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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) 2005 activities and our FY 2006 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 also to *create* 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 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 Eight 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 eight strategic research thrusts that DARPA is emphasizing today are:

- Detection, Precision ID, Tracking, and Destruction of Elusive Surface Targets
- Robust, Secure Self-Forming Tactical Networks
- Networked Manned and Unmanned Systems
- Urban Area Operations

- Detection, Characterization and Assessment of Underground Structures
- Assured Use of Space
- Cognitive Computing
- Bio-Revolution

Urban Area Operations is our newest thrust, driven partly by Iraq and partly by the increasing likelihood that future conflicts will be fought in densely populated areas. The investments in the Urban Area Operations thrust area are closely integrated with the investments DARPA has in the other seven thrusts. These investments are part of our ever-changing investment strategy for the technologies our future generations of warfighters will need.

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

<u>Detection, Precision ID, Tracking, and Destruction of Elusive Surface Targets</u>

For many years, the Department of Defense has steadily improved its ability to conduct precision strike against fixed, and other predictable targets. However, experience shows we still need better ways to detect, identify, track, and defeat elusive surface targets. America's adversaries realize they must constantly remain on the move, and hide when not on the move, if they are to survive against the United States' superior precision strike capabilities. For a number of reasons, it remains difficult to strike targets that are hiding, moving, or whose destruction requires near real-time reaction by U.S. forces. Hence, 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?"

DARPA is assembling the sensors, exploitation tools, and battle management systems needed to meet this challenge by seamlessly melding sensor tasking with strike operations. Success will blur or even erase barriers between the Intelligence and the Operations functions at all levels of command, which has large implications for U.S. military doctrine and organization.

As an example of our vision, 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. This information could be used to cue laser detection and ranging (LADAR) sensors to look more closely at those potential targets. These LADAR sensors, which are another DARPA project, could provide exquisitely detailed three-dimensional images of the vehicles hiding under trees, allowing us to identify them as tanks or trucks or something else.

We are also developing software to "stitch-together" information from a variety of sensors (e.g., moving target indicator radar, synthetic aperture radar, optical, video, and acoustic sensors), and then cue the sensors to obtain more information. For example, changes detected by radar could cue ladar sensors to watch a new arrival. Conversely, if a Predator operator lost track of a target because it entered a forest, radar could be cued to search for the vehicle. All in all, we are taking a very comprehensive approach to finding, identifying, tracking and destroying targets.

Let me give you some specific examples of what we are doing:

DARPA's Airborne Video Surveillance program succeeded in matching frames from unmanned air vehicle (UAV) video to geospatial reference imagery provided by the National Geospatial-Intelligence Agency with targeting accuracies of 7-10 meters. This automatic linking of UAV video to existing maps is a dramatic and low-cost improvement that will greatly improve the operational flexibility of coordinate-seeking weapons such as Joint Direct Attack Munition, Joint Standoff Weapon, and modern Army artillery. Our current Video Verification and Identification program is building on the success of this work.

Under our Advanced ISR (intelligence, surveillance, and reconnaissance) Management program, DARPA developed a tool for planning, scheduling, and tasking U.S. intelligence collection and surveillance platforms. The tool can perform dynamic replanning as the battlespace situation changes. Its effectiveness was verified in recent Air Force exercises and it is now included in the Collection Management Mission Applications – the system for collection management used by ISR planners and managers.

DARPA's Knowledge-Aided Sensor Signal Processing and Expert Reasoning (KASSPER) program uses topography, terrain features, road networks, and synthetic aperture radar imagery to greatly reduce false alarms and improve the detection of low-speed targets. With KASSPER, false alarms have been reduced by a factor of 100 even in the presence of highly irregular background clutter and we can detect objects moving only half as slowly as we could before. Technologies from KASSPER will start to transition to Joint STARS this year.

Robust, Secure Self-Forming Tactical Networks

The DoD 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 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 as reliable, available, and survivable as the weapons platforms they connect. They must distribute huge amounts of data quickly and precisely across a wide area. They must form themselves without using or building a fixed infrastructure. They must withstand attempts by adversaries to destroy, disrupt, or listen in on them. These challenges must be met, as 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. This means conducting research in areas that include mobile *ad hoc* self-forming networks; information assurance and security; spectrum management; and anti-jam and low probability of detection/intercept communications.

