Human Assets* refers to DARPA's work in Biological Warfare Defense (BWD). DARPA's comprehensive BWD program began in the mid-1990s in response to a growing awareness of the biological warfare threat to the U.S. It covers sensors to detect an attack, technologies to protect people in buildings and manage the response to an attack, vaccines to prevent infection, therapies to treat those exposed, and decontamination technologies to recover the use of an area.
- *Enhancing System Performance* refers to creating new mechanical systems with the autonomy and adaptability of living things by developing materials, processes, and devices inspired by living systems. For example, DARPA-supported researchers are studying how geckos climb walls and when legs have advantages over wheels and tracks. The idea is to let nature be a guide toward better engineering.
- *Maintaining Human Combat Performance* is aimed at ensuring that humans don't become the weakest link in fast-paced, combat operations. The goal is to learn what we can from the life sciences to keep the individual warfighter as strong, alert, and endurant as he or she was before deploying, and to be able to administer self-help when battlefield injuries occur.
- *Tools* are the variety of techniques and insights on which the other three areas rest.

Let me give you some example of our work here.

DARPA Bio-Revolution work started in the mid 1990s with novel technologies for biological warfare defense (BWD). Over the past three years, DARPA's Triangulation Identification for Genetic Evaluation of Biological Risk (TIGER) program has developed and demonstrated a biowarfare agent detection and identification sensor that can rapidly identify any human pathogen and quantify how much pathogen is present. This sensor has performed successfully, even in the presence of complex samples that would cause state-of-the-art sensors to trigger false alarms. TIGER's flexibility and speed was demonstrated during the SARS epidemic of 2003, when the sensor was quickly configured to detect the presence of the SARS virus in patient samples.

Two years ago, prompted by the attacks on the Congress, we started an aggressive effort to eliminate the threat of anthrax. This year we are completing our investments in six highly novel technologies. One of those approaches, CpG, boosts the immune system and enhances the effectiveness of the anthrax vaccine, and is entering the FDA's Investigational New Drug testing protocols. If CpG works in humans, we should be able to rapidly immunize troops and "stretch" the vaccine stockpile. Two other promising approaches are directed towards later-stage anthrax infections: one uses enzymes from phages, natural predators of specific bacteria, to kill the anthrax outright; and the second uses a protein to block the assembly of the anthrax toxin.

To find new approaches to locomotion and control, researchers in our Enhancing System Performance programs are studying such things as how insects run over rough terrain, and how flies avoid capture. For example, RHex is a wirelessly controlled robot with legs that mimics the movement of a cockroach. RHex has demonstrated that its legs help it move across difficult terrain that would stop a tracked or wheeled vehicle, such as rubble piles and railroad tracks. The robot is being developed further with integrated sensors for the military.

We have also demonstrated a synthetic optical lens that mimics the advantages of biological lenses by emulating the elegant, adaptable lens structure of a fish eye. This bio-inspired, reconfigurable lens system has the potential to produce a 30x zoom, yet be compact enough to be carried on a small unmanned aerial vehicle.

In order to markedly improve our ability to provide blood products whenever and wherever needed, DARPA's program in long-term storage of blood products has already demonstrated a radical breakthrough in preserving platelets, a key to stopping severe bleeding. Current standards mandate that platelets be stored for only five days under refrigeration and with constant stirring. This storage requirement makes them extremely hard to transport and store at the front of the battlefield. We have found a way to preserve platelets for up to two years without refrigeration, with complete preservation of clotting function. Current data indicate that we will be able to extend this technology to red blood cells in the near future.

DARPA's program in preventing cognitive degradation as a result of sleep deprivation illustrates how the Bio-Revolution will help maintain our troops' combat performance. This program is researching an investigational therapy for Alzheimer's dementia, Ampakine, which also seems to mitigate the effects of fatigue so that soldiers can stay mentally sharp and effective for extended periods without using any of the current generation of stimulants.

Here are what we hope some of our other Bio-Revolution programs will find ways to do:

- Reduce acute pain more effectively and safely than morphine without hindering a warfighter's cognitive abilities;
- Greatly improve the first aid that troops in far-forward areas can give themselves when injured; and
- Enhance our warfighters' stamina with a heating/cooling mitt that may enable them to regulate internal body temperature and function longer in extreme environments. These mitts have actually been used by several professional and college athletes.

This research is tailored to maintaining the performance of our troops in the specific and unique environments they encounter in combat. This is a special population with special problems and the Food and Drug Administration must approve any treatment before it can be used.

Perhaps the program that best exemplifies the "revolution" in Bio-Revolution is the Human Assisted Neural Devices program. This program is finding ways to detect and directly decode signals in the brain so that thoughts can be turned into acts performed by a machine. This has actually been demonstrated, to a limited degree, with a monkey that was taught to move a telerobotic arm simply by thinking about it.

