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Statement by

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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) 2006 activities, and our FY 2007 plans to continue transforming our military through technological innovation.

DARPA's original mission was to prevent technological surprises like the launch of Sputnik, which in 1957 signaled that the Soviets had beaten the U.S. into space. Our mission is still to prevent technological surprise, but over the years it has changed to include *creating* technological surprise for our adversaries. Stealth is an example of how DARPA has created technological surprise.

DARPA conducts its mission by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.

DARPA is the Department of Defense's (DoD) only research agency not tied to a specific operational mission. DARPA is designed to be the "technological engine" for transformation, supplying advanced capabilities, based on revolutionary technological options, for the entire Department.

This is a unique role within DoD. The Department's operational components naturally tend to focus on nearer-term needs because they must meet urgent needs and requirements. Consequently, a large organization like the DoD needs a place like DARPA whose only charter is radical innovation.

DARPA's Nine Strategic Thrusts

DARPA's strategy for accomplishing its mission is embodied in strategic thrusts. Over time, as national security threats and technical opportunities change, DARPA's strategic thrusts change. DARPA's flexibility and ability to change direction quickly allows it to react swiftly to emerging threats.

The nine strategic research thrusts that DARPA is emphasizing today are:

- Robust, Secure Self-Forming Networks
- Detection, Precision ID, Tracking, and Destruction of Surface Targets
- Urban Area Operations

- Networked Manned and Unmanned Systems
- Detection, Characterization and Assessment of Underground Structures
- Assured Use of Space
- Cognitive Computing
- Bio-Revolution
- Core Technologies

I will tell you about these thrusts and the forces driving them, along with some illustrative examples.

In keeping with the theme of today's hearing, I am going to highlight threats. But in many cases our work is opportunity-driven or capability-driven (to create surprise) as well as threat-driven.

Robust, Secure Self-Forming Networks

The DoD is in the middle of a transformation towards "Network-Centric Operations." The promise of network-centric operations is to turn information superiority into combat power so that the U.S. and its allies have better information and can plan and conduct operations far more quickly and effectively than any adversary.

At the core of this concept are networks – networks that must be at least as reliable, available, and survivable as the weapons platforms they connect, if not more so. They must distribute huge amounts of data quickly and precisely across a wide area. And they must form themselves without using or building a fixed infrastructure.

These networks give our warfighters great tactical and strategic capabilities.

But our great capability presents a natural target for our enemies, and it would be logical for them to want to attack these networks.

So our networks must be designed to withstand attempts to destroy, disrupt, or be exploited through intercept. These challenges must be met because our networks are becoming at least as important as our weapons platforms.

So, our challenge here is, "How can we build the robust communication networks needed for network-centric warfare?"

DARPA is working to ensure that U.S. forces will have secure, assured, high-data-rate, multi-subscriber, multipurpose (e.g., maneuver, logistics, intelligence) networks for future forces. We conduct research in anti-jam and low probability of detection/intercept communications; information assurance and security; spectrum management; and mobile, *ad hoc* self-forming networks.

For example, our Networking in Extreme Environments (NETEX) program is working to create ultra wideband wireless networks for robust and efficient military communications and sensing. Ultra wideband devices are capable of automatically forming hard-to-detect communications and sensor networks in areas where traditional technologies do not perform well, such as in urban or other cluttered, harsh environments. This past year, experiments demonstrated that NETEX technology exceeded its ultra wideband communication tactical voice/data radio range and jam performance objectives.

Frequency spectrum is a valuable commodity. The neXt Generation (XG) Communications program will provide more assured communications and greater wireless networking capacity by increasing spectrum availability and utility for the U.S. military 10- to 20-fold. XG will do this by dynamically allocating spectrum across frequency, time, and space without interfering with use by the spectrum owner. XG will allow networks to be set up much more quickly, without waiting for someone to allocate spectrum. In a recent simulation, the program demonstrated a 10-times increase in spectrum access, as compared to manual frequency assignment, for a battalion-set of tactical radios operating in a congested urban environment. A prototype system is currently being built that will exercise the system's ability to form and adapt tactical communications networks to available spectrum without interfering with other spectrum users.

The Optical and Radio Frequency Combined Link Experiment (ORCLE) program will combine the high data-rate capability of laser communications, the high reliability of radio frequency communications, and clever network management to ensure compact, high quality, reliable, high bandwidth networked communications, even if some of the links are affected by atmospheric or physical obstructions.

Recently, an ORCLE prototype system demonstration at White Sands Missile Range proved the promise that combining optical and radio frequency technologies would provide more reliable, high-data-rate communications than either could achieve on its own. We expect to conduct a final multi-node air-to-air-to-ground demonstration in early 2007.

A major element of our networks is Command and Control.

Last year I told you about our Command Post of the Future (CPOF) technology, being used today by the Army in Iraq.

CPOF is a distributed command and control system that allows command and control centers to be wherever the commanders are, without regard to a fixed geographic location. The Army is using CPOF because it gives them more flexibility and insight, and allows them to share information and respond more quickly.

At this point in time, three divisions have successfully fielded CPOF. The 4th Infantry Division has been using CPOF in combat in Baghdad since their deployment in late 2005.

LTG Chiarelli, now commanding the Multi-National Corps – Iraq (MNC-I), requested the Army field CPOF to the entire MNC-I. This effort began in January 2006.

There are now over 200 CPOF systems in use in Iraq between the Division and MNC-I, and the number is rapidly increasing. CPOF is fielded to MNC – I, three division-level headquarters, all of 4th Infantry Division's brigades and their subordinate battalions.

CPOF has succeeded beyond all expectations. There are now additional requests for immediate fielding support from the entire joint community, each of the other services individually, and several inter-agency groups, as well as requests for high priority expansion within the Army.

The final transfer of CPOF deployment from DARPA to an Army Program of Record was scheduled for April 2006, but has now been effectively transitioned to the Army's PEO two months early.

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 current network defense capabilities to mount an adequate defense. DARPA's Dynamic Quarantine of Worms (DQW) program is developing an integrated system of detection and response to quarantine zero-day worms and stop them from spreading.

This past year, DQW achieved a major milestone by demonstrating a prototype system that successfully quarantined the peak infection of a super-worm in a test network to less than 10 percent of the network, while restoring all infected systems within one hour. Without DQW, the same network was devastated within two seconds.

This marks a major achievement on our way to developing networks that are as reliable, available, and survivable as the weapons platforms they connect.

The Future Combat Systems Communications (FCS-C) program has developed a mobile, *ad hoc* network designed to enable ground and airborne on-the-move and stationary network centric operations. Its envisioned performance would be comparable to that of the anticipated Joint Tactical Radio Systems' Wideband Network Waveform, e.g., high data-rate (greater than five million bits per second), cross-banding, mobile networking. The FCS-C network was recently upgraded with new and modified software such that FCS-C would now operate as a gateway, rather than as a router network.

The result was demonstrated interoperability among various current and future communications radios – via the network, not the radio.