For example, our Networking in Extreme Environments program is working to create ultra wideband wireless networks for robust and efficient military communications and sensing. Ultra wideband devices should be 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. So far, the program has gained a thorough understanding about how ultra wideband systems interact with current radio systems, one key to determining the ultimate value of ultra wideband.

In the area of information assurance, 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 program will develop an integrated system of detection and response devices to quarantine zero-day worms and stop them from spreading before other parts of the network are protected.

Other DARPA-developed network security tools proved to be very effective at the 2004 Joint Warrior Interoperability Demonstration, a virtual military exercise conducted each year by the Office of the Chairman of the Joint Chiefs of Staff. These tools were able to provide protection and help network administrators clean up the network after an accidental security incident. Lessons from these exercises help provide information on which network security technologies the DoD should procure. More generally, technology from our Network Modeling and Simulation program has been adopted by a number of other agencies throughout the DoD, such as Space and Naval Warfare Systems Command, Joint Forces Command, and the Defense Information Systems Agency to do a better job of designing communication networks.

An example of what we are doing in the areas of networks for our forces deployed in Iraq today is the Marine Airborne Retransmission System (MARTS) program. The Marine Corps has an urgent need to securely extend the range of tactical radios in its area of operations. MARTS does this by using a tactically transportable aerostat system, which retransmits through antennas aloft and uses fiberoptics to connect to the ground station radios. An aerostat tethered at 3000 feet altitude can retransmit a radio signal over an area approximately 160 miles in diameter. The aerostat underwent its first test flight the first week in February, and the first system will be deployed with the Marine Corps in Iraq very soon.

Networked Manned and Unmanned Systems

Fully autonomous unmanned platforms offer great promise as warfighting platforms integrated with other elements of our joint forces. DARPA is working with the Services toward a vision of filling the battlespace with unmanned systems 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 that also lowers the risk of U.S. casualties. The challenge here is "How can we combine manned and unmanned systems to create entirely new types of capabilities?"

Over the last several years, the Services have come to appreciate that combining unmanned with manned systems can enable 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. A network of collaborating systems will be far more capable than the sum of its individual components.

DARPA is working on a variety of unmanned vehicles for both the air and the ground, ones suited to a variety of missions and levels of environmental complexity. 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 28 flights, carried up to 500 pounds, traveled at over 135 knots, and stayed aloft for over seven hours. A number of other vehicles are part of our support to the Army's Future Combat Systems program. These include the Micro Air Vehicle, which is a backpackable ISR system for dismounted soldiers, the Unmanned Ground Combat Vehicle for fire support, and several other platforms for ISR and tactical strike. Our Netfires program, a fully networked containerized missile system, has transitioned to an Army development program for fielding as early as 2008.

A prominent program here has been Joint Unmanned Combat Air Systems (J-UCAS), which the Office of the Secretary of Defense asked DARPA to manage in FY 2005. J-UCAS is a joint Air Force and Navy program to accelerate the development of networked unmanned combat air vehicles for suppressing enemy air defenses, providing precision strike and persistent surveillance. The program builds on DARPA's earlier work on unmanned combat air vehicles. The program will develop new air vehicles, but the key to J-UCAS will be its Common Operating System (COS), which will manage its network services and other system resources (e.g., sensors, weapons, and communication links). The combination of the air vehicles, control stations, and the COS, in conjunction with other manned and unmanned systems, will create an entirely new and powerful global strike capabilities.

In the last year we have made solid progress in J-UCAS, including several "firsts." A demonstrator vehicle successfully delivered an inert GPS-guided smart bomb from 35000 feet at 440 miles per hour; the weapon precisely hit the target. Control of a vehicle was handed off to a control station 900 miles away – and back again – while the vehicle was beyond-line-of-sight.

Various features required to operate on a carrier deck were demonstrated. And, perhaps most importantly, two demonstrator vehicles flew together as a single team controlled by only one operator on the ground.

In FY 2006, management and funding for the program will move to the Air Force.

In another "first," DARPA held its first Grand Challenge in March 2004. DARPA is using the special prize authority authorized by Congress to recognize outstanding achievements in basic, advanced, and applied research, technology development, and prototype development that have the potential for application to the performance of the military missions of the Department of Defense (DoD). The concept is similar to the prize awarded to Charles Lindbergh for his solo flight across the Atlantic Ocean that then spurred Americans toward innovation and development in aviation.

