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Madam Chairman, Subcommittee Members and staff: I am very pleased to submit this discussion of DARPA's FY 2002 activities and our FY 2003 plans to continue to transform our military through technological superiority. I will also describe what we are doing to help win the war on terror in Operations Enduring Freedom and Noble Eagle.

DARPA has occupied a special role and mission within the Department of Defense since the time of Sputnik. Our mission is to provide the research and development that bridges the gap between fundamental discoveries and their military use. The work we support is necessarily high-risk and high-return *because* we are trying to fill that gap. We try to imagine what a military commander would want and accelerate that future into being, thereby changing people's minds about what is technologically possible.

"DARPA prevents technological surprise" also characterizes our mission over the years. To do this, we work to fill the gap between discovery and use before our adversaries can. However, DARPA, at its very best, not only prevents technological surprise, but creates technological surprise for our adversaries. An example of this is DARPA's development of stealth – a dramatic technological capability that continues to put our adversaries at a disadvantage.

Our mission in the Department creates a role that complements, but is no substitute for, the work of the Service science and technology establishments. A DARPA program does not start with what a military commander wants *today*. Instead, we look at what *future* commanders might want. We look beyond today's known needs and requirements because, as military historians have noted, "None of the most important weapons transforming warfare in the 20th century – the airplane, tank, radar, jet engine, helicopter, electronic computer, not even the atomic bomb – owed its initial development to a doctrinal requirement or request of the military."[1] *None* of them. And to this list, DARPA would add stealth and Internet technologies.

At DARPA, we constantly focus on dramatically changing how we will fight in the future. Our unique mission has made us the technological engine of military transformation.

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[1] John Chambers, ed., *The Oxford Companion to American Military History* (New York: Oxford University Press, 1999) p. 791

I returned to DARPA last June, having been a DARPA Office Director in the 1980s. When I had my job interview with the Secretary of Defense, I was given two charges: First, I was told to make DARPA like it used to be – an entrepreneurial "hotbed." Second, I was told that DARPA was to give the United States military more robust capabilities in space, so that our nation can maintain unhindered access to space and protect United States space capabilities from enemy attack – one of Secretary Rumsfeld's six transformational goals.

In his January speech on transformation at National Defense University, the Secretary said that he needed the Department to take "...a more entrepreneurial approach to developing military capabilities, one that encourages people, all people, to be proactive and not reactive, to behave somewhat less like bureaucrats and more like venture capitalists; one that does not wait for threats to emerge and be 'validated,' but rather anticipates them before they emerge and develops new capabilities that can dissuade and deter those nascent threats." That is DARPA at its very best. I believe that the Secretary had DARPA partly in mind when he said that. Also, the Section 1101 experimental hiring authority given to us by Congress is playing an important role in allowing us to hire the people we need to stay entrepreneurial.

Let me tell you more about what we're doing in our role as the Department's technological engine of transformation. You are familiar with our work in stealth and information technologies. DARPA has also made major contributions in areas such as precision-guided munitions and real-time command, control, communications, computers, surveillance, and reconnaissance. So what are we doing today to build on that legacy?

First, DARPA's vision is to fill the battle space with networked unmanned vehicles. Political support from Congress, particularly in this committee, top-level Service and DoD leadership, and technical progress are all coming together to make that happen. One of our flagship efforts is the Future Combat Systems (FCS) program, which has major unmanned components. Under the leadership of U.S. Army Chief of Staff General Eric K. Shinseki and his team, we will transform how the Army fights.

The Future Combat Systems is the cornerstone of the Army's efforts to create what it calls the Objective Force. The Objective Force will respond to the full spectrum of land combat. It will be, in the Army's words, "responsive, deployable, agile, versatile, lethal, survival, and sustainable." Within the FCS program, we have been developing concepts and technologies for a force that can deploy within 96 hours and be highly lethal and survivable in the year 2010. FCS is conceived of as a system-of-systems, and not a particular platform. What makes FCS different is that we are *starting* with the *network* that will make these goals possible – we're *not* starting with a specific platform, or a set of platforms, which we then try to network together.