The long-term Defense implications of finding ways to turn thoughts into acts, if it can be developed, are enormous. The nearer-term benefit will be to our injured veterans, who would be able to control prosthetics in a natural way never before imagined. DARPA's researchers are working with the Veteran's Administration to make this a reality.

DARPA's Core Technology Foundations

While DARPA's eight strategic thrusts are strongly driven by national security threats and opportunities, a major portion of DARPA's research emphasizes areas largely independently of current strategic circumstances. These core technology foundations are the investments in fundamentally new technologies, particularly at the component level, that historically have been the technological feedstocks enabling quantum leaps in U.S. military capabilities. DARPA is sponsoring research in materials, microsystems, information technology, and other technologies that may have far-reaching military consequences.

In fact, these technologies often form enabling chains. Advanced materials led to new generations of microelectronics, which, in turn, led to new generations of information technology. And information technology is the key technology for Network Centric Operations.

DARPA's support of these foundations naturally flows into its strategic thrusts with a fair amount of productive overlap. For example, some of the work under the Bio-Revolution thrust could also be considered part of the materials work, and the information technology work is being reshaped by the Cognitive Computing thrust.

Materials

The importance of materials technology to Defense systems is often underestimated. Many fundamental changes in warfighting capabilities have sprung from new or improved materials. The breadth of this impact is large, ranging from stealth technology to information technology.

Let me give you a powerful recent example. In the mid-1990s, DARPA worked on lowering the cost of a ceramic called boron carbide. At the time, it might have been easy for someone who was not a materials scientist to consider the work esoteric. Boron carbide was expensive, and the Services had little interest in it. However, DARPA's investments eventually led to inexpensive plates of boron carbide, helping to clear the way for the improved Interceptor body armor that is today able to protect our troops in Iraq and Afghanistan.

In keeping with this kind of impact, DARPA maintains a robust and evolving materials program to push new materials opportunities and discoveries that might change way the military operates.

DARPA's current work in materials includes the following areas:

- *Structural Materials and Components* – low-cost and ultra-lightweight, designed for structures and to accomplish multiple performance objectives in a single system;
- *Functional Material*s – advanced materials for non-structural applications such as electronics, photonics, magnetics, and sensors;
- *Smart Materials and Structures* – materials that can sense and respond to their environment; and
- *Power and Water* – materials for generating and storing electric power, for purifying air or water, and harvesting water from the environment.

DARPA's Titanium initiative (DTi) aims to dramatically change the way titanium is extracted from the ore, synthesized into existing and new, heretofore unobtainable alloys, and fabricated into primary product forms, e.g., specifically blast- and ballistic-resistant plate and sheet to meet Defense needs. The initial thrust of the program is the elimination of the 100-year-old Kroll process for extracting titanium, and replacing it with efficient, environmentally benign electrolytic or chemical processes. If successful, DTi will also result in substantially reduced cost, with a target of less than four dollars per pound in the billet or primary product form – and may be as low as only two times the cost of aluminum. Achieving DTi's goals could make it economically feasible to use titanium in place of steel in ships and armored vehicles, which would vastly improve their ability to resist attack and make armored vehicles more amenable to air-lift.

<u>Microsystems</u>

Microelectronics, photonics, and microelectromechanical systems (MEMS) are three key technologies for the U.S. military, enabling it to see farther, with greater clarity, and communicate information in a secure, reliable and timely manner.

The DoD relies upon unique aspects of these technologies to support advanced sensing, communication and other critical functions. As such, integration of DoD-specific components with commercial manufacturing and integration practices are key for many DoD systems.

DARPA led much of the early development that led to the microelectronics industry that we know today. Today, while the commercial microelectronics industry continues to aggressively push on productivity and scaling of two-dimensional integrated circuits, DARPA is developing the technical foundation for the next revolution we refer to as the three-dimensional integrated microsystem. This will enable a new class of components with optimized performance that sense and adapt to the environment across the full spectrum; that dynamically configure to the mission at hand; that influence and actuate elements of the environment with micro-scale precision; and that provide a communications channel that is nearly impossible to detect or jam, yet is perfectly clear.

The commercial microelectronics sector is rapidly approaching the ability to build electronic systems containing a trillion transistors in roughly a liter-volume and dissipating less than 100 watts or so. This is about the same complexity as the human brain, and it certainly gives us enormous potential for future electronic systems. However, the highest payoff opportunities for the Department lie in the convergence of several core technologies, namely, the ability to integrate these trillions of transistors with novel nanostructures, photonics, and MEMS. By leveraging the convergence of these technologies, designing new architectures, and integrating them in entirely new ways, we plan to open the field of the Integrated Microsystem.