Specifically, interoperable communications was demonstrated by Army Signal School personnel at Fayetteville, Tennessee, and Ft. Benning, Georgia, among the following current digital and analog systems: Voice over Internet Protocol; the ITT Soldier Radio; the Enhanced Position Location Reporting Systems (EPLRS); HAVEQUICK I/II (PRC-117); the Single Channel Ground and Airborne Radio System (SINCGARS/PRC-119); and the High Frequency MAN-PACK Radio (HFMR/PRC-150).

We showed that it was possible to have previously incompatible tactical radios talk seamlessly among themselves and to more modern systems. We believe that this offers a potentially more affordable route for military communications interoperability in the future.

This upgraded FCS-C system has been transitioned to U.S. Special Operations Command for their evaluation and use.

The heart of many networks, especially self-forming networks, is having identical time at all the nodes. Today this time, in many cases, is provided by the Global Positioning System (GPS).

Current and future threats will work hard to prevent our networks from using GPS as a time standard. To deal with possible loss of GPS, DARPA has been developing microelectromechanical (MEMS) systems technology to create a chip-scale atomic clock that will be only one cubic centimeter in volume. This past year we demonstrated a complete atomic clock the size of three sugar cubes that required only 100 milliwatts of power, approximately the same as a wireless PC card. The current chip-scale atomic clock will allow a network node, such as a Soldier using a Single Channel Ground and Airborne Radio System (SINCGARS), to maintain synchronous operation with the network for several days without GPS.

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

For many years, the Department of Defense has steadily improved its ability to conduct precision strike against fixed, and other predictable targets. In recent years, America's adversaries have realized that, if they are to survive the United States' superior precision strike capabilities, they either have to move, hide, or "blend-in."

The basic challenge behind this thrust is, "How can we find and defeat any target – and only that target – anywhere, anytime, and in any weather?"

As an example, DARPA is working on foliage-penetrating radar that could be used to spot potential targets hiding under forest canopies over a large area in all weather. These radars produce images that reveal features that are usually hidden: vehicles, structures, roads, and waterways. But the images are hard for humans to interpret.

Our Wide Area All Terrain Change Indication Technologies (WATCH-IT) program has developed software to automatically extract features from these images. We use change detection to monitor the arrival and departure of vehicles; interferometry to estimate terrain height; and tomography to construct three-dimensional models of structures hidden under the trees. This past fall, U.S. Southern Command used this radar to survey areas of interest in the South American jungle.

The information from these radars can be used to cue laser detection and ranging (LADAR) sensors to look more closely at those potential targets. LADAR sensors measure the range from the sensor to every spot in an image, and so actually produce a three-dimensional shape.

The Exploitation of 3D Data (E3D) program has been developing tools to find and classify vehicles from LADAR images. E3D has demonstrated the ability to distinguish not only one kind of tank from another, but even one kind of sport utility vehicle from another. This is critical in operations like Operation Iraqi Freedom, where the enemy frequently travels in civilian vehicles. We have also been able to recognize vehicles that can appear in many different configurations – backhoes and bulldozers – that can be used by enemy combat engineering teams.

DARPA's Synthetic Aperture LADAR for Tactical Imaging (SALTI) program is on the verge of producing the world's first airborne synthetic aperture LADAR images. Synthetic Aperture LADAR will combine the resolution and image interpretability of visual cameras with the standoff range and day/night flexibility of traditional radio frequency Synthetic Aperture Radar systems.

This combination will provide the warfighter with unprecedented capability to identify targets at ranges well beyond those of today's real aperture systems. The SALTI team is nearly finished assembling the sensor system that will be used to produce some of the first airborne synthetic aperture LADAR images in flight tests, scheduled to occur in early 2006.

The Persistent Operational Surface Surveillance and Engagement (POSSE) program, jointly funded with the Joint Improvised Explosive Device Defeat Organization, will bring the power of airborne surveillance to bear in the fight against insurgents in Iraq. Airborne surveillance can fill in gaps. We are building and exercising a prototype system at the National Training Center, leveraging work of the Joint IED Defeat Center of Excellence there, before deploying POSSE to Iraq.

<u>Urban Area Operations</u>

Our adversaries know that if they present a fixed or mobile target on the open battlefield, we will find and destroy it. By moving into cities, our adversaries hope to limit our advantages, draw more of our troops into combat, and inflict greater U.S. casualties, and cause mistakes that harm civilians and neutrals.

Our Urban Area Operations thrust is aimed at creating technology to help make joint operations in cities as effective as operations in non-urban areas.

Why are military operations in cities so difficult?

Cities are filled with buildings, alleys, and interlocking tunnels, which provide practically limitless places to hide, store weapons, and maneuver. Cities are hubs of transportation, information, and commerce, and they are homes for a nation's financial, political, and cultural institutions. Cities are densely packed with people and their property. Adversaries can mix in among the people and property, using them as shields to limit our military options. And insurgents don't just mix in, they blend in, making it even harder.

In this environment, our current warfighting technology that works so superbly in the open and even in the rugged natural terrain of the traditional battlefield is less effective.

Our current stand-off reconnaissance technology was simply not designed for urban environments.

Our weapon systems are not as precise as we would like, and our vehicles and tactics that work so effectively in the open are not optimized for close-quarter operations.

Let me describe some of the things we are working on in a little more detail.

DARPA is developing persistent, staring reconnaissance, surveillance, and target acquisition (RSTA) systems to vastly improve what we know about what's going on throughout a city. Our goal is to extend our awareness down to the level of a city block, so our forces have unprecedented awareness that enables them to shape and control the conflict as it unfolds. These capabilities must operate in near-real-time, producing actionable intelligence that is shared through robust, secure communications at all command echelons.

For example, hundreds of patrols go out each day in Iraq. During these patrols, our Soldiers and Marines interact with the local population and build an understanding of the environment and the pattern of life. The critical importance of human intelligence in counter-insurgency operations means that each individual on a patrol has a significant role as an information-gatherer.

DARPA's Advanced Soldier Sensor Information System and Technology (ASSIST) program focuses on tools to enhance the intelligence gathering capabilities of our ground troops. We are developing special sensors, networks, and databases so that a patrol leader could directly add to, and tap into the collective experience of previous patrols, including the details of what has been encountered in specific neighborhoods.

ASSIST will help intelligence analysts and front-line patrol leaders build and share knowledge of what's going on in various city neighborhoods. ASSIST is beginning to be integrated into training exercises of Army units preparing for redeployment in Iraq.

The Networked Embedded Systems Technology (NEST) program is providing a common software infrastructure for future sensor nets, and we're demonstrating it in some exciting ways.

In a test at Ft. Benning last year, we showed that an *ad hoc* network of simple acoustic sensors could determine the source of a rifle shot to within two meters, within two seconds of the shot. This year, we're testing a sensor network over a 10 square kilometer area to simulate detecting people trying to cross a border or facility perimeter.

Our Combat Zones That See program is networking conventional video cameras together to monitor the movement of vehicles. Computers embedded in each camera find and characterize (e.g., color, size, number of wheels) vehicles in view, and this information – including information about where each vehicle is parked or moving – is sent to a monitoring site, where the data is stitched together.

Last year we proved that the concept would work, and we are installing it at a base in Iraq so that we can extend perimeter security into surrounding neighborhoods.