Within DARPA, our FCS portfolio of programs emphasizes command-and-control, communications, sensors, the Netfires precision missile system, and unmanned and semiautonomous ground and air vehicles. For example, our A160 Hummingbird unmanned, long-duration helicopter had its first flight in January of this year. Unmanned platforms and vehicles enable the FCS system-of-systems to put fewer warfighters directly in harm's way. Moreover, because unmanned vehicles do not require heavy armor to protect people, they are lighter and easier to deploy.

Afghanistan has given us a glimpse of how unmanned air vehicles may shape the future. The Global Hawk, a DARPA program that transitioned to the Air Force in 1998, has played a key role in Operation Enduring Freedom by providing U.S. commanders with high-altitude, long-endurance, unmanned aerial reconnaissance over the area of operations. And the Predator, which was originally unarmed and grew out of the 1980s DARPA program called Amber, provides close-in combat surveillance and can now be equipped with Hellfire missiles.

DARPA currently has three unmanned air combatant programs underway: the Unmanned Combat Air Vehicle (UCAV) with the Air Force, UCAV-N with the Navy, and Unmanned Combat Armed Rotorcraft (UCAR) with the Army. These innovative programs are focused on enabling the *next* revolution in unmanned aerial weapon systems. We are not adding a weapons capability to an existing platform. Rather, we are focusing from the start on the technologies, processes, and system attributes that will help transform each of the Services: how the Air Force suppresses enemy air defenses, how the Navy suppresses enemy air defenses and conducts extended reconnaissance, and how the Army conducts armed reconnaissance and attack.

The Unmanned Combat Air Vehicle is a joint program with the Air Force to develop an unmanned aircraft that can be used to suppress enemy air defenses, thereby complementing piloted aircraft for extremely dangerous missions, and/or to conduct strike missions. Our current vision is that up to four UCAVs could simultaneously be supervised by a single battle manager. The last sentence contains two aspects at the heart of the UCAV revolution. First, UCAVs are not flown as one flies a Predator or Global Hawk or any unmanned platform today. Rather, the vehicles have sophisticated on-board adaptive mission planning, which will allow them to conduct the entire mission without continuous human oversight. Second, each of those vehicles is also directly linked to its fellow unmanned wingmen and can perform multi-ship cooperative targeting, tracking, attack, and assessment. UCAVs will hunt for relocatable and mobile targets in “four-packs” under the supervision of a skilled operator.

This is not about autonomous machines. It is about blending the best traits of man and machine. There is always a person in-the loop to provide the timeless qualities of human judgment and insight to supervise the unmanned systems and manage the battle. Operators will be assisted by decision aids that allow them to focus on the operational art of war, leaving the implementation details to the unmanned element of this synergistic blend of man and machine intelligence.

While striving to mature these challenging command and control concepts, the UCAV program has not lost sight of keeping this new weapon system affordable. The program emphasizes making UCAVs low-cost (roughly 50 percent lower purchase price than an F-16CJ and 75 percent lower operating costs) and storable, unattended, for long periods of time – the “wooden round” idea.

UCAV continues to make solid progress across the four major program focus areas: first flight, coordinated multi-vehicle flight, system B design, and acquisition planning. We have completed two of the three series of taxi tests required before a safe first flight, which is now planned for later this spring. Software is under development to support the critical multi-vehicle flight demonstrations scheduled for next summer, and we have begun designing the X-45B fieldable prototype, which will take the next major step toward an operational system and support future demonstrations of military utility and operational value. Overall, the program is on the maximum acceleration path in support of the Congressional goal of fielding 30 systems by 2010. DARPA has managed this program in close cooperation with the Air Force. In fact, the early and sustained participation of Air Force warfighters and developers has been a key factor in our success. DARPA is leading the program until the critical multi-vehicle flight tests are completed in Summer 2003, when we will transfer program management responsibility to the Air Force.

The Navy's variant of the UCAV, the UCAV-N program, is at a much earlier stage of development. In addition to the UCAV missions of suppression of enemy air defense and strike, the UCAV-N will also be tasked with extended surveillance. This additional requirement could lead to a vehicle that is significantly (i.e., 50 percent) larger than UCAV and it must be carrier-compatible and in-flight refuelable.