DARPA's first use of the prize authority is to accelerate technology development in autonomous ground vehicles. DARPA offered a $1 million prize to anyone that could develop an autonomous, unmanned ground vehicle that could travel approximately 150 miles in under 10 hours across desert roads and trails between Barstow, California, and Primm, Nevada. The vehicles had to be truly autonomous, and only two commands were allowed – start and stop. And the teams would not know the route beforehand – in fact, they received the route navigation points just two hours before the start signal.

DARPA designed this Grand Challenge to spur innovation in a very difficult technical area so as to help DoD meet the Congressional goal that one-third of the Armed Forces' operational ground combat vehicles be unmanned by 2015. The autonomous vehicles would remove our men and women from harm's way by letting the autonomous vehicles take over dangerous combat support missions, such as that faced by our supply convoys in Iraq today.

The Grand Challenge for autonomous ground vehicles serves an important part of our overall technical strategy. For years DARPA funded programs to develop the technologies necessary for a truly autonomous ground vehicle, and, still today, there are programs underway at DARPA. While there is measurable technical progress in each of these programs, the progress has not been quick enough on the ability to develop an autonomous vehicle that could navigate a long route, avoid obstacles, and do it with an average speed that is tactically useful to the joint forces.

This is where the Grand Challenge helps – to win the prize, teams competing in the Grand Challenge must develop vehicles that can successfully travel tactically relevant distances and speeds. This is a truly daunting technical goal, but not too daunting that no one was interested in trying to win the prize, and a place in the history books.

One hundred and six entrants filed applications to compete, and, through a series of selection processes, 15 teams were selected as having vehicles safe and capable enough to attempt the route for the prize.

Here's what *Scientific American*[1] reported about the March 13 event:

> Of the 15 vehicles that started the Grand Challenge … not one completed the 227 kilometer course. One crashed into a fence, another went into reverse after encountering some sagebrush, and some moved not an inch. The best performer, the Carnegie Mellon entry, got 12 kilometers before taking a hairpin turn a little too fast. The $1-million prize went unclaimed. In short, the race was a resounding success. The task that the Pentagon's most forward-thinking research branch … set out was breathtakingly demanding. Most bots can barely get across a lab floor, but DARPA wanted them to navigate an off-road trail at high speed with complete autonomy. The agency had expected maybe half a dozen teams, but more than 100, ranging from high school students to veteran roboticists, gave it a try. The race … has concentrated the minds of researchers, blown open the technological envelope and trained a whole generation of roboticists. They will be out there again next October.

All across the nation, from garages to high schools, from universities to corporate laboratories, hundreds – perhaps thousands – of people worked on solving a problem important to the DoD. We had hoped that the Grand Challenge would excite many people, but it grew into something much, much bigger than anyone had imagined. The Congressionally authorized prize authority inspired many smart people who would not ordinarily work on a problem important to DoD, dedicating long days, nights and weekends toward finding a solution. The Grand Challenge yielded more benefit for DoD than the technology developed for the vehicles, or the distance the vehicles traveled.

DARPA will run the Grand Challenge again on October 8, 2005. The end goal remains the same: build an autonomous ground vehicle that can travel the fastest across approximately 150 miles of tough desert roads and trails in under 10 hours – but the prize will be two million dollars. As of this date, 195 teams have applied to compete in the Grand Challenge from 37 states and three foreign countries. Thirty-five teams are university-based, and three are from

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1 *Scientific American* **291**, 6, p. 6 (December 2004)

high schools. Eventually, we will invite 40 teams to a national qualification event, from which 20 teams will be selected to compete.

Urban Area Operations

Our newest strategic thrust, announced last March, is Urban Area Operations. Like many in the DoD, we have been concerned about the challenges of urban warfare and have been studying the issue. The conflict in Iraq precipitated this strategic thrust and continues to shape it. We held a major solicitation on this topic last year, and the overall thrust continues to take form. Because this is our newest thrust and one that is directly grappling with some of the problems uppermost on everyone's mind, it merits discussing at some length.

Each year the world's urban areas increase in population and area. By 2025, nearly 60 percent of the world's population will live in cities. And, our adversaries know that if they present a fixed target on the open battlefield, or even a mobile target on the open battlefield, we will find it and destroy it. So more and more they will choose to resist us in cities. These basic facts suggest that our forces must be increasingly prepared to operate in urban areas.

