BRIDGING THE GAP

DARPA

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

2004

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DARPA: An Overview

1. Purpose

This document describes the Defense Advanced Research Projects Agency's (DARPA) current strategy in broad terms. It provides a top-level view of DARPA's activities of particular interest to the research community and other elements of the Department of Defense (DoD).

2. DARPA in General

2.1. Mission, Management, and Organization

> *DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.*

DARPA's mission implies one imperative for the Agency: radical innovation for national security. DARPA's management philosophy reflects this in a straightforward way: bring in expert, entrepreneurial program managers; empower them; protect them from red tape; and determine quickly the projects that need to be started and the projects that should be stopped.

To maintain an entrepreneurial atmosphere and the flow of new ideas, DARPA steadily rotates program managers through the Agency, with most program managers serving for only 4 years. The idea is that the best place from which to get new ideas is new people. New people also ensure that DARPA has very few institutional interests besides innovation, because new program managers are willing to redirect the work of their predecessors—and even undo it, if necessary.

Another notable feature of DARPA's management philosophy is that the Agency has very limited overhead and no laboratories or facilities. Again, the idea is to minimize any institutional interests that might distract the Agency from its imperative for innovation.

DARPA's current technical organizational structure is shown in Figure 1. This chart implies more formal structure than is actually the case at DARPA. In general, the character and mission of DARPA offices change over time as DARPA focuses on different areas. Offices are created and disbanded as DARPA changes direction.

The basic purpose of offices is to create synergy by bringing together experts with similar interests so they can interact with each other. DARPA has found that combining people with the same interests can lead to a nonlinear generation of ideas. The office directors recruit outstanding program managers and develop the office synergy, while keeping the program managers broadly on track with the office theme.

The office theme or vision is set by the DARPA Director reflecting his interactions with the Secretary and Under Secretaries of Defense, Chairman of the Joint Chiefs of Staff, Combatant Commanders, Service Secretaries, Service Chiefs, Service units, and the staffs at each DoD level.

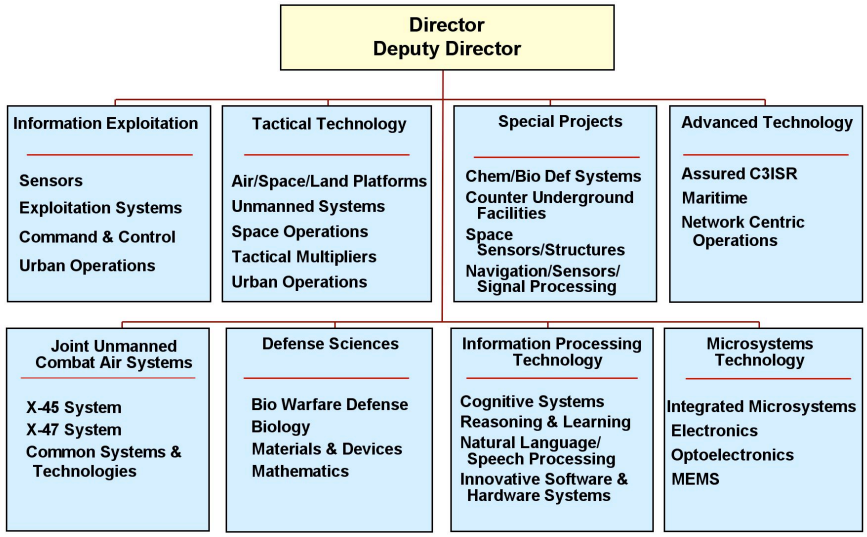

Figure 1: DARPA's organization.

There are two basic types of technical offices at DARPA: technology offices and systems offices. The technology offices are the Defense Sciences Office, Microsystems Technology Office, and Information Processing Technology Office. They focus on new knowledge and component technologies that might have significant national security applications. The system offices are the Tactical Technology Office, Special Projects Office, Advanced Technology Office, Information Exploitation Office, and Joint Unmanned Combat Air Systems Office. These offices focus on technology development programs leading to products that more closely resemble a specific military end-product; i.e., an item that might actually be in the military inventory. As a practical matter, a fair amount of overlap exists between the two types of offices; the work in the technology offices often shapes the work of the systems offices, and vice versa.

DARPA has several special authorities to assist the Agency in carrying out its unique mission in accordance with its flexible management philosophy. For example, DARPA has an Experimental Personnel Authority[1] that allows it to maintain its entrepreneurial edge by hiring expert program managers from industry at competitive salaries, and do it much faster than under normal Civil Service rules.

DARPA pioneered the use of Other Transactions Authorities[2], which allow much more flexible contracting arrangements with firms and universities than normally possible under the Federal Acquisition Regulations.

Finally, DARPA has the authority to award prizes to encourage technical accomplishments[3], similar to the prize awarded to Charles Lindbergh for his nonstop transatlantic flight to Paris. DARPA is making use of this authority for the first time to sponsor a challenge of fully autonomous, unmanned ground vehicles to go from California to Nevada in March 2004, with a prize of $1 million.[4]

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1 5 USC 3104 Note

2 10 USC 2371 and 10 USC 2371 Note

3 10 USC 2374a

4 http://www.darpa.mil/grandchallenge

2.2. DARPA's Role in DoD

DARPA fulfills a unique role within DoD. As a Defense Agency, DARPA reports to the Secretary of Defense. The Director, Defense Research and Engineering, is DARPA's Principal Staff Assistant (PSA). As the only DoD research agency not tied to a specific operational mission, DARPA supplies technological options for the entire Department and is designed to be the "technological engine" for transforming DoD.

This unique role is needed because near-term needs and requirements generally drive the Army, Navy, Marine Corps, and Air Force to focus on nearer term needs at the expense of major change. Consequently, a large organization like DoD needs a place like DARPA whose *only* charter is radical innovation.

DARPA looks beyond today's known needs and requirements because, as military historians note, "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."[5] *None* of them. And to this list, DARPA would add unmanned systems, stealth, and Internet technologies.

DARPA's Outreach

Among the individuals who have been briefed on major elements of DARPA's current strategy are:

- U.S. Vice President Richard B. Cheney
- Secretary of Defense Donald H. Rumsfeld
- Secretary of the Navy Gordon R. England
- Secretary of the Air Force Dr. James G. Roche
- Chairman of the Joint Chiefs of Staff General Richard B. Myers
- Acting Under Secretary of Defense for Acquisition, Technology and Logistics Michael W. Wynne
- Under Secretary of Defense for Intelligence Stephen A. Cambone
- Army Chief of Staff General Peter J. Schoomaker
- Chief of Naval Operations Admiral Vern Clark
- Air Force Chief of Staff General John P. Jumper
- Commandant of the Marine Corps General Michael W. Hagee
- Vice Chief of Naval Operations Admiral Michael G. Mullen
- Commander, U. S. Strategic Command, Admiral James O. Ellis, Jr.
- Commander, U.S. Northern Command, General Ralph E. Eberhart
- Commander, U.S. Joint Forces Command, Admiral Edmund P. Giambastiani, Jr.
- Commander, U.S. Special Operations Command, General Bryan Brown
- Commander, U.S. Army Training and Doctrine Command, General Kevin P. Brynes
- Commander, U.S. Air Forces in Europe, General Robert H. Foglesong
- Director, Defense Research and Engineering, Ronald M. Sega
- Assistant Secretary of the Army for Acquisition, Logistics and Technology Claude M. Bolton, Jr.
- Assistant Secretary of the Navy for Research, Development and Acquisition John J. Young, Jr.
- Assistant Secretary of the Air Force for Acquisition Marvin R. Sambur
- Under Secretary of the Air Force Peter B. Teets
- Commander, Air Force Material Command, General Lester L. Lyles
- Commander, Air Force Space Command, General Lance Lord
- Director, National Imagery and Mapping Agency, Lieutenant General (Ret.) James R. Clapper, Jr.
- Director, Defense Threat Reduction Agency, Stephen M. Younger

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

DARPA's approach is to imagine what a military commander will want in the future and accelerate that future into being—thereby changing people's minds about what is technologically possible today.

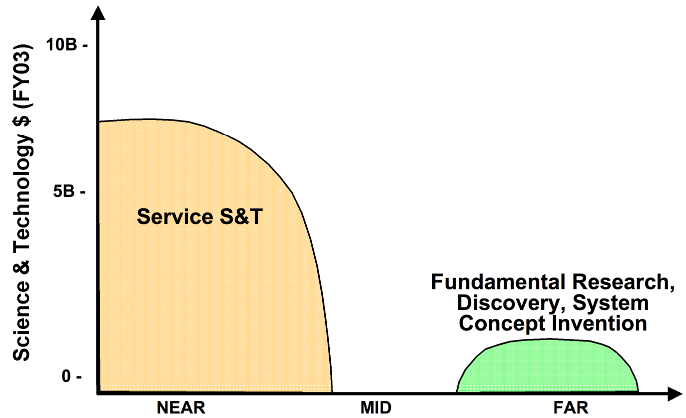

Figure 2: Timelines and investments in science and technology.