Our Multispectral Adaptive Networked Tactical Imaging System (MANTIS) program recently developed a new camera that provides unprecedented night vision, even on a moonless night. We are now miniaturizing these cameras and mounting them on Soldiers' helmets.

MANTIS will network them together to allow a Soldier to see the same scene as his buddy around a corner, so they can quickly come up with a coordinated plan of action.

Another typical urban mission requires a U.S. team to pursue adversaries inside a multi-story building. Currently, the defenders have a major advantage in knowing the interior layout. Technology that would allow our team to quickly map the inside of the building would go a long way to improving the team's effectiveness and safety.

This summer, troops conducting urban operations will be able to sense through over 12 inches of concrete to determine if someone is hiding inside a building or behind a wall. DARPA's Radar Scope does not provide images, but will provide critical situation awareness by enabling troops to determine whether a room is occupied before entering it. The unit weighs less that a pound and a half, runs on AA batteries, and will cost under $1000 in production quantities.

When traveling in a convoy, road noise makes it is difficult to know if you are under fire. DARPA's low-cost Boomerang shooter detection and location system tells people in a convoy whether they are being fired upon, and where the shots are coming from. Boomerang has been improved, based on results from the 50 original units deployed in Iraq, and an additional 66 upgraded units have been deployed to Iraq with superior system performance.

Because the enemy can suddenly emerge at close-quarters and fire on our forces, we are providing advanced, lightweight Bar Armor to the Marine Corps to protect our troops, HMMWVs, and trucks from rocket-propelled grenade (RPG) attacks. To-date, 50 vehicle kits for Bar Armor have been sent to the Marines in Iraq, and Army Buffalo kits are in production.

Also, we are also developing novel, high-strength nets to stop mortar rounds and RPGs. Counter-mortar nets have successfully caught 60 mm mortar rounds, while counter RPG nets have proven successful at ranges of at least 50 meters.

Dense Inert Metal Explosive (DIME) is an entirely new form of very powerful, focused explosive that does not produce fragments outside its designed blast radius, making it ideal for close quarters and situations where collateral effects are a concern. Tests have shown that this warhead is effective in deflecting rocket-propelled grenades.

Keeping suicide bombers at-bay, while maintaining freedom of movement for our warfighters, is a key challenge. DARPA has demonstrated an artificial polymer "snow," which makes the ground very slippery, and also a technique for rapidly restoring traction.

This system has been successfully tested on roadways and walkways, and has been transitioned to the Joint Non-Lethal Weapons Directorate and the Marines.

Networked Manned and Unmanned Systems

DARPA is working with the Services toward a vision of filling the battlespace with unmanned systems networked with manned systems. Teaming people with autonomous platforms will create a more capable, agile, and cost-effective force that also lowers the threat to U.S. personnel.

Combining unmanned with manned systems enables new combat capabilities or new ways to perform hazardous missions. Improved processors and software are achieving the dramatic increases in on-board processing needed for unmanned systems to handle ever more complex missions in ever more complicated environments. Networking these vehicles in combat will improve our knowledge of the battlespace, targeting speed and accuracy, the survivability of the *network* of vehicles, and mission flexibility.

DARPA is developing a range of unmanned air vehicles.

Our A-160 program is working towards an unmanned helicopter for intelligence, surveillance, and reconnaissance (ISR) missions, with as much as 32 hours endurance at 15,000 feet. So far, A-160 vehicles have made 35 flights, carried up to 500 pounds, traveled at over 135 knots, and stayed aloft for nearly 12 hours.

Further, a number of other unmanned air vehicles are part of our support to the Army's Future Combat Systems program, including the Micro Air Vehicle and the Organic Air Vehicle - II.

The Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration program is delivering a low-cost, platoon-level "hover and stare" ISR system for the dismounted Soldier. This program has successfully completed a month-long field experiment using 10 air vehicles with the 3rd Brigade, 25th Infantry Division, United States Army Pacific. In October 2006, 50 air vehicles with refinements will be delivered to the 25th Infantry Division for experimentation.

Upon successful completion of that experimentation, those MAV units may be deployed to Operation Iraqi Freedom. The Army and the FCS Lead System Integrator are proceeding with plans to develop the Class I FCS Unmanned Aerial Vehicle utilizing the MAV ducted fan system.

The Organic Air Vehicle - II (OAV-II) program is developing a company-level "hover and stare" unmanned air vehicle (UAV) system with autonomous collision avoidance, heavy fuel engines, and acoustic treatments. OAV-II's gimbaled day/night, high-resolution cameras with an embedded laser designator gives the UAV a very capable reconnaissance, surveillance, targeting, and acquisition package. This program has completed design work, wind tunnel testing, engine testing, collision avoidance and path planning testing, and acoustics testing. Critical design review and contractor downselect will occur in 2006 *en route* to initial vehicle flight testing.

The Wasp micro air vehicle has shown remarkable capability for its size and weight (14 inch wingspan, approximately one-half pound), potentially providing our warfighters with backpackable, organic surveillance capabilities. Wasp is capable of loitering in excess of one hour at 35 miles per hour, and provides unobtrusive, real-time imagery from low altitudes. The imagery can also provide coordinate positions of objects of interest within the image.

Wasp has sophisticated autopilot modes that permit autonomous operation, including flight between GPS waypoints, altitude-hold, heading-hold, and loiter. The vehicle allows for hands-free operation and, in an emergency, can be left by the operator to continue its mission and be reacquired at a later time from a different location. A waterproofed variant has been field-tested at-sea by the Navy; it can land in the ocean and spend extended periods of time in the water without damage.

The Navy deployed Wasp in-theater in FY 2005, accumulating hundreds of flight hours in support of operations. DARPA and the Marines have been collaborating closely to field-test and evaluate Wasp systems. In a joint DARPA-Marine Corps field technical evaluation, the Marines are using DARPA-provided Wasp systems to develop Wasp CONOPS and tactics, techniques, and procedures. The Marines are establishing a "fly away cell" of Wasp operators for deployment with active Marine units in Operation Iraqi Freedom and Operation Enduring Freedom as an evaluation of the micro air vehicle by the Corps. Additional Wasp vehicles are planned for Twentynine Palms for training of Marines before they deploy.

DARPA has also been focused on revolutionizing unmanned ground vehicles (UGVs). One key UGV program is the DARPA Grand Challenge.

The DoD has been interested in autonomous ground vehicle technology for a long time as a way to reduce the number of troops in harm's way on the battlefield. In fact, Congress has set a goal that one-third of the operational ground vehicles be autonomous by 2015. We decided to offer a large cash prize to energize and transform the field: the 2005 DARPA Grand Challenge offered two million dollars to whoever built a completely autonomous vehicle that could travel approximately 132 miles along a difficult desert route with the fastest time under 10 hours.

We wanted to accelerate the technologies needed, like sensors, control algorithms, and, in particular, systems integration – the art of putting it all together, sometimes called "the secret sauce" – the key technical challenge in developing truly autonomous ground vehicles.