It is worth considering what makes operating in cities distinctive. A city's geometry and demography are very different than the traditional battlefields of open- or semi-open terrain so effectively dominated by U.S. forces today. Cities have buildings and tunnels and a complex three-dimensional terrain with many places to hide and maneuver. Think of mountain ranges or other rugged terrain, but with a much finer structure – one scaled to cities because they are man-made environments. And cities are densely packed with people and their property.

This has several consequences. Vehicles, weapons, and tactics that work effectively in open – even rugged – natural terrain, often work far less well in the confines of a city. Our current surveillance and reconnaissance systems simply cannot provide enough information of the type needed to understand what's really going on throughout a city. In most cases of urban warfare, standoff attack will not be sufficient, and close combat tends to be chaotic with many casualties.

In cities, uniformed adversaries and their equipment are mixed in among the civilian population, equipment and infrastructure. And insurgents are not just mixed in – they blend in. And operations in cities, perhaps more than in other settings, will be strongly constrained by political considerations. Achieving our political goals will usually not be a simple matter of capturing territory or reducing something to rubble. The fighting in Najaf last summer is a good example of this reality.

In short, the advantages U.S. forces enjoy on traditional battlefields are drastically reduced in cities. This is why our adversaries will be temped to fight us or resist us there; it is a logical response on their part. By drawing us into cities, our adversaries hope to limit our advantages, draw more of our troops into combat, inflict greater U.S. casualties, and, perhaps equally important, undermine our ultimate political goals by causing the U.S. to make more mistakes that harm civilians and neutrals.

The proof of this is in Iraq: the power, pace, and precision of our forces quickly demolished the Iraqi armed forces on the traditional battlefield. The current insurgency is not fighting the same way.

So our challenge is this: "How can we operate as effectively in the cities as we do on traditional battlefields, and what are the new tools we need?" We chose the word "operate" carefully: this cannot just be about traditional force-on-force urban combat, as important as that problem is. We also need to improve our stability and security operations after major combat is over. Just as the tools for combat on the traditional battlefield may not be well-suited to urban combat, the tools for urban combat may not necessarily be well-suited for stability operations. We need better tools across this entire spectrum of operations.

In general, we need far better and different information and coverage from our surveillance systems and sensors, more precision and options in our maneuvers and command and control, and much finer control over the force we apply. Ideally, we would then know much more about what's going on in a city, we could easily discern friend from foe, we could move around quickly – even using the vertical dimension to our advantage – and, when we needed, we could apply well-calibrated lethal or non-lethal force with great precision.

Let me talk in a little more detail about our vision for this thrust and describe some of the things we are working on and would like to expand.

One critical key to improved urban operations will be persistent, staring reconnaissance, surveillance, and target acquisition (RSTA) systems that vastly improve what we know about what's going on throughout a city in all three dimensions and over time. We need persistent staring RSTA systems that are as well tailored to cities as our current RSTA systems are to the traditional battlefield. If you are on an open plain you can see what is going on miles away, but in a city, you may not know what's going on a block away. We have to change that.

We need a network, or web, of sensors to better map a city and the activities in it, including inside buildings, to sort adversaries and their equipment from civilians and their equipment, including in crowds, and to spot snipers, suicide bombers, or IEDs (improvised explosive devices). We need to watch a great variety of things, activities, and people over a wide area and have great resolution available when we need it. And this is not just a matter of more and better sensors, but just as important, the systems needed to make actionable intelligence out of all the data. Closely related to this are tagging, tracking, and locating (TT&L) systems that help us watch and track a particular person or object of interest. These systems will also help us detect the clandestine production or possession of weapon of mass destruction in overseas urban areas.

There was a recent incident in Iraq where one of our UAVs spotted some insurgents firing a mortar. Then the insurgents climbed back into their car and drove away. The good news was that the UAV was able to track the car so U.S. helicopters could go after it and destroy it. The bad news was that, at one point, some of the passengers got out. Then we had to decide whether to follow those individuals *or* the car because we simply did not have enough coverage available. If we'd had other sensors available, we would have had a better chance of getting all of those insurgents.

If we could quickly track-back where a vehicle came from, it would greatly help us deal with suicide car bombers. It is difficult, if not impossible, to deter the bombers themselves, just as you cannot deter a missile that has already been launched. But, one key to deterrence that has been missing is reliable attribution, or a "return address." If we knew where the car came from, using, for example, RSTA systems that allowed us to quickly trace the car carrying the explosives back to the house or shop it came from, we could then attack that place and those people.