Figures 2 and 3 illustrate how DARPA works. These figures show where science and technology (S&T) funding is invested along a notional timeline from "Near" to "Far," and is indicative of how long it takes for an S&T investment to be incorporated into an acquisition program.

The Near bubble in Figure 2 represents most of the work of the Service S&T organizations. Service S&T tends to gravitate toward the Near side because the Services emphasize providing technical capabilities critical to the mission requirements of *today's* warfighter. This is excellent S&T, and it is crucial because it continuously hones U.S. military capabilities; e.g., improving the efficiency of jet engines. However, it is typically focused on known systems and problems.

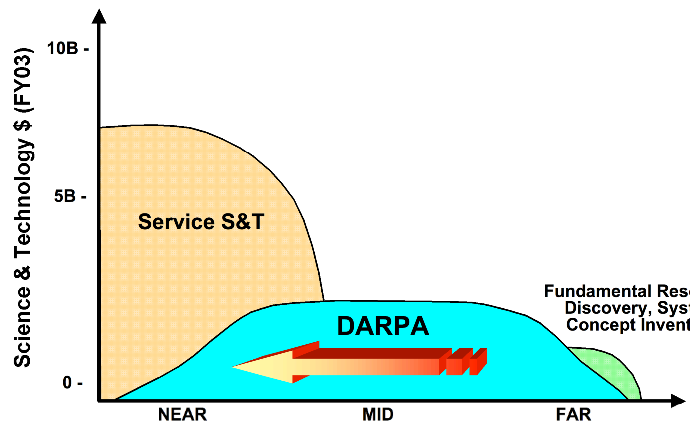

Figure 3: DARPA's role in science and technology.

The Far bubble in Figure 2 represents fundamental discoveries, where new science, new ideas and radical new concepts typically first surface. People working on "the Far side" have ideas for entirely new types of devices or new ways to put together capabilities from different Services in a revolutionary manner. But the people on the Far side have a difficult, sometimes impossible time obtaining funding from those on the larger Near side because of the Near side's focus on current, known problems.

DARPA was created to bridge the gap between these two groups. Its mission, shown in Figure 3, is to find the people and ideas on the Far side and accelerate those ideas to the Near side as quickly as possible.

DARPA emphasizes what *future* commanders might want and pursues opportunities for bringing entirely new core capabilities into DoD. Hence, DARPA mines fundamental discoveries—the Far side—and accelerates their development and lowers their risks until they prove their promise and can be adopted by the Services. DARPA's work is high-risk and high-payoff precisely because it bridges the gap between fundamental discoveries and their military use.[6] This focus on bridging the gap has meant that, even though much of DARPA's work takes years to reach payoff, DARPA is also very "fleet of foot" and capable of completing quick reaction projects to emerging threats during a conflict. The inset discussion, "Shaping DARPA's Strategy," provides a more detailed discussion of how DARPA chooses its programs.

Whenever there have been technological surprises, the people typically surprised are on the Near side. There are always a few people on the Far side who knew that something could be done, but could not obtain the resources to execute their ideas.

By mining the Far side and bridging the gap between what might be done and what is done, DARPA prevents technological surprise for the United States and creates technological surprise for our adversaries.

2.3. Some Major DARPA Accomplishments

Over the past 4 decades, DARPA and its management methodology have been very successful at "bridging the gaps" in Figure 3.[7]

Figure 4 illustrates some of DARPA's preeminent accomplishments since the early 1960s.

DARPA was borne of the space age. The launch of Sputnik in 1957 also launched DARPA, so all the Agency's initial projects were space-related. However, the Agency nearly ceased to exist when DARPA's space programs were transferred over to the National Aeronautics and Space Administration and the National Reconnaissance Office.

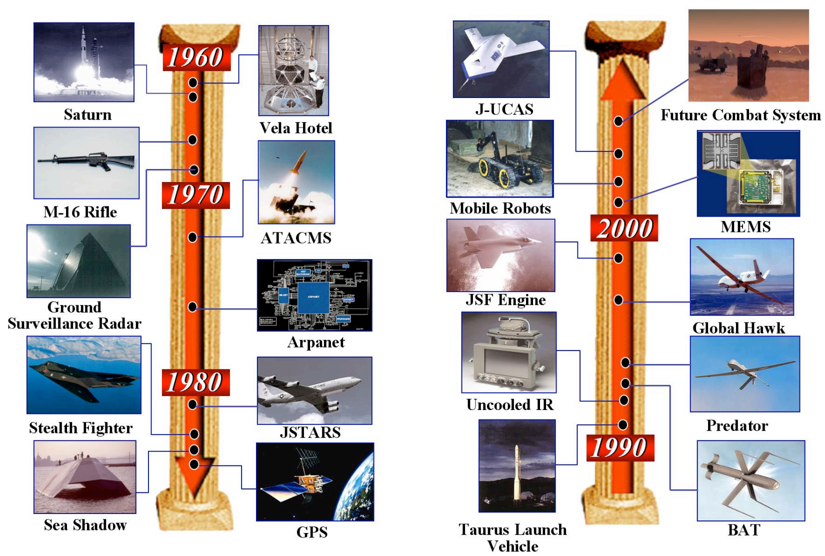

Figure 4: Key DARPA accomplishments spanning more than 4 decades.

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6 In line with DARPA's mission, only about 5 percent of DARPA's research is basic research. Basic research is inside the green bubbles and is primarily supported by the Service S&T organizations (with ONR having a primary role), and organizations like the National Science Foundation, the National Institutes of Health, and the Department of Energy. Basic research creates new knowledge and technical *capacity*, whereas DARPA creates new *capabilities* for national security by accelerating that knowledge and capacity into use.

7 In 2003, the Institute for Defense Analysis released its report (www.darpa.mil/body/pdf/P-3698_Vol_1_final.pdf) documenting the major contributions DARPA system projects made to the revolution in military affairs.

Shaping DARPA's Strategy

Basic Challenge and Focus: A basic challenge for any military research organization is matching military problems with technological opportunities, including the new operational concepts those technologies make possible. Parts of this challenge are extremely difficult because: (1) some military problems have no easy or obvious technical solutions; and (2) some emerging technologies may have far-reaching military consequences that are still unclear. DARPA focuses its investments on this "DARPA-hard" niche – a set of technical challenges that, if solved, will be of enormous benefit to U.S. national security, even if the risk of technical failure is high. Other factors also shape DARPA's investments:

- DARPA emphasizes research the Services are unlikely to support because it is risky, does not fit their specific role or missions, or challenges existing systems or operational concepts;
- DARPA focuses on capabilities military commanders might want in the future, not what they know they want today;
- DARPA insists that all programs start with good ideas and good people to pursue them; without both these things, DARPA will not start a program.

Notable Features: DARPA's decision-making process is somewhat unusual for a government agency. It is informal, flexible, and yet highly effective because it focuses on making decisions on specific technical proposals based on the factors discussed above.

There are two reasons for this. DARPA is a small, flat organization rich in military technological expertise. There is just one porous management layer (the Office Directors) between the program managers and the Director. With less than 20 senior technical managers, it is easy to make decisions. This management style is essential to keeping DARPA entrepreneurial, flexible and bold. DARPA's management philosophy is to pursue fast, flexible, and informal cycles of "think, propose, discuss, decide, and revise." This approach may not be possible for most government agencies, but it has worked well for DARPA.

The Basic Process: DARPA uses a top-down process to define problems and a bottoms-up process to find ideas, involving the staff at all levels. DARPA's upper management and program managers identify "DARPA-hard" problems by talking to many different people and groups. (See "DARPA's Outreach" on p. 3) This process includes:

- Specific assignments from the Secretary of Defense or Under Secretary for Acquisition, Technology and Logistics;
- Requests for help from the Service Secretaries and Chiefs, Joint Staff, and Unified Combatant Commands;
- Discussions with senior military leaders on "What are the things that keep you awake at night?";
- Research into recent military operations to find situations where U.S. forces have limited capabilities and few good ideas;
- Discussions with Defense Agencies such as the Defense Threat Reduction Agency, the National Geospatial-Intelligence Agency, the Defense Information Systems Agency, and the Defense Logistics Agency;
- Discussions with intelligence community agencies such as the Central Intelligence Agency and the National Security Agency; and
- Discussions with other government agencies or outside organizations such as the National Science Foundation and the National Academy of Sciences.
- Visits to Service exercises or experiments.

During DARPA's program reviews, which occur throughout the year, DARPA's upper management looks for new ideas from program managers (or new program managers with ideas) for solving these problems. At the same time, management budgets for exploring highly speculative technology that have far-reaching military consequences.

Program managers get ideas from many different sources, such as:

- Their own technical communities;
- Suggestions from DoD-wide advisory groups, including the Defense Science Board and Service science boards;
- Suggestions from DARPA-sponsored technical groups, including the Information Science and Technology Study Group and the Defense Science Research Council;
- Suggestions from industry or academia, often in response to published Broad Area Announcements or open industry meetings such as DARPATech;
- Surveys of international technology;
- Breakthroughs in DARPA or other research programs; and,
- Small studies and projects used to flesh out ideas, often referred to as "seedlings."