To date, DARPA's work on UCAV-N has been the preliminary design, analysis, and technology risk reduction required under what we call Phase I. Very shortly we expect to announce selections for Phase II, in which the detailed design and actual fabrication of UCAV-N will take place.

The Unmanned Combat Armed Rotorcraft is the newest of the three programs, with Phase I beginning this year. The goal of UCAR is an unmanned, affordable, survivable armed vertical take-off and landing system that can identify and attack targets farther in front of U.S. ground forces – doing a dangerous and critical mission while putting fewer soldiers in harm's way. Such a system would be an important element of the Army's Objective Force and will build on what we're learning about collaboration among unmanned vehicles in the UCAV program. During Phase I of the program, we will do the necessary studies to define the system concept, requirements, risk reduction roadmap, and effectiveness and affordability goals.

A second area where DARPA is continuing to push transformation is precision strike, building on a long tradition of work like Assault Breaker in the early 1980s. The war in Afghanistan showed us how precision strike, in the words of the Chairman of the Joint Chiefs before this Committee, means "... the bomb is no longer solely an area weapon, but is going to be used like bullets from a rifle, aimed precisely and individually." Timely, accurate, and precise delivery of bombs and missiles helped us overthrow a hostile regime in short order with very few American or unintended casualties. Yet our experience there has also shown us that major challenges remain in target detection, identification, and tracking.

To bolster our work in this area, I have recently established a new office at DARPA, the Information Exploitation Office (IXO). IXO is assembling the sensors and the information technologies needed to find and destroy the right land targets in any terrain, in any weather, moving or not, at any time.

Let me give you some examples of what we are doing. Currently, one of the best ways for our adversaries to avoid being killed is to keep moving. The Affordable Moving Surface Targeting Engagement (AMSTE) program will demonstrate how, by making only minor modifications to existing and planned systems, we can network and integrate multiple stand-off radars and long-range weapons like Joint Direct Attack Munitions and Joint Stand-Off Weapons to affordably, precisely, and rapidly destroy individual moving surface vehicles.

Another example of our work in time-critical precision strike is the Advanced Tactical Targeting Technology program (AT3). Enemy air defense systems are using increasingly sophisticated tactics and technology, and AT3 is aimed squarely at this threat. The overall program goals are to target surface-to-air missile (SAM) launchers to an accuracy of 50 meters from 50 miles away within 10 seconds after the enemy's radar turns on, a dramatic improvement over today's capabilities.

The technology produced by AT3 will provide the precise coordinates of an enemy air defense unit immediately after it turns on its radar. Providing precise coordinates quickly will allow a weapon to destroy the SAM threat before it can run and hide. AT3 employs non-dedicated platforms, such as tactical fighters, reconnaissance aircraft, UAVs, and UCAVs, to rapidly detect and locate enemy radars by sharing measurements of radar signals using existing tactical data links.

A third program, Tactical Targeting Network Technologies (TTNT), is developing the wireless communications technology needed for future time critical precision strike by a system of systems network. TTNT will provide the communications glue, if you will, allowing systems like AMSTE and AT3 to achieve their full potential. TTNT's goals include: real-time capacity allocation; high-priority messaging; data rates high enough for secure video; low costs; and compatibility with existing tactical data links such as Link 16.

Programs such as AMSTE, AT3, and TTNT will tear down the historical separation between sensors and shooters, the separation between the J2 Intelligence staff and the J3 Operational staff. This is an extraordinarily difficult problem, both technically and organizationally. Our job here at DARPA is to answer those who say, "It can't be done," by demonstrating that it can.

A third area we are transforming is how our systems will talk to each other. The key to network centric warfare is secure, seamless, high-data-rate communications, and DARPA is leading the way in developing those technologies for both untethered, i.e. wireless, and tethered networks.