Once people realize that whoever helps launch a suicide attack will themselves be targeted (and since it's unlikely that everyone in a suicide bombing organization has a suicide wish) we would start to deter attacks. At a minimum, we would destroy more of the people and infrastructure behind the attacks, and make subsequent attacks more difficult. We are pursuing this sort of capability with our Combat Zones That See program.

Now, consider a U.S. team raiding a house looking for insurgents. This team has probably never been to the house before, and perhaps has never even been to the immediate neighborhood. In an unfamiliar place with many similar buildings, it's easy to become confused and break into the wrong place, even with GPS. Breaking into the wrong building has two effects: the enemies get away, and, at a minimum, you probably just made some new enemies.

Instead, imagine that the team could prepare for the raid using clear, three-dimensional images of the actual neighborhood and the specific building that had been collected in advance. The team could use those images to practice and "see" their entire trip to the building before they actually start out on their mission so they'd be far more likely to enter the right building. Our Urbanscape program is working on the technologies to do this.

Another typical urban mission could require a U.S. team to pursue adversaries inside a multi-story building. Currently, the defenders inside the building have a major advantage in knowing the interior layout. If we had technology that would allow our team to quickly map the inside of the building and, perhaps, even tell them where the bad guys are, this would go a long way to improving the team's effectiveness and safety. Our Building Structure and Activity Assessment program is developing this capability.

Thinking more broadly than RSTA, we are also interested in how to improve our intelligence on general social, political, and economic conditions. In particular, it would help to have tools to predict the onset of a rebellion or, failing that, help us understand more clearly the likely or possible responses to our actions, i.e., tools to wargame our stability operations.

Another major focus of the Urban Area Operations thrust is Command and Control for Urban Warfighting, aimed at developing command and control systems and intelligence analysis tools specifically suited for urban operations. The goal is collaborative systems that allow our warfighters to see and understand what is happening throughout an urban area and then direct their actions in real time. RSTA and TT&L will give us much better information, but we must then use that information to direct what we are doing in a precise way, perhaps reaching down as far as the individual soldier.

Our Command Post of the Future (CPOF) technology, being used today by the Army in Iraq, is an early indication of what we are striving for. CPOF is a distributed command and control system that creates a virtual command post. With CPOF, command and control centers could 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. By studying the steps usually taken after specific types of events, DARPA is working with the Army to enhance CPOF to automatically alert people to take those steps whenever another such events happens, which would allow our warfighters to respond faster. Major General Pete Chiarelli, Commander of the 1st Calvary Division in Iraq, has told us, "CPOF is saving lives."

This thrust also embodies our work in Asymmetric Warfare Countermeasures, including those devoted to countering the threat of IEDs. The IED problem is very difficult, and we are actively pursuing and continuing to search for ideas to detect or disable IEDs. In fact, the IED problem has been central in shaping our thinking about urban operations generally. We have seen the great difficulty we've had with even costly *partial* solutions to the IED problem, ones which, in many cases, the insurgents are able to quickly work-around. Our discussions with Commandant Hagee of the Marine Corps reinforced our belief that the key to limiting IEDs will be identifying their *source*; this is one of the reasons for our strong emphasis on RSTA in this thrust.

Finding "sources" is also the key behind DARPA's low-cost Boomerang shooter detection and location system, which we continue to improve based on results from the 50 units deployed so far in Iraq. When you are traveling in a convoy it's difficult to know if you are being shot at because of road noise. With Boomerang, people in the convoy can tell if they are being shot at and where the shots are coming from, so they can defend themselves more effectively.

We are also exploring ways to thwart rocket-propelled grenade (RPG) attacks. We are transitioning an advanced, lightweight bar armor to the Marine Corps to protect HMMWVs and trucks. We are testing novel, high-strength nets to stop RPGs and mortars. And, our Iron Curtain project will develop and test a system to destroy RPGs and missiles by shooting them down with bullets before they can strike a vehicle.

Another facet of the urban operations thrust is modeling and simulation tools, which we believe will be particularly helpful for improving training. For example, we have leveraged multi-player PC game technology to help train units going to Iraq on better ways to avoid being ambushed. After a few times through the simulation, and after having "died" a few times, the lessons on what to watch for and how to react tend to stick in the warfighters' minds. And, we have married speech recognition technology with video game techniques to create a Tactical Iraqi Language Tutor that quickly teaches everyone, not just linguists, the Arabic needed to get basic "Who? What? and Where?" information, while getting along with the locals by conducting a civil affairs mission in a PC virtual world. Our troops are even taught the physical gestures and social conventions needed to help establish trust.