Vetting a Program: During reviews of both proposed and on-going programs, DARPA's assessment is often guided by a series of questions. These seemingly simple queries help reveal if a program is right for DARPA:

- What is the project trying to do?
- How is it done now and what are the limitations?
- What is truly novel in the approach that will remove those limitations and improve performance? By how much?
- If successful, what difference will it make?
- What are the interim technical milestones required to prove the hypothesis?
- What is the transition strategy?
- How much will it cost?
- Are the programmatic details clear?

A new mission emerged to counter a threat that no Service or agency was tackling: intercontinental ballistic missiles (ICBMs). From approximately 1960 to 1970, DARPA was the driving force behind the United States' technology advancements in ballistic missile defense. In 1968, the Army Ballistic Missile Defense Agency was created, and the ballistic missile defense mission was transferred from DARPA.

In the 1960s, DARPA's Project AGILE pursued a modification of the Colt AR-15 rifle to develop what is now known as the M-16 assault rifle, the standard-issue shoulder weapon in the U.S. military.

DARPA began developing the technologies for stealthy aircraft in the early 1970s under the HAVE BLUE program, which led to prototype demonstrations in 1977 of the Air Force's F-117 tactical fighter that proved so successful in Operation Desert Storm. After the successes of the DARPA HAVE BLUE Stealth Fighter program, DARPA launched the TACIT BLUE technology demonstration, which contributed directly to the development of the B-2 bomber deployed by the Air Force. DARPA's stealth technology has also gone to sea: the SEA SHADOW, built in the mid-1980s, employs a faceted shape similar to that of the F-117 to achieve reduced radar cross section, while the twin hull construction contributes to wake reduction and increased sea-keeping capabilities.

The Global Hawk and Predator unmanned aerial vehicles (UAVs) have been prominent in Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom. DARPA started on the concept of a high altitude, long-range, extended loiter unmanned system in the 1970s as the TEAL RAIN program. After a number of significant technical breakthroughs, the Global Hawk high altitude endurance UAV transitioned from DARPA to the Air Force in 1998. Development of Predator began in 1984 as DARPA's AMBER program. The Tier 2 Predator medium-altitude endurance UAV evolved directly from DARPA's AMBER and Gnat 750-45 designs and was operationally deployed in the mid-1990s.

The most famous of all DARPA technology development programs is the Internet, which began in the 1960s-1970s with the development of the ARPANet and its associated TCP/IP network protocol architecture. DARPA's development of packet switching is the fundamental element of both public and private networks, and it spans DoD, the Federal Government, the U.S. industry, and the world (see Section 3.5).

A crucial characteristic about several of these accomplishments, which holds true for many DARPA programs, is that it took a long time from an idea's conception to fruition and use by the U.S. military. DARPA has shown itself very willing to repeatedly tackle hard technical problems, even in the face of previous failure, if the technology offers revolutionary new capabilities for national security. Patience and persistence are required attributes for those who pursue high-risk technology, but they are often rewarded with extremely large payoffs.

2.4. Transitioning DARPA Technologies

Transitioning technology—getting technology from research and into use—is a difficult challenge, partly because so many different types of organizations may need to be involved; i.e., S&T organizations like DARPA, the acquisition community, the warfighting/requirements community, and the firms that actually produce the product.

The very nature of a technology strongly shapes how it transitions. For example, a component technology like a new material or microchip is likely to get to the warfighter when a prime contractor incorporates it into a system, without the Service acquisition program necessarily having decided on it *per se*. This means the key decisions are made by industry—prime contractors and subcontractors.

On the other hand, a large system development program such as Global Hawk requires the warfighting community to establish a formal requirement for the system, thereby charging the acquisition community with actually purchasing it. New systems simply do not diffuse their way into military use, like a new material might.

The transition challenge is exacerbated for DARPA because its focus is on high-risk, revolutionary technologies and systems, which may have no clear home in a Service, are Joint, or threaten to displace current equipment or doctrine. All these factors tend to create resistance, or at least barriers, to the use and adoption of a new technology.

Figure 5 is a simplified illustration of three methods DARPA uses to transition technology to the warfighter.

Figure 5: DARPA transition methods.

The first bar illustrates the majority of DARPA's transition activities. DARPA invests about 90 percent of its funds at organizations outside the Federal Government, primarily at universities and in industry. Over time, this investment leads to new capabilities in industry and steadily reduces the risks of the underlying technology. At some point, a company becomes confident of its ability to make a new technology for a predictable cost and schedule that it will propose the technology to someone other than DARPA. DARPA's investment reduces the risk of a technology to the point where firms themselves are willing to make it, use it, or otherwise bid it back to the rest of DoD.

However, companies will not propose a new technology to a Service customer if they are not confident the Service customer will accept it. The second bar in Figure 5 shows how DARPA removes this impediment. To build potential Service customers for DARPA technology—someone to whom these companies can bid with confidence—DARPA deliberately executes about 80 percent of its funding through the Services. That is, a Service organization acts as DARPA's agent and is the organization that signs the contracts with the research performers and monitors the day-to-day technical work. A cadre of people is created inside a Service which is familiar with a DARPA technology, who can vouch for it, and who can shepherd it into a Service acquisition program. Once the company is confident it can build a technology and a Service is willing to accept it, the technology transitions and DARPA is, typically, forgotten.

DARPA occasionally builds prototypes of a large, integrated system such as Global Hawk. Such programs reduce the risks in a new system to the point where the warfighting community can be confident it will get a new and cost-effective capability. However, without proper planning such programs can run into a 2-year funding gap between the time the Service is convinced it wants the system and when the DoD financial system can effectively respond. To prevent these and other problems, DARPA tries to ensure transition of prototypes by negotiating a memorandum of agreement (MOA) with the Service adopting the system, such as the one for Unmanned Combat Armed Rotorcraft with the Army. The earlier the MOA is negotiated, the better it works since it is easier to plan the needed outyear funding, instead of trying to find it later.

In addition, to strengthen its connections with the Services, DARPA has military officers on staff who serve as operational liaisons. They keep DARPA informed about what the Services might want and keep the Services informed about what DARPA is developing.

3. Current Strategic Thrusts

Strategy can be described as "the evolving pursuit of a central mission through changing circumstances." Consequently, over time, DARPA changes much of what it is doing in response to the different national security threats and technological opportunities facing the United States.

As a result of this constant strategic reassessment, DARPA emphasizes research in eight strategic thrusts:

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

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

The Department of Defense has steadily improved its ability to conduct precision strike against both stationary and moving ground targets. As a result, recent conflicts have shown, in the words of the Chairman of the Joint Chiefs, ". . . the bomb is no longer solely an area weapon, but is going to be used like bullets from a rifle, aimed precisely and individually."[8] Timely, accurate, and precise delivery of bombs and missiles has helped the United States overthrow hostile regimes in short order with comparatively few American or unintended casualties. Yet experience shows that major challenges remain in target detection, identification, and tracking.

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8 General Richard Myers, Chairman of the Joint Chiefs of Staff, Oral Testimony before the Senate Armed Services Committee, February 5, 2002.

It is still difficult to strike targets that are hiding, using evasive tactics such as frequent starts and stops, or require a rapid reaction by U.S. forces in order to be destroyed.

To provide a focused response to these challenges, DARPA is assembling the sensors, exploitation tools, battle management systems, and information technologies needed to rapidly find and destroy ground targets in any terrain, in any weather, moving or idle, at any time, with minimum accidental damage or casualties. To do this, we are seamlessly melding sensor tasking with strike operations, leveraging the development of platforms that carry both capable sensors and effective weapons. Of course, this implies blurring or even erasing conventional barriers between the intelligence and operations functions at all levels of command. This is a difficult technical challenge that requires a joint approach with potentially large implications for U.S. military doctrine and organizations—truly a DARPA-hard problem (see Figure 6).

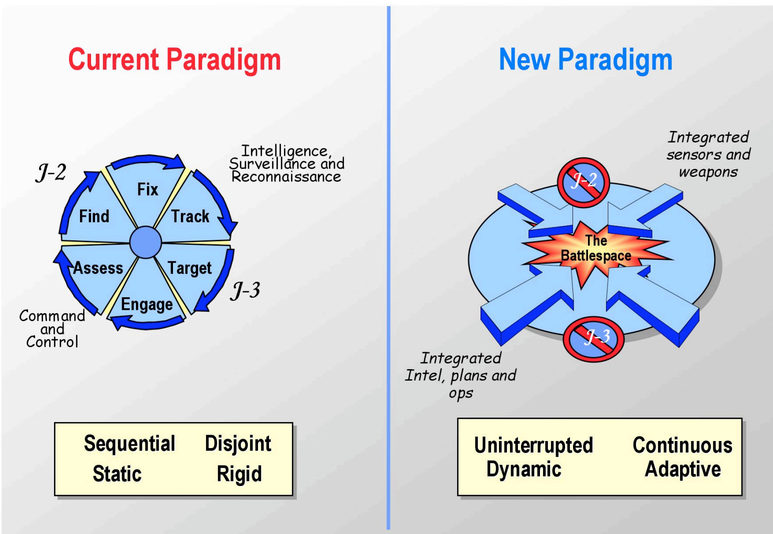

Figure 6: End barriers between Intelligence (J-2) and Operations (J-3).