In the wireless world, four programs illustrate our goals. The FCS Communications program is prototyping the technologies needed for the high bandwidth, low probability of intercept radio links crucial to making FCS work. Our Small Unit Operations Situational Awareness System is the first ad-hoc, mobile, all-terrain radio frequency network system for dismounted infantry. The Terahertz Optical Reachback program will provide high bandwidth optical networks to tactical units in theater. Our Next Generation program will make 10 to 20 times more spectrum available to our military by dynamically allocating spectrum across frequency, space, and time; we call it "tuning for daylight."

For tethered networks, DARPA is working aggressively to counter computer network attacks. For example, we are working on software "wrappers" that can enfold malicious incoming attachments and prevent them from getting at the system resources they need to spread. And our Autonomic Distributed Firewall technology places a firewall inside every computer on a network -- a firewall that can communicate with the other firewalls -- providing much more robust protection than a traditional single network firewall.

A fourth area where we are continuing to help transform our military is space. Recall that DARPA *started off* as a space agency, when the shock of Sputnik caused Americans to believe that our Cold War adversary had seized "the ultimate high ground." Space continues to be the high ground, it has recaptured our attention, and DARPA once again is investing in that arena.

The ability to maintain unhindered access to space and to protect our space capabilities from enemy attack is one of Secretary Rumsfeld's six transformational goals. In order to do so, DARPA is pursuing several new space programs.

First of all, to enable us to get to space and stay there, we have our new Responsive Access, Small Cargo, Affordable Launch (RASCAL) and the Orbital Express programs. RASCAL is designing and developing a low-cost orbital insertion capability for dedicated, micro-size (50 kilogram) satellite payloads. RASCAL will provide flexible access to space using a combination of reusable and low-cost expendable vehicle elements. Orbital Express will demonstrate the feasibility of refueling, upgrading, and extending the life of on-orbit spacecraft using automated spacecraft. This will lower the cost of doing business in space and will provide radical new capabilities for military spacecraft, such as high maneuverability, autonomous orbital operations, and satellites that can be reconfigured as missions change or as technology advances.

If one is going to space, one needs to know what is in space – space situational awareness. DARPA's new Space Surveillance Telescope program is developing a ground-based, large-aperture optical telescope with a very wide field of view using curved focal plane array technology. This will facilitate the detection and tracking of very faint objects in deep space. It is not intended as an imaging system, but, rather, as a search-and-detect capability. Both detection sensitivity and search coverage rate will be approximately an order-of-magnitude better than current capabilities.

To use space-based assets to gather information about objects on the ground, we are beginning the Innovative Space-based radar Antenna Technology program. The physics of this mission calls for a much larger antenna than has previously been considered. This drives the program's development of novel technologies and conceptual designs aimed at producing extremely lightweight, compact, and affordable space-based radar antennas that meet the stressing requirements of continuous, tactical tracking of ground moving targets for intelligence, surveillance and reconnaissance.

Finally, to protect our space satellites DARPA is initiating programs like the Satellite Protection and Warning/Space Awareness (SPAWN) program. SPAWN will demonstrate the feasibility of using micro-satellites to provide enhanced, near-field space situational awareness for U.S. space assets in geosynchronous orbit.

Since September 11th, the war on terrorism has been foremost in everyone's minds. I want to take a few minutes to tell you about some of the DARPA technologies that are being used to support Operation Enduring Freedom.

In Afghanistan today, warfighters are using six-inch-long, pen-sized water purification kits developed by DARPA that consume plain salt tablets and purify up to 300 liters of water on a single camera battery. They're using hand-held phrase translation devices in the field and at our embassy in Kabul that convert phrases spoken by our soldiers directly into local, native languages such as Pashto, Urdu, and Dari. Having worked with the Air Force to reduce critical Link 16 network shortfalls demonstrated in Kosovo, DARPA-developed software tools are being used in Operation Enduring Freedom to reconfigure a theater-wide Link 16 network for military aircraft in a few hours – a task that previously took many weeks. And lastly, small ground robots developed in DARPA's Tactical Mobile Robotics program deployed to Afghanistan in support of Operation Enduring Freedom.