We also wanted to enlarge the autonomous ground vehicle research community. We wanted to tap into that great reserve of American ingenuity that normally does not do business with the Department of Defense. More people means more ideas, energy, and progress.

Finally, we wanted an existence proof that this technology could really work: that an autonomous vehicle could actually travel significant distances across difficult terrain at militarily relevant speeds, like a human driver. History shows technology progresses rapidly once it is shown that something can be done.

Prize competitions attract publicity and inspire excitement, so they are good at creating a broad push in a technical area. They are also designed to allow the participation and contributions of new people by lowering administrative barriers. And prizes require that you demonstrate a result – our existence proof.

Autonomous ground vehicles are well suited for a prize competition because most of the basic component technologies needed are available and are not overly expensive: people have vehicles; computers are fairly cheap; and sensors are commercially available. Even the servo-mechanisms to control a vehicle are available from the handicapped driver market.

The real challenge is not in the components, it's putting them together to create an autonomous "driver" that can maneuver the vehicle intelligently at militarily relevant speeds. Mostly this requires intellect, imagination and lots of hard work – which makes for a good prize contest. Getting involved is limited by one's personal capabilities, and not by the amount of available capital.

You may recall that we held the first running of the Grand Challenge in March 2004. Fifteen finalists attempted the course, and the farthest distance traveled was seven miles. Given the distance achieved, some observers believed that the task was too difficult for existing solutions, and it would be many years before anyone would develop an autonomous ground vehicle that could finish the route in the required time.

But we knew otherwise. DoD's senior civilian agreed with us that the program was an overwhelming success at inspiring new ideas, and that there was evidence that the technology could be accelerated. A decision was made to continue the program, and, in fact, authorization was given by the Under Secretary of Defense for Acquisition, Technology and Logistics to increase the prize to $2 million dollars.

The first Grand Challenge was viewed as setting a benchmark that showed the true difficulty of the problem, but the difficulty did not deter the participants' zeal to solve the problem. The participants certainly believed a solution was much nearer than what the conventional experts predicted.

The second running of Grand Challenge gave them their chance, and they responded. One hundred ninety-five teams from 36 states, including 160 new teams, applied. Thirty-five teams came from universities. We even had applications from three high schools! Following a well-established video review process, DARPA personnel visited 118 teams to assess their progress towards developing an autonomous vehicle capable of driving long distances while avoiding obstacles. Following these visits, DARPA selected 43 semifinalists. Seventeen university teams and one high school team were among the finalists.

These 43 semifinalists competed in the National Qualifying Event at the California Speedway in Fontana, California, last September. There, we checked out the safety and performance of the vehicles on a 2.2 to 2.6 mile track under conditions resembling those on the actual course. That narrowed the teams down to a number we could manage on the day of the event. As we headed to the event, based in Primm, Nevada, we had 23 teams from 13 states: 14 teams were from universities, 14 teams had competed in the 2004 Grand Challenge, and nine were new entries.

Early in the morning of October 8, two hours before daybreak, operations began. We gave each of the teams a computer disk with GPS waypoints that revealed the 132 mile desert route to them for the first time. At sunrise, the vehicles were cued up at the start of the course and, at roughly 5-minute intervals, each was given a "Start" command from a manned chase vehicle.

The 132-mile course, about the distance between Baghdad and Tikrit, was over rough desert terrain that some of our military people said looked just like Iraq. It included unmarked roads, long and narrow tunnels, bridges, railroad crossings, obstacles, ditches, and a sharp, narrow winding mountain road through "Beer Bottle Pass."

Beer Bottle Pass was one of the last stretches of the course, and it was a challenge all by itself. If you missed a turn and went over the side, it was a few hundred feet down to the bottom. Driving the pass concentrated the minds of our human drivers.

The event started as the sun was just appearing above the eastern mountain range. Most, if not all, of the Grand Challenge staff thought that no vehicle would finish, let alone make it within 10 hours (except yours truly of course).

There was elation among the 2000+ spectators during the day because so many of the teams were doing so well, and it started to look like a finisher was possible. There were also periods of disappointment when a team's vehicle failed.

In the end, five teams completed the course: Stanford University (winner of the $2 million prize), two teams from Carnegie-Mellon University, a team from the Gray Insurance Company, and a team from Oshkosh Truck. The first four of these teams completed the course in under 10 hours.

The winning vehicle, Stanford University's Stanley, averaged over 19 miles per hour – a speed that is militarily relevant.

All but one of the 23 teams went farther than the farthest team did in 2004, proving the success of the prize format.

And as for Beer Bottle Pass – we were reminded that robots don't get nervous. The five vehicles never hesitated as they navigated the winding, narrow road leading to victory.

Clearly, significant progress had been made since 2004 – much more than the conventional experts predicted.

I want to highlight one team in particular that embodied what we were trying to accomplish with the Grand Challenge.

Gray Team was fielded by a small, family-owned company that sells insurance in Metairie, Louisiana. An employee read about the Grand Challenge in *Popular Science* and said, "We have a pretty good IT department, let's give this a try."

Gray Team enlisted students from Tulane University and began putting together their team. After hurricane Katrina, we actually lost contact with them for awhile. But despite the hurricane – and the fact that some of the team members actually lost their homes – they bounced back, bringing their vehicle, the aptly named "Kat-5," to the National Qualifying Event.

Their vehicle completed the 132-mile course with an average speed of 17.5 miles per hour.

The Gray Team shows what a prize competition can do. The team came from a small company, and they did not have the inherent resources of a large defense contractor or a university. But the publicity and challenge of a prize brought forth an important contribution on their part to a technology that matters to the national defense.

And it was not only the finishers who made a contribution. There are other technologies developed by teams that didn't finish. For example, in sensors, the high school team developed an interesting idea for tracking a vehicle's position as though it were a giant optical computer mouse. And another team developed a unique spinning laser sensor that could discern an object the size of a person out to a range of 500 feet.

We are very pleased with the results of the Grand Challenge. We advanced the technology considerably, particularly the "special sauce" of systems integration. We broadened and energized the field – 17 universities with over 200 students made it to the National Qualifying Event.

And we came away with five existence proofs that autonomous vehicles could handle some real-world challenges, distances, and speeds. That alone will change peoples' minds about what is possible, attract more energy to the field, and speed up progress.

The DARPA Grand Challenge proved a prize competition can be a powerful and exciting way to promote technical progress, but it's not for every problem.

We want to make sure our next Grand Challenge is just as productive as this one, so we are in the midst of considering what to do next that would be just as beneficial to our military and as exciting.

The Grand Challenge also showed the power of a prize to promote progress in a field under the right circumstances. It has proved a valuable tool in DARPA's "toolbox."

The Administration is requesting that the Congress extend our Prize Authority for five years, as it would otherwise expire in September 2007. We think that our Grand Challenges has shown the power of a prize when used under the right circumstances, and we believe that we will be able to continue to make use of this powerful authority.

I hope the Committee will look favorably on our request for a five-year extension.

Detection, Characterization and Assessment of Underground Structures

Some of the most dangerous threats we face have now gone underground to hide from our joint forces' intelligence, surveillance, reconnaissance, and warfighting capabilities.