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

DARPA's sensor work is exemplified by the Standoff Precision Identification in Three Dimensions (SPI-3D) program. It is developing an airborne laser identification detection and ranging (LIDAR) sensor to provide positive target identification from standoff ranges via high resolution, three-dimensional representations. SPI-3D will be cued by wide area surveillance sensors, such as synthetic aperture radar, which can determine the presence of possible targets but may be unable to confirm target type or identity. SPI-3D technology will close this gap, allowing commanders to positively identify targets in accordance with our rules of engagement. In the Jigsaw program, a new airborne LIDAR sensing technology is being developed that yields accurate three-dimensional representations of military targets hidden under camouflage and in foliage (see Figure 7).

An example of DARPA's work in time-critical precision strike is the Advanced Tactical Targeting Technology (AT3) program. By sharing radar measurements among several platforms, AT3 can leverage nondedicated assets, such as fighter aircraft, to detect and locate enemy surface-to-air radars to an accuracy of 50 meters, from 50 miles away, and within 10 seconds after the enemy's radar turns on—a dramatic improvement over today's capabilities.

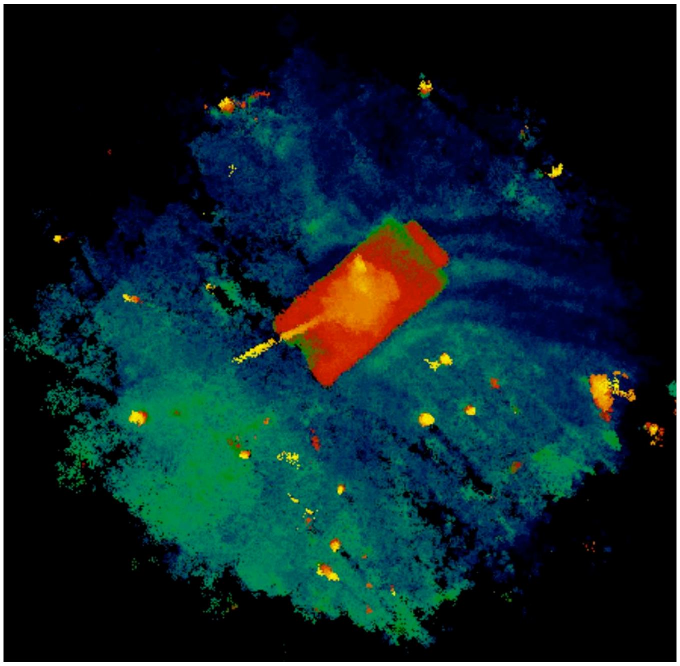

Figure 7: Jigsaw image of a tank hidden under trees.

In the Dynamic Tactical Targeting (DTT) program, DARPA is developing a prototype system to track and identify time-sensitive targets. DTT computationally "stitches" together short target tracks obtained from a variety of tactical sensors (e.g., moving target indicator radar, synthetic aperture radar, optical, video, and acoustic sensors) to track and identify targets through stops and starts, while overcoming tactics intended to evade any one sensor type. DTT will enable mission commanders to keep track of time-critical targets until they can be destroyed.

3.2. Location and Characterization of Underground Structures

Adversaries are well aware of the U.S. military's sophisticated intelligence, surveillance, and reconnaissance capabilities and global reach and have been building deeply buried underground facilities to hide what they are doing and to protect themselves against attack. These facilities can vary from the clever use of caves to complex, carefully engineered bunkers (see Figure 8). Such installations are used for a variety of purposes, including ballistic missiles, leadership protection, command and control, and the production of weapons of mass destruction.

Figure 8: Underground facility.

To meet the challenge posed by the spread of these facilities, DARPA's Counter-Underground Facility program is developing and using a variety of sensor technologies—seismic, acoustic, electro-optical, radio frequency, and chemical—to characterize underground facilities. The program is working on tools to answer the questions, "What is this facility's function? How busy is it now? What are its structures and vulnerabilities? How might it be attacked? Did an attack destroy the facility?" To provide answers, DARPA has created two-orders-of-magnitude improvement in ground-sensor sensitivity and developed advanced signal processing for clutter rejection in complex environments. Underground facility characterization and battle damage assessment will be demonstrated in August 2004 using these advanced systems. New initiatives in this arena include efforts to enable wide-area search for the detection of unknown urban underground facilities on rapid (i.e., tactical) timescales and work to determine the interconnectivity of urban facilities and caves.

3.3. Networked Manned and Unmanned Systems

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

Two broad trends combined to make this thrust feasible. There is an increasing appreciation within the Services that combining unmanned with manned systems can enable new combat capabilities or new ways to perform hazardous missions. Improved processors and software permit the major increases in onboard processing needed for unmanned systems to handle ever more complex missions in ever more complicated environments. Moreover, networking these vehicles in combat can improve our knowledge of the battlespace, targeting responsiveness and accuracy, the survivability of the *network* of vehicles, and mission flexibility. A group of collaborative systems is far more capable than the sum of its individual components.

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

More recently, the Office of the Secretary of Defense established the Joint Unmanned Combat Air Systems (J-UCAS) program at DARPA to accelerate DoD's progress in making networked unmanned combat air vehicles a reality for suppressing enemy air defenses, precision strike, and persistent surveillance. The program is a joint DARPA, Air Force, and Navy program, building on DARPA's earlier work on unmanned combat air vehicles for the Air Force (Unmanned Combat Air Vehicle [UCAV]) and Navy (UCAV-Navy). DARPA will lead the program until it reaches operational assessments, at which time a transition to the Services will begin. The program will develop new air vehicles (Figure 9), but the heart of the J-UCAS system will be the network that combines those vehicles with other manned and unmanned systems to create an entirely new type of unified fighting force.

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

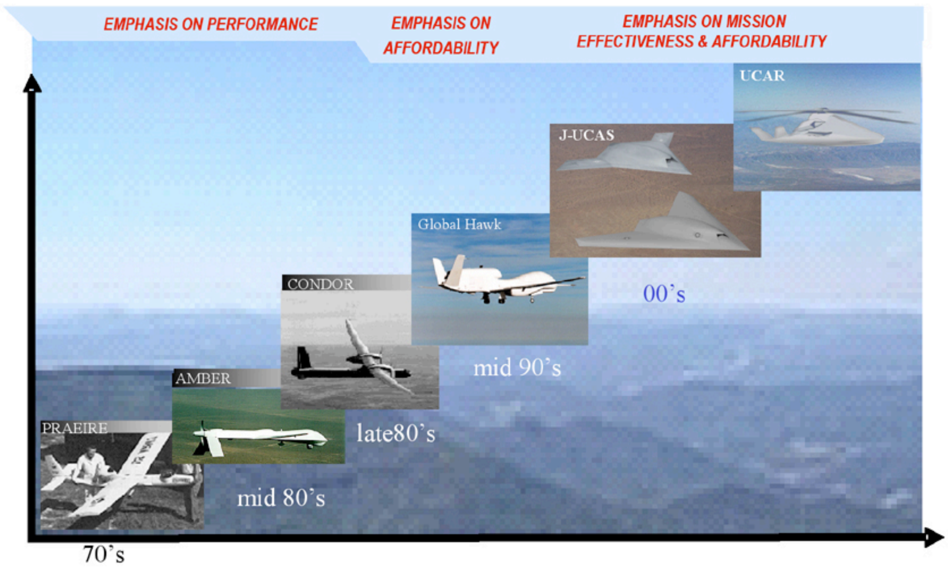

Figure 9: Evolution of DARPA's UAV programs.

3.4. Robust, Secure Self-Forming Tactical Networks

The DoD is in the middle of a transformation to what is often termed "network-centric operations" (see Figure 10). In simplest terms, the promise of network-centric operations is to transform information superiority into combat power. The United States and coalition allies will have better information to collaborate, share knowledge, and synchronize joint operations far more quickly and effectively than our adversaries. In essence, this next level of networking will use "better brains" to create a more agile and effective brawn.