To this end, one representative example of the technologies we are pursuing is the three-dimensional circuit architecture, which will be foundational to the Integrated Microsystem. We believe that by dividing a circuit into a number of blocks, implementing each block on a separate semiconductor layer, and then stacking the layers on top of one another, we will increase performance, reduce overall system size, and create entirely new options for device architecture and materials integration. Instead of thinking only in terms of scaling two-dimensional devices to smaller sizes, we will change the paradigm to one of volumetric integration.

Moreover, today's state-of-the-art semiconductor processes give us the ability to build structures with a degree of edge smoothness that was previously unattainable. This will make it possible to build optical structures, including wave guides, alongside transistors and MEMS on a single substrate, and will result in high performance nanophotonics and electronics integrated on a single chip. Such chips will also be scalable into the third dimension, as we stack them with other devices into highly Integrated Microsystems.

Such capabilities could enable autonomous and interactive systems that can reason, sense, communicate, and actuate. Such systems will be able to operate unattended for years at a time, and they will give the DoD an overwhelming capability and advantage in response to surprise or emerging threats.

These Integrated Microsystems might also enable small, and effective robotic systems that work autonomously in concert, to decisively engage and defeat a wide variety of enemy forces across the entire spectrum of conflict.

Information Technology

DARPA's information technology efforts build on traditional and revolutionary computing environments. Our programs strive to provide such things as improved device/system control, autonomous vehicle navigation, more robust and secure software systems, human-robot and robot-robot collaboration, and enhanced human cognition.

While DARPA's Cognitive Computing thrust is shaping DARPA's core technology foundation work in information technology, we are pursuing development in several other critical areas:

The High Productivity Computing Systems program focuses on the productivity or value of a system, instead of its raw, theoretical computing speed, in order to improve by a factor of 10 to 40 the efficacy of high-performance computers for national security applications. This program will maintain information superiority in areas such as weather and ocean forecasting, cryptanalysis, and computing the dispersal of airborne contaminants.

The performance of DARPA language translation technology on Arabic news feeds has advanced significantly – from essentially garbled output, yielding only the main topic of an article, to nearly edit-worthy text, often understandable down to the level of individual sentences. Combining this new translation technology with improved speech-to-text technology makes it possible to construct end-to-end integrated systems to monitor Arabic satellite news channels and websites automatically and continuously. DARPA is improving these key technologies, so that decision-makers can receive a broad range of critical information quickly.

DARPA's Quick Reaction Programs

Many of the systems used today in Afghanistan and Iraq benefited from DARPA investments made many years ago. But there are a number of items in use that might be described as "direct from DARPA." Let me mention a few:

- The Phraselator is a hand-held device that translates spoken English phrases into prerecorded phrases in a foreign language. It has been used to communicate with injured Iraqis and prisoners of war, at checkpoints, and for peacekeeping.
- The water pen is a compact device that sterilizes water with an oxidant solution created from salt, water and an electric current. Thousands of these devices are on their way to our troops in Iraq.
- Our Arabic language translation programs are being used to produce an Iraqi "Early Bird"-style clipping service in English from Arabic sources. This has saved Iraqi lives – our medical forces were able to learn immediately where wounded civilians were located because they were able to read local newspapers and transcripts of radio broadcasts.
- Our SOFTools mission planning software was used by Special Forces to plan the rescue of PFC Jessica Lynch.
- Software from our Command Post of the Future program is being used by the command post of the Army's First Cavalry Division to distribute itself across space, instead of being in one spot.

We want to keep these coming. The following is just a sample of what we are doing:

One of the hardest things about sniper attacks on convoys is knowing you are being shot at – it is hard to hear over the road noise Over the last few months, DARPA funded development of an acoustically based, vehicle-mounted sniper detection system to help our convoys detect sniper fire and determine the direction it is coming from. Troops have tested and trained with these systems, and 50 are on their way to Iraq. If they work well, we're prepared to buy almost 1,000 more.

We have a program that is testing the use of Kevlar air-bags to thwart rocket-propelled grenade attacks. The idea is to detect the incoming rocket-propelled grenade and then deploy an airbag to smother the round so it doesn't go off and deflect it slightly. Because rocket-propelled grenades use directional shaped charges, deflecting it should greatly reduce the damage, even if the round still goes off.

We are also working on various ways to detect improvised explosive devices. One of these involves a technique for detecting, identifying, and locating radio frequency-controlled improvised explosive devices in the considerable background clutter typical of cities.

To improve communications among our warfighters, we are working on using Aerostats to connect line of sight systems like SINCGARS (Single Channel Ground and Airborne Radio System) and EPLRS (Enhanced Position Location Reporting System), and on an inflatable communications tower in a box.

I hope my remarks today have given you a sense of our programs, as well as a sense of our vision and ambitions, of which I am equally proud. Thank you for this opportunity to appear today. I would be pleased to answer any questions you have.