Underground is the last refuge our adversaries have to hide people and material and conceal their manufacturing and transportation operations. It is also one of the last places they can survive an attack.

Underground facilities can vary from the clever use of caves to complex, carefully engineered bunkers in both rural and urban environments. They could be used for a variety of purposes, including protecting leadership, command and control, hiding artillery and ballistic missiles launchers, and producing and storing weapons of mass destruction.

Our challenge here is, "How can we find out what is going on inside deeply buried structures?" DARPA is developing ground and airborne sensor systems with two-orders-of-magnitude improvement in sensor performance, combined with advanced signal processing for clutter rejection in complex environments.

Our Low Altitude Airborne Sensor System (LAASS) program is aimed at finding and imaging the layouts of large, underground structures – structures that might serve as production and storage facilities for weapons of mass destruction, command and control centers, or hide ballistic missiles.

In proof-of-concept testing, LAASS has provided excellent performance, and we have begun prototype development. Technologies from LAASS and our Counter-Underground Facility Ground Sensor program have been used in testing and systems development efforts by a number of agencies responsible for understanding and prosecuting hard and deeply buried targets. Some of these technologies have also been taken to Iraq for testing and use.

While large, developed facilities have long been recognized as strategic threats, there is increasing need to find and characterize small underground structures. These include caves that serve as hiding places and tunnels for smuggling weapons and infiltrators across borders. Caves and tunnels provide secret entry into sensitive areas, such as Baghdad's International Zone, and may even contain prisons, weapons laboratories, or nuclear power plants.

DARPA has developed several technologies under the Remote Interconnected Tunnel Assessment (RITA) and Cross-Border Tunnel programs to aid in the search and prosecution of these threats, especially when exploited by terrorist organizations.

RITA completed a successful field demonstration using the Academy at West Point as a testbed. There are many known tunnels underneath West Point buildings. RITA found all of these plus one more that was not identified on an older map provided to the RITA team.

<u>Assured Use of Space</u>

The national security community uses 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 present an attractive target. We should not assume our advantages will never be challenged.

In FY 2001, DARPA began 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 Support to the Warfighter:* reconnaissance, surveillance, communications, and navigation to support military operations down on earth – extending what the U.S. does so well today.

The Falcon program is designed to vastly improve the U.S. capability to promptly reach orbit.

In 2006, the Falcon program will launch the first of a series of new, low-cost, small launch systems that could be used to deliver new hypersonic test vehicles to near-space, and satellites into orbit. These new systems will enable an affordable and responsive launch vehicle capability for payloads in the 1000 pound class, reducing the cost of launch by over 50 percent. By the end of 2008, Falcon will have conducted flight tests of hypersonic test vehicles, using them to assess designs, components, and materials for reusable hypersonic cruise vehicles that could revolutionize space access and near-space transportation. These hypersonic test vehicles will focus the nation's hypersonic technology development, and spur progress in this critical area for our nation's defense.

DARPA is developing technologies to maximize the military utility of small launch vehicles. One way that we are doing this is improving the capabilities of small satellites. The Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) program is integrating a variety of advanced technologies which have not been previously flight-tested.

The Orbital Express program will also provide on-orbit servicing capabilities. It will remove fuel as a constraint to satellite operations and allow us to rapidly deploy new technologies in response to evolving threats. Over the past year, Orbital Express has successfully powered up its "servicer" spacecraft and developed a capture mechanism and robotic arm for vehicle integration. Orbital Express is scheduled for launch in late 2006.

The new F6 (Future Fast, Flexible, Fractionated, Formation-Flying Spacecraft) program takes an even more technically aggressive approach to combining separately launched space payloads and spacecraft subsystem elements. F6 will develop methods for satellite payloads and subsystem elements to operate in close formation, dividing mission requirements between nodes of the formation. Satellite systems could be repaired or upgraded by placing a new, wirelessly connected element into the formation. The systems could be less vulnerable to attack or failure because the components are physically separated. This capability also promises improved reliability and reduced risk from launch failures.

The Space Surveillance Telescope program will enhance our space situational awareness by developing a large-aperture optical telescope with very wide field of view, using curved focal plane array technology to detect and track very faint objects in space. This past year the program has successfully completed its initial milestones in developing curved mosaic charge-coupled device (CCD) cameras and telescope mount design.

DARPA's Innovative Space Based Radar Antenna Technology (ISAT) program is developing large, revolutionary radar antennas to provide continuous tactical-grade tracking of moving ground targets.

These antennas would be extremely lightweight, and achieve a 100-fold reduction in length when stowed for launch. Once on-orbit, such antennas would use entirely new unfolding methods, pioneered by DARPA, to achieve a structure that could be, in the fully operational version, the length of the Empire State Building, or approximately 300 meters long.

This past year DARPA successfully built and deployed a section of the antenna on the ground, and, while simulating the orbital dynamics that deform the antenna, we successfully measured the position and shape of the antenna to within one millimeter. This coming year the antenna section will be deployed and tested in a thermal chamber that more accurately represents the space environment, and the position measurement techniques will be integrated with calibration algorithms to compensate for changes to the antenna shape in real-time.

The ISAT space-based demonstration of a one-third-scale antenna is tentatively planned for 2010.

Satellite communications are a vital linchpin to our national security, but satellites are inherently vulnerable to uplink jamming. The Novel Satellite Communications program will ensure reliable satellite communications to ground forces – even those operating close to high power radio frequency sources on the same frequency. A real-time demonstration of the Novel Satellite Communications technologies is planned for 2008.

Nuclear detonations in low earth orbit present a threat to orbiting satellites. Nuclear radiation from a space detonation can be trapped by the earth's magnetic field to enhance the number of energetic particles in the belts that can quickly degrade or destroy satellite electronics.

The DARPA Sleight of Hand program seeks to reduce this risk by using high power Very Low Frequency radio transmissions to accelerate the decay of the energetic particles out of the belts.

In addition, the Rad-Hard By Design program has developed design tools for integrated circuits so radiation-resistant chips can be made using commercial processes. This work, being executed jointly with the Air Force and the Defense Threat Reduction Agency, can reduce the cost of radiation-hardened electronics by reducing the need for specialized, dedicated fabrication facilities. It can also allow DoD satellites to more easily make use of state-of-the-art electronic devices.

The X-ray Navigation and Autonomous Position Verification (XNAV) program will allow satellites to use pulsars as naturally occurring clocks to define the position of spacecraft in the absence of Global Positioning Satellites. Pulsars provide extremely regular pulses of radiation in a variety of wavelengths from radio waves to gamma rays. XNAV will detect the bright x-ray flashes from these distant objects and use the relative timing of these signals to determine location – much like a GPS receiver uses the signals from GPS satellites.

Cognitive Computing

Computing technology is central to maintaining the technological superiority of the U.S. military. The automation challenges facing DoD in the future – autonomous platforms that behave reliably without constant human intervention, intelligence systems that effectively integrate and interpret massive sensor streams, and decision support systems that keep up with, and adapt to rapidly changing conflicts – depend on creating more flexible, competent, and autonomous software.