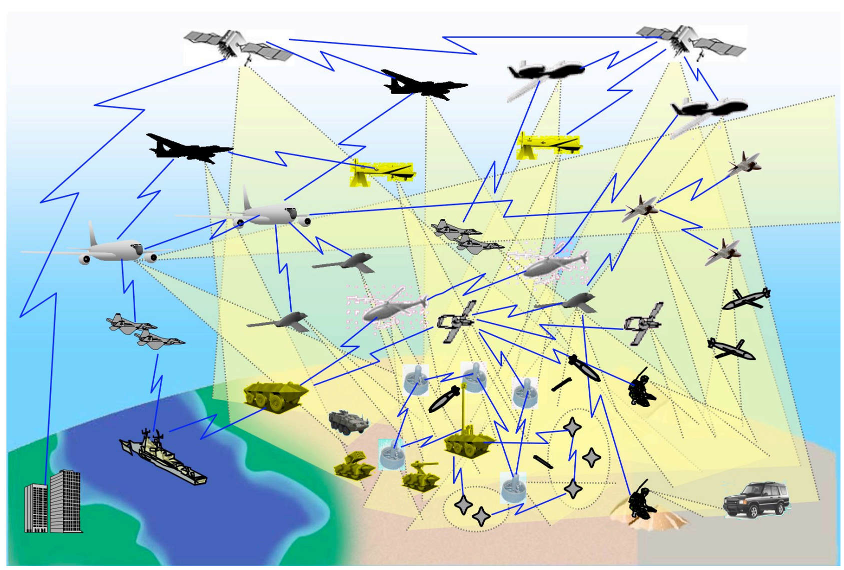

Figure 10: Networked Operations.

At the heart of this concept are survivable, assured communications at all combat levels. DARPA's goal is a communications network that will survive and provide a critical level of service, even when attacked. DARPA continues its revolutionary thrusts to ensure that U.S. forces will have secure, assured, high-data-rate, multisubscriber, multipurpose (e.g., maneuver, logistics, intelligence) networks for the future unified forces. This means conducting research in areas including *ad hoc* self-forming networks, information assurance and security, software programmable radios, spectrum management, network interoperability, and anti-jam and low probability of detection/intercept communications techniques.

An example of how DARPA developments in component technology are enabling these robust networks is the wristwatch-sized Chip-Scale Atomic Clock. Microelectromechanical systems (MEMS) technology is used to place an entire atomic clock onto a single chip, reducing its size and power consumption by factors of 200 and 300, respectively (see Figure 11). Chip-scale atomic clocks will greatly improve the mobility and robustness of military communication and navigation devices because it will be able to provide the timing signal when the global positioning system (GPS) is lost. Frequency references from atomic clocks will improve communications channel selectivity and density. Atomic clocks will also enable ultra-fast frequency hopping for improved security, jam-resistance, and data encryption. In GPS receivers, they will greatly improve the jamming margin, help continuously track positions, and quickly reacquire a GPS signal. In surveillance, atomic clocks will improve the resolution of Doppler radars and locate radio emitters.

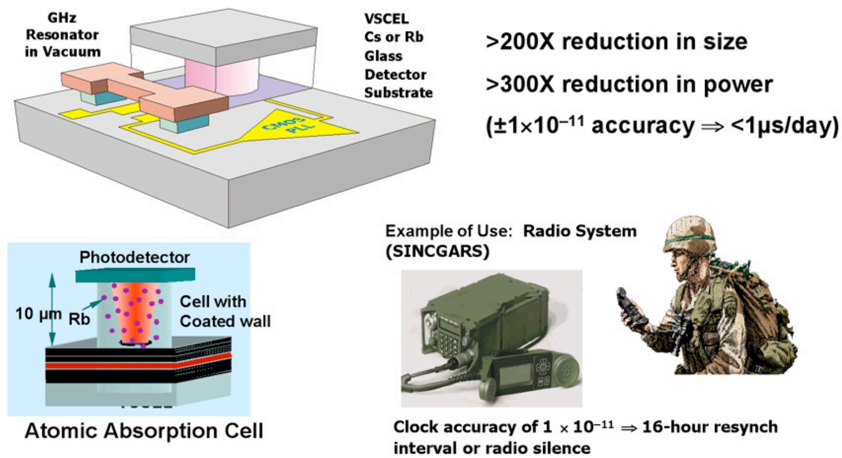

Figure 11: Chip-Scale Atomic Clock: Ultra-miniaturized, low-power, atomic time and frequency reference units.

The Adaptive Joint Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance Node (AJCN) Advanced Concept Technology Demonstration (ACTD) program is a prime example of DARPA's research activities in network communications. The AJCN ACTD is a multipurpose, reconfigurable "radio frequency device in the sky." The program will be a single system that can simultaneously do any and all of the following: link up previously incompatible radios, conduct signals intelligence, conduct electronic warfare, and conduct information warfare.

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

The threat against military networks from computer worms that have never been seen before, and that exploit previously unknown network vulnerabilities ("zero-day worms") has exceeded commercial industry's ability to mount an adequate defense. The Dynamic Quarantine of Worms (DQW) program will develop a system of integrated detection and response devices that will dynamically quarantine computer-based worms attacking military networks. The DQW program is focused on zero-day worms and stealthy worms that would normally slip into military networks undetected. While it may be nearly impossible to stop the initial infection from a zero-day worm, DQW's strategy is to quarantine the worm in a section of the network. "Vaccines" can then be automatically synthesized and distributed to protect other networks from a large scale infection.

The final example is the neXt Generation (XG) Communications program, which will make 10 to 20 times more spectrum available to the U.S. military by dynamically allocating spectrum across frequency, time, and space (Figure 12) on a noninterference basis with the spectrum owner. This capability has been described as “tuning for daylight.”

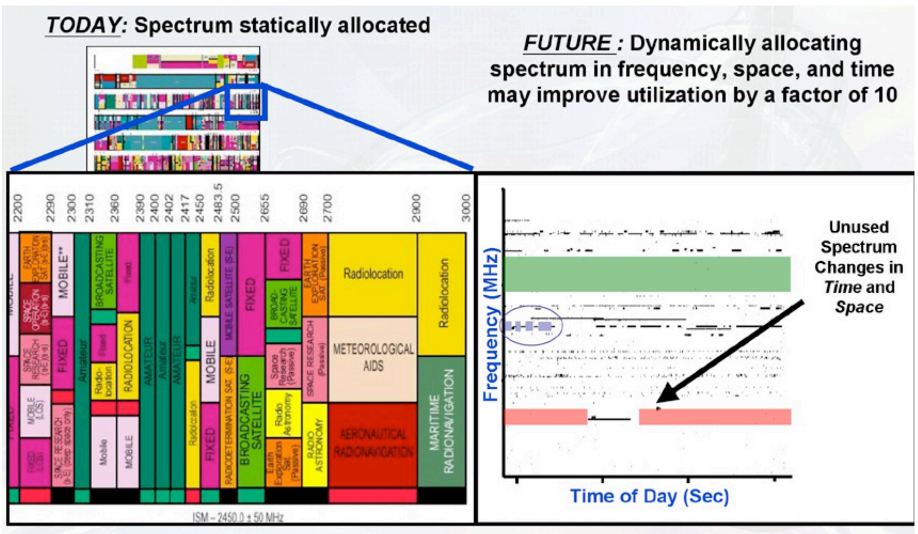

Figure 12: XG Communications program.

3.5. Cognitive Computing

Many elements of the information technology revolution have vastly increased the effectiveness of the U.S. military 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.

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

In response, DARPA is again tackling Licklider’s vision in a strategic thrust, “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 previous expert systems.

There are a number of reasons to believe the time is ripe for a more successful attempt at completing Licklider's vision, including recent great strides in artificial intelligence and related disciplines, such as speech processing and machine learning; dramatic improvements in microelectronics and computing power; and an ongoing revolution in neural and brain science that could provide insights to be applied to computers.

To meet the challenge and opportunity, DARPA has structured its efforts in cognitive computing to catalyze innovative work in single cognitive systems, collaborative teams of cognitive systems, and collective cognition from large numbers of small non-cognitive elements (Figure 13). Each area will demonstrate the power of merging reasoning, learning, perception, and communication technologies. These areas will be supported and complemented by broad-based technology efforts in the hardware, software, and integration techniques needed.

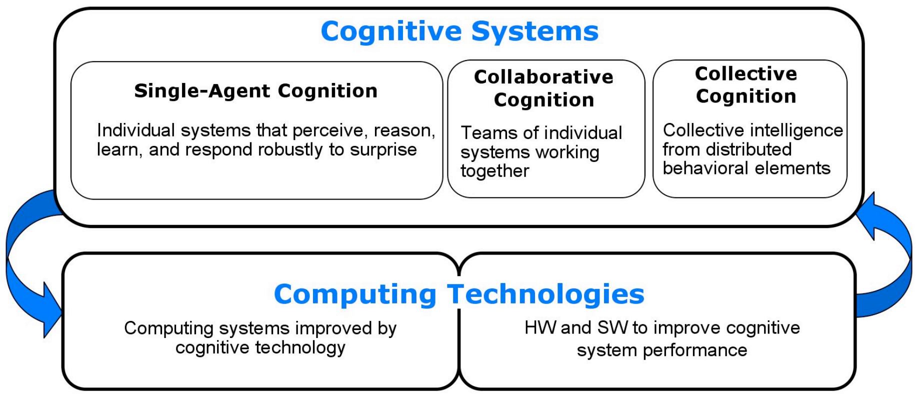

Figure 13: Cognitive Computing at DARPA.