On the American homefront, DARPA technology has been used in homeland defense, Operation Noble Eagle. A commercial version of the DARPA consequence management program, LEADERS, provided medical surveillance for signs and symptoms of a biological attack in New York state within 24 hours of the attack on the World Trade Center. The Centers for Disease Control and Prevention (CDC) also used LEADERS to monitor for specified syndromes from hospitals within in the New York City area and report them back in real-time to CDC in Atlanta via the Internet. Robots from the Tactical Mobile Robotics program were sent to New York City to assist in search and rescue operations. And lastly, DARPA personnel served as science advisors to the team responsible for the anthrax decontamination on Capitol Hill. After analyzing the decontamination technologies that might be used for the cleanup of the Hart Building, the team selected the chlorine dioxide approach developed under DARPA's ongoing Immune Building program; this technology proved both effective and safe.

All these technologies were available to respond to the terrorist attacks on our nation because Congress had provided years of patient funding to develop them. Patience pays off.

DARPA has several ongoing programs to help prosecute the war on terrorism. Since the mid-1990s, DARPA has had a significant program in biological warfare defense, covering sensors to detect biological agents, vaccines to prevent infection, therapies to treat people who have been exposed, and decontamination technologies to recover the use of contaminated equipment and locations.

An example of this work, and one that illustrates why it is so exciting, is the Unconventional Pathogen Countermeasures program, which is focused on developing therapies broadly useful across many classes of biological warfare agents. For example, we are working on a new class of drug designed to attack the DNA of bacteria, viruses, and malaria, and that may eventually prove useful against threats ranging from anthrax and plague to smallpox.

One of the great challenges in the war on terrorism is to know our enemy – who he is, where he is, and what he's doing. In order to focus our efforts, I established another new DARPA office, the Information Awareness Office (IAO). IAO is developing the information systems needed to find, identify, track, and understand terrorist networks and vastly improve what we know about our adversaries. We will use the light of information technology to take away the shadows they hide in.

For example, IAO's Evidence Extraction and Link Discovery program is aimed at finding terrorist networks hidden in the mountains of diverse data that we collect. The Wargaming the Asymmetric Environment program is explicitly aimed at predicting the behavior of terrorist groups in some detail, an extremely difficult challenge. Usually what we do now is issue broad warnings to the public to be on guard, like the several that were announced following September 11th. Wargaming the Asymmetric Environment seeks to move from those broad warnings to more specific predictions. In short, we want to go from predicting the terrorist "climate" to predicting the terrorist "weather." Some would argue that this is an outrageous goal, one that is not possible to achieve. I agree it sounds outrageous, but what if we can do it? That is why it is a DARPA program.

In addition, IAO's Total Information Awareness program is now setting up a testbed at the Army's Intelligence and Security Command to test our new technologies on real-world threat data.

I'd like to now discuss some of our investments in fundamentally new technologies, particularly at the component level, that have often been the technological feedstocks enabling quantum leaps in U.S. military capabilities.

Building on our long tradition in cutting edge information technology, DARPA is pursuing cognitive computer systems – computer systems that know what they are doing. Our current information systems are crucial to national defense, but are expensive to create and debug, require us to adapt to them, cannot coordinate effectively with one another, and are inefficient and prone to failure. We want to develop computing systems that think – that are selfmonitoring and self-healing. Cognitive computers can reconfigure themselves as necessary, generate their own code, respond to naturally expressed human directives, and be configured and maintained by non-experts, and therefore last much longer than current systems. We are developing software, networks, components and full systems that are self-aware. We don't expect to reach our ultimate goal for many years, but we are starting now on the underlying technology.

Another traditional DARPA strength has been microelectronics, including photonics and micromechanical systems (MEMS), which continue to be core enablers for military systems. As the commercial microelectronics world approaches the end of Moore's Law within the next decade, the chips that emerge, containing trillions of nano-scale CMOS devices, will have a revolutionary impact on chip-scale, high-speed digital processing for future military systems. Integrating this advanced CMOS technology with radio frequency and analog components, including photonic sources and sensors and MEMS devices, will allow far more adaptable sensor and actuation systems. We foresee intelligent chips that can adapt in real-time, maintaining peak performance while tracking signals over a wide spectral range, and MEMS-based resonators for compact chip-scale oscillators with atomic clock precision. DARPA's goal is to create chips that reason and adapt, enable smarter sensors, and achieve human-like performance. Ultimately, our vision is a more adept human warfighter who uses microelectronics to achieve machine-like precision.