Military personnel, especially commanders and their staffs, will have access to a wide array of rapidly changing information. This has the potential of greatly increasing their effectiveness, but also increases their cognitive burden in an already stressful environment.

DARPA's cognitive computing technology offers key opportunities for alleviating the cognitive burden on commanders and their staffs by anticipating actions to be taken in specific situations and by composing and coordinating the *ad hoc* teams that need to be involved.

The goal of the Personalized Assistant that Learns (PAL) program is to use machine learning technology so information systems can adapt, in real time, to the changing conditions confronting military commanders. PAL systems will automatically adjust to new environments and new users, helping commanders adapt to evolving situations and priorities and new command center personnel become effective more quickly.

PAL is a nationwide research effort, combining the work of 21 universities with other research institutions. PAL will integrate multiple learning technologies into a software system to assist its user by being personalized to that user and, over time, refining what it can do and learning new skills.

For example, the current PAL system learns to automatically create portfolios of information its user needs for an upcoming task. It also adjusts its problem-solving for tasks such as planning and scheduling meetings as it learns about its user's needs. PAL has produced revolutionary new techniques for transferring knowledge learned in one task to solving problems in completely different contexts.

In the last year, PAL technology has proven it can learn by being given a "before and after" test using questions similar to those that could be asked of a human assistant. There was a significant improvement in the test results because of learning.

Learning technology developed under PAL has also been applied to raw data taken from Command Post of the Future (CPOF) operations in Iraq in order to learn models of command activities. CPOF messages were analyzed to learn to identify topics of interest (e.g., checkpoints, routes, and mortar attacks) and the networks of individuals who were involved in handling those topics. A PAL algorithm learned to recognize points where a CPOF user changed his focus of attention. A third application of PAL learning technology identified relationships among CPOF objects (e.g., objectives, activities, units, maps, and reports) by examining the particular networks of users that shared them.

These successful applications of PAL technology to CPOF data represent first steps toward the ability to learn and characterize the operational patterns of a command center. By using those learned patterns to anticipate users' information needs, a cognitive assistant would help users handle additional tasks, as well as tasks of greater complexity, by gathering needed information in advance, coordinating teams, and managing message traffic.

Beyond cognitive assistants, as DoD increasingly employs autonomous, unmanned and intelligent systems, the need for systems that can understand and respond to new and unique situations is growing dramatically. If successful, cognitive computing research will also lead toward highly capable autonomous systems that could help the warfighter in situations that are both manpower-intensive and dangerous.

The Integrated Learning program is creating new computer learning technology that will enable systems to learn to perform complex planning tasks simply by watching warfighters at work. When a human is shown a complex task and asked to repeat it, that person uses background knowledge about the world, knowledge just learned from the teacher, feedback from the environment and the task itself, and the results of mental reasoning and simulation. The Integrated Learning program is an ambitious effort to develop technologies that can perform this kind of learning and is focused on several military applications, including air tasking orders and planning.

The Transfer Learning program addresses the critically important problem of being able to learn knowledge from specific instances in such a way that it can be re-used and applied to new situations. The program will result in technology that will enable computers to use skills, techniques, and knowledge learned for one task to provide superior performance on novel (previously unseen) tasks. By combining ideas from several distinct sub-disciplines, the program intends to achieve a 100-times reduction in the time to perform novel tasks, and with improved accuracy. The transition paths for technology developed in this and other programs could be cognitive system components for systems like PAL, or direct military applications.

These and other Cognitive Computing programs hold the promise of a whole new generation of computer systems that will be more mission-capable, adaptable, self-sufficient, self-reliant, and easier to deploy and maintain. The result will be much more effective military systems as well as fundamentally new technical capabilities.

<u>Bio-Revolution</u>

Over the last decade and beyond, the U.S. has made an enormous investment in the life sciences. DARPA's "Bio-Revolution" thrust seeks to answer the question, "How can we use the burgeoning knowledge from the life sciences to help the warfighter?"

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

- *Protecting Joint Forces* counters the threat from biological warfare and includes sensor technology to detect an attack, technologies to protect people in buildings, 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 man-made systems with the autonomy and adaptability of living things by developing technology inspired by living systems.
- *Maintaining Joint Forces Combat Performance* is aimed at improving the warfighter's ability to maintain peak physical and cognitive performance once deployed, despite extreme battlefield stresses such as heat and altitude, prolonged physical exertion, sleep deprivation, and a lack of sufficient calories and nutrients.
- *Tools* are the variety of techniques and insights on which the other three areas rest.

In our work to protect joint forces, DARPA's program to accelerate critical therapeutics is developing an Artificial Immune System (AIS) that will serve as an *in vitro* test platform to accurately test the human response to vaccines. The project, now in its second phase, has developed a system that mimics critical elements of the human immune system.

In the next 18 months, the prototype AIS will be fully developed and will become automated, so that large numbers of vaccines can be tested against large numbers of human cells.

DARPA's Triangulation Identification for Genetic Evaluation of Risk (TIGER) program has developed a universal sensor that can detect any type of pathogen – even unknown and engineered ones – through an innovative method of measuring and weighing nucleic acid sequences.

The TIGER system has been rigorously validated for use in biodefense applications, including surveillance for biological weapons agents in environmental samples and analysis of a broad range of biological samples for important human pathogens.

TIGER is nearing completion. One system is being installed at U.S. Army Medical Research Institute of Infectious Diseases at Fort Detrick, Maryland, to be used for analysis of novel and emerging pathogens. Another is being installed at the Naval Health Research Center in San Diego, California, for monitoring respiratory pathogens that affect troop readiness.

The goal of DARPA's Handheld Isothermal Silver Standard Sensor (HISSS) program is to develop a handheld biological warfare agent sensor capable of laboratory-quality detection of the full spectrum of biological threats on the battlefield: bacteria, viruses, and toxins. The handheld size of the sensor is enabled by the isothermal nature of the assays (eliminates heating and cooling devices), and by performing the assays in a compact, microfluidic cartridge.

HISSS assays were compared head-to-head with the current silver standard laboratory assays used to detect bacteria, viruses, and toxins, and all of the HISSS assays showed false alarm rates significantly lower than the standard laboratory assays. More recently, this same advantage over standard laboratory assays was demonstrated in a flow-through system, which moves HISSS significantly closer to its ultimate, operational goal for the warfighter.

Our work to maintain joint forces combat performance includes important research in both acute and long-term care for injured troops.

The Peak Soldier Performance program has developed a completely new approach to maintaining normal body temperature in the face of extreme heat. The Rapid Thermal Exchange Device is a special cooling glove into which one hand is inserted. A slight vacuum is applied to the palm, which contains special blood vessels that can act like radiators. Cold water circulates through the grip, and, as a result, large amounts of blood can be rapidly cooled, maintaining normal body temperature even in extreme heat or during exertion.

The device has been so successful in preliminary evaluation by the military that 125 prototype units are now deployed with an Army combat brigade in Iraq. In the next year, we will design and manufacture specially adapted devices for warfighters in vehicles and aircraft, as well as dismounted troops.

A "warming glove" version of this technology has been developed, and the first military re-warming tests are being conducted at the Marine Mountain Warfare Training Center.