With these and other technologies, our strategic thrust in Urban Area Operations promises to make major contributions to our military capabilities.

<u>Detection, Characterization and Assessment of Underground Structures</u>

Our adversaries are well aware of the U.S. military's sophisticated intelligence, surveillance, and reconnaissance assets and the global reach of our strike capabilities. In response, they have been building deeply buried underground facilities to hide various activities and protect them from attack.

These facilities can vary from the clever use of caves to complex and carefully engineered bunkers in both rural and urban environments. They are 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?" To provide answers, 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.

For example, our Low Altitude Airborne Sensor System (LAASS) program should show that sensor payloads on a wide range of air vehicles could dramatically increase search rates and our detailed characterizations of underground facilities. LAASS will be the first sensor system to reveal the connections among underground facilities that were not seen during their construction, and it will be able to distinguish active facilities from those that are abandoned. This will allow prioritization of attacks, as well as allow us to find buried, but inert, targets such as escape tunnels and weapons caches.

Assured Use of Space

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 there is no reason to believe they will remain unchallenged forever.

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 Engagement:* reconnaissance, surveillance, communications, and navigation to support military operations down on earth – extending what the U.S. does so well today.

In our Access and Infrastructure activities, the Falcon program 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 quickly position intelligence, surveillance, and reconnaissance payloads, while reducing its reliance on forward and foreign basing. This year, the Falcon program will launch the first of a series of new, low-cost, small launch systems to deliver new hypersonic test vehicles to near-space. By 2008, Falcon will have conducted flight tests of two generations 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.

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 deep space. This past year the program successfully demonstrated a subscale telescope sensor composed of a mosaic of curved focal plane arrays, a key technology milestone for the program.

The U.S. national security community and American society depend on communications satellites. We must be prepared for adversaries that might try to deny us their use by jamming them. Under Space Mission Protection, the Novel Satellite Communications program is aimed at keeping our communication satellite systems secure. Last year, DARPA successfully demonstrated a new approach to dramatically improve our satellites' protection against jamming. This year we are developing the technology to fully exploit this new technique; a real-time demonstration of the Novel Satellite Communications technologies is planned for 2008.

In space-based engagement, the Innovative Space Based Radar Antenna Technology (ISAT) program is developing large, revolutionary radar antennas to provide continuous tactical-grade tracking of moving ground targets or airborne targets, such as cruise missiles. These antennas would be extremely lightweight and, when stowed for launch, would be about the size of a sport utility vehicle. Once on-orbit, such antennas would unfold to a structure that could be, in the fully operational version, the length of the Empire State Building. This past year DARPA successfully built and deployed a single section of the antenna on the ground, and we successfully demonstrated techniques that would measure the position and shape of the antenna to within one millimeter on-orbit. Multiple sections of the antenna will be built this next year, combined, and deployed and tested in a thermal vacuum chamber that simulates the space environment. The ISAT space-based demonstration of a one-third-scale antenna is planned for 2010.

Cognitive Computing

Many elements of the information technology revolution that have vastly improved the effectiveness of the U.S. forces and transformed American society (e.g., time-sharing, personal computers, and the Internet) were given their impetus by J. C. R. Licklider, a visionary scientist at DARPA some 40 years ago. Licklider's vision was of people and computers working symbiotically. He envisioned computers seamlessly adapting to people as partners that would handle routine information processing tasks, thus freeing the people to focus on what they do best – think analytically and creatively – and greatly extend their cognitive powers. As we move to an increasingly network-centric military, the vision of intelligent, cooperative computing systems responsible for their own maintenance is more relevant than ever.

Despite the enormous progress in information technology over the years, information technology still falls well short of Licklider's vision. While computing systems are critical to U.S. national defense, they remain exceedingly complex, expensive to create, insecure, frequently incompatible, 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 revisiting Licklider's vision as its inspiration for the strategic thrust, "Cognitive Computing." Cognitive computers can be thought of as *systems that know what they're doing*. Cognitive computing systems "reason" about their environments (including other systems), their goals, and their own capabilities. They will "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 expert systems.