For example, DARPA's Personalized Assistant that Learns (PAL) program will create intelligent personalized assistants for many tasks. It imagines the potential for a commander's assistant, an intelligence analyst's assistant, and a decision-maker's executive assistant. These assistants "learn" about preferences and procedures by interacting with their human partners and will accept direct, naturally expressed guidance. They will anticipate the human's needs and prepare materials to be ready just in time for their use. These new and unprecedented artificial helpers will help reduce military staffing needs in many key places and will help ensure decisions are made in a timely fashion and with the best possible preparation. Successful implementation of a PAL will help realize Licklider's vision of human-computer symbiosis.

The strategic thrust of cognitive computing is a template shaping DARPA's core technology foundation work in information technology (see Section 4.3).

3.6. Assured Use of Space

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

These advantages—and the dependencies that come with them—have not gone unnoticed, and there is no reason to believe they will remain unchallenged or untested forever. As the Rumsfeld Commission explained, "An attack on elements of U.S. space systems during a crisis or conflict should not be considered an improbable act. If the U.S. is to avoid a 'Space Pearl Harbor,' it needs to take seriously the possibility of an attack on U.S. space systems."[9]

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

In FY 2002, the Secretary of Defense directed DARPA to begin an aggressive effort to ensure that the U.S. military retains its preeminence in space by maintaining unhindered U.S. access to space and protecting U.S. space capabilities from attack. Figure 14 depicts DARPA's space strategic thrust with five elements.

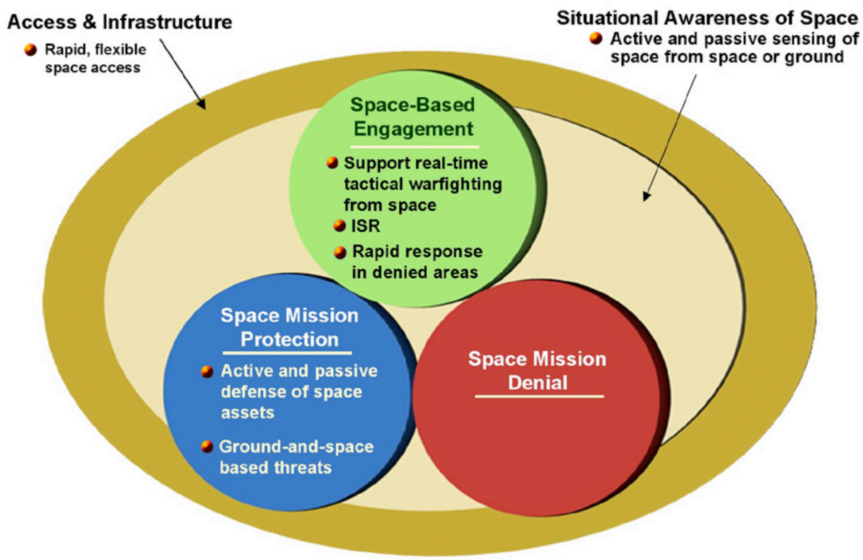

Figure 14: DARPA's space thrust.

- Access and Infrastructure refers to rapid and affordable access to space.
- Situational Awareness refers to knowing what else is in space and what that "something else" is doing.
- Space Mission Protection refers to protecting U.S. assets in space from harm.
- Space Mission Denial refers to preventing adversaries from using space to harm the United States. or its allies.
- Space-based Engagement refers to reconnaissance, surveillance, communications, and navigation to support military operations on earth, extending what the United States does so well today.

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9 Honorable D. H. Rumsfeld, Chairman, Rumsfeld Commission, *Report of the Commission to Assess United States National Security Space Management and Organization* (January 11, 2001).

DARPA focuses most of its efforts on the first four thrusts, while the efforts in space-based engagement are emphasizing technology complementary to research being done by the National Reconnaissance Office.

Examples of DARPA's space programs are Responsive Access, Small Cargo, Affordable Launch (RASCAL); Orbital Express; Space Surveillance Telescope (SST); and Force Application and Launch from the Continental United States (FALCON). RASCAL is designed to place small payloads in orbit on a moment's notice by launching them from a high-speed, high-altitude aircraft that eliminates a large and expensive first stage booster. Orbital Express will demonstrate the feasibility of using automated spacecraft to refuel, upgrade, and extend the life of appropriately designed on-orbit spacecraft. This will lower the cost of doing business in space and will provide radical new capabilities for military spacecraft, such as high maneuverability (which will make our satellites more difficult to track, hide from, or attack), autonomous orbital operations, and satellites that can be reconfigured as missions change or as technology advances. The SST program is developing a ground-based, wide-aperture, deep field-of-view optical telescope. It will search for very faint objects in geosynchronous orbit, e.g., new and unidentified objects that suddenly appear with unknown purpose or intent.

FALCON-Hypersoar (Figure 15) is designed to vastly improve the U.S. capability to reach orbit or almost anywhere on the globe promptly from bases in the continental United States. This capability will improve the military's ability to strike fleeting targets far overseas or quickly position intelligence, surveillance, and reconnaissance payloads while reducing its reliance on forward and foreign basing. FALCON will proceed in stages, including a small, low-cost launch vehicle; a common payload vehicle; and, eventually, a hypersonic vehicle. The ultimate goal is to deliver 12,000 pounds of payload 9,000 miles away in less than 2 hours. The technology required for FALCON will drive major progress in achieving low-cost, responsive access to space.

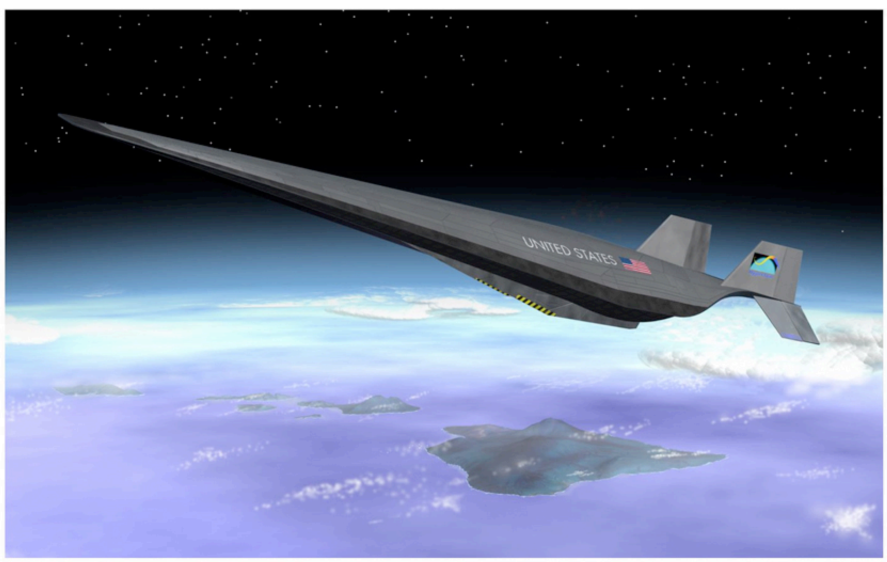

Figure 15: FALCON-Hypersoar

3.7. Bio-Revolution

DARPA's strategic thrust in the life sciences called, Bio-Revolution, is a comprehensive effort to harness the insights and power of biology to make U.S. warfighters and their equipment stronger, safer, and more effective. It stems from several developments.

Over the last decade and earlier, the United States made an enormous investment in the life sciences, so much that it has become commonplace to say that the world is entering a "golden age" of biology. One would be hard-pressed to find a better example of the far right side of Figure 2 than the plethora of fundamental new discoveries in the life sciences reported every day. DARPA is mining these new discoveries for concepts and applications that could enhance U.S. national security in revolutionary ways.

There has been a growing recognition of synergies among biology, information technology, and micro-/nano-technology. Advances in one area often benefit the other two, and DARPA has been active in information technology and microelectronics for many years.

DARPA's programs to thwart the threat of biological attack have brought significant biological expertise into the Agency. An impetus and capability were created to begin a major exploration of the national security potential of cutting-edge research in the life sciences.

The bio-revolution thrust has four broad elements, as shown in Figure 16:

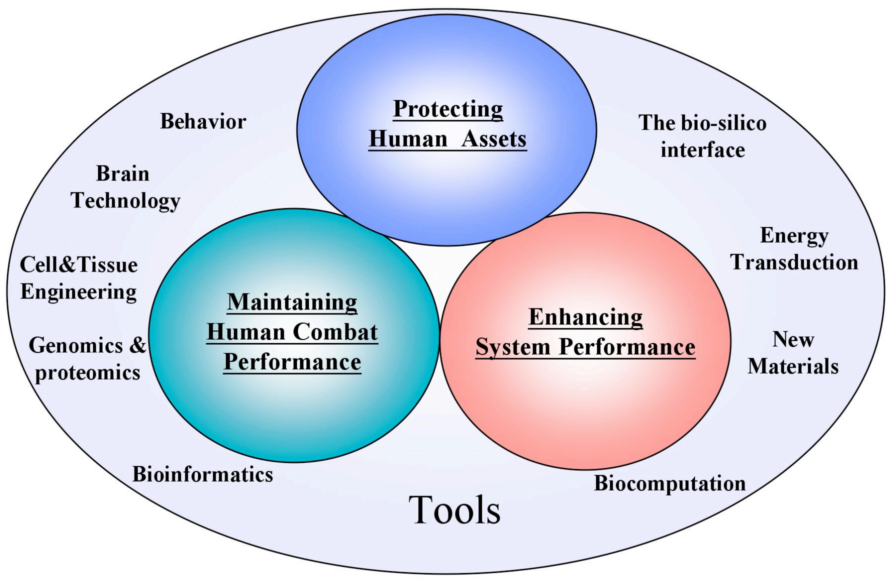

Figure 16: DARPA's Bio-Revolution thrust.