To stop bleeding on the battlefield, DARPA's Deep Bleeder Acoustic Coagulation (DBAC) program will produce a portable device to stop deep internal bleeding, which could be operated on the battlefield by non-specialized personnel. The approach will utilize novel, high intensity focused ultrasound (HIFU) to detect, locate, and coagulate deep internal bleeders. The DBAC team includes test and standards development experts for HIFU devices at the FDA's Center for Devices and Radiological Health. Involving the U.S. Food and Drug Administration at the start of the program will help ensure that the transition from DARPA to the battlefield will occur as quickly as possible.

If severe bleeding is already taking place, the Surviving Blood Loss program will revolutionize combat trauma care in such situations by developing therapies that allow Soldiers to survive otherwise fatal blood loss for up to six hours until definitive care can be provided. In the first year of the program, DARPA investigators have achieved unprecedented and previously unimagined survival benefits in experimental animal systems using approaches ranging from inducing a hibernation-like state, to high-dose hormone therapy following hemorrhage. We see clear pathways for these research breakthroughs to become life-saving therapeutics.

Sometimes Soldiers critically wounded on the battlefield need the hospital brought to them, so in the early 1990s DARPA developed the Life Support for Trauma and Transport (LSTAT). LSTAT is a highly integrated, self-contained, technological "stretcher" intended to bring the capabilities of an intensive care unit forward, providing all necessary life support in a single unit, including cardiopulmonary monitoring, intravenous infusions, ventilator support, and blood chemistry analysis. LSTAT was fielded, but the system was costly and heavy (200 pounds) to deploy except in rear-echelons and for evacuation out of theater. To give LSTAT true battlefield-mobility, the LSTAT-lite program, co-funded by the Army Medical Research and Materiel Command and DARPA, is using miniaturization technologies to redesign LSTAT into a less-expensive platform that weighs only 50 pounds. LSTAT-lite will be ideal for casualty care in urban or mountainous terrains, on ships, and in all types of air and ground evacuation vehicles. LSTAT-lite is expected to go into production in 2008.

Last year I told you about the important work in our Human Assisted Neural Devices (HAND) and Revolutionizing Prosthetics programs. Our vision is simple but bold: to develop technologies for limb prostheses that are fully and naturally functional, neurologically controlled limb replacements having normal sensory abilities. This will allow wounded active duty Soldiers to rapidly return to service with artificial limbs that work as well as the ones they had.

Our vision includes not only regaining fine motor control, such as the ability to type on a keyboard or play a musical instrument, but also the ability to sense an artificial limb's position without looking at it, and to actually "feel" precisely what the artificial limb is touching by relaying sensations through residual nerves.

We have had three key breakthroughs on our way towards this vision.

The first and most important breakthrough came with DARPA's unequivocal demonstration that we can decode motor signals from the brain. This meant that a subject's motor signals to move an arm could be decoded from neural signals in the brain and directly translated to command a robotic arm.

The second major breakthrough came in 2005, when researchers at SUNY Health Science Center in Brooklyn, New York, showed that the perception of feeling can be created even when nothing is actually being touched. By stimulating the portion of a monkey's brain that is responsible for feeling touch, researchers observed specific responses just as if the animal were actually touching an object.

This work is unlike previous studies that showed vague gross movement in response to brain stimulation. This research is the first in which, through stimulation of precise brain areas, specific neural patterns can be reproduced that are nearly identical to those observed during actual touching and grasping tasks. This is important because sensory feedback is crucial to be able to feel objects that they are grasping, so that they will experience and use their prosthesis as an arm instead of as a tool.

The third breakthrough, also in 2005, is connecting signals between the prosthetic and the brain using the amputee's remaining, natural nerve system (e.g., in the case of an upper limb amputee, using nerve bundles in the shoulder). DARPA researchers have developed a micro-sensor that sends and receives signals to-and-from the nerves without causing nerve damage. This sensor's design allows the nerves to grow through the sensor itself – while the nerves continue to function normally – eventually enabling us to detect and/or input motor or sensory signals into the Soldier's remaining peripheral nerves.

DARPA has assembled two impressive teams of the world's leading neuroscientists, engineers, computer technologists, signal processors, physicians, surgeons and even combat amputees. Within two years, one team will deliver for clinical trials an upper limb with markedly enhanced functional capabilities compared to current prostheses, featuring many more degrees of freedom of movement and built from the most advanced, lightweight, functional materials. Four years from now, the second team will deliver for clinical trials an upper limb that is not only functionally superior, but one that is controlled by the brain and provides full sensory feedback to the patient.

Core Technologies

The eight DARPA strategic thrusts detailed to this point are strongly driven by national security threats and opportunities. In presenting them, I have primarily talked in terms of systems because we have learned, over our nearly 50 years of existence, that in order to transition technology, you have to talk in the language of the user – which, typically, is the ultimate new system capability that the technology will enable.

However, at the end of the day DARPA is still a technology development organization, and one constant Strategic Thrust has been, and will always be Core Technologies.

These core technologies are the investments in fundamentally new technologies, particularly at the component level, that historically have been the technological feedstocks creating opportunities for 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.

Materials

The importance of materials technology to Defense systems is critical and longstanding: 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.

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.

I'd like to illustrate our work with some examples from DARPA's efforts in Smart Materials and Structures, and Power and Water.

In collaboration with the Navy's PEO-Carriers, DARPA is transitioning its lightweight materials technology in a demonstration of a jet blast deflector (JBD) that requires no water cooling. The deflector structure alone would be 50 percent lighter than conventional jet blast deflectors, with concomitant reductions in lifting and auxiliary equipment. The advanced JBD also offers increased reliability by eliminating corrosion attendant with water-cooling. This technology helps CVN 21 achieve its target goals for weight distribution throughout the carrier.

Smart materials will also help our Soldiers carry ever-heavier and more cumbersome loads into combat – particularly when we account for body armor, which is critical in the close quarters of urban warfare. DARPA's Exoskeleton program has been developing and demonstrating the critical technologies such as power, control, and actuation that will lead to a self-powered external structure to enable a Soldier to effortlessly carry over 100 pounds of additional weight. This spring we plan to demonstrate full body exoskeletons that will enable a Soldier carry 150 pounds of payload without feeling the weight. The current plan is for Exoskeleton to transition to the Army in FY 2008 after it has successfully met the Army's metrics.

Instead of increasing the weight our solders can carry, DARPA's Palm Power program has taken the opposite tack and been developing advanced, portable power sources (20-150 watt) that will significantly reduce the weight associated with carrying today's military power sources – typically primary batteries – into the battlefield.

This year, we demonstrated a fuel cell running on propane, a fuel available worldwide, which will reduce the weight carried by up to a factor of 10 for multi-day missions. This success has opened the way for a variety of other fuel cell opportunities, including the development of a 30 watt cell for use in the Boomerang system.

In titanium, DARPA has identified at least two promising technologies that offer the potential for radically reducing the cost of titanium to a price of $2 to $3 a pound for military-grade quality. This program is now moving from the feasibility stage to a prototype operation. This will be a true paradigm shift, as occurred in the use of aluminum once we learned how to produce it economically.