As an example of how we are working to get the computers to adapt to people – instead of the other way around – our Improving Warfighter Information Intake Under Stress program is designing next-generation Tomahawk missile battlestations that will monitor the weapon operator's cognitive state. The battlestation will then adapt how the battlespace information is presented to operators so that it enhances their ability to make critical strategic and/or tactical time-sensitive targeting decisions.

Bio-Revolution

Over the last decade and more, 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 Human Assets* from biological warfare includes sensors 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 Human 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.

Let me give you some examples of our work.

DARPA is conducting important work in our Human Assisted Neural Devices and Revolutionizing Prosthetics programs. Our vision is simple but bold: to dramatically improve the quality of life for amputees by developing limb prostheses that are fully and naturally functional and neurologically controlled limb replacements that have normal sensory abilities. The goal is for amputees to return to a normal life, with no limits whatsoever, with artificial limbs that work as well as the ones they have lost.

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. To do this, DARPA's work in materials, sensors, power systems, and actuators will be integrated to develop a highly advanced, multiple degree-of-freedom, lightweight mechanical limb.

Our ultimate goal is to gain full, natural, neural control of this advanced prosthetic limb – durable, lifelike, and complete with sensory feedback. On the way towards this vision, we will create prosthetic arms that are vast improvements over the current state-of-the-art and technologies that will be directly applicable to advanced prosthetics for the lower extremities. DARPA is working closely with the Department of Veterans Affairs to make this a reality.

DARPA's Handheld Isothermal Silver Standard Sensor program is working toward providing our warfighters with a lightweight, handheld detector capable of sensing the full spectrum of biological threats: bacteria, viruses, and toxins. In a laboratory test last year, this sensor achieved nearly perfect detection performance, while minimizing the false alarms that plague today's sensor technologies.

Our Immune Building Program is focused on protecting the occupants of buildings from the release of chemical or biological agents directly inside or very nearby and dealing with the consequences of the attack. The first fully functional Immune Building is scheduled for completion in 2006 at Fort Leonard Wood, Missouri. And a portable version of DARPA's chlorine dioxide gas decontamination technology is being developed for use by the Department of Defense, the Department of Homeland Security, and the Environmental Protection Agency.

The Powerswim program is using the highly efficient way sea animals swim to design a new swimming device. Ordinary swim fins push through the water, like oars push a boat, and are about 10% efficient. The Powerswim program is developing a device that uses fin lift for propulsion – it basically "flies" through the water – with an efficiency of 80%. This could double the speed and range of U.S. Navy SEALS, allowing them to arrive on-shore much faster and much less fatigued. In another maritime example of using biology, we are looking at fuel cells that could produce electric power from plankton and ocean bacteria to power sensors and surveillance systems on the ocean floor for many years.

DARPA's Soldier Self-Care program is developing a highly effective novel pain medication that neutralizes the *chemical* trigger for pain before it can stimulate the nerves. Progress has been so substantial that we have funded a clinical trial at Walter Reed Army Medical Center in late 2005 to reduce the incredible pain of soldiers following amputation or severe limb trauma whose pain cannot be effectively treated with current medications. If successful, it will be a major step towards obtaining Food and Drug Administration approval of this medication for treating acute pain on the battlefield.

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.

<u>Materials</u>

The importance of materials technology to Defense systems is easy to underestimate: 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.

We have been working on "multifunctional materials" – materials that combine structure with other functions, such as batteries that can bear loads. DARPA's WASP micro air vehicle uses these structural batteries to combine its power supply with its wings, allowing this small (less than 200 gram, 12-inch wingspan) micro air vehicle to fly for 1 hour with the current sensor suite, almost three times longer than other, comparably equipped vehicles of similar size. (With a reduced payload, WASP has flown for nearly 2 hours.) WASP is being evaluated by the U.S. Marine Corps and the Nimitz Strike Group as a surveillance asset.

DARPA's rapid reaction program in advanced armor materials is developing an updated version of the Viet Nam-era "gun truck" to protect our convoys in Iraq. The gun trucks are a standard military 5-ton Army or Marine truck with an armored gun box in place of the cargo container. Thirty prototype gun box kits were recently sent to U.S. forces in Iraq and Kuwait, and preliminary reports from the theater indicate that the gun trucks provide our troops and convoys with protection and comfortable and comparatively spacious operating quarters.