- Protecting Human Assets refers to DARPA's work in biological warfare defense (BWD). DARPA's comprehensive and aggressive BWD program began in the mid-1990s in response to a growing awareness of the biological warfare threat to the United States. It covers sensors to detect an attack, technologies to protect people in buildings and manage the response to an attack, vaccines to prevent infection, therapies to treat those exposed, and decontamination technologies to recover the use of an area.

- Enhancing System Performance refers to creating new mechanical systems with the autonomy and adaptability of living things by developing materials, processes, and devices inspired by living systems. For example, DARPA-supported researchers are studying how geckos climb walls and when legs have advantages over wheels and tracks (Figure 17). The idea is to let nature be a guide toward better engineering.

Figure 17: Bio-inspired hexapod, RHex, emulates cockroach-like locomotion to traverse difficult terrain.

- Maintaining Human Combat Performance is aimed at ensuring that humans do not become the weakest link in fast-paced, lethal combat operations. The goal is to learn what we can from the life sciences to keep the individual warfighter as strong, alert, and endurant as he or she was before deploying, and administer medical self-help when battlefield injuries occur.
- Tools are the variety of techniques and insights on which the other three areas rest.

DARPA's program in preventing cognitive degradation as a result of sleep deprivation illustrates how the Bio-Revolution will help our troops. This program is investigating ways to mitigate the effects of fatigue so soldiers can stay alert and effective for extended periods without suffering deleterious mental or physical effects and without using any of the current generation of stimulants. Other Bio-Revolution programs are developing ways to:

- Reduce acute pain that will be more effective and less dangerous than morphine while not affecting a soldier's cognitive skills,
- Preserve platelets and other blood products so they are promptly available in extremely isolated battlefields, and
- Greatly improve the effectiveness of first aid that troops in far-forward areas can self-administer when injured.

This research is tailored to the specific environments our troops encounter in combat. The Food and Drug Administration must approve any treatment before it can be used.

Perhaps the program that best exemplifies the "revolution" in Bio-Revolution is the Human Assisted Neural Devices. This program is finding ways to detect and directly decode signals in the brain so that thoughts can be turned into acts performed by a machine. This capability has been demonstrated, to a limited degree, with a monkey taught to move a telerobotic arm simply by thinking about it (Figure 18). The long-term Defense implications of finding ways to turn *thoughts into acts*, if it can be developed, are enormous. Imagine U.S. warfighters that need only to use the power of their thoughts to do things at great distances.

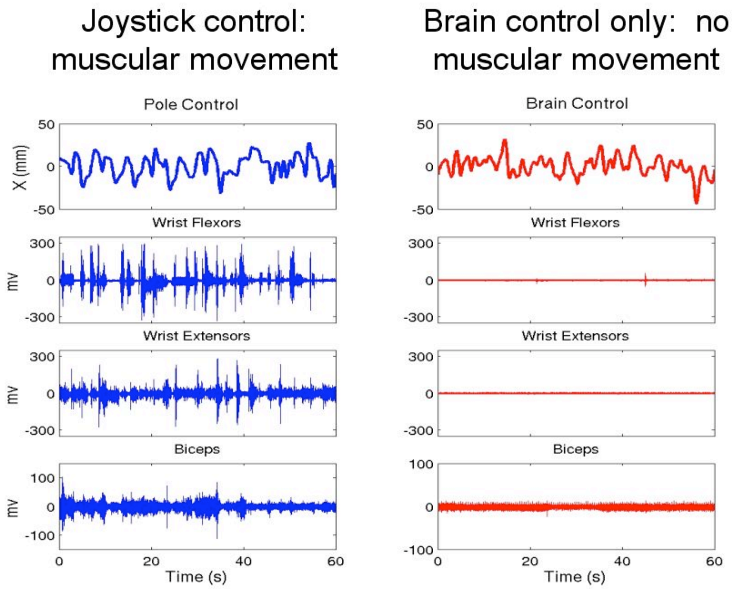

Figure 18: Electromyograms comparing monkey's control of telerobotic arm via joystick and brain control only.

However, the immediate benefit will be to injured veterans, who would be able to control prosthetics in a natural way never before imagined. DARPA's researchers are working with the Veteran's Administration to make this a reality.

3.8. Force Multipliers for Urban Area Operations (New Thrust)

Urban area operations can be the most dangerous, costly, and chaotic forms of combat. The number of military operations in urban areas is increasing, and this trend will likely continue for the foreseeable future. Each year, existing urban areas increase in population and size; experts predict that by 2025, nearly 60 percent of the world's population will live in urban areas.

Adversaries will seek to conduct operations in urban areas as a way to mitigate the United States' superior ability to quickly destroy fixed and mobile targets in open and semi-concealed areas.

Accordingly, DARPA has created a new strategic thrust, Force Multipliers for Urban Area Operations.

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

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

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

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

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

DARPA has a number of programs underway to support these initial concepts. New initiatives are exploring ways to navigate accurately inside buildings and underground in urban tunnels. Other programs seek to allow forces to accurately determine a building's layout before they enter, along with capabilities to determine whether hostile personnel are hiding in the building.

The UrbanScape program promises to eliminate position uncertainty by processing both LIDAR and video data to rapidly generate 3-D, small scale, up-to-date digital maps of urban areas. The CROSSHAIRS program will track sniper bullets and determine the direction of hostile fire.

These examples represent the research work underway to support the new thrust area. The ideas are not sufficient, however, and new ideas are welcome.

4. 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 independent 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 sponsors research in materials, microsystems, information technology and other technologies that may have far-reaching military consequences.

In fact, these technologies often form enabling chains. Advanced materials have enabled new generations of microelectronics, which, in turn, have enabled new generations of information technology, which is the enabling technology for network-centric operations (see Section 3.4).

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

4.1. Materials

The importance of materials technology to Defense systems is often underestimated. Many fundamental changes in warfighting capabilities have sprung from new or improved materials. The breadth of this impact is large, ranging from stealth technology, which succeeds partly because materials can be designed with specific responses to electromagnetic radiation, to information technology, which has been enabled by advances in materials for computation and memory.

In keeping with this broad impact, DARPA maintains a robust and evolving materials program. DARPA's approach is to push new materials opportunities and discoveries that might change way the military operates. In the past, DARPA's work in materials has led to such technology revolutions as new capabilities in high-temperature structural materials for aircraft and aircraft engines, and the building blocks for the world's microelectronics industry. The materials work DARPA is supporting today is building on this heritage of major contributions.

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

- Structural Materials and Components: low-cost, ultra-lightweight structural materials and materials designed to accomplish multiple performance objectives in a single system;
- Functional Materials: advanced materials with a nonstructural function for 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.

For example, DARPA's Structural Amorphous Metals (SAM) program is advancing a new class of bulk materials with amorphous or "glassy" microstructures. As a result of this microstructure, SAM alloys have unique and previously unobtainable combinations of hardness, strength, damage tolerance, and corrosion resistance. Possible uses for SAM alloys include corrosion-resistant, nonmagnetic hulls for ships and self-sharpening penetrators to replace depleted uranium. DARPA's Initiative in Titanium aims to develop revolutionary processes for low-cost extraction of titanium metal from oxide ores. The approaches include electrolytic processes that are similar to those developed for aluminum that reduced its cost from that of a precious metal to an everyday material.

Progress in smart materials and devices has provided the fundamental technologies that are making possible the construction of an external skeleton that will work unobtrusively and in concert with a soldier to support a 100-pound backpack.

Another program is developing materials that will lead to fuel cells to reduce the weight of batteries carried by reconnaissance units from more than 200 pounds to less than 20 pounds and novel approaches for generating water from air.

The Morphing Aircraft Structures program is developing technologies aimed at building air vehicles that can radically change their shape in flight (Figure 19). This capability would allow a plane to fundamentally and dynamically vary its flight envelope, much like a bird, so a single air vehicle could perform multiple, radically different missions.