Microsystems

Microelectronics, photonics, and microelectromechanical systems (MEMS) are three key technologies for the U.S. military, enabling it to sense, process, communicate, and act on information in a secure, reliable and timely manner. These core technologies maintain our advantage to see and engage our adversaries before they can see us.

The future lies in exploiting advances in nano-science and nanotechnology, where matter is manipulated at the atomic scale to develop new capabilities and to integrate various technologies to create still-more-complex capabilities in ever smaller and lower-power packages.

DARPA envisions adaptable microsystems for enhanced radio frequency and optical sensing; more versatile signal processors for extracting minute signals in the presence of overwhelming noise and intense enemy jamming; high-performance communication links with assured bandwidth; and intelligent chips that allow a user to convert data into actionable information in near-real-time.

Taken together, these capabilities will create information superiority by improving the ability of the mobile warfighter to collect, process, manage, and act on information – ultimately allowing U.S. Forces to think and react more quickly than the enemy in a rapidly change battlespace.

We are taking the same microsystems approach and exploiting MEMS technology to develop a complex chemical gas sensor, a combined gas chromatograph and mass spectrometer on a chip. Initial results show this micro-version of the laboratory "Gold Standard" for chemical gas identification can separate over 20 chemical peaks, and do this much faster than the larger laboratory system. We expect to have a complete micro gas analyzer in three years that could be fielded with an individual warfighter.

Ultraviolet emitters developed by DARPA have been integrated into a compact, low-cost, biosensor that uses multi-wavelength fluorescence for a new class of early warning systems being transitioned to the Defense Threat Reduction Agency, and is being developed further by the Department of Homeland Security.

Microwave sensors will extend the performance of future radar, electronic warfare, and communications systems, and the advanced power electronics will reduce the size and weight of the power conversion stations in future aircraft carriers and contribute to realizing tactical electromagnetic weapons.

To increase the volumetric density of transistors in digital circuits, we continue to extend 3D integration, where multiple layers of transistors are stacked one on top of one another. This year we demonstrated the first step in producing infrared imaging arrays with 3D integrated readout electronics. This new focal plane architecture enables the imaging of a wider range of scenes and the ability to identify low-light images in the presences of bright objects.

Information Technology

Information Technology is one of DARPA's most important, long-standing core technology foundations. No other enabling technology has been as instrumental in DoD's drive towards network-centric operations.

Our work in Information Technology is closely intertwined with our strategic thrust in Cognitive Computing, and forms the foundations for advancing cognitive systems. However, it is also a core technology that supports an even broader set of information technology problems and opportunities.

Numerous studies have documented the importance of high performance computing to U.S. national security. Unfortunately, current trends in commercial high performance computing are creating serious technology gaps that jeopardize U.S. superiority in this area.

DARPA's High Productivity Computing Systems (HPCS) program was created to bridge that gap and provide a new generation of economically viable, productive peta-scale systems for national security in the 2010 timeframe. The technology we are developing will allow us to design weapons systems that are more capable in an uncertain future. How stealthy will the aircraft we're developing actually be? What is the expected weather in a potential area of operations in five days? How can we gather, organize, and process petabytes of signals intelligence? Answering these questions requires computing capabilities significantly beyond what we have today.

HPCS not only fulfills a national security requirement, but it is also a necessity if the U.S. is to remain a leader in computing technology. HPCS will provide both the peta-scale hardware architectures and the software environments to enable delivery of peta-scale-level products to the market much faster, and with much better designs for usability.

HPCS Phase II, with three competing teams, will end later this year. Each team has provided a preliminary system design and specifications for a new, highly productive computer language. We anticipate that two teams will be selected to compete in Phase III, where the designs will be finalized and taken through development and demonstration. Other agencies, both internal and external to DoD, have participated in HPCS: the National Security Agency, and the Department of Energy's Office of Science and National Nuclear Security Agency have committed funding for the Phase III effort.

Another significant element of our work in Information Technologies is our support of global military operations by working to vastly improve the machine translation and distillation of material in foreign languages.

Both today and in the future, U.S. forces must be ready to operate around the globe, often on short notice, in unfamiliar places where English is not the native language. For their safety and effectiveness, they must understand a wide range of new and changing information that appears first, and often only, in foreign languages, including what is being said by various leaders to the people in the area of operations and how the local populace is reacting.

There are not enough human translators, and technology is the only feasible solution. State-of-the-art technology developed under DARPA support is currently being used in Iraq by U.S. Central Command, as well at U.S. Special Operations Command headquarters, as a partial solution to this problem.

Our current systems are able to translate newscasts and other sources, and provide translations at a sufficient level to be a very important filter for deciding the importance of a particular program or article, and whether it warrants a complete and more accurate translation. But an accurate translation still requires human intervention, and it requires additional humans to analyze the translated articles.

The goal of DARPA's Global Autonomous Language Exploitation (GALE) program is the translation and distillation of all foreign language material (television shows, chat forums, newspapers) in near-real-time, and storage in a searchable database.

Imagine a military commander getting an "Early Bird" every morning that summarizes, in English, all the important material that has appeared in print, on the internet, and on television about his geographical area of concern. The commander could type keywords into his computer and see the entire articles both translated to the accuracy of a human translator and the original sources, complete with pictures.

GALE, widely recognized as the national program in machine translation, is working to achieve this very ambitious goal by 2010. The program, being worked initially both for Arabic and Chinese, will improve the quality of translation to become nearly human-translator-quality. The translation quality will improve from today's 55 percent accuracy to 95 percent accuracy, for both text and speech foreign documents. The program will also improve distillation capability, and is expected to perform better than human analysts working under time constraints.

DARPA is concerned about the apparent decay of talent and interest in Computer Science over the past five years.

There is data which shows that the percentage of incoming freshmen stating that they wanted to go into Computer Science has dropped from nearly 4 percent in 1999 to less than 1.5 percent in 2004.

DARPA feels that a major reason for the decline is the lack of new, exciting ideas that will attract the brightest and the best of our youth to go into this field. A recent article from a Princeton professor cites similar concerns. But there are still many who do not believe that the issue is the lack of visionary exciting new ideas. It is exciting ideas that attract resources, not vice versa.

DARPA, by itself, cannot change this attitude and the resulting decline. But we do recognize the importance of cultivating new talent in the academic computer science community that understands DoD's challenges.

The DARPA Grand Challenge has spurred new interest in Computer Science as participants created new learning algorithms for their autonomous vehicles. But this is not enough.

We are beginning a new program, the Computer Science Study Group, that will train early-career computer science investigators in DoD's needs and priorities.

This program will competitively select and fund approximately a dozen young computer scientists in its first year, with additional scientists to be selected in future years. We will provide mentors from the senior academic and military community to these younger scientists who will, we hope, become the new visionary leaders in this discipline.

These efforts, by themselves, will not reverse the trend. We do hope however that they will initiate an awareness into the issues behind what is a real decline in Computer Science.

I hope my remarks today have given you a sense of our programs and our ambitions. Thank you for this opportunity to appear today. I would be pleased to answer your questions.