In the last few years, DARPA has had a significant and growing emphasis in the biological sciences, above and beyond what we're doing in biological warfare defense. We are taking inspirations from biology and combining these with DARPA's existing core competencies in the physical sciences, information technology, engineering and materials, to create new devices and systems for the warfighter that incorporate the incredible capabilities of living systems. That is, they are more adaptive, fault-tolerant, and dynamic in their response to an ever-changing environment.

For example, we are looking to biological systems to enable us to create better hardware. DARPA's Controlled Biological and Biomimetic Systems program is designing shoebox-sized, legged robotic vehicles that can clamber over rough and overgrown terrain where wheeled and tracked vehicles can't. We are exploring the use of distributed animal sentinels – foraging, social insects like honeybees – as environmental sentinels to collect and report on bioagents and explosives. Living, swarming sensors if you will.

We are also working to harness biology itself to directly enhance the performance of our warfighters via several programs to make our soldiers stronger and safer. For example, our Continuous Assisted Performance program is looking for ways to prevent fatigue and enable soldiers to remain awake, alert, and effective for up to seven days straight without suffering mental or physical deleterious effects. Our Metabolic Engineering program is investigating whether naturally occurring states such as hibernation might one day be temporarily induced in soldiers who have been severely injured. And DARPA's Persistence In Combat program is looking for ways to take hospital-level emergency trauma care to the farthest-forward battlefield area of operations, i.e., directly to the individual, injured warfighter, by equipping him with non-invasive therapeutics he can self-administer to control bleeding and pain and dramatically accelerate wound healing. This will enable all but the most severely wounded warfighters to stay in the fight and reduce additional casualties among fellow soldiers who would otherwise come to his aid.

Thus far in my testimony, I have dwelt on DARPA systems for which the military applications are fairly clear. However, one of the most exciting things about DARPA is our work on technologies whose exact military *uses* are not clear, but their *usefulness* is. This is part of what makes being the DARPA Director such a fun job.

For example, our Brain Machine Interface program has demonstrated that a monkey can control a robot arm using only his thoughts. Let me be clear about this: we are not tapping into the monkey's nerve impulses that control his arm. Rather, we are monitoring his actual thoughts and intentions: the monkey *thinks* about moving a robotic arm, an implanted probe detects his brain's neurological impulses, those impulses are wirelessly transmitted to a robotic arm located in another room, and the robot arm moves. Simultaneously, the monkey's thought signals are also sent out via another DARPA development, the Internet, to a lab 700 miles away, where he simultaneously controls another robotic arm. So the monkey also uses his brain to do mechanical work via the Internet!

Thus, we are finding ways to turn *thoughts into acts*. We do not yet fully understand the potential implications of this work. But imagine how useful and important it could be for a warfighter to use only the power of his thoughts to do things at great distances.

Think about our military commanders years from now. Envision them commanding warfighters who then can do things merely by thinking about them; who remain in action and effective for seven days and nights without sleep; who, if injured, can self-administer rapid-healing medications that enable them to stay in the fight, and who, if *seriously* injured, could be placed in temporary hibernation to prolong their lives until they can be evacuated to a hospital.

Will all these technologies work? We don't know yet. But I would be willing to bet you this: if we pursue these technologies now, develop them successfully, and get them into the hands of our future warfighters, the U.S. military commander in the field years from today will value them highly. And our nation's adversaries will fear them.

Finally, I note the Department is frequently hampered by a demanding set of statutory requirements, which restricts our flexibility and, thus, our ability to adapt to changing circumstances. I ask the Committee to support the President's "Freedom to Manage" initiative, so that we would be better able to efficiently and effectively execute the programs you entrust us with.

Thank you for this opportunity to submit testimony to the subcommittee.