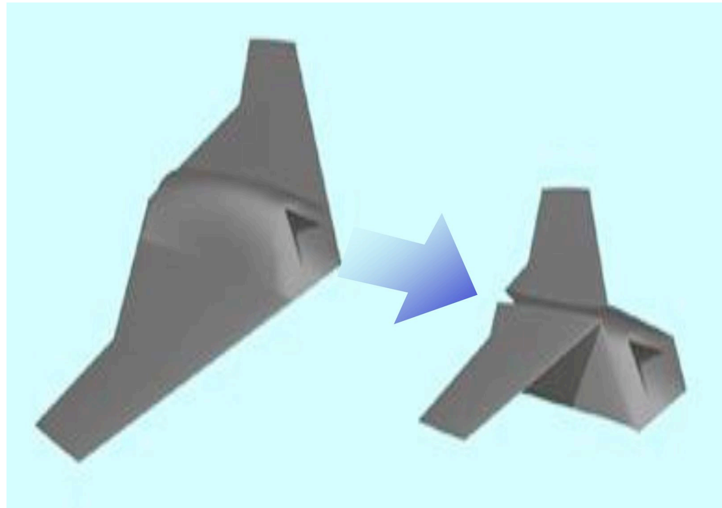

Figure 19: Morphing Aircraft.

4.2. Microsystems

Microsystems — microelectronics, photonics, and MEMS)—are key technologies for the U.S. military, enabling U.S. forces to see farther, with greater clarity, and better communicate information in a timely manner.

DARPA is building on these accomplishments by shrinking ever-more-complex systems into chip-scale packages, integrating the three core hardware technologies of the information age into "systems-on-a-chip." It is at the intersection of microelectronics, photonics, and MEMS that some of the greatest challenges and opportunities for DoD arise. Examples include integrating MEMS with radio frequency electronics and photonics; integrating photonics with digital and analog circuits; and integrating radio frequency and digital electronics to create mixed signal circuits.

The model for this integration is the spectacular reduction in transistor circuit size under Moore's Law: electronics that once occupied entire racks now fit onto a single chip containing millions of transistors. As successful as this progress has been, the future lies in increasing the level of integration among a variety of technologies to create still-more-complex capabilities. DARPA envisions intelligent microsystems that enable 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 allow the U.S. military to think and react more quickly than the enemy and create information superiority by improving how warfighters collect, process, and manage information.

An example is the Molecular Electronics program. Within 10 to 15 years, today's dominant computer switch technology, complementary metal oxide semiconductor (CMOS) transistors, will reach its lower size limits and no longer advance according to Moore's Law. Anticipating this, the Molecular Electronics program is seeking to develop a new class of devices and circuits based on molecular switches that are 100 to 1000 times smaller than current CMOS transistors and have the potential to reach a trillion switches per square centimeter. This development seeks to reduce the size, weight, and power of these processors, allowing greater computing power to be packed into ever smaller volumes while increasing the "smarts" of military systems while lightening the soldiers' load. There has been solid progress towards this goal: in FY 2004, DARPA expects to demonstrate the first 16-kilobit memory based on molecular switches.

4.3. Information Technology

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

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

- The aim of the Improving Warfighter Information Intake Under Stress program is to directly, but noninvasively, measure human cognitive load so information can be presented to the warfighter or commander in a way that does not overload human cognition when mental processes are pressed to the limit. This capability will enable warfighters working under high-stress conditions to be more effective, and will fundamentally change the nature of the human-machine interface by finally creating interfaces that adapt to the user, rather than the other way around.

- DARPA continues to push significant improvements in the machine translation of natural languages. DARPA's handheld, one-way speech translation device was used in Operations Enduring Freedom and Iraqi Freedom. In at least one instance, its use led to the discovery of a large cache of weapons and the location of enemy forces. More generally, the performance of machine translation technology on Arabic news feeds has advanced from essentially garbled output to nearly edit-worthy text, often understandable down to the level of individual sentences. This work points the way to unprecedented capabilities for exploiting huge volumes of speech and text in multiple languages.

Information technology at DARPA has been instrumental in many crucial developments: the mouse, firewalls, asynchronous transfer mode, synchronous optical networks, TCP/IP, packet-switching, search engines, and natural language processing. Twenty years from now, today's research will have enabled a new and scarcely imaginable legacy of robotics, network-centric operations, and cognitive systems.

5. Working with DARPA

5.1. Researchers

Individuals with a great idea that could revolutionize national security technology should think about working with DARPA.

DARPA "mines the Far side" (Section 2.2), funding high-risk, high reward technical opportunities for improving national security, and accelerating them toward fruition. We are always looking for great ideas.

Do not constrain your great ideas up front by how you think DARPA may react to them. Just because DARPA does not appear active in an area does not mean it will not take a great technical idea and run with it. In fact, these types of new ideas sometimes lead to whole new areas of research.

The key to working with DARPA is through a program manager who can help in any number of ways: give feedback if an idea is suited to DARPA; help shape the idea so it is a better fit to an ongoing or upcoming DARPA program; or, in some cases, significantly change what he or she is planning to do based on a good idea. A big part of a program manager's job is to find great ideas on which to build new program. Technical exchanges with DARPA program manager are the foundation of working with DARPA.

A DARPA program manager may ask: What are you trying to do? How is this done now, and what are the limitations? What is truly novel in the approach that will remove those limitations and improve performance? By how much? If an idea is successful, what difference will it make to DoD? Through questions like these, the program manager will help sort out the state of the art, what is being done elsewhere, and how/whether the idea fits at DARPA.

The best place to locate a program manager with whom to work is DARPA's web pages (www.darpa.mil) and its offices' broad agency announcements (BAAs). BAAs are a very flexible form of soliciting proposals and identify the applicable program managers. Once you have found the right ones, give them a call or send them an e-mail message to start the technical discussion. If a program manager is not identified, refer to the DARPA directory on the website to contact the office whose scope is closest to your interest.[10]

DARPA offices hold Industry Days and post their BAAs in FedBizOpps, the General Services Administration service in which all Federal procurements over $25,000 in value are synopsized (www.fedbizopps.gov). Information on DARPA solicitations can be found in the Solicitations section on the DARPA home page. Most DARPA offices have "always open" BAAs, so proposals may be officially entertained at any time. Additional information on doing business with DARPA is available at www.darpa.mil/body/dobdar.html.

DARPA understands that proposals involve enormous work and expense, and many DARPA solicitations encourage a short white paper or pre-proposal submission. This approach allows program managers to provide prompt feedback on the likelihood of a proposal being selected.

Another way to receive DARPA funding is through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, which are exclusively for small businesses. Both the SBIR and STTR programs consist of three phases: Phase I is a 6-month feasibility study, with awards up to $99,000; Phase II is a 2-year proof of principle effort, with awards generally up to $750,000; and Phase III refers to obtaining funding outside the SBIR program. Each fiscal year, DoD publishes two SBIR solicitations in October and May

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[10] Program managers are listed on the "Directory of DARPA Technical Staff" link on our home page. E-mail can be sent to webmaster@darpa.mil or the DARPA General Information Line can be contacted at (703) 526-6630.

and one STTR solicitation in January. DARPA participates in these solicitations and generally has between 30 and 60 SBIR topics, with a budget of about $65 million each year, and 10 STTR topics with an annual budget of about $7 million. More information on DARPA's SBIR and STTR programs can be found at www.darpa.mil/sbir/, including links to the DoD solicitations at www.acq.osd.mil/sadbu/sbir. For additional SBIR/STTR information, contact the SBIR help desk at 1-866-216-4095.

Because DARPA focuses on technically risky research, it has an active management style. DARPA programs focus on achieving specific, well-defined objectives. Each project has a specified endpoint, with specific milestones to chart progress so DARPA can accurately manage expectations. If necessary, the program will be reshaped along the way to better reach the endpoint.

DARPA will accept the hardest technical challenge, and will work *you* very hard to reach it.

5.2. Service Personnel Seeking Information on DARPA Programs

DARPA's military operational liaisons serve as points of contact for the Services. Service representatives with technical questions or needs are encouraged to contact the liaisons or a DARPA program manager working the area closest to a particular area of interest.

Army:	COL Gasper Gulotta (arrives in July 2004)
Navy:	CAPT Christopher R. Earl (571) 218-4219, cearl@darpa.mil
Air Force:	Col Jose A. Negron, Jr. (703) 696-6619, jnegron@darpa.mil
Marines:	Col Otto Weigl (703) 696-4209, oweigl@darpa.mil

DARPA's military operational liaisons may also be contacted via SIPRNET at [username]@darpa.smil.mil.

6. Additional Information

Additional information on DARPA's offices and programs is available www.darpa.mil.

The DARPA Director's March 27, 2003, testimony to the Subcommittee on Terrorism, Unconventional Threats and Capabilities of the House Armed Services Committee may be found at http://www.darpa.mil/body/NewsItems/pdf/hasc_3_27_03final.pdf.

A fact file has been assembled as a ready reference for those interested in DARPA's research portfolio. It contains short summaries of selected DARPA programs arranged by our strategy and may be found at http://www.darpa.mil/body/pdf/FINAL2003FactFilerev1.pdf. More in-depth information is contained in DARPA's budget requests at http://www.darpa.mil/body/budg.html.

Updates to all these documents, as well as news releases about DARPA programs, can be found at http://www.darpa.mil/body/news.html.