We are also working to develop significantly improved armor materials for these trucks. One DARPA program is pursuing a lightweight composite armor that uses the same steel wire reinforcement found in steel-belted radial tires, and embeds these wires in a polymer matrix. If successful, this novel material could be a moldable, low-cost, easily manufactured, lower-weight alternative to conventional steel armor, while providing the same or greater protection to our warfighters. Initial ballistic tests on these new materials are very promising.

In collaboration with the Navy, we are exploring DARPA advanced material technology to establish the feasibility of a passively cooled jet blast deflector for CVN 21, which could also be retrofit to the existing fleet. This system would be 50 percent lighter by eliminating noisy and heavy hydraulics and water-cooling systems associated with conventional jet blast deflectors, while freeing up space and power for other equipment.

Our DARPA Titanium Initiative aims to completely revolutionize the way titanium is extracted from the ore and fabricated into product forms of interest to the DoD. The goal of the program is to achieve substantially reduced cost (less than four dollars per pound) and increased availability of large volumes of titanium. Our intention is to achieve a revolution similar to that in aluminum, which was transformed from a precious metal to a commodity at the turn of the 20th century. The program is on-track to develop processes that will meet all the DoD requirements for aerospace and other applications.

<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.

DARPA is shrinking ever-more-complex systems and enabling new capabilities into chip-scale packages, integrating microelectronics, photonics, and MEMS into "systems-on-a-chip." It is at the intersection of these three core hardware technologies of the information age that some of the greatest challenges and opportunities for DoD arise.

The future lies in increasing the integration among a variety of technologies to create still-more-complex capabilities. DARPA envisions intelligent microsystems for systems with enhanced radio frequency and optical sensing, more versatile signal processors for extracting signals in the face of 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 how the warfighter collects, processes, and manages information – ultimately allowing U.S. Forces to think and react more quickly than the enemy.

An example of the move to integrated microsystems is the 3-D Integrated Circuits program. Conventional 2-D circuits are limited in performance by the long signal interconnects across ever larger circuits and by existing circuit architectures. By moving to three dimensions, we can shorten the signal paths and introduce additional functions in each layer of three-dimensional stacked circuits that will change the way designers can exploit circuit complexity.

Advanced materials are important drivers in developing new, advanced microsystems. An example is the progress being made in wide bandgap semiconductor devices for ultraviolet emitters, microwave sensors, and high power electronics. The ultraviolet emitters are being integrated into a compact, low-cost, biosensor based on multi-wavelength fluorescence for a new class of early warning systems being transitioned to the Defense Threat Reduction Agency. The 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 station in future aircraft carriers or enable tactical electromagnetic weapons.

In the past year, wide bandgap ultraviolet light emitters at 280 and 340 nanometers have been incorporated into a prototype biological threat early warning system. Initial field data shows it outperforms the Army's Biological Aerosol Warning System (BAWS), with a projected 50 times lower cost. The successful development of a low cost bio-sensor with a low false alarm rate, a key to fielding any sensor system, will revolutionize how biological monitoring and defense is performed.

Also over the last year, our work on wide bandgap radio frequency devices has established new benchmarks for power density from a microwave transistor, with close to a 30-fold increase over conventional approaches. This work will enable high performance radio frequency systems to be deployed on restricted-size platforms, such as unmanned air vehicles.

Finally, our work on wide bandgap power switching devices able to stand-off over 10,000 volts has led to the Navy considering, via an MOA between DARPA, PEO Aircraft Carriers, and the Chief of Naval Research, the insertion of compact, multi-level signal conversion stations based on this technology in future aircraft carriers that will reduce the size and weight of the power substation by a factor of two, while adding performance.

Information Technology

The DoD is undergoing a transformation to network-centric operations to turn information superiority into combat power. Supporting this, DARPA's information technology programs are building on both traditional and revolutionary computing environments to provide the kind of secure, robust, efficient, and versatile computing foundation that our network-centric future requires. We will also create radical new computing capabilities to make the commander and the warfighter more effective in the field.

An important part of our work in information technology is machine language translation. In past years, we have reported how DARPA's one-way Phraselator is being used in Iraq and Afghanistan. Recently, we demonstrated the first rudimentary two-way Pashto Phraselator; we are now working towards making a natural two-way speech translator for Iraqi Arabic. In addition, CENTCOM now uses technology from two other DARPA human language technology programs to help produce a variety of intelligence reports. Their analysts do this using our eTAP-Arabic system, which combines automatic transcription and automatic translation to convert Arabic newswire and news broadcasts to English text